STUDIES ON MAN-BITING *SIMULIUM* AND THE PREVALENCE OF ONCHOCERCIASIS AT DALLE VILLAGE, NEAR KAFANCHAN, KADUNA STATE, NIGERIA.

BY

ISHAYA HARUNA NOCK

A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, AHMADU BELLO UNIVERSITY, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE (M.Sc.) IN ZOOLOGY.

AUGUST, 1985.

D E D I C A T I O N

To my wife and Daughter (Grace and Sophie)

and

To all in the struggle to liberate the
50 million 'held captive in the prison
cells' of onchocerciasis.

THESIS APPROVAL

This thesis by NOCK, Ishaya Haruna meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University and is approved for its contribution to scientific knowledge.

Dr. C.G. Vajime
Internal Examiner
Department of Biological Sciences, Ahmadu Bello University,
Zaria, Nigeria.

Dr. S. Prasertphon
Chief, WHO Vector Control Unit,
Kaduna
External Examiner

Dr. Z. Husain
Internal Examiner
Department of Biological Sciences, Ahmadu Bello University,
Zaria, Nigeria.

25/X/85
Professor G.E. Osuide
Dean, Postgraduate School
Ahmadu Bello University
Zaria, Nigeria.

DECLARATION

I hereby declare that this thesis is a record of my own research work. It has not been presented by me in any previous application for a higher degree.

Ishaya Haruna Nock

14th Aug. 1985

Date

ACKNOWLEDGEMENT

I wish to express my profound gratitude to my supervisor, Dr. C. G. Vajime, for his untiring efforts in supervising this work.

My sincere gratitude goes to Dr. W. G. Gregory (Head, Entomology Division, Nigerian Institute for Trypanosomiasis research, NITR, Kaduna), for critically reading over the first draft of the review of literature.

I also wish to thank staff of NITR., particularly Mr. Y. S. Kayit and the laboratory assistants of Parasitology Division, Vom, who assisted in the survey for breeding sites and the survey for onchocerciasis in the Dalle population. Mr. A. R. Lawal kindly typed the thesis.

Finally, I am most grateful to the authorities of NITR, particularly the Director, Alhaji Y. Magaji, for granting me study leave and providing the financial requirements for this work.

Towards the end of the work, some financial aid came from grants in aid of Dr. C. G. Vajime's research work; I am also grateful.

ABSTRACT

A survey of breeding sites was carried out in the river systems of the Upper and Lower Jos Plateau, covering 3 states, namely, Bauchi, Kaduna and Plateau. Five active breeding sites of Sirnuliun damnosum s.l. were found, one of these, site 8, near Dalle village by River Kogun is new, therefore, this study was focused *on* the Dalle area. Some studies on man-biting Simulium were carried out by examining the fly biting density, infective biting density and transmission potential in relation to the prevalence of the disease in the human population at Dalle village. The Dalle study covered a six month period: June - August and October. December, 1984,which represent the wet and dry seasons respectively.

The fly biting density, infective biting density and transmission potential! are shown to vary with the day, month and season. In the wet season, these were 4,193; 153 and 281 respectively. For the dry season, these dropped to 1,532: 71 and 38 respectively, The highest and lowest fly biting densities were found in June and December respectively.

Of 223 people examined, 21 (9.4°/c) were found positive for onchocerciasis; 10 and 11 of these were males and females respectively.

The disease prevalence showed an increase with age, pre-school children (less than 6 years) did not show any infection; the highest prevalence was observed in the age group of 56 years and above. The prevalence was higher in men than women. The intensity of infection was low (4,8 microfilariae/snip), but showed an increase with age, reaching a peak in the 36-45 year age group.

Generally, there were no severe clinical features of the disease (like blindness) among the inhabitants of Dalle village.

It is suggested that the high transmission of the disease is associated with the microfilarial load in the human population of Dalle and the neighbouring villages; while the fall in fly biting density especially in July, is attributed to the hours of the day in which no adult flies catches were made because of rain and to the effect of flood on larval settling sites. The adverse dry season conditions affected the survival rate of the flies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER ONE

GENERAL INTRODUCTION

Onchocerciasis is an insidous non-fatal disabling disease which is transmitted by some species of Simulium. The disease is widespread in Africa (Jamnback, 1976); Yemen Arab Republic (Merighi and Parrinello, 1969; Garms and Kerner , 1982); Mexico (Davies, 1974; Mallen, 1974); and in Central and South America (Convit, 1974; Corredor, 1974; Hamon, 1974; Marroquin, 1974; Moraes, 1974). A comprehensive account of the prevalence of the disease in these regions has been published (Anonymous, 1976).

Onchocerciasis has a long standing history which dates back to 1874 and 1893 (Nelson, 1981a) when John O'Neil and Leuckart discovered Onchocerca volvulus microfilariae and adult worms respectively. Later in 1914, Robles associated severe ocular complications to onchocerciasis; while Blacklock (1926), discovered the Simulium vector.

The biting nuisance of Simulium flies and the disease transmitted coupled with the grave socioeconomic repercussions provoked worldwide concern towards the control of the disease; and for over the past 50 years (Davies, 1983), man has been engaged in the struggle of controlling the disease in order to effectively reduce the prevalence of the disease and to reclaim the deserted fertile agricultural lands associated with river valleys endemic for onchocerciasis (Anonymous, 1973a).

Despite past and current control programmes, the current estimate of affected persons is still astronomical.

It is currently estimated that over 50 million people are affected by the disease throughout the world (Scharlau, 1981); 30 million affected in Africa (Nelson, 1970; 1964b); 20 million in the West Africa subregion (Jamnback, 1976); and over 300,000 in Northern Nigeria alone (Crosskey, 1973). Onchocercal blindness affects about 200,000 - 300,000 people throughout the world (Thylefors, 1978), about 70,000 in the Volta River Basin Area (Anonymous, 1973a), and about 20,000 in Northern Nigeria alone (Budden, 1956). In many villages in the savanna region of West Africa, 10°/o - 20°/o blindness rates and 30°/o cases of impaired vision have been estimated (Nelson, 1970; Anonymous 1973b; 1978a; Crosskey, 1973).

The severity of onchocerciasis is usually well marked in hyperendemic areas where the rate of onchocercal blindness and cases of impaired vision are highest. In such endemic areas, the affected persons pose a socio-economic problem to both Government and the immediate community; as the farming strength of the population is considerably reduced, crop output falls below subsistence level, thus hunger, malnutrition and disease set in. Consequently, fertile agricultural lands generally associated with the river valleys are deserted for less fertile uplands areas (Hamon and Hartman, 1973; Buck, 1974a; Bradley, 1976; Le Berre *et al.* 1977). In the end, the demographic stratification is disturbed in terms of age and sex distribution (Anonymous, 1978a).

The socio-economic repercussions associated with the disease are usually great but difficult to quantify (in terms of morbidity, loss of man hours, reduced productivity and treatment cost).

These problems are further compounded by the lack of prophylactic drugs or vaccines against the disease. The current control attempts include nodulectomy, drug treatment of affected individuals and the destruction of *Simulium* larvae at their breeding sites.

In Nigeria, the incidence of the disease was first reported by Parsons (1909). Since then, only peice-meal proppection of the disease in relation to its transmitting vector has been done: no serious attempts were made to look into the socio-economic effects of the disease. However, the few recent research reports on the epidemiology and socio-economic effects of the disease have given an insight of high rates of onchocercal blindness coupled with land desertion (Bradley, 1976; Edungbola, 1982). In addition, Crosskey (1979), estimated that about 300,000 km^2 of land area in Northern Nigeria alone is affected by the *Simulium* vector.

If Nigeria's present effort to boost the nation's agricultural economy must succeed, special attention must be given to its fertile agricultural lands along river valleys in which onchocerciasis is endemic.

The National Onchocerciasis control programme (NOCP), envisaged for Nigeria, should therefore be accompanied by pre-control data required for monitoring the success of such a scheme. These are lacken at the moment as it has been reported (Crosskey (1979), that apart from providing general background information, the existing data in Nigeria have no value.

This present study which covers Dalle village near Kogun River, is one of the few aimed at providing some information on; new foci of the vector species, and the capacity of the vector species to act as vectors of O. volvulus in relation to the prevalence of the disease in human population of Dalle village.

CHAPTER TWO

LITERATURE REVIEW

Introduction

Human onchocerciasis is caused by Onchocerca volvulus, a phasmid nematode belonging to the super-family Filarioidea and the family Filaridae (Soulsby, 1968; Chitwood and Chitwood, 1974). The transmitting vectors are certain species of Simulium of the insect family Similiidae (Crosskey, 1981a). This family, despite its relatively small size, it has been difficult to classify on account of its remarkable morphological homogeneity (Crosskey, 1981a), and the compounded problem of its sibling nature (Dunbar, 1959; Rothels, 1981). This has resulted in no universally agreed and stable classification of the family. However, an outline classification of the world fauna for ready reference has been provided by Crosskey (1981a). An account of the general distribution, morphology, life cycle and the importance of blackflies is given by Crosskey (1973; 1981b) and Service (1980). Similarly, a detailed description of the distribution of the disease throughout the world (Crosskey, 1973; Jamnback, 1976; Anonymous, 1976), and the life cycle of the parasite (Nelson, 1970; Anonymous, 1976; Wenk, 1981), have been published.

In this review presented below, attention is focused on: the vectors of O. volvulus, the mode of disease transmission by Simulium vectors, the pathology and clinical features of the disease, therapy plus complication, the current control attempts and the socio-economic importance of the disease.

Vectors of Onchocerca volvulus

In Africa and South Arabia.

Simulium damnosum s.l.

Simulium damnosum s.l. has been reported as the major vector of O. volvulus in tropical Africa and South Arabia. Its distribution coincides with that of onchocerciasis in West and Central Africa (Jamnback, 1976), and the Yemen Arab Republic (Merighi and Fabrinello, 1969; Garms and Kerner, 1982). Some species of S. damnosum s.l. have been reported from East and South Africa (Browne, 1976; Jamnback, 1976)., and in the Sudan (Hasseeb, Satti and Sheriff, 1962), The distribution of Simulium damnosum s.l. in Nigeria in relation to the various bioclimatic factors and onchocerciasis in particular has been discussed by Crosskey (1957; 1979; 1981c).

Simulium damnosum was first recognised as a species complex by Dunbar (1966). About ten years later, at least 26 distinct cytospecies have been identified in Africa (Dunbar and Vajime, 1972), eight formally described and named (Vajime and Dunbar, 1975), all but one (S. yahense) have been found breeding in some localities in Nigeria (Dunbar and Vajime, unpublished).

Simulium neavei group

This group is made up of eight species (Raybould and White, 1979). Of these, only two, S. neavei and S. Woodi are known to be vectors of onchocerciasis in the East African subregion (Jamnback, 1976). Accounts of the distribution, biology and role of these species as vectors of onchocerciasis within that subregion are given by Anonymous (1976); Jamnback (1976), and Raybould and White (1979).

Other possible vectors

Apart from some members of S. damnosum complex and of the S. neavei group, there are incrimatory reports on some other Simulium species as possible vectors of O. volvulus in Africa. These include S. bovis (Crosskey, 1957); S. vorax. S. adersi, S. nyasallandicum (Wegesa, 1967; 1970; Anonymous, 1976); S. ovazzae and S. albivirgulatum (Anonymous, 1976).

In Mexico, Central and South America

Simulium ochraceum has been reported as the major vector in these areas; S. metallicum, S. callidum, S. exiguum and S. guianense s;.l. have also been incrimated (Hamon, 1974; Jamnback, 1976; Crosskey, 1981b). Based on laboratory studies, Gibson and Dalmat (1952), incrimated S. gonalezi, S. haematopotum and S. veracruzanum as possible vectors in these areas.

Identification of Simuliids

The simuliids are small stout-bodied midges commonly known as blackflies. They are usually black but may have contrasting patterns of white, silvery or yellow hairs on their bodies and legs. The Neotropical species are predominantly yellow or orange in colour (Crosskey, 1973; Service, 1980). Adult blackflies measure about 1.5 - 4mm long (Service, 1980), averaging 2 - 3mm long (Jamnback, 1976). When viewed from the side, they have a rather humped thorax.

Head region

The head has a pair of compound eyes which are separated in the females by a broad frons (dichoptic condition), whereas in the males, they occupy almost all the head region and touch above the bases of the antennae (holoptic condition). The antennae are short and stout and have 9 - 12 segments of rather uniform size (majority of the antennae are 11 - segmented) (Crosskey, 1973). The mouthparts are short and relatively inconspicuous except the five-segmented maxillary palps which hang downwards (Service, 1980). The biting fascicle of the females consists of a labrum with apical teeth, a pair of mandibles and a pair of maxillae both having fine teeth at their tips, and on the hypopharynx. Such teeth are absent in the males and in some non-biting females in which the teeth are atrophied (Crosskey, 1973).. Behind these mouthparts is the relatively large labium which terminates in a pair of fleshy labellae.

Thracic region

The thorax is covered dorsally with very fine and appressed hairs, which can be black, white, silvery, yellow or orange and may be arranged in various patterns. The relatively short legs are similarly covered with fine and closely appressed hairs and may be of uniform colour or contrasting bands of pale, white and dark colour. The wings are short, broad and colourless or almost so. When at rest, they are closed flat over the body like the blades of a closed pair of scissors (Service, 1980).

Abdominal region

The abdomen is short and squat and covered with inconspicuous closely appressed fine hairs. In neither sex are the genitalia very conspicuous.

A detail description of the identification of adults, pupae, larvae and eggs of simuliids has been discussed by Crosskey (1962; 1973), and Jamnback (1976).

Identification of adult S. damnosum s.l.

Simulium damnosum s.l. includes very important vector species in the transmission of O. volvulus in tropical Africa especially in Nigeria. The differentiation of S. damnosum s.l. from 27 other species of the genus reported found in Nigeria (Vioukov, Prasertphon and Knudsen, 1982) is of importance especially in the studies of transmission indices. The identification is based on the presence of dorsal hair crest of the fore-tarsus and the white band of the hind barsi-tarsus (Crosskey, 1973; Service, 1980). This is applicable to the whole species complex. However, the advent of cytological studies has further differentiated the species into cytological entities. Currently, the use of behavioural characters, ecological and immunological characteristics (Anonymous, 1977) biochemical (Anonymous, 1978b; Meredith, 1982) and morphological characters (Disney, 1970; Garms, 1978; Quillevere and Sechan, 1978; Kurtak, Raybould and Vajime, 1981, Peterson and Dang, 1981) have been intensified in a bid to easen and quicken the identification of the sibling species.

Identification of *O. volvulus* larvae in simuliids

It has been observed, that many man-biting simuliids are not exclusively anthropophilic, because many of the insects also feed on animals and birds (Nelson, 1970). The presence in simuliids of filarial worms whose infective larvae have similar morphological characteristics in-distinguishable from those of *O. volvulus* has been reported (Anonymous, 1966, Duke, 1967; Nelson, 1970; Poinar, 1977; Omar and Garms, 1981): for instance *Ornithofilaria* species, *Mansonella ozzardi* and some 'unknown' infective filarial larvae have been confused with *O. volvulus* larvae in simuliids. The main yardstick for identifying O. volvulus from such other species is from the size. The mean length of the infective larvae of O. volvulus in simuliids is 566 microns with a range of 440-700 microns (Anonymous, 1966; Nelson, 1970). The same authors have given detail account on the criteria used in differentiating the the infective larvae of O. volvulus from other infective filarial larvae. Bain (1968) and Duke (1968b), have discussed in detail the sizes of all the developmental stages of O. volvulus in simuliids.

Identification of microfilariae and adult O. volvulus in man.

Microfilariae

The microfilaria of O. volvulus is unsheathed and large, measuring 270-320 microns in length by 5 microns in diameter (Neafie, 1972; Anonymous, 1976; Martinez-Palomo, 1978; Martinez-Palomo and Martinez-Baez, 1977). The anterior end is bluntly rounded and has a cephalic clear space, 7-11 microns long; a nerve ring is located 60-65 microns from that end. The posterior end tapers to a fine point with a caudal clear space 9-15 microns long (Neafie, 1972).

It has been observed that many skin and blood dwelling microfilariae, for instance, Dipetalonema streptocerca, D. perstans, Loa loa, Mansonella ozzardi, Wuchereria bancrofti and Brugia malayi, resemble O. volvulus morphologically (Markell and Voge, 1976). They are differentiated on the basis of the distribution of nuclei and their presence or absence in the extreme caudal portion, and the presence or absence of a sheath at their posterior end. Accounts on the staining method and key for the differentiating these species have been given by Chatterjee (1976), Markell and Voge (1976), and Omar and Garms (1981).

Adult worms

Adult worms of O. volvulus lie in deep-seated tissues and in superficial fibrous nodules (onchocercomata) just below the skin of man (Crosskey, 1973). They are wire-like filiform and blunt at both ends, white opalescent and transparent, with distinct transverse striations. The males are smaller, measuring 19-42mm in length by 130-210 microns in diameter. The females measure 33.5-50cm in length by 220-400 microns in diameter (Neafie, 1972, Sasa, 1976); but sometimes up to 70cm in length (Crosskey, 1973).

Aspects of the feeding behaviour of Simuliids and the transmission of O. volvulus

Only female blackflies feed on blood. Many of them feed exclusively on birds (ornithophilic), others on non-human mammalian hosts (zoophilic), but several species also bite man (anthropophilic). Crosskey (1973), and Service (1980), reported that some man-biting species seem to prefer various large animals such as donkeys and cattle and bite man as a second choice, while others appear to find man as almost or equally attractive host. No species is known to bite man alone (Service, 1980). *Simulium damnosum* s.l. feeds on both avian and mammalian blood (Crosskey, 1973).

Sight is important in host location for several species, but host odour may be of similar importance (Thompson, 1976a; 1976b; 1977; Service, 1980). Thompson (1976a), observed that in the savannah region of West Africa, *Simulium damnosum* s.l. seems to locate its host mainly by sight along.

It has been observed that most *Simulium* vectors of *O. volvulus* bite man in the body region where the concentration of microfilariae is highest (Blacklock, 1926; Nelson, 1970; Crosskey, 1973; Jamnback, 1976; Renz and Wenk, 1983). In tropical Africa, *Simulium* vectors of onchocerciasis bite man predominantly in the lower region; whereas in Mexico, Central and South America, the bites are concentrated in the upper region of the body. In man, these regions have been observed by the above authors to have the highest concentration of *O. volvulus* microfilariae.

Several blackflies species travel several distances away from their breeding sites in search for bloodmeals. Such long distant flights may be assisted by winds (Magor and Rosenberg, 1980; Service, 1980), birds (Crosskey, 1973), or vehicles (Walsh, 1972).

During blood feeding, the host skin is stretched, cut and then pierced by the mouthparts of the flies. Crosskey (1973) and Wenk (1981), observed that the host's skin is first stretched by the labrum and its apical teeth; cut by the saw-toothed apices of the mandibles working towards each other, and then pierced by the toothed maxillae and the hypopharynx. The labrum later assist in opening the wound which allows the mandibles, maxillae and the hypopharynx to penetrate the host's tissue to a depth of some 120-150 microns. Blood gains access to a canal enclosed anteriorly by the labrum and posteriorly by one of the paired overlapping mandibles. Blood uptake is slow, and complete engorgement usually takes at least 4-6 minutes, while prolonged feeds take up to 15 minutes or more (Blacklock, 1926; Crosskey, 1973). After a blood meal, blood engorged females find shelter and rest in vegetation, on trees, and other such sites until the blood meal is digested, which according to Gordon and Lavoipierre (1962), and Service (1980) takes 2-3 days in the tropics and 3-8 days or longer in non-tropical regions; the speed of digestion depends on temperature.

The uptake and transmission of O. volvulus

Simuliids are 'pool-feeders'. Their feeding habit is associated with the tearing of the host's skin and the release of microfilariae into the well of blood from which imbibition takes place. The long engorgement time enhances the likelihood of microfilariae being imbibed; the relatively long female life span also permits the embibed microfilariae to develop to the infective stage (Crosskey, 1973). However, it has been observed that not all microfilariae embibed by the flies survive; many are destroyed by the mouthparts and in the body of the fly (Reid, 1978, Hashiguchi, Kawabata, Ito and Recinos, 1981); as high intake has been reported to have adverse or lethal effect on the fly (Duke, 1962a; 1966; Omar and Garms, 1977). The microfilariae that survive develop in stages to the infective stage (Duke, 1968b; Reid, 1981). Eight to 10 days after an infected blood meal, the microfilariae have developed to the infective stage; the female fly is also due for its third blood meal and can transmit the infective larvae to a susceptible host (Reid, 1981; Wenk, 1981).

Factors affecting the transmission of O. volvulus

It has been observed that the fly biting density in a particular area is affected by the season. In tropical Africa and Southern Mexico, Simulium vectors of onchocerciasis bite in large numbers predominantly in the wet and dry seasons respectively (Crosskey, 1957; 1973). This difference in biting density is influenced by the river's water level, water temperature, water velocity, hydrogen iron content, amount of organic substances and the concentration of dissolved salts; these have been reported to affect the development of the immature stages of Simulium (Garms, 1973; Grunewald, 1981).

It follows therefore that where the conditions are optimal, increase in both breeding and biting would be expected. The daily changes in humidity and temperature also affects the daily fly biting density (Garms, 1973).

In onchocerciasis, the parasite O. volvulus microfilariae do not undergo self-multiplication in either the host or the vector (Nelson, 1970). The degree of infection is therefore dependent on the number of infective bites received by man in a unit time (infective biting rate) and the total number of infective larvae inoculated into man by the infective flies per unit time (transmission potential) (Duke, 1968a; Phillippon, 1977; Garms, 1978; Walsh, Davies and Cliff, 1981). Furthermore, the infective biting density and the transmission potential are dependent on many interrelated factors, viz; the longevity of the flies, their ability to support the development of O. volvulus, their degree of zoophily, and the size of the human population and availability of reservoir of microfilariae in the human population (Duke, 1968a). Prolonged longevity of infected flies thus ensures the developmnet of microfilariae to the infective stage and their subsequent transmission, while the tendency for flies to prefer animals to man may account for a low fly biting density on man. Man has been reported to be the natural host of O. volvulus. The size of the human population and availability of a reservoir of microfilariae in the human population therefore ensure the continuous inter-human transmission of

O. volvulus (Nelson, 1970). De sole and Kloos (1976), observed a high prevalence rate of onchocerciasis in an area with favourable breeding habitat for the vector and a large human population, with the later serving as a good reservoir of O. volvulus, while a contrary observation was made in an area with ideal breeding habitat but with sparse and scattered human population (thus providing a poor reservoir of O. volvulus). It therefore follows that the fly infective biting density and the transmission potential are affected by the human size and availability of a reservoir of microfilariae in the human population.

Pathogenesis and Pathology of onchocerciasis

The pathogenesis of onchocerciasis in man is not well understood and literature on the subject is scanty. However, there is a general agreement that the pathology in the skin, eyes and subcutaneous tissues is associated with the presence of microfilariae and not the adult worms (Nelson, 1970; 1981b; Bryceson, 1976; Garner, 1976; Anderson and Fuglsang, 1977). The pathology of the disease is due to the toxic effect and immunological reactions to dead microfilariae of O. volvulus but it is still not understood by what natural means, if at all, man is capable of killing microfilariae (Nelson, 1980; 1981b).

Ocular onchocerciasis

Ocular involvement in onchocerciasis is usually common in heavily infected persons especially those with head nodules (Duke and Anderson, 1972a; Fuglsang, Anderson and Marshall, 1976). Nelson (1981b) reported that the eyes of heavily infected persons become invaded with microfilariae when the skin microfilarial density exceeds 500/mg and reaches 10/mg in the facial skin. The invasion of the eye cornea and the subseqnet death of the microfilariae give rise to a cellular reaction around the dead microfilariae. Bryceson (1976), Thylefors (1978) and Nelson (1981b), observed that there is usually the accumulation of cells (histocytes and eosinophils) around the dead microfilariae which subsequently leads to disintegration and lysis, leaving a blurred greyish opacity called 'snowflake', 'fluffy' opacities or 'onchocercal punctate keratitis'. Futher invasion of the cornea by microfilariae (in large numbers) gives rise to sclerosing keratitis which is a permanent corneal damage. Duke (1972) and Thylefors (1978), observed that sclerosing keratitis usually starts at the 3 - 5 and 7 - 9 O'clock positions in the limbal zone of the cornea and spreeds firstly to the lower half and later to the whole cornea. Finally, when this damage extends up to the pupillary area and beyond, blindness sets in. This is the common cause of blindness which usually develops in the second decade of intense infection (Thylefors, 1978).

The involvement of the anterior eye is characterised by an inflamatory process around degenerating microfilariae. Although the inflamatory reaction is not clear, the presence of lymphoid cells and eosinophils is suggestive of an allergic process (Garner, 1976; Bartlett, et al, 1978; Thylefors and Rolland, 1979). Experimental evidence has shown that the process is at least in part, IgE-mediated and probably accounts for the presence of eosinophils (Bryceson, 1976; Garner, 1976). Anterior uveitis often seen in some patients is either granulomatous due to the direct microfilarial invasion of the iris and the ciliary body, or non-granulomatous due to response to free microfilarial antigens (Garner, 1976). The uveal involvement can lead to complications such as atrophy of the iris, anterior synechiae (with subsequent obstruction of the chamber angle, and glaucoma) and posterior synechiae (Thylefors, 1978). Glaucoma has been associated with ocular onchocerciasis and may account for many cases of blindness, even in the young age groups (Anderson and Fuglsang, 1977; Thylefors, 1978).

The involvement of the posterior segment takes the form of either inflamatory or atrophic lesions or both (Anderson, Fuglsang and Bird, 1976; Garner, 1976). The lesions of the posterior segment of the eye involve the optic nerve, the rectina and choroid. The optic nerve may show acute papillitis with oedema and congestion. Thylefors (1978), observed that this stage rapidly develops into permanent post-neuritic optic atrophy which is common in onchocerciasis.

Clinical features and Geographic difference

Onchocerciasis is generally characterised by a wide variety of skin changes, eye lesions, nodules, lymphatic pathology and some systemic effects. The most important lesions are those of the eyes which gradually lead to impairment of vision to complete blindness; these have already been presented above.

Skin changes

These are characterised by pruritis (itching), rash, wrinkling, thickening of the skin (lickenification) and hyperpigmentation (which lead to 'lizard' or 'crocodile' skins), depigmentation (which leads to 'leopard' skin), and skin atrophy (Nelson, 1970; Duke and Anderson, 1972a; Duke, 1974a). 'Leopard' skin is a common feature of the disease in some parts of Nigeria (Edungbola, Oni and Aiyedun, 1983); this is attributed to persistent skin scratching following bites of Simulium flies (Fuglsang, 1983).

Nodules

The accumulation of adult onchocercal worms in the tissue gives rise to subcutaneous nodules, 0.5cm-10cm in diameter (Duke, 1974a; Nelson, 1981b); a nodule may contain over 100 adult worms (Chandler and Read, 1961). Some nodules are subcutaneous and palpable, others are not, but lie between the muscles, against the capsules of joints or the periosteum of the bones. These give rise to deep-seated pains in patients (Duke and Anderson, 1972a; Duke, 1974a; Nelson, 1981b).

Lymphatic pathology

The infilteration of microfilariae and the drainage of microfilaria infected skin along the lymphatic system causes obstruction (Gibson and Connor, 1978). As a result, the lymph nodes (especially the femoral and inguinal glands) are enlarged giving rise to hanging groin, herniae, hydrocele, lymph scrotum and elephantiasis (Nelson, 1970; Connor, 1974; Duke, 1974a; Ripert et al 1977; Gibson and Connor, 1978).

Systemic effects

In heavily infected individuals, microfilariae gain access into the blood stream and finally into the various systems of the body like the glomeruli of the kidney (then to the urine), cerebrospinal fluid, the sputum and the optic nerve. However, the clinical and pathological significance of microfilariae in most of these organs and systems are not yet known (Duke, 1974a).

The clinical features presented above vary with respect to geographic regions. Studies have confirmed the existence of distinct strains or biological variants of O. volvulus showing difference in antigenicity (Bryceson, 1976), histology (Omar and Garms, 1981) and pathogenicity (Duke and Anderson, 1972b). These differences have given rise to the African and American, savanna and forest (in Africa) forms of onchocerciasis (Nelson, 1970; Duke, 1972; Anonymous, 1976). The biological variants are equally transmitted by the corresponding Simulium vectors, thus forming an Onchocerca - Simulium complex (Duke, Lewis and Moore, 1966; Duke, 1970; 1972). However, the efficiency of the transmitting vectors (in transmitting O. volvulus) and the host immune response may also play a part (Duke, 1974a).

In the Western Hemisphere, the disease is characterised by mild skin lesions. In Guatemala and Mexico, head nodules are common and the risk of ocular complications are grave while in Venezuala and South America, infections and ocular risk are less (Duke, 1974a). In the Yemen Arab Republic, the disease is associated with blackened skin lesions of sowda and with enlarged femoral glands (Merighi and Parrinello, 1969; Duke, 1974a).

The clinical features of the disease in West Africa vary with respect to the forest and Sudan savanna zones. In the former, the disease is characterised by skin and gland lesions, nodules, low microfilarial density and low ocular involvement, blindness rate is about 3°/o (Duke, 1974a). In the savanna, nodules, skin and gland lesions are less common, but microfilarial densities and ocular complications are high, while blindness rate range from 10-20% (Nelson, 1970; Anonymous, 1973a; 1978a; Anderson and Fuglsang, 1974).

Diagnosis

The diagnosis of onchocerciasis is based on the demonstration of O. volvulus microfilariae in the eye or the skin, or of adult worms in subcutaneous nodules (Duke and Anderson, 1972a). A diagnosis may be based on purely clinical findings or by immunological tests (Nelson 1970; Duke and Anderson, 1972a). The demonstration of microfilariae in the cornea or anterior chamber of the eye involves the use of a slitlamp or an ophthalmoscope; microfilariae in the skin are observed as they emerge from skin snips placed in physiological saline or distilled water. Diagnosis based on clinical grounds suffer two disadvantages, viz; the variable nature of the disease picture (Duke, 1972; Anonymous, 1966), and the tendency of other helminth infections to mimic onchocerciasis

(Nelson, 1970). Similarly, the immunological tests have proved non-specific and may therefore give rise to false positive results (Nelson, 1970; Duke and Anderson, 1972a). An indirect immunological test, the Mazzotti test, is recommended for suspected patients whose skin snip report is negative (Nelson, 1970).

Skin snipping

The most ideal method of diagnosis is the demonstration of microfilariae from the skin snips of suspected patients. This method has been used by several workers including Duke (1962b), Duke and Anderson (1972a), Brinkmann (1974), Buck (1974b), Kale, Bammeke and Ayeni (1974), Sowa and Sowa (1975), Schulz-key (1978), Albiez, Schulz-key and Brinkmann (1978) and Awadzi, Roulet and Bell (1980), but with some variation in the timing of the emergence of microfilariae, the size of the snipped skin and the body region from which the skin is snipped. These and other variations applied by individual workers has made the comparison of epidemiological data difficult. However, Kale (1978; 1981), recommended the reconstituted technique as most ideal for field investigations. This technique involves the use of a corneoscleral punch instrument with a 2-mm bite for snipping the skin. The skin is placed in two drops of 0.85°/o saline on a slide, left uncovered and kept wet for 1 hour after which a drop of 10°/o formal saline is added to arrest the continuous emergence of microfilariae. A count of the microfilariae is then taken immediately under a microscope; alternatively, the slide is allowed to dry and later reconstituted with one drop of distilled water at anytime the examination is desired. According to Kale (1981), the reconstitution and examination may be made several months later.

Therapy and complications

Nodulectomy

This is the systemic removal of skin nodules containing adult worms. This method of treatment is currently in practice in Guatemala where a mass denodulization campaign has been launched (Scharlau, 1981). By removing the nodules, the microfilarial density is kept below a critical level under which severe clinical manifestations do not occur. This practice has not been given much attention in Africa. This may be due to the fact that nodules are less common and often impalpable and difficult to find (Thylefors, 1978).

Chemotherapy

Although there are still no satisfactory drugs for the mass treatment of onchocerciasis, two drugs, Diethylcarbamazine Citrate, DEC, (Banocide, Hetrazan, Notezine, Carbicide, and 3799 R.P.), a microfilaricide with little or no macrofilaricidal effect, and Suramin (Bayer 205, Antrypol), a macrofilaricide with some microfilaricidal action, have been used for the treatment of onchocerciasis (Duke and Anderson, 1972a; Nelson, 1981b). The disadvantages of using these drugs for mass treatment is inherent in the toxic and allergic reactions they may produce in infected persons (Duke, 1972; 1974b; Tejan-Jallon, 1974; Anderson and Fuglsang, 1976; Bryceson, Warrell and Pope, 1977). For instance, pruritis, dermatitis, local lymphoidenitis, fever, headache, anorexia, malaise, hypertension and even deaths have been reported in cases treated with DEC (Duke and Anderson, 1972a; Nelson, 1981b), while Suramin has been reported (Fuglsang and Anderson, 1974; Nelson, 1981b), as being nephrotoxic, and in heavily infected persons, exfoleative dermatitis and death have been observed. In order to alleviate some of these adverse effects, Sowa and Sowa (1978) and Nelson (1981b) recommended that the drugs be administered in conjunction with an antihistamine.

It has been observed that treatment of individuals born and bred in low to moderate endemic areas of onchocerciasis gives rise to serious adverse effects associated with the drugs (Duke and Anderson, 1972a; Duke, 1974b; 1976). According to these authors, such individuals have struck a balance with the parasite and therefore show no disease symptoms. However, they recommended those with threatened eye lesions, severe skin reactions and heavy skin infection for treatment. At present, the combination of DEC and Suramin has been reported as the best treatment for onchocerciasis. A detail description of the mode of administration is discussed by Thylefors (1978).

Symptomatic treatment

Skin lesions

It has been observed (Duke and Anderson, 1972a) that itching skin may become secondarily infected from scratching. The lesions are best kept dry by liberal application of double-strength calamine lotion with 2°/o phenol added or with siccolam paste (B.D.N.), Ulcerated lesions may be cleaned out with eusol and dusted with a powder made from ground phthalysulphathalazole tablets. The lesions due to loss of elasticity and disturbance of lymph drainage i.e. hanging groin, herniae, hydroceles and scrotal elephantiasis, may required surgical treatment after the parasites have been eliminated.

Eye lesions

Damaging reactions in the eye due to parasitocidal treatment are unusual. However, should such treatment produce red eye, whether indicating an inflammation of the cornea and conjuctiva (keratoconjuctivitis) or of the iris and ciliary body (iridocyclitis) of onchocercal origin, Duke and Anderson (1972a), recommended the use of neomycin/betamethasone drops or ointment on 3 hourly basis until the inflammation is controlled. For secondary glaucoma and cataract, surgical treatment is recommended. Lesions of the posterior segment can be halted by eliminating O. volvulus while capsules of vitamin A, B complex or both can also be administered.

Prophylaxis and control

There are at present no known prophylactic drugs or vaccines against onchocerciasis. It has been reported that for over the past 50 years, man has been engaged in the control of the vectors of onchocerciasis through the use of insecticides (Davies, 1965; 1983; Jamnback, Duflo and Marr, 1970; Prentice, 1974; Ogata, 1981; Walsh, Davies and Cliff, 1981; Peterson, Adams and De Leon, 1983). In 1974, the largest blackfly control operation was launched in the Volta River Basin Area of West Africa with the World Health Organization (WHO) as the executing agency; this programme, which is expected to last 20 years is already reported to have encouraging results (Walsh, Davies and Cliff, 1981). However, it has been reported that Simulium larvae have developed some degree of chemical resistance to both chlorophoxim and temophos (Abate[R]), being used in the control operation (Crosskey and Lane, 1982). This therefore calls for the use of alternative larvicides.

Biological control has been tried and attempts at mass production of pathogens and parasites against the larvae and adult flies have been made (Service and Elouard, 1980; Couch and Paul, 1981; Finney, 1981; Nolan, 1981). For instance, laboratory and field studies have shown that Bacillus thuringiensis var isralensis, serotype H14 (ONR-60A/WHO 1897), is pathogenic to blackfly larvae including those of Simulium damnosum s.l. (Undeen and Berl, 1979; Colbo and Undeen, 1980, Lacey and Undeen, 1984). The practical field application of this bacterium in the control of S. damnosum s.l. is currently going on in the control operations of the Volta river Basin Area of West Africa especially in areas where chemical resistance has developed (Anonymous, 1982; 1983).

It has been observed that the construction of dams across rivers reduces the water velocity of such rivers upstream thereby discouraging the breeding of blackflies. However, poorly constructed dams with spillways may act as good breeding sites (Burton and McRae, 1965; Anonymous, 1966; Dubitskii, 1981). Duke and Anderson (1972a) and Nelson (1981b), have suggested the wearing of protective clothes and the avoidance of breeding sites especially at periods when biting densities are highest as personal protective measures against the disease.

These measures may not however be very applicable in Nigeria because the farming season (wet season) coincides with the period at which biting densities are highest (Crosskey, 1957, 1979).

Socio-economic importance of onchocerciasis

Onchocersiasis incurs great socio-economic losses to several communities affected by the disease. The degree of loss vary from one area to another depending on the endemicity of the disease which has been found to vary even within closely situated villages and towns. Observations made in the Upper Volta River Basin Area (Anonymous, 1973b), lead to the following endemicities; 0-9.9°/o sporadic endemicity; 10-39.9°/o low (hypo) endemicity; 40-69,9°/o medium (meso) endemicity; 70°/o and above high (hyper) endemicity.

The disease picture and severity are most visibly observed in hyperendemic areas where rates of onchocercal blindness range from 10°/o - 20°/o (Nelson, 1970; Anonymous, 1973b; 1978a). This blinding effect coupled with cases of impaired vision, intense body itching and the nuisance biting effect of *Simulium* flies keep a large sector of the population away from active farming activities; this fact lowers the capacity and crop output of the affected communities below subsistence level (Hamon and Hartman, 1973). Hunger, malnutrition and disease set in; the desertion of fertile farmlands generally associated with the river valleys follows (Hamon and Hartman, 1973; Buck, 1974a; Bradley; 1976; Le Berre et al, 1977). This finally leads to depopulation of already settled areas and over-crowding in less fertile upland areas; such movement disrupts the social and demographic stratification of the population (Anonymous, 1978a).

In most developing African countries, foreign labour force engaged in the construction industry (especially in the building of dams near Simulium breeding sites) are maintained at very considerable cost. Accordingly, contract costs are usually high to take care of overhead medical bills of such a labour force (Anonymous, 1966; Hamon and Hartman, 1973).

Because of the great socio-economic losses associated with onchocerciasis, the World Health Organization (WHO), in collaboration with seven West African countries, is currently engaged in the control of the disease in the Volta River Basin Area in order to reclaim deserted lands for onward resettlement of the population (Anonymous, 1973b; Walsh, Davies and Cliff, 1981).

In Nigeria, although studies on the socio-economic effects of onchocerciasis have not been given serious attention, the little information available indicates that the situation is similar to that in the Volta River Basin Area (Bradley, 1976; Crosskey, 1979; Edungbola, 1982).

Cases of blindness and the desertion of settlements have been reported (Bradley, 1976; Edungbola, 1982). It is now also known that the disease is endemic in many villages and towns than earlier thought, while the situation in most villages and towns still remains obscure.

In highlightening the dangers posed by the disease in Nigeria, Vajime (1982), in a review, draws on works done in Eastern and Western Africa to point a vivid picture of the havoc caused by the disease to man and the associated adverse effects on national economy.

In consideration of the great losses associated with the disease and the reported success of the on-going control programme in Volta River Basin Area, the Governments of Nigeria and other West African countries not already in the control programme have requested for the extension of the programme into their territories (Walsh, Davies and Cliff, 1981). According to the Nigerian Fourth National development plan report, a national onchocerciasis control programme (NOCP) is envisaged to be launched.

Bearing this in mind, this present study focuses on Simulium - onchocerciasis investigations in Dalle village near Kogun River. It is hoped that the investigation will shed light on the fly biting density, infective biting density and transmission potential in relation to the prevalence of disease.

Although the present work is limited in scope, it is hoped that the data obtained will contribute to the pool of information obtained from similar investigations in many parts of the country: it is expected that such collective data could serve as an estimate of base-line data for the multiplicity of onchocerciasis foci throughout the country.

CHAPTER THREE

MATERIALS AND METHODS

Preliminary Surveys

The choice of Dalle village near Kafanchan (Fig. 1) for this present study came after some preliminary surveys within the river systems of the Upper and Lower Jos Plateau, covering 3 states, namely, Bauchi, Kaduna and Plateau.

The surveys were carried out between August, 1983 to May, 1984 (10 months), in order to determine suitable breeding sites of *Simulium damnosum* s.l.. The visits to the rivers were prompted by published reports (Crosskey, 1956; 1979; 1981c; Braide and Aladesanmi, 1982; Uchay, 1982), of the presence of the disease, breeding sites or both.

The breeding sites were determined where the river flow was swift especially where the hard pre-cambrian rocks had surfaced to form the bed-rock of the river; thus creating rapids and falls. *Simulium* larvae and pupae were looked for on trailling vegetations, on stones and twigs (Plate I).

The rivers surveyed on the Jos Plateau include: Assob, Zagun, Ribon and Gada while Galma, Kogun, Mafara, Gurara, Sarkin Pawa and Mada, were surveyed in the Lower Jos Plateau (Fig. 2: Appendix 1).

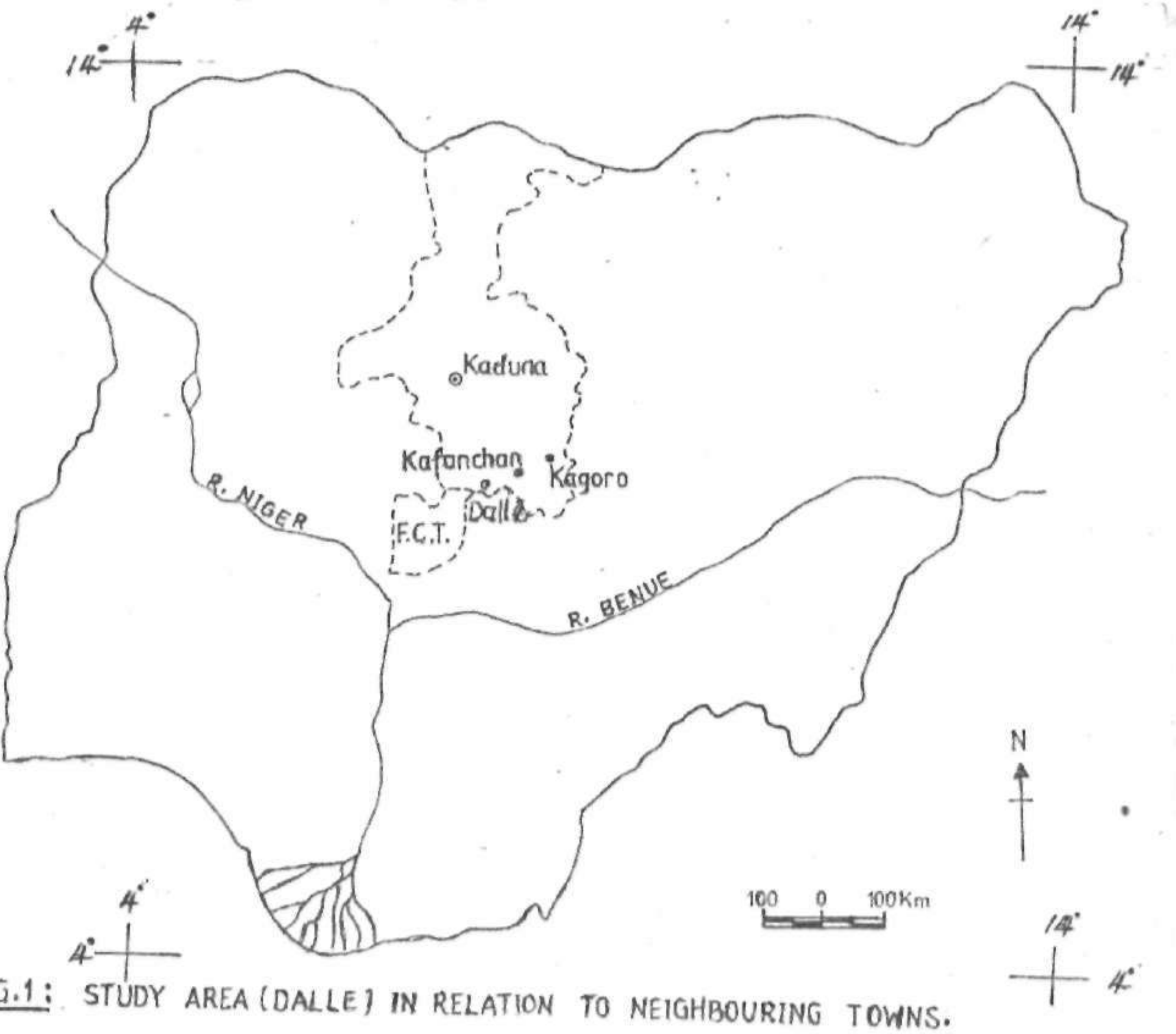

FIG.1: STUDY AREA (DALLE) IN RELATION TO NEIGHBOURING TOWNS.

FIG. 2: RIVER SYSTEMS SURVEYED FOR SIMULIUM DAMNOSUM S.L. BREEDING SITES (AUGUST 1983 - MAY 1984).

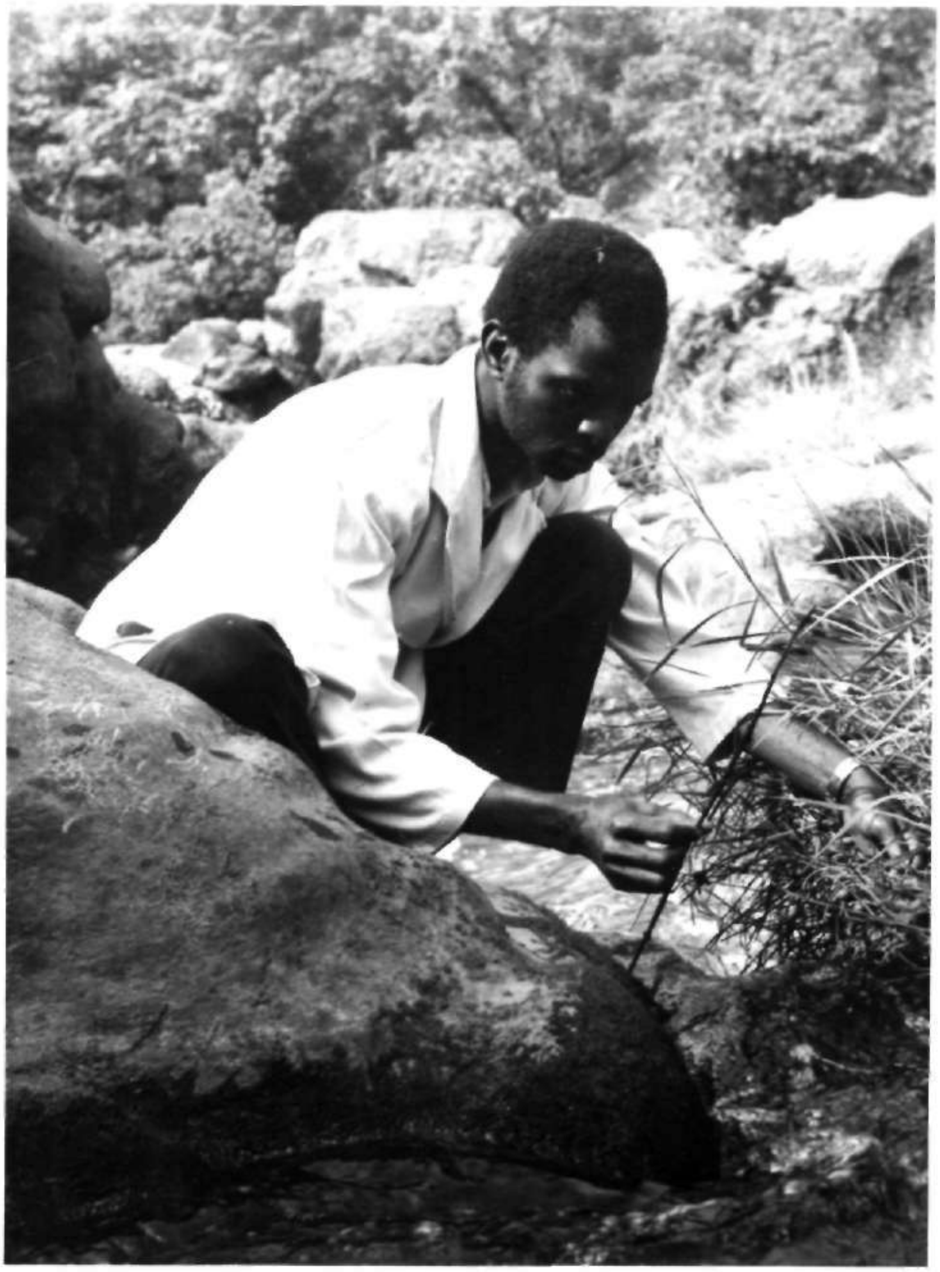

PLATE I: Simulium larvae and pupae (not visible in photography) collection on trailling vegetation.

Study Area

Dalle village.

Dalle village lies within latitudes $9^{O}24'N$- $9^{O}25'N$ and longitudes 8^{O} 13'E - 8^{O} 14 'E in the woodland Guinea savanna area of Nigeria. It is situated near Kogun River (Fig.3), in the Jema'a Local Government Area of Kaduna State. The area is bordered by mountain ranges from the north to the east while River Kogun from the north is bordered by thick forest gallery characteristic of river fringes of the Guinea savanna. Its rich agricultural farmlands extends from the west to the south along the river valley towards Jagindi. The whole Dalle inhabitants (men and women) are rural farmers; crops such as Guinea corn, maize, yams, cassava, rice and groundnuts are extensively grown.

Dalle village is situated about 120km on the South West of Jos; and about 40km from the western escarpment of the Jos Plateau around the Kafanchan/Kagoro area. It receives an annual conventional rainfall of about 1625mm (Croeskey, 1979); and has a population of about 500 people.

Kogun River

The Kogun river runs towards the north of Dalle village from its source at the Kagoro hills. The hills are

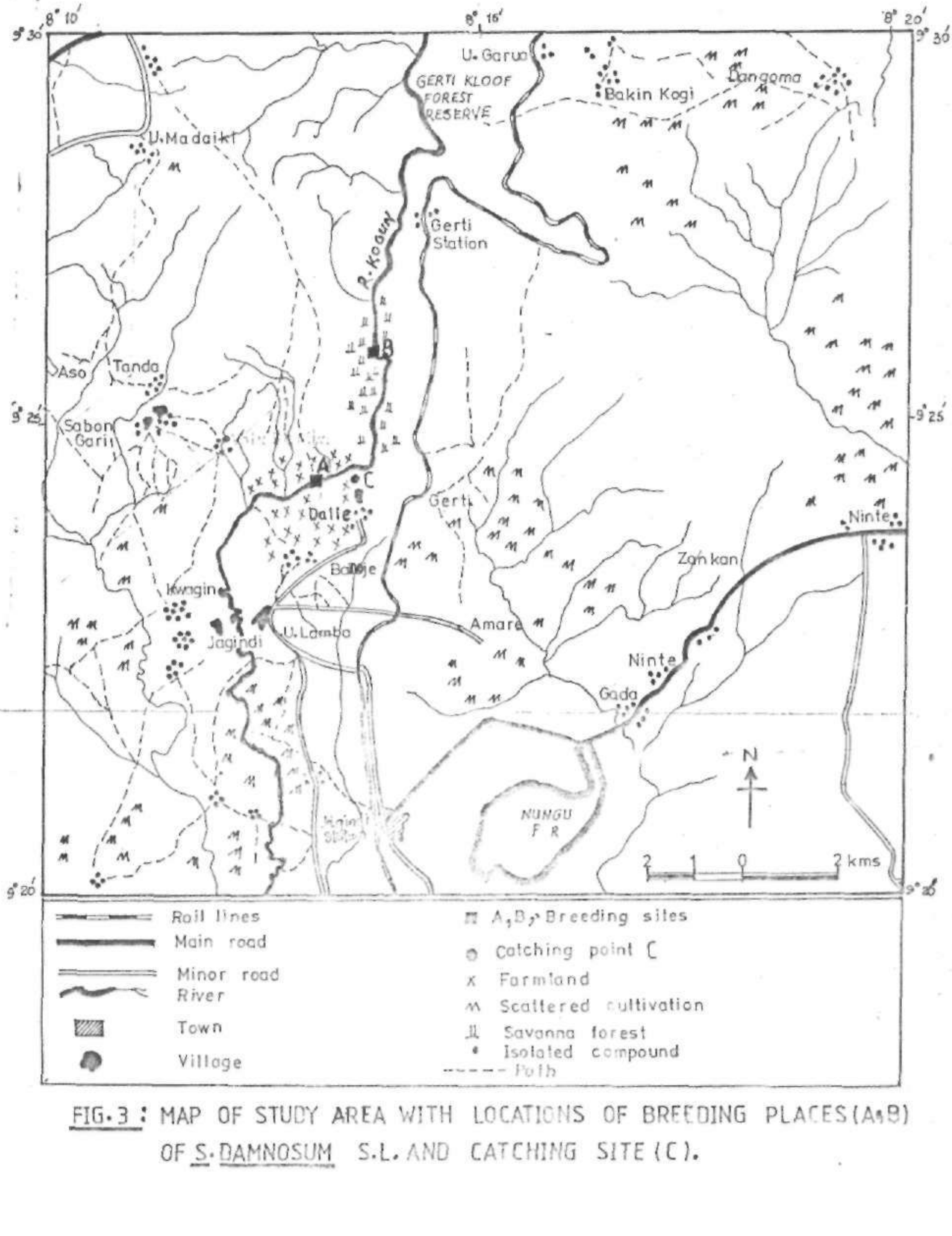

FIG. 3 : MAP OF STUDY AREA WITH LOCATIONS OF BREEDING PLACES (A & B) OF S. DAMNOSUM S.L. AND CATCHING SITE (C).

situated by the western escarpment of the Jos Plateau. As the river decends the hills, it forms numerous rapids and falls in areas where the hard precambrain rocks had surfaced along its length, noticeably at Kagoro, Matsirga village near Kafanchan, and near Dalle village at points A and B (Fig.3).

The Kafanchan/Kagoro area receives a conventional/relief (orographic) rainfall of about 1750mm per annum (Crosskey, 1979). The amount of rainfall received here determines to a greater extend the volume of water in the Kogun River as far as Dalle village, and even beyond. The high and frequent rainfall experienced in that area between July - September, is responsible for the flood experienced around Dalle village and beyond to the Fadamas.

Entomological investigation

Catching site

To determine the biting densities of S. damnosum s.l., fly catches were generally carried out weekly over a period of six months (June - August and October - December) at point C (Fig. 3). However, during the preparatory phase of this work, one week was lost in June. Catching point C is located on the bank of River Kogun, some 45 meters away from the nearest house north of the village. Although there was substantial breeding at points A and B, which were initially marked as catching sites, these points had to be abandoned early in June, in preference for C which featured a lot of farming activity and was said by the farmers to habour populations of biting flies.

Catching method

All fly catches were made using a human bait collector (Plate II). Four collectors worked alternatively on hourly basis from 0700 - 1800 hours local time. They wore short trousers to their knees or long trousers folded to their knees, and sat with bare legs on a chair placedunder a clear shaded area, catching all flies that settled on them. Flies were collected individually in plastic tubes (5cm by 1cm) and the numbers were recorded hourly. They were kept in a cool-box containing ice-blocks until needed. Hourly notes were made on rain.

PLATE II: Human Bait Collector collecting adult flies of S. damnosum s.l.

Dissecting methods

All flies caught were identified as female S.damnosum s.l. before they were dissected. Flies were dissected as described by Lewis (1957; 1958), Duke (1968a), and Reid (1981), in order to determine the parous rates and infections with O. volvulus. Flies that could not be dissected the same day were stored overnight in the refrigerator. Flies immobilized by cooling were killed by light pressure with forceps. The more active specimens were killed with chloroform vapour. Each fly was dissected (using Shute's needles) separately in a drop of saline containing a trace of liquid detergent under a compound dissecting microscope. After opening the abdomen, parous and nulliparous flies were easily identified by the presence of fat-body which was voluminous in the nullipars and absent or nearly so in the parous flies. This was further confirmed by examining the malphigian tubules. In the parous flies, they were opaque with transparent patches or completely transparent, while in the nulliparous flies, they were completely opaque (Lewis, 1957; Crosskey, 1958; 1973; Garms, 1973; Anonymous, 1976).

The head, thorax and abdomen were dissected separately and all the stages of develping larvae were recorded. All third-stages were recorded as infective; those that were observed in the head were recorded separately and used in computing the fly infective biting densities and transmission potential as formulated by Duke (1968a) and Walsh et al. (1978).

Parasitological investigation at Dalle village

The prevalence of O. volvulus was investigated in the population from children below the ages of one to the adults over 55. Skin snips were taken using the method described by Kale (1978; 1981). Using a corneosleral punch (E-2802, Holth Storz , Germany) with a 2mm bite, snips were taken from both sides of the iliac crest after sterilizing the area with a cotton swab containing absolute alcohol. The area was similarly sterilized after snipping. The snips were placed in 2 drops of 0.85°/o saline on a clean glass slide (7.5cm by 2.5cm). They were kept wet for one hour after which one drop of 10°/o formol saline was added. After, the slides were allowed to dry and later transported to the laboratory at Vom and examined the next day. Before examination, each slide was reconstituted by adding one drop of distilled water on the dry spot; the microfilariae that emerged were examined and counted under a compound microscope. The number of microfilariae that emerged from the two snips were averaged and recorded as microfilariae/snip/hour.

Prior to snipping, the name, sex, age, and occupation, of all individuals were recorded.

CHAPTER FOUR

RESULTS

Preliminary observations

The results obtained from the preliminary surveys are presented below and summarised in appendix 1: the collection sites are also presented below, marked in Fig. 2 and shown in Appendix 1.

River Assob (at Hawn Kibo near Assob falls, site 1).

This river was first visited on 25 August, 1983. The hard pre-combrain rocks form the bedrock of the river, creating rapids and falls. The river was fast flowing and laden with sediments. No single Simulium larvae or adult flies were available for collection.

The river was revisited on 3 November, 1983: a large number of S. hargreavesi, S. vorax, S. cervicornutum and few S. damnosum s.l. larvae were collected on trailling vegetation. No adult flies were caught.

River Assob (at Angwan Boka; 3-4km downstream from Assob falls, site 2).

A visit was made here on 3 November, 1983. The hard pre-cambrain rocks still form the bedrock of the river, creating rapids. S. damnosum s.l. and S. adersi larvae were collected on trailling vegetation. An average adult catch of 2 flies/man/day was made between 10 November, 1983 - 20

April, 1984, while an onchocerciasis prevalence rate of 8.4°/o was recorded in the inhabitants during a skin snip survey conducted on 14 February, 1984.

River Zagun (at Zagun village, site 3).

The river was visited on the 13 September, 1983. Several rapids were observed along the river especially where the hard pre-cambrian rocks had surfaced to form the bedrock of the river. Large numbers of S. hargreavesi larvae were collected on trailling vegetation. No adult flies were caught.

River Ribon (at Maijuju, site 4).

The river bed was devoid of the hard pre-cambria rocks, no Simulium larvae were collected when the river was visited on 2 November, 1983.

River Gada (at Gada village, site 5).

This river was visited on 14 November, and 6 December, 1983. The river bed was also devoid of the hard pre-cambrian rocks. The water level was low; S. hargreavesi larvae were collected on trailling vegetation at localised rapids created by fallen logs of trees and at sharp river bends. No adults flies were caught.

River Galma (near Kudaru, site, 6).

A visit was made here on 20 September, 1983. The pre-cambrian rocks form the bedrock of the river creating rapids where large numbers of S. damnosum s.l. larvae were found and collected on trailling vegetation. Adult S. damnosum s.l. were caught.

River Kogun (at Kagoro, site 7).

This river was visited on 27 September, 1983. The river has its source here. The hard pre-cambrian rocks form the bedrock of the river from Kagoro to a rail bridge near Matsirga 6-7km from Kagoro. As the river decends Kagoro hills, it flows swiftly forming several rapids and a fall at the bridge near Matsirga. Only few S. hargreavesi larvae were collected on trailling vegetation. The water was very clear and devoid of sediments.

River Kogun (at Dalle, site 8).

This site was visited on 10 May, 1984. The hard pre-cambrian rocks which characterise the river bed at its source had resurfaced over an extensive length of the river near Dalle village thus, creating numerous rapids and a fall (Plate III) at point B (Fig. 3). Large numbers of Simulium damnosun s.l. larvae and pupae were collected on trailling vegetation, adult flies were also caught biting men.

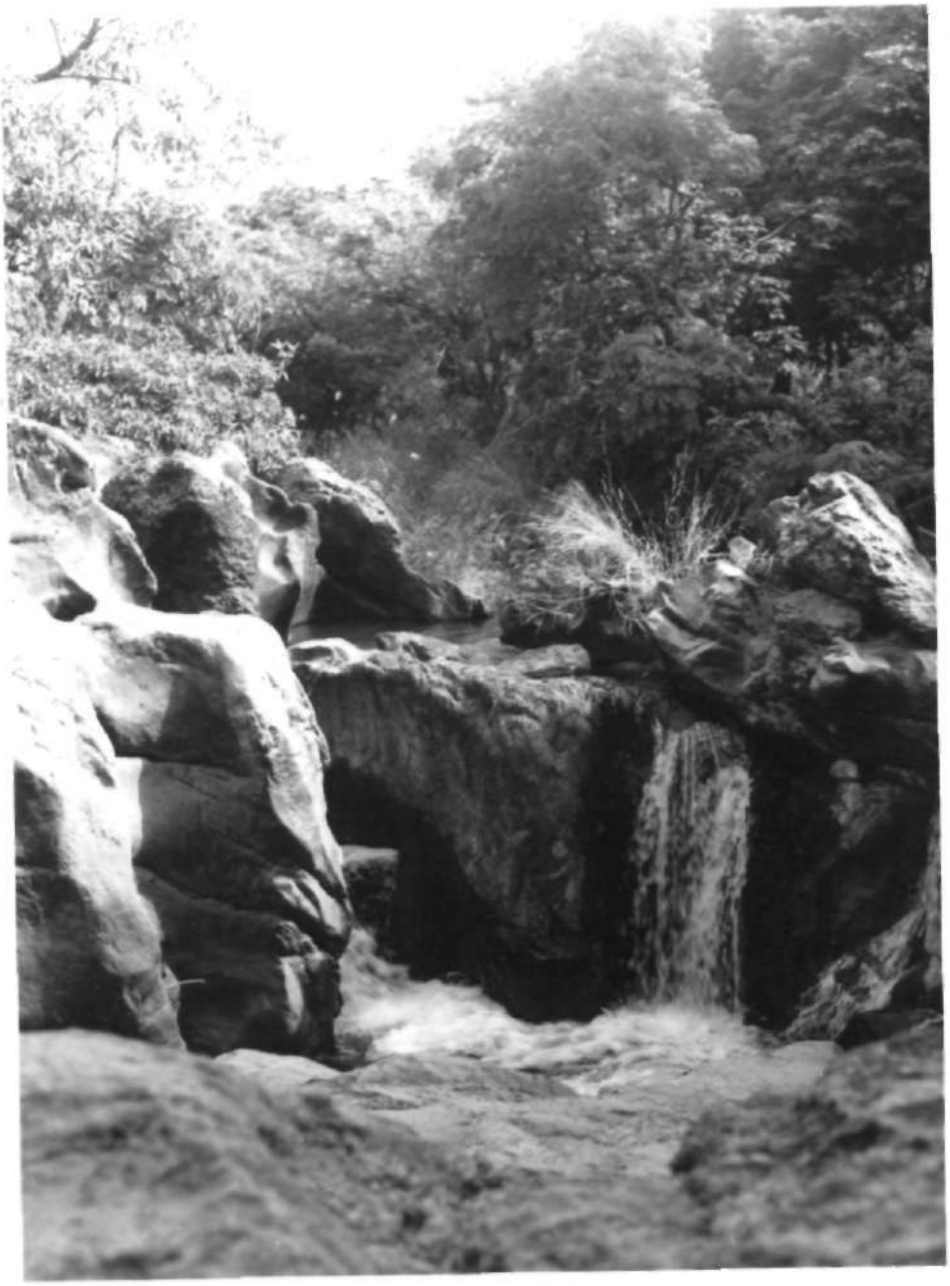

PLATE III: River Kogun near Dalle village flowing over the hard pre-cambrian rocks to form a waterfall.

River Mafara (near Mafara village, site 9).

The hard pre-cambrian rocks form a substantial length of the river bed, thus providing rapids and a fall. Large numbers of S. hargreavesi, S. vorax and a few number of S. damnosum s.l. larvae were collected on trailling vegetation when the site was visited on 13 December, 1983. No adult flies were caught.

River Gurara (near Gantan village, site 10).

This site was visited on 27th April, 1984. The river bed was devoid of the hard pre-cambrian basement rocks. The river was slow flowing and laden with sediments. No Simulium larvae were seen for collection.

River Sarkin Pawa (at Iri Station, site 11).

During a visit to the river on 12 May, 1984, no Simulium larvae were seen for collection. Rapids exist where the hard pre-cambrian rocks had surfaced to form the bedrock of the river. A local dam has been built across the river near the rail station.

River Mada (on Akwanga-Keffi road, site 12).

A visit was made here on 16 May, 1984. The pre-cambrian basement rocks form the bedrock of the river, creating several rapids. The water was very turbid and laden with sediments. No Simulium larvae were seen for collection.

Dalle Survey

Entomological Investigation

In this section of the investigation, results obtained were grouped into two categories, (a) June - August and (b) October - December, representing the wet and dry seasons respectively.

The fly biting density and transmission potential

During June - August, a total of 490 flies were caught and dissected (Table 1; Appendix 2). 226 of these were parous while 264 were nulliparous. Of the parous flies, 22 (9.7°/o) were infected with a total infective filarial (O. volvulus) load of 71 (33,23, 15 from the head, thorax and abdomen respectively). The total number of potentially infective parous flies (i.e. those on third or subsequent bloodmeal) was 194; the total fly biting density, infective biting density and transmission potential for this period were 4,193; 153 and 281 respectively (Appendix 2 and 3).

During October - December, a total of 198 flies were caught and dissected. 77 of these were parous while 121 were nulliparous. 8 (10.4°/o) of the parous flies were infected with a total infective fliarial load of 18 (5,10, 3, from the head, thorax and abdomen respectively). As shown in Appendix 2 and 3, the total number of potentially infective parous flies was 52/for the period; the total biting density, infective

TABLE 1: The results of dissection of *S. damnosum* s.l.

Period of Investigation	Total number of flies							Total number of infective larvae	
	Caught and age distribution	Dissected	Infected	Infected (%)	with third stage larvae only (a)	with developing infection only (b)	with mix infection (a.b)	in head region only	in head and body region
June 1984	161 Parous (P) 64 Nulliparous (N) 97	161	8	4.9* 12.5**	4	1	3	11	21
July 1984	138 P 72 N 66	138	5	3.6* 6.9**	2	1	2	8	10
August 1984	191 P 90 N 101	191	9	4.7* 10.0**	4	1	4	14	40
Total (June-August 1984)	490 P 226 N 264	490	22	4.4* 9.7**	10	3	9	33	71
October 1984	102 P 37 N 65	102	6	5.8* 15.2**	4	0	2	3	15
November 1984	71 P 30 N 41	71	2	2.8* 6.6**	0	1	1	2	3
December 1984	25 P 10 N 15	25	0	0.0* 0.0**	0	0	0	0	0
Total (Oct. -Dec. 1984)	198 P 77 N 121	198	8	4.0* 10.3**	4	1	3	5	18

* Based on total number of all flies.. ** Based on total number of parous flies

biting density and transmission potential were 1,532; 71 and 38 respectively.

Conventional rain typical at Dalle village introduced a bias on the hourly, daily and monthly fly catches in relation to parous and nulliparous flies during the wet season (Fig. 4 and 5). As can be seen in Fig. 4 and Appendix 2; with no rain experienced in June, the total number of flies caught per man per day was 54; this figure was reduced to 35 and 48 during the rainy months of July (with 2 hours of rain in the morning and 4 hours in the evening) and August (with 6 hours of rain in the morning) respectively.

Details of the various paramenters of S. damnosum s.l. and their derivation as formulated by Duke (1968a), are given in Appendix 2.

Fly Biting Cycles

From the wet and dry season observations represented above, it is clear that the fly biting densities, which showed both daily and monthly variations (Fig. 6A, B, C, D; Appendix 4), were higher in the rainy season. During this season, the highest biting density (85 flies) for both parous and nulliparous flies was observed in August between 1300 - 1600 hours (Fig. 6C; Appendix 4).

The total biting activity of parous flies show a sharp rise at about 1000 hours and reached a peak at 1300 - 1400 hours.

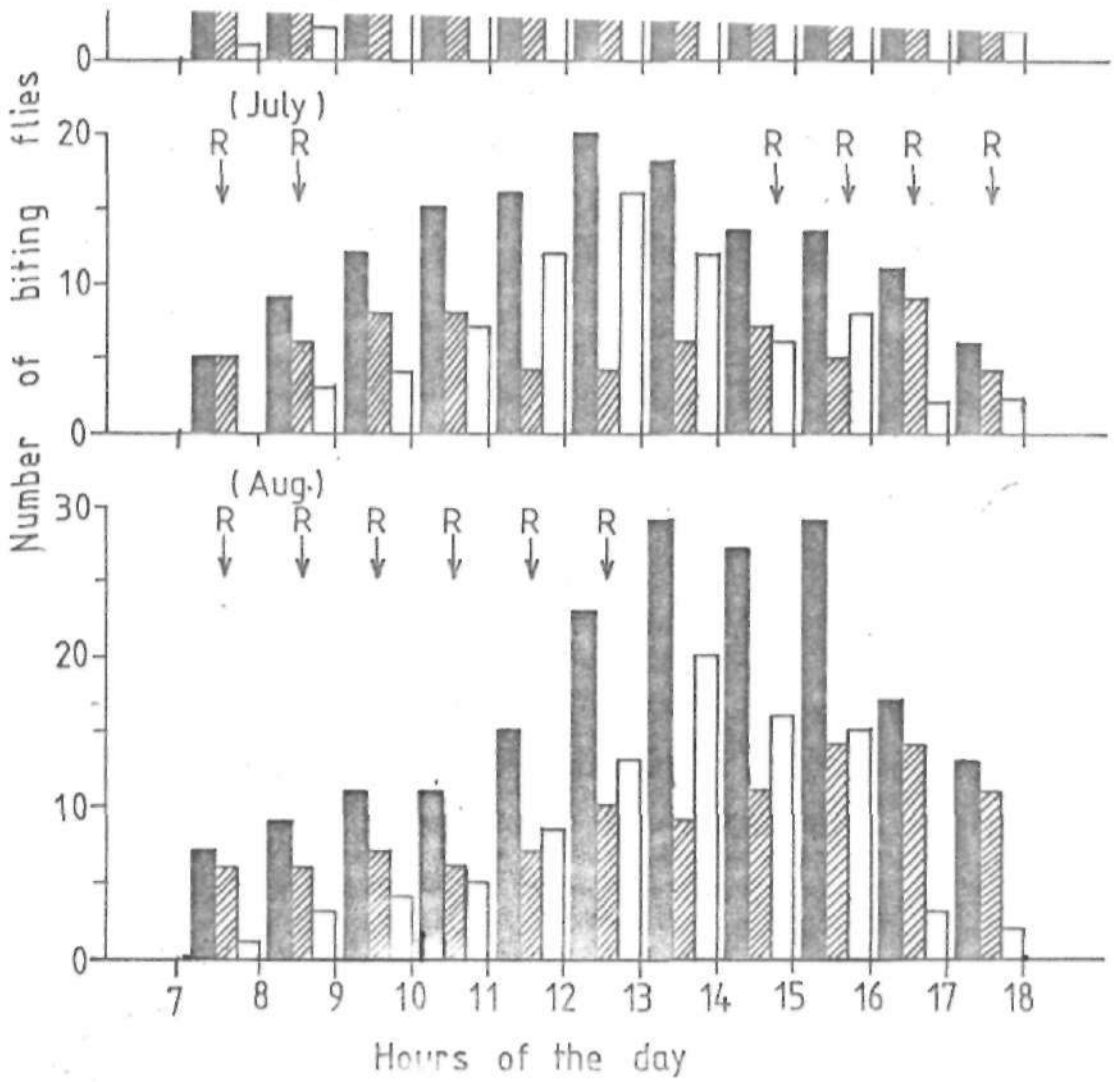

FIG. 4: RAIN EFFECT ON THE HOURLY FLY BITING DENSITY IN RELATION TO PAROUS AND NULLIPAROUS FLIES (JUNE - AUGUST 1984). [shaded] all flies; [open] parous flies; [hatched] nulliparous flies. R = rain.

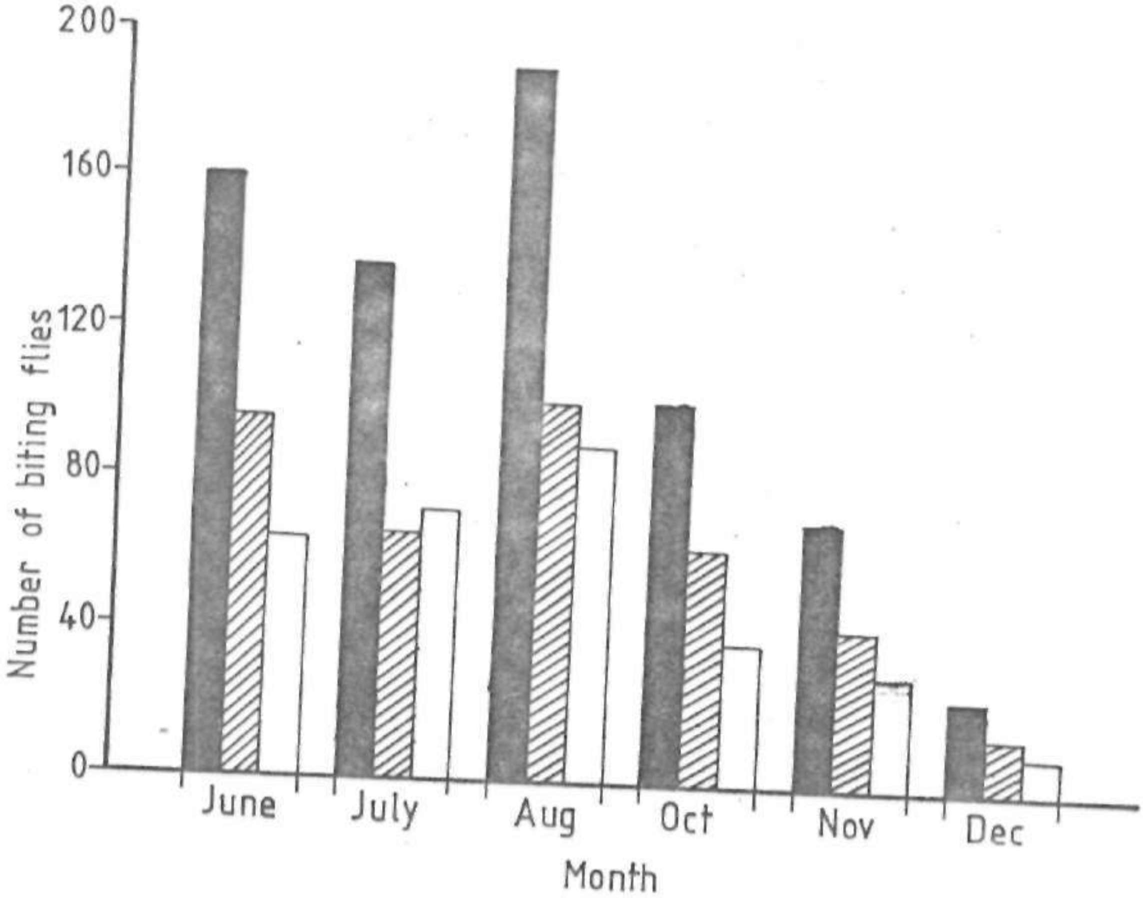

FIG. 5: MONTHLY VARIATION IN FLY BITING DENSITY.
all flies; nulliparous flies;
parous flies.

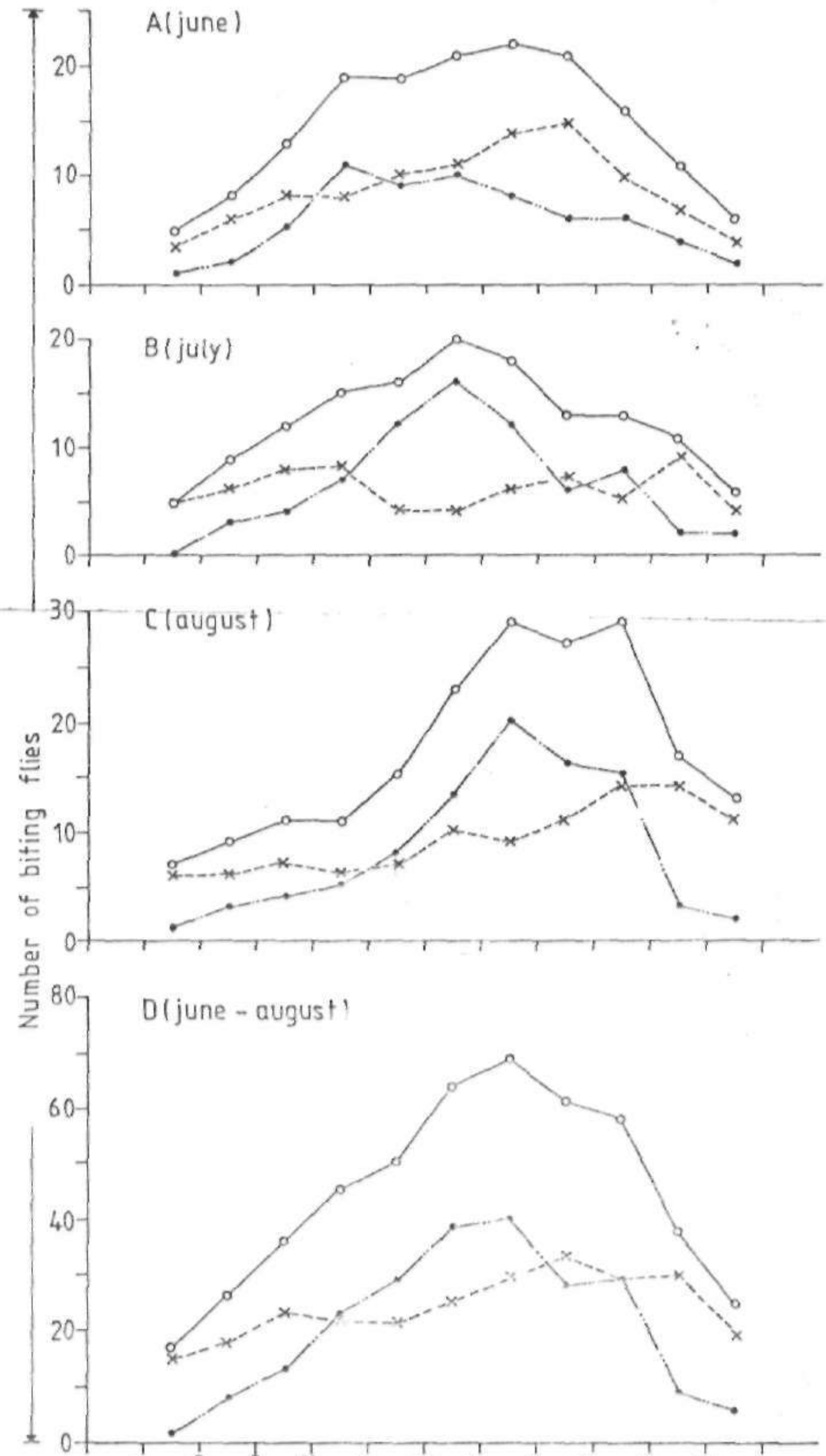

FIG. 6: HOURLY TOTAL FLY BITING DENSITY IN RELATION TO PAROUS AND NULLIPAROUS FLIES (JUNE - AUGUST).

o——o ALL FLIES; •——• PAROUS FLIES;

x----x NULLIPAROUS FLIES

In constrast, the total biting activity of nulliparous flies increased later in the day at about 1200 hours and reached a climax between 1400 - 1500 hours (Fig. 6D0.

During the dry season (October - December), the highest biting density (43 flies) for both parous and nulliparous flies was observed in October between 1200 - 1500 hours) (Fig. 7A; Appendix 4). The hourly and monthly variations in biting rates, clearly noticeable in the wet season for both catogories of flies, is also observed in the dry season (Fig. 7A, B, C).

The total activity of parous flies began slowly in the morning, rose sharply and reached a maximum at 1200 - 1300 hours.

Conversely, the total biting rate of nulliparous flies was slow but attained a steep peak between 1400 - 1500 hours (Fig. 7D).

A numerical comparism of parous flies and nullipars encountered throughout the study (Fig. 5), shows a monthly preponderance of nullipars; the only exception to this pattern was observed in July when more par ous flies were caught biting.

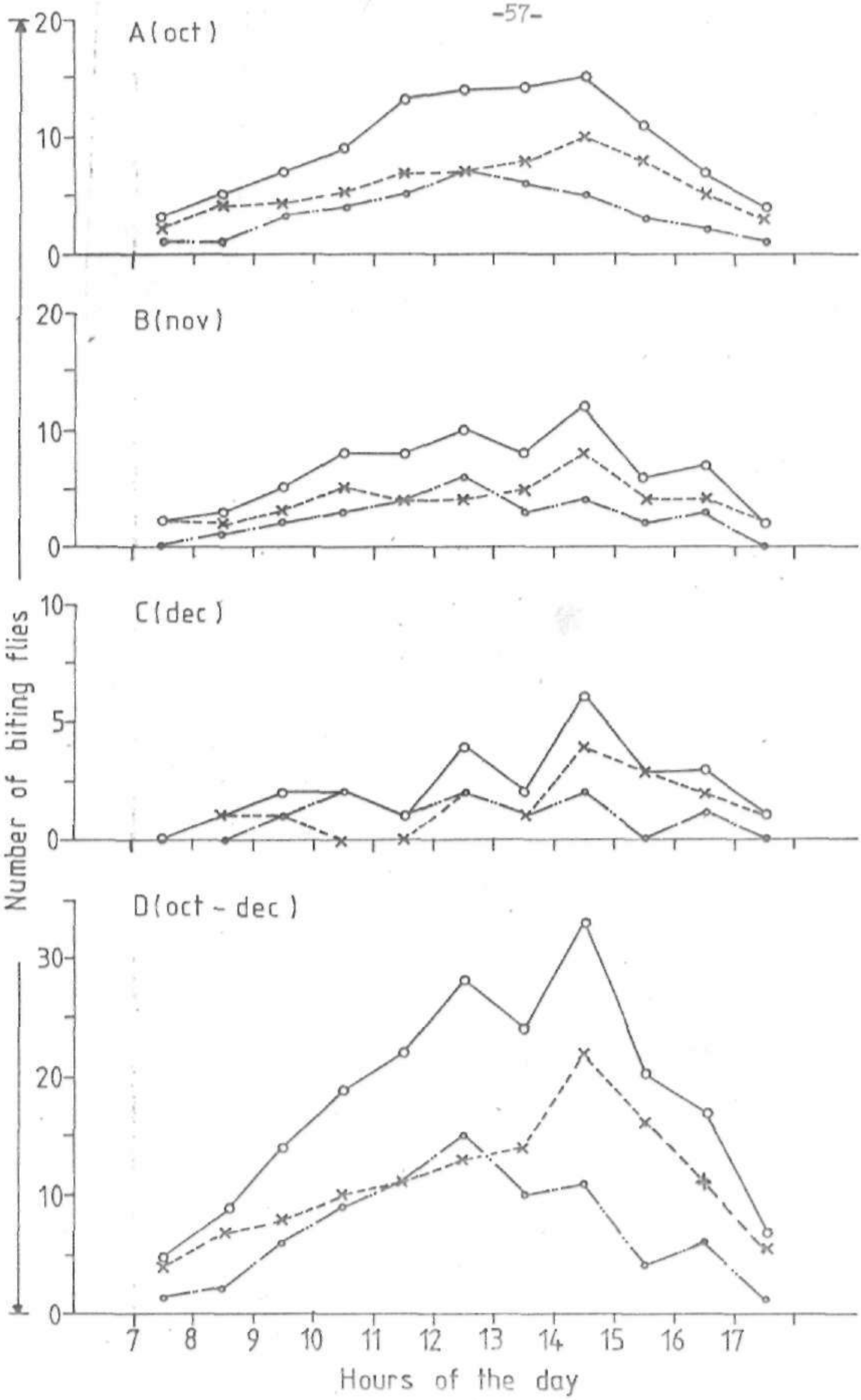

FIG. 7: HOURLY TOTAL FLY BITING DENSITY IN RELATION TO PAROUS AND NULLIPAROUS FLIES (OCT. - DEC.).
o——o ALL FLIES •—··—• PAROUS FLIES
×---× NULLIPAROUS FLIES

The prevalence of O. volvulus infection in the human population.

In a total population of 223 persons skin snipped, 94 (42.2°/o) and 129 (57.8°/o), were males and females respectively (Table 2). 21 (9.4°/o) were positive for onchocerciasis in the entire population; of this, 10 (10.6%) and 11 (8.5 %) were males and females respectively.

Although the intensity of infection, that is, the mean number of microfilariae/snip/hour was highest in the 26 - 35 year age group, the highest prevalence rate was found among the 56 year age group and above and higher in men than women. These observations are graphically shown in Fig. 8.

Table 2: Prevalence of Onchocerciasis by sex and Age groups

Age group (year)	Total No. Examined		No. with positive skin.		Precentage positive		Both sexes			
	Male	Female	Male	Female	Male	Female	Total No. Examined	Total positive	Percentage positive	Mean No of mf/snip
<1	1	1	0	0	0.0	0.0	2	0	0.0	0
1-5	13	21	0	0	0.0	0.0	34	0	0.0	0
6-15	33	19	1	1	3.0	5.3	52	2	3.8	1.5
16-25	14	31	1	0	7.1	0.0	45	1	2.2	2.0
26-35	13	29	2	2	15.4	6.9	42	4	9.5	7.8
36-45	3	7	2	1	66.7	14.3	10	3	30.0	6.8
46-55	4	11	0	4	0.0	36.4	15	4	26.7	3.6
>55	13	10	4	3	30.8	30.0	23	7	30.4	4.1
Total (<1->55)	94	129	10	11	10.6	8.5	223	21	9.4	4.8

Mf. Microfilariae

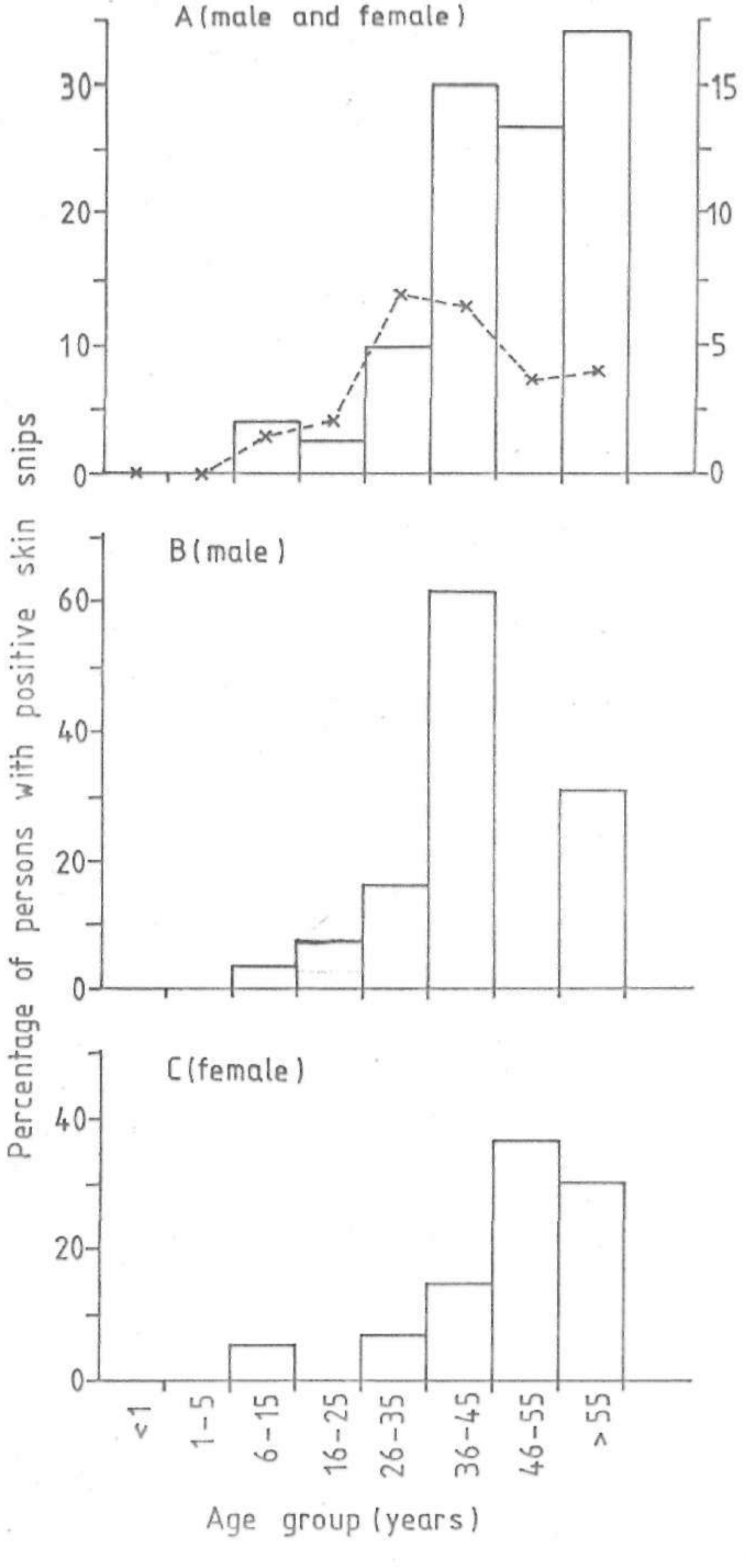

FIG. 8: PERCENTAGE OF PERSONS WITH POSITIVE SKIN SNIPS IN RELATION TO SEX AND AGE GROUPS (histograms) AND MICROFILARIAL DENSITY. x---x = Mean no. of mf/snip/hr.

CHAPTER FIVE

DISCUSSION

Preliminary Surveys

The results of the preliminary surveys have confirmed earlier reports (Crosskey, 1979; 1981c) that the breeding of Simulium damnosum s.l. is associated with rivers which flow over the surface of the hard pre-cambrian rocks. The results also indicate that breeding could also be adversely affected by fast but unsteady water currents laden with sediments; these factors, adverse water current and sediments reduce larval settlement sites and create conditions for larvae to be easily washed downstream (Baker, Mandiagu-ma Mapila and Batwanga, 1977). These factors probably account for the observations made at River Assob during the first visit on 25 August, 1983 and later on the 3 November, 1983. They may also be responsible for the number of active breeding sites of S. damnosum s.l. on the Lower Jos Plateau, in contrast to only one active breeding river (River Assob) on the Plateau escarpment to the apparent lack of a single breeding site on the Upper Jos Plateau.

It is important to note that the results of the surveys are interpreted with caution as they are not without bias. The time and number of visits made were very likely to have affected the results, as the presence or absence of Simulium is associated with other breeding parameters such as water temparature, water level, hydrogen ion concentration, the concentration of dissolved salts and the amount of organic matter; these factors are in turn influenced by the season of the year (Garms, 1973; Grunewald, 1981). Furthermore, man's interference along such river systems might have affected some of the factors responsible for good breeding in the past. For instance, in 1982, Gregory (Pers. Comm.) collected large population of man-biting adult flies and larvae at Iri Station (R. Sarkin Pawa; site 11), but probably as a result of a dam construction in the vicinity of site 11 (Fig. 2), no adult flies or larvae were found in th area during the present study.

It must be emphasised that the problem of logistics coupled with the bad roads associated with many of these rivers made complete survey of the river systems impossible. It is therefore possible that some Simulium breeding sites might have been overlooked during the surveys.

At the end of the preliminary surveys, the Galma River (at Kudaru) and Kogun River (at Dalle), proved suitable sites for good breeding of S. damnosum s.l.. Dalle village was finally chosen for this present work in preference to Kudaru as a result of published records of previous works done on the prevalence of the disease, fly biting densities and transmission of onchocerciasis at Kudaru (Crosskey, 1954; Amuta, 1981). No such records exist for Dalle village.

Dalle Survey

The principal aim of this investigation has been the elucidation on man-biting Simulium in relation to the prevalence of onchocerciasis at Dalle village. The discussion examines the results obtained in three main sections:

(a) the fly biting density, infective biting density and transmission potential with respect to the wet and dry seasons.

(b) the prevalence of onchocerciasis in the human population, and

(c) the relationship between disease prevalence and transmission potential.

(a) Fly biting density, infective biting density and transmission potential.

It is evident fromt the results obtained that S. damnosum s.l. breed favourably and bite in large numbers in the raining season (Table 1). This is manifested by a large preponderance of both categories of flies in the wet season. This finding supports earlier reports elsewhere in Nigeria (Crosskey, 1954; Amuta, 1981).

The wet season is also the period of greater transmission as indicated by the numbers of potentially infective parous flies, infective biting density and transmission potential (Appendix 2).

During the wet season, farmers in Dalle village are actively involved in farming activity thus increasing the chances of man-fly contact and subsequent transmission. In general, this period favours the radial dispersal of the flies (Le Berre, 1966; Garms, 1973).

In contrast, linear dispersion (Le Berre, 1966; Garms, 1973) of the flies is experienced in the dry season. During this period, man is less engaged in farming activities except towards November/December when crop harvest begins. In order words, unfavourable dry season conditions not only reduce fly populations but restrict fly movement.

Considering the biting densities (Appendix 2), what the results convey is that if it is possible to expose a human-being to the bites of the flies all day, from June - August and October - December, as is the case in this study, the person is likely to receive total infective bites of 153 and 71 during the wet and dry seasons respectively. Such a person is also likely in the course of these bites, to receive total filarial load of 281 and 38 during the wet and dry seasons respectively (Appendix 2).

A consideration of fly biting densities and infective biting densities lead to the concept of transmission potential as proposed by Duke (1968a) and modified by Walsh et al, (1978), The formulae have been used by several workers to study fly population trends and relate these to entomological and clinical findings. It is at present being used in assessing the effectiveness of the onchocerciasis control programme in the Upper Volta region and the tolerable level of O. volvulus transmission for resettlement area (Walsh, Davies and Cliff, 1981).

With the proposed concept, Duke (1968a), carried out similar but more extensive work over one year at Bolo, in the forest region of Cameroon.

The results show a higher preponderance in biting densities, infective biting densities and transmission potentials during the dry season. Duke attributed the fall in transmission in the wet season to the high fly mortality rates associated with adverse weather conditions like excessive rainfall, low temperature and least sun.

The results of this study at Dalle village in the Guinea savanna region of Nigeria are contrary to Duke's findings at Bolo in the forest zone of Cameroon. The climatic differences make data comparison difficult. It is worthy to note that although thepresent work is limited in scope, the results however serve as guide on the pattern of onchocercal transmission at Dalle.

It must however be noted that in calculating the transmission potentials for Bolo, Duke (1968a), assumed that all third stage larvae found in the flies were infective and would be subsequently inoculated into man when bitten by infective flies. Garms (1973), cautioned against such an assumption as it grossly over estimates the actual reality. Duke (1973), later observed that only 80°/o of the infective larvae actually leave a fly when it feeds and only 40°/o of infected flies shed all larvae to become negative. Therefore, in calculating the transmission potentials for Dalle village, only third stage larvae found in the head were considered in calculating the transmission potentials; this according to Walsh, et al (1978), closely approximates the number of third stage larvae to be transmitted.

The fly biting densities (Fig. 6 & 7), show hourly, daily and monthly variations with respect to the season. The highest number of flies caught was in August, the lowest was in December (Fig. 5).

The total fly catches made for each month during the rainy season was influenced by the hours of the day in which no flies were caught because of rain. This reduced the total fly catches for the month of July. Although rain fell in both July and August; it fell in July within the peak of nulliparous flies (Fig. 4). This affected the total number of nullipars (Fig. 5), and the biting times of parous and nulliparous flies.

However, if the results obtained from June - December are critically examined, it becomes obvious from the biting densities, infective biting densities, and transmission potentials, that the month of June was the most favourable time for fly breeding, biting and transmission (Appendix 2). This probably suggests that good breeding and transmission take place in the early rains. In the middle of the rains, the river is at flood due to excessive rainfall recorded in Dalle and around the river's source in the Kafanchan/Kagoro area. This created a fast but unsteady water current laden with sediments; these have been reported to reduce larval settling sites and cause detachment and subsequent wash-down of larvae downstream (Baker, Mandiagu-ma-Mapila and Batwanga, 1977). In addition, the excessive hours of rainfall forces adult flies to shelter thereby reducing man-fly contact and the survival rate of the flies (Duke, 1968a).

When, the total percentage of infected parous flies is considered with respect to the wet and dry seasons, a slight percentage increase in infected parous flies (10.4°/o dry season; 9.4°/o wet season) is observed (Table 1; Appendix 2). This implies that man-fly contact was also high in the dry season despite the fact that man is said to be less engaged in farming activity during this period.

This observation can be explained in the light of the fact that the inhabitants of Dalle village constantly frequent the river which serves as the source of water for their domestic use; this factor may account for the apparent increase in man-fly contact during the dry season.

However, the dry weather conditions adversely affected the survival rate of the flies as indicated by the number (52) of parous flies on third or subsequently bloodmeal, thus accounting for the low infective biting density (71) and transmission potential (38) (Fig. 2).

Fly biting cycle

The biting cycles of parous and nulliparous flies show marked differences, with the parous biting in the morning to early afternoon hours while nullipars bite largely during late afternoon hours (Fig. 6 and 7).

These phenomena have been previously observed (Lewis, 1956; Le Berre, 1966; Duke, 1968a; Disney, 1970), and explanatory suggestions based principally on intrinsic/ extrinsic factors including the time of adult emergence from the pupae have been advanced by Le Berre (1966), Duke (1968a) and Disney (1970).

This present work (Fig. 6 and 7; Appendix 4), supports the observation by Duke (1968a), that oviposition possibly takes place in the early morning or late in the evening of the previous day thus, explaining the wave of parous flies in search for blood meals at about 1000 hours. At this time of intense parous activity, nullipars may be mating and feeding on plant sugar before seeking for blood meals in the afternoon.

(b) The prevalence of onchocerciasis in human population

In this study, a 9.4°/o prevalence rate for onchocerciasis is observed, indicating that the disease is sporadic (Anonymous, 1973a) in Dallo village.

The results show an increase in the prevalence of the disease with age. Pre-school children (age of less than six years) did not show any infection. This observation suggests that the older age groups have had more exposure to the bites of the flies. Pre-school children do not actively participate in farming activities and generally do not frequent the river except when taken there. This lowered their chances of coming into contact with the flies thus, lowering also the chances of transmission. However, the long pre-patent period generally associated with the parasites in man (Duke, 1972; Anonymous, 1976), may also be attributed to this observation.

The increase in intensity of infection and its subsequent decline with increase in age, is in line with earlier findings reported by Bryceson (1976).

The decline can be explained in the light of the fact that as one advances into old age, one's activity with respect to farming strength reduces. This keeps man away from the farms thus lowering man's frequent contact with the flies and the intensity of infection; the intensity of infection is directly related to the number of infective bites received by man (Duke, 1968a). Also at this age, skin atrophy which is associated with the later part of the disease (Connor, 1974), may not favour the further establishment of the parasites. Added to this, the immune response (Somorin, Heiner & Ajugwo, 1977; Bartlett, et al, 1978), may also contribute appreciably in keeping down the intensity of infection.

In Dalle village, men and women actively participate in farming activities and there is no cultural/religious observance which absolutely restricts the women-folk to household work. The higher prevalence rate observed in men might be due to the more active and frequent involvement of the men on the farm.

(c) Relationship between disease prevalence and transmission potential

The infective biting density and transmission potential depend on many interrelated factors; one of which is the size of the human population and the availability of reservoir of microfilariae in the human population on which the flies feed (Duke, 1968a). These facts have been confirmed by Duke (1968c) and De Sole and Kloos (1976). Therefore, for any reasonable amount of transmission to take place, there must be a large and ready source of O. volvulus microfilariae.

The low prevalence of the disease (9.4°/o) coupled with a low intensity of infection (4.8mf/snip) in the village of Dalle is evident of a poor reservoir of microfilariae of O. volvulus in the small human population. The low figures may not account for the high number of infected flies (30; 4.4°/o) in the total fly population (688) caught biting man. The high infection rate is also reflected by the infective biting density (224) and transmission potential (319) obtained from a total fly biting density (5,725) for the whole period of investigation. It is therefore reasonable to suggest that the human population of the neighbouring villages such as Bonoje (Fig.3), may be contributing appreciably to the pool of O.volvulus reservior from which the flies feed.

The village of Dalle may be considered hypoendemic for onchocerciasis (Anonymous, 1973b; Philipon, 1977). The accepted values for tolerable levels of O. volvulus transmission for a resettlement area as practiced in the Volta River Basin Area, are Annual Biting Rates (ABR) of less than 1,000 and an Annual Transmission Potential (ATP) of less 100. For Dalle village, the total Biting Rate and Transmission Potential for just six months are shown to be higher than the tolerable level of O. volvulus transmission and this therefore calls for prompt control measures.

However, the complete lack of severe clinical manifestations (like impaired vision or blindness) among those found positive for onchocerciasis (Table 2), coupled with several cases of intense body itching and the low microfilarial load in the human population suggest that the 'forest' type of transmission which extends to greater part of the Guinea Savanna (Duke, Lewis and Moore 1966; Duke, 1970), may be taking place at Dalle.

Thus, further elucidation on this study requires data on opthalmological parameters and on the strain of O. volvulus being transmitted by S. damnosum s.l. in the village.

Summary and Conclusions

A six month study (June - August and October - December) was carried out on some aspects of man-biting Simulium in relation to the prevalence of onchocerciasis at Dalle village.

The biting densities of the flies are shown to vary with the hour, day, month and season. The highest biting density (191 flies) was recorded in August: the lowest (25 flies) in December. Higher biting and transmission was found favourable in the wet season especially in the month of June, thus indicating more favourable biting and transmission in the early rains.

The prevalence of onchocerciasis in the human population was low (9.4°/o): the highest prevalence rate was found in the age group of 56 years and above and higher in males than females. The intensity of infection was also low (4.8mf/snip), but generally increased with age reaching a peak in the 26-35 year age group.

The investigation concludes that the human population in Dalle village and other neighbouring villages may provide the reservior of O. volvulus, as indicated by the high infective biting density and transmission potential. It further concludes that the fall in biting densities in July and August (highest in June) may be attributed to rain effect at Dalle and the Jos Plateau area; and that the fall in onchocerciasis transmissibility in the dry season is attributed to the adverse dry season conditions on the survival rate of the flies.

The study suggests that the 'forest' type of transmission associated with the forest and greater parts of the Guinea Savanna regions may be taking place at Dalle village .

Further work involving opthalmological investigations and the strains of _O. volvulus_ transmitted in the area is required to verify this suggestion.

REFERENCES

Albiez, E. J., Schulz-Key, H. and Brinkmann, U.K. (1978). Comparative studies on the quantitative assessment of the microfilarial densities in onchocerciasis. Trans. Roy. Soc. Trop. Med. Hyg. 72, 417 - 419.

Amuta, E. U. (1981). Some aspects of the epidemiology of onchocerciasis in three villages, Kaduna State, Nigerian. M.Sc. thesis, Department of Zoology, University of Jos.

Anderson, J. and Fuglsang, H. (1974). 'Some aspects of ocular onchocerciasis', In: Research and control of onchocerciasis in the Western Hemisphere (Martins da Silva, M. edition), Pan American Health Organization, Scientific Publication, Washington, D. C., 30 - 34 pp.

Anderson, J. and Fuglsang, H. (1976). Ocular onchocerciasis 'at risk' patients and their treatment. Tropenmed. Parasit , 1. 13.

Anderson, J. , Fuglsang, H. (1977). Ocular onchocerciasis. Trop. Dis. Bull., 74, 257 - 272.

Anderson, J., Fuglsang, H. and Bird, A.C. (1976). The morphology of posterior segment lesions of the eye in patients with onchocerciasis. Trans. Roy. Soc. Trop. Med. Hyg., 70, 378 - 396.

Anonymous, (WHO), (1973a).

Onchocerciasis in th eVolta River Basin Area. Joint report of UNDP., F. A. O., I.B.R.D. and W.H.O. O.C.P./73.1.

Anonymous, (WHO), (1973b).

Onchocerciasis control in the Volta River Basin Area. Report of the preparatory Assistance Mission to Governments of: Dahomey, Ghana, Ivory Coast, Mali, Niger, Togo, Upper Volta. OCP/73.1 Geneva, 1973.

Anonymous, (WHO), (1966).

WHO expert committee on onchocerciasis. Wld. Hlth. Org. Techn. Rep. Ser., No. 335.

Anonymous, (WHO), (1976).

Epidemiology of onchocerciasis. Report of a WHO expert committee. WHO techn. Rep. Ser. No. 597.

Anonymous (WHO), (1977).

Species complexes in insects vectors of disease (Blackflies, Mosquitoes, Tsetse flies). WHO/VBC/77. 656; WHO/ONCHO/77 - 131 Mimeogr. Doc.

Anonymous (WHO), (1978a).

Onchocerciasis control Programme in the Volta Basin Area. Evaluation Report, Part 1.

Anonymous (WHO CONSULTATION), (1978b).

Species complexes in the Simuliidae, Bull. Wld. Hlth. Org., 56, 53 -61.

Anonymous (WHO), (1982).

Biological control of vectors of disease. Techn. Rep. Ser. No. 679 (6th report of WHO expert Committee on vector Biology and control).

Anonymous (WHO), (1983).

Integrated vector control. Techn. Rep. Ser. No. 688 (7th report of WHO Expert Committee on vector Biology and Control).

Awadzi, K., Roulet, H. and Bell, D. R. (1980)

The chemotherapy of onchocerciasis V:A standard method for the determination of microfilarial density in skin snips. Ann. Trop. Med. Parasit., 74. 363 - 366.

Bain, O. (1968).

Morphology of the larval stages of Onchocerca volvulus in Simulium damnosum and a redescription of the microfilaria WHO/ONCHO/68.70.

Baker., R. H. A., Mandiangu-ma-Mapila, L. and Batwanga, D. (1977).

'Entomology' In: Onchocerciasis in Zaire (Rodger, F.C. edition), Pergalmon Press, Oxford, 141 - 152 pp.

Barlett, A., Turk, J., Ngu, J., Mackenzie, C. D., Fuglsang, H. and Anderson, J. (1978)

Variation in delayed hypersensititity in onchocerciasis Trans. Roy. Soc. Trop. Med. Hyg., 72, 372 - 378.

Blacklock, D. B. (1926).

The development of Onchocerca volvulus in Simulium damnosum. Ann. Trop. Med. Parasit., 20, 1 - 40.

Bradley, A. K. (1976).

Effects of onchocerciasis on settlement in the middle Hawal valley, Nigeria. Trans. Roy. Soc. Trop. Med. Hyg. 70, 225 - 229.

Braide, E. I. and Aladesanmi, T. (1982).

Onchocerciasis in Iri, Kaduna State. Proceedings of The first National Conference on Onchocerciasis. Kaduna Nigeria. September, 1982. 21 pp.

Brinkmann, U. K. (1974).

A field method for the assessment of microfilarial densities in onchocerciasis. Proceed. third inter. cong. of Parasit. Vol. II, Facta Publication, Vienna, 603 - 604 pp.

Browne, S. G. (1976).

Onchocerciasis and the skin. South Afr. Med. J. 50. 301 - 304.

Bryceson, A. D. M. (1976).

What happens when microfilariae die? Trans. Roy. Soc. Trop. Med. Hyg. 70. 397 - 401.

Bryceson, A. D. M., Warrell, D. A. and Pope, H. E. (1977).

Dangerous reactions to treatment of onchocerciasis with diethlycarbamazine. Br. Med. J., 19. 742 - 744.

Buck, A. A. (1974a).

'Global problem of onchocerciasis and its economic impart' In: Research and control of onchocerciasis in the Western Hemisphere (Martins Da Silva, M. edition), Pan American Health Organization, Scientific Publication, Washington, D.C. 3 - 10 pp.

Buck, A. A. (1974b). (Editor).

Onchocerciasis, symptomatology, pathology, diagnosis WHO, Geneva.

Budden, F. H. (1956).

The epidemiology of onchocerciasis in Northern Nigeria. Trans. Roy. Soc. Trop. & Hyg. 50., 366 - 378.

Burton, G. J. and McRae, T. M. (1965).

Dam-spillway breeding of Simulium damnosum Theobald in Northern Ghana. Ann. Trop. Med. Parasit., 59, 405-412.

Chandler, A. C. and Read, C. P. (1961).

Introduction to Parasitology (Tenth edition) Toppan Printing Company, Singapore, 473 - 513 pp.

Chatterjee, K. D. (1976).

Parasitology. Chatterjee Medical Publishers, Calcutta, 187 - 188 pp.

Chitwood, B. G. and Chitwood, M. B. (1974).

Introduction to Nematology. University of Park Press, Baltimore.

Colbo, M. H. and Undeen, A. H. (1980).

Effect of Bacillus thuringiensis var isralensis on non-target insects in stream trails for control of Simuliidae. Mosquito News, 40. 368 - 371. (Quoted by Nolan, R. A., 1981).

Connor, D. H. (1974).

'Pathology of onchocerciasis and main geographic and local characteristics of the diseas' In:

Research and control of onchocerciasis in the Western Hemisphere (Martins da Silva, M. edition), Pan American Health Organization, Scientific Publication, Washington, D.C. 11 - 24 pp.

Convit, J. (1974).
'Onchocerciasis in Venezuela' In: Research and control of onchocerciasis in the Western Hemisphere (Martins da Silva, M. edition), Pan American Health Organization, Scientific Publication, Washington, D.C., 105 - 111 pp.

Corredor, A. (1974).
'Onchocerciasis in the Republic of Colombia' In: Research and control of onchocerciasis in the Western Hemisphere (Martins da Silva, M. w edition), Pan American Health Organization, Scientific Publication, Washington, D.C. 116 - 121 pp.

Couch, T. L. and Paul, A. L. (1981).
'Factors affecting industrialization of entomopathogens' In: Blackflies, the future for biological methods in integrated control. (Laird, M. edition), Academic Press London, 335 - 339 pp.

Crosskey, R. W. (1954).
Onchocerciasis in the Galma Valley Area Northern Nigeria, West Afr. Med. J., 3, 75 - 79.

Crosskey, R. W. (1956).
The distribution of Simulium damnosum Theobald in Northern Nigeria. Trans. Roy. Soc. Trop. Med. Hyg. 50, 379 - 392.

Crosskey, R. W. (1957).

Man - biting behaviour in _Simulium bovis_ De Meillon in Northern Nigeria, and infection with development developing filariae. Ann. Trop. Med. Parasit., _51_, 80 - 86.

Crosskey, R. W. (1958).

The body weight in unfed _Simulium damnosum_ Theobald and its relation to the time of biting, the fat-body and age. Ann. Trop. Med. Parasit., _52_, 149 - 157.

Crosskey, R. W. (1962).

The identification of the larvae of African _Simulium._ Bull. Wld. Hlth. Org., _27_, 3 483 - 489.

Crosskey, R. W. (1973).

Simulium (Blackflies, German: Kriebel-mucken) In: _Insects and other Arthropods of medical importance_ Smith, K. G. V. edition), British Museum (Natural History) London, 109 - 153 pp.

Crosskey, R. W. (1979).

An appraisal of current knowledge of _Simulium damnosum_ s.l. in the Federal Republic of Nigerian in relation to the development of an onchocerciasis control campaign. WHO/VBC/79.717; WHO/ONCHO/79. 150.

Crosskey, R. W. (1981a).

"Simuliid taxonomy - The contemporary scene" In: _Blackflies, the future for biological methods in integrated control._ (Laird, M. edition), Academic Press, London, 3-18 pp.

Crosskey, R. W. (1981b).

"Geographical distribution of Simuliidae". In: Blackflies the future for biological methods in integrated control. (Laird M. edition), Academic Press, London, 57 - 68.

Crosskey, R. W. (1981c).

A review of Simulim damnosum s,l. and human onchocerciasis in Nigeria, with special reference to the geographical distribution and the development of a Nigeria National Control Campaign. Tropenmed. Parasit. 32, 2 - 16.

Crosskey, R. W. and Lane, R. P. (1982).

'Dr. rene le berre and onchocerciasis control programme In: Antenna Bull. Roy. Ent. Soc. Lond. 6, 208 - 214.

Davies, J. B. (1965).

An assessment of the insectidal control of Simulium damnosum Theobald in Abuja Emirate, Northern Nigeria from 1955 - 1960. II: The effect on the incidence of onchocerca larvae in the vector. Ann. Trop. Med. Parasit., 59, 43 - 46.

Davies, J. B. (1974).

'Problems facing the control of Simulium species in the onchocerciasis zones of Mexico'. In: Research and control of onchocerciasis in the Western Hemisphere (Martins da Silva, M. edition), Pan American Health Organization, Scientific Publication, Washington, D.C., 96 - 99 pp.

Davies, J. B. (1983).

Onchocerciasis, vector control - 50 years ago. (correspondence). Trans. Roy. Soc. Trop. Med. Hyg. 77, 139 - 140.

De Solle, G. and Kloos, H. (1976).

Transmission patterns of onchocerciasis in South-West Ethiopia. Parasitologia, 18, 53 - 65. (Trop. Dis. Bull. 1978, 75, Abst. No. 2977, 1118 pp.).

Disney, R. H. L. (1970).

The timing of blood meal in Simulium damnosum Theobald. Ann. Trop. Med. Parasit., 64, 123 - 128.

Dubitskii, A. M. (1981).

"Blackflies control occasioned by major Hydroelectric project in the USSR from 1955 - 1965". In: Blackflies; the future for biological methods in integrated control (Laird, M. edition) Academic Press, London, 75 - 84 pp.

Duke, B. O. L. (1962a).

Studies on the factors influencing the transmission of onchocerciasis. II: The intake of Onchocerca volvulus microfilariae by Simulium damnosum and the survival of the parasite in the fly under laboratory conditions. Ann. Trop. Med. Parasit., 56, 255 - 263.

Duke, B. O. L. (1962b).

A standard method of assessing microfilarial densities in onchocerciasis survey. Bull. Wld. Health. Org. 27, 629 - 632.

Duke, B. O. L. (1966).

Onchocerca - Simulium complexes III: The survival of Simulium damnosum after high intakes of microfilariae of incompatible strains of Onchocerca volvulus, and the survival of the parasite in the fly. Ann. Trop. Med. Parasit., 66, 495 - 500.

Duke, B. O. L. (1967).

Infective filarial larvae other than Onchocerca volvulus in Simulium damnosum. Ann. Trop. Med. Parasit., 61, 200-205.

Duke, B. O. L. (1968a).

Studies on factors influencing the transmission of onchocerciasis. IV: The biting - cycles, infective biting density and transmission potential of 'forest' Simulium damnosum. Ann. Trop. Med. Parasit. 62, 95-106.

Duke, B. O. L. (1968b).

Studies on factors influencing the transmission of onchocerciasis. V: The stages of Onchocerca volvulus in wild 'forest' Simulium damnosum, the fate of the parasites in the fly, and the age distribution of the biting population. Ann. Trop. Med. Parasit., 62, 107 - 116.

Duke, B. O. L. (1968c).

Studies on factors influencing the transmission of onchocerciasis, VI: The infective biting potential of Simulium damnosum, in different bioclimatic zones and its influence on the transmission potential. Ann. Trop. Med. Parasit., 62, 164 - 170.

Duke, B. O. L. (1970).

Onchocerca - Simulium complexes. VI: Experimental studies on the transmission of Venezuelan and West African strains of Onchocerca volvulus by Simulium metallicum and Simulium exiguum in Venezuela. Ann. Trop. Med. Parasit., 64, 421 -431.

Duke, B. O. L. (1972).

Onchocerciasis. Brit. Med. Bull. 28, 66 - 71.

Duke, B. O. L. (1973).

Studies on factors influencing the transmission onchocerciasis VIII: The escape of infective Onchocerca volvulus larvae from 'forest' Simulium damnosum. Ann. Trop. Med. Parasit., 67, 95 - 99.

Duke, B. O. L. (1974a).

'Clinical manifestations and Geographic differences'. In: Research and control of onchocerciasis in the Western Hemisphere (Martins da Silva, M. edition), Pan American Health Organization, Scientific Publication, Washington, D. C., 25 - 29 pp.

Duke, B. O. L. (1974b).

'Treatment of Onchocerciasis'. . In: Research and control of onchocerciasis in the Western Hemisphere (Martins da Silva, M. edition), Pan American Health Organisation, Scientific Publication, Washington, D.C. 46 - 53 pp.

Duke, B. O. L. (1976).

Onchocerciasis and its therapy. Tropenmed. Parasit., 1, 11 - 14.

Duke, B. O. L. and Anderson, J. (1972a).

Onchocerciasis and its treatment. Trop. Doctor, 2, 107-144.

Duke, B. O. L. and Anderson, H. (1972b).

A comparison of the lesions produced inthe cornea of rabbit eye by microfilariae of the forest and Sudan - Savannah Strains of Onchoverca volmulus from Cameroon, I: clinical picture. Tropenmed. Parasit., 23, 354 -368.

Duke, B. O. L., Lewis, D. J. and Moore, P. J. (1966).

I: Transmission of forest and Sudan-Savanna strains of Onchocerca volvulus, from Cameroon by Simulium damnosum from various West African bioclimatic zones. Ann. Trop. Med. Parasit., 60, 318.

Dunbar, R. W. (1959).

The salivary gland chromosomes of seven forms of blackflies included in Eusimulium aureum Flies. Can. J. Zool., 37, 495 - 525.

Dunbar, R. W. (1966).

Four sibling species included in Simulium damnosum Theobald (Diptera: Simuliidae) from Uganda. Nature, London, 209, 597 - 599.

Dunbar, R. W. and Vajime, C. G. (1972).

The Simulium (Edwardsellum) damnosum complex: A report on cytotaxonomic studies to April, 1972. WHO/ONCHO/72.100. Mimeogr. Doc.

Edungbola, L. D. (1982).

Prevalence of onchocerciasis in Ile-Ife District, (Ifelodun), Kwara State, Nigeria. Trop. and Geogr. Med., 34, 231 - 239.

Edungbola, L. D., Oni, G. A. and Aiyedun, B.A. (1983).

Babana Parasitic disease project I: The study area and preliminary assessment of onchocercal endemicity based on the prevalence of 'leopard skin'. Trans. Roy. Soc. Trop. Med. Hyg. 77, 303 - 309.

Finney, J. R. (1981).

'Potential of mermithids for control and in vitro culture' In: Blackflies: The future for biological methods in integrated control (Laird M. edition), Academic Press, London, 325 - 333 pp.

Fuglsang, H. (1983).

'Leopard skin' and onchocerciasis (correspondence). Trans. Roy. Soc. Trop. Med. Hyg. 77, 881.

Fuglsang, H. and Anderson, J. (1974).

'Side effects of suramin'. IN: Research and control of onchocerciasis in the Western Hemisphere (Martins da Silva, M. edition), Pan American Health Organization, Scientific Publication, Washington, D.C. 54 - 57.

Fuglsang, H. Anderson, J. and Marshall, T. F. De C (1976).

The head nodule and onchocerciasis in Africa. WHO/VBC/76.124.

Garms, R. (1973).

Quantitative studies on the transmission of Onchocerca volvulus by Simulium damnosum in the Bong Range, Liberia. Tropenmed, Parasit., 24, 358 - 372.

Garms, R. (1978).

Use of morphological characters in the study of Simulium damnosum s.l. populations in West Africa. Tropenmed. Parasit., 29, 483 - 491.

Garms, R. and Kerner, M. (1982).

Anthropophily of Simulium damnosum s.l. and its role as a vector of human onchocerciasis in the Yemen Arab Republic. Tropenmed. Parasit., 33, 175 - 180.

Garner, A. (1976).

Pathology of ocular onchocerciasis: human and experimental. Trans. Roy. soc. Trop. Hyg. 70, 374 - 377.

Gibson, D. M. and Connor, D. H. (198 (1978).

Onchocercal lymphadenitis: Clinicopathologic study of 34 patients. Trans. Roy. Soc. Trop. Med. Hyg. 72, 137 - 154.

Gibson, D. M. and Dalmat, H. (1952).

Three new potential intermediate hosts of human onchocerciasis in Guatemala. Am. J. Trop. Med. Hyg. 1., 848 - 851.

Gordon, R. M. and Lavoipierre, M. M. J. (1962).

(The family Simuliidae'. IN: Entomology for students of Medicine, Blackwell Scientific Publications, London, 140 - 147 pp.

Grunewald, J. (1981).

'Hydro-chemical and Physical characteristics of the larval sites of species of the Simulium damnosum complex'. In: Blackflies: The future for biological methods in integrated control (Laird M. edition), Academic Press, London, 227 - 235 pp.

Hamon, J. (1974).

'Onochocerciasis vectors in the Western Hemisphere', In: Research and control of onchocerciasis in the Western Hemisphere (Martins da Silva, M. edition), Pan American Health Organization, Scientific Publication, Washington, D.C., 58 - 68 pp.

Hamon, J. and Hartman, L. (1973).

Onchocerciasis - Poverty and Blindness. Magazine Wld. Hlth. Org. 1 - 11.

Haseeb, M. A., Satti, M. H. and Sheriff, M. (1962).

Onchocerciasis in the Sudan. Bull. Wld. Hlth. Org., 27, 609 - 615.

Hashiguchi, Y., Kawabata, M., Ito, S. and Recinos, M. M. (1981).

Limited fly load and development of Onchocerca volvulus microfilariae in Guatemalan Simulium ochraceum. J. Halminth, 55, 189 - 196.

Jamnback, H. (1976).

Simuliidae (Blackflies) and their control. WHO/VBC/76. 653. Mimeogr. Doc.

Jamnback, H., Duflo, T. and Marr, D. (1970).
Aerial application of larvicides for control of Simulium damnosum in Ghana - a preliminary trial. WHO/VBC/70. 181; WHO/ONCHO/70.79. Mimeogr. Doc.

Kale, O. O. (1978).
A simplified technique for counting onchocercal microfilariae in skin snips. Bull. Wld. Hlth. Org. 56, 133 - 137.

Kale, O. O. (1981).
Onchocerciasis: ways of improving the reconstituted method of counting microfilariae in skin snips. Trans. Roy. Soc. Trop. Med. Hyg. 75, 101 - 102.

Kale, O. O., Bammeke, A. O. and Ayeni, O. (1974).
An evaluation of skin snip techniques used in the quantitative assessment of microfilarial densities of Onchocerca volvulus. Bull. Wld. Hlth. Org. 51, 547 - 549.

Kurtak, D. C. Raybould, J. N. and Vajime, C. G. (1981).
Wing tuft colours in the progeny of single individuals of Simulium squamosum (Enderlein). Trans. Roy. Soc. Trop. Med. Hyg., 75, 126.

Lacey, L. A. and Undeen, A. H. (1984).
Effect of formulation, concentration and application time on the efficacy of Bacillus thuringiensis (H-14) against blackfly (Diptera: Simuliidae) larvae under natural conditions. J. Economic Ent., 77, 412-418. (Review of Applied Entomol. 1984, 72 (12), Abstr. No. 3233).

Le Berre, R. (1966).

Contribution a l'etude biologique et ecologique de Simulium damnosum Theobald, 1903 (Diptera: Simuliidae). Men. ORSTOM. 17, 1-204. (Quoted by Disney, R. H. L. 1970).

Le Berre, R. Walsh, J. F., Davies, J. B., Philippon, B. and Garms, R. (1977).

Control of onchocerciasis: medical entomology - a necessary pre-requisite to socio-economic development. Trans. Roy. Soc. Trop. Med. Hyg. Medical Entomology Centenary, Symposium proceedings, London, 70 - 75 pp.

Lewis, D. J. (1956).

Biting times of parous and nulliparous Simulium damnosum Nature, London, 178, 98.

Lewis, D. J. (1957).

Aspects of the structure, Biology and Study of Simulium damnosum. Ann. Trop. Med. Parasit., 51, 340 - 358.

Lewis, D. J. (1958).

Observation on Simulium damnosum Theobald at Lokoja in Northern Nigeria. Ann. Trop. Med. Parasit., 52, 216 - 231.

Magor, J. I. and Rosenberg, L. J. (1980).

Studies of winds and weather during migration of Simulium damnosum Theobald (Diptera: Simuliidae), the vector of onchocerciasis in West Africa. Bull. ent. Res. 70, 693-716.

Mallen, M. S. (1974).

Onchocerciasis in Mexico'. In: Research and control of onchocerciasis in the Western Hemisphere (Martins da Silva, M. edition), Pan American Health Organization, Scientific Publication Washington, D.C., 112 - 115 pp.

Marroquin, H. F. (1974).
'Robles' disease (American onchocerciasis) in Guatemala', In: Research and control of onchocerciasis in the Western Hemisphere (Martins da Silva, M. edition), Pan American Health Organization, Scientific Publications Washington, D. C., 100 - 104.

Meredith, S. E. O. (1982).
Enzyme identification of Simulium damnosum s.l. caught biting man. Ann. Trop. Med. Parasit., 76, 375 - 376.

Merighi, B. and Parrinello, A. E. (1969).
Presenza di Simulium damnosum Theobald (Diptera: Simuliidae) in Yemen. Ann. First Super. Sanita. 5. 197-199

Markell, E. K. and Voge, M. (1976).
Medical Parasitology. (Fourth edition), W. B. Saunders company, London, 266 - 304 pp.

Martinez-Palomo, A. (1978).
Ultrastructural characterisation of Onchocerca volvulus microfilaria. J. Parasitol. 64, 127 - 136.

Martinez-Palomo, A. and Martinez-Baez, M. (1977).
Ultrastructure of the microfilaria of Onchocerca volvulus from Mexico. J. Parasitol. 63, 1007 - 1018.

Moraes, M. A. P. (1974).

'Onchocerciasis in Brazil', In: Research and control of onchocerciasis in the Western Hemisphere (Martins da Silva M. edition), Pan American Health Organization, Scientific Publication, Washington, D. C., 122 - 128 pp.

Neafie, R. C. (1972).

Morphology of Onchocerca volvulus. Am. J. Clin. Path. 57, 574 - 586.

Nelson, G. S. (1970).

'Onchocerciasis'. In: Advances in parasitology, 8, 173-224.

Nelson, G. S. (1981a).

Issues in filariasis - a century of enquiry and a century of failure. Acta Tropica, 38, 197 - 204.

Nelson, G. S. (1981b).

Filarial infections. International Medicine, 1, 77-82.

Nolan, R. A. (1981).

"Mass production of pathogens", In: Blackflies: the future for biological methods in integrated control (Laird, M. edition), Academic Press, London, 319 - 324.

Ogota, K. (1981).

'Preliminary report of Japan-Guatemala onchocerciasis control pilot project'. In: Blackflies: the future for biological methods in integrated control. (Laird, M. edition), Academic Press, London, 105 - 115.

Omar, M. S. and Garms, R. (1977).
Lethal damage to Simulium metallicum following high intakes of Onchocerca volvulus microfilariae in Guatemala. Tropenmed. Parasit. 28, 109 - 119.

Omar, M. S. and Garms, R. (1981).
Histological differentiation of filarial larvae found in Simulium damnosum s.l. in West Africa, Tropenmed. Parasit. 32, 259 - 264.

Parsons, A. C. (1909).
Filaria volvulus Leukart, Its distribution, structure and pathological effects. Parasitol. 1, 359 -368.

Peterson, B. V. and Dang, P. T. (1981).
'Morphological means of separating siblings of the Simulium damnosum complex (Diptera: Simuliidae), In: Blackflies: the future for biological methods in integrated control (Laird, M. edition), Academic Press, London, 45 - 56.

Peterson, B. V., Adames, A. J. and De Leon, L. (1983).
Bionomics and control of Blackflies (Diptera: Simuliidae) at the Fortuna Hydroelectric project, Panama, J. Med. Entomol., 20, 399 - 408.

Philippon, B. (1977),
A study of the transmission of Onchocerca volvulus by Simulium damnosum in tropical Africa. Travaux et Documents ORSTOM., No. 63, 308 pp (Trop. Dis. Bull. 1978, 75, Abstr. No. 675).

Poinar, G. O., Jr. (1977).

A synopsis of nematodes occuring in blackflies (Diptera: Simuliidae). Bull. Wld. Hlth. Org., 55, 509 - 515.

Prentice, M. A. (1974).

'Simulium control program in Uganda'. In: Research and control of onchocerciasis in the Western Hemisphere (Martins da Silva, M. edition), Pan American Health Organization, Scientific Publication, Washington, D.C. 87 - 95 pp.

Quillevere, D. and Sechan, Y. (1978).

Morphological identification of Simulium squamosum and Simulium yahense. Trans. Roy. Soc. Trop. Med. Hyg. 72, 99 - 100.

Raybould, J. N. and White, G. B. (1979).

The distribution, bionomics and control of onchocerciasis vectors (Diptera: Simuliidae) in Eastern Africa and the Yemen, WHO/VBC/79.706: WHO/ONCHO/79.149. Mimeogr. Doc.

Reid, G. D. F. (1978).

Cibarial armature of Simulium vectors of onchocerciasis. Trans. Roy. Soc. Trop. Med. Hyg., 72, 438.

Reid, G. D. F. (1981).

Studies on British species of Simulium in relation to the transmission of onchocerciasis in the Laboratory. Ph.D. thesis, University of London.

Renz, A. and Wenk, P. (1983).

The distribution of microfilariae of <u>Onchocerca volvulus</u> in the different body region in relation to the attacking behaviour of <u>Simulium damnosum</u> s.l. in Sudan Savannah of Northern Cameroon. Trans. T Roy.Soc. Trop. Med. Hyg. <u>77</u>, 748 - 752.

Ripert, C., Reidel, D., Yang, R., Founda, Onana, A. and Zimflou, I. A. (1977).

Epidemiological study of onchocerciasis in five villages of the Sanaga Valley (Cameroon). Bull. Soc. Path. Exot., <u>70</u>, 178 - 186. (Trop. Dis. Bull. 1978, <u>75</u>, Abstr. No.2976).

Rothfels, K. (1981).

'Cytotaxonomy: Principles and their application to some Northern species-complexes in Simulium', In: <u>Blackflies: the future for Biological Methods in integrated control</u> f (Laird, M. edition), Academic Press, London, 19-29 pp.

Sasa, M. (1976).

'Filariasis due to <u>Onchocerca volvulus</u>'. In: <u>Human Filariasis</u>. University Park Press, Baltimore, 149 -189 pp.

Scharlau, G. (1981).

Onchocerciasis - Chemotherapy: a risk approach. Trop. Doctor, <u>11</u>, 8 - 14.

Schulz-key, H. (1978).

A simple technique to assess the total number of Onchocerca volvulus microfilariae in skin snips. Tropenmed. Parasit., 29, 51 - 54.

Service, M. W. (1980).

'Blackflies (Diptera: Simuliidae)'. In: A guide to medical entomology. MacMillan Press London, 71 - 77 pp.

Service, M. W. and Elouard, J. M. (1980).

Serological identification of the predators of the complex of Simulium damnosum Theobald (Diptera: Simuliidae) in the Ivory Coast. Bull. ent. Res., 70, 657 - 663.

Somorin, A. O., Heiner, D. C. and Ajugwo, R. E. (1977).

Immunoglobulin E. in Nigeria onchocerciasis. Am. J. Trop. Med. Hyg., 26, 872 - 876.

Soulsby, E. J. L. (1968).

Helminths, Arthropods, and protozoa of domesticated Animals. J. W. Arrowsmith LTD, London, 293 - 311 pp.

Sowa, J. and Sowa, C. S. I. (1975).

Quantitative assessment of microfilarial load in onchocerciasis. Trans. Roy. Soc. Trop. Med. Hyg. 28, 428 - 430.

Sowa, J. and Sowa, C. S. I. (1978).

Long-term treatment of onchocerciasis in children with low doses of diethylcarbamazine. Ann. Trop. Med. Parasit., 72, 79 - 85.

Tejan-Jallon, I. I. (1974).

Some observations on onchocerciasis in the Koinadugu District of Seirra Leone. Trop. Doctor, 4 46.

Thompson, B. H. (1976a).

Studies on the attraction of Simulium damnosum s;.l. (Diptera: Simuliidae) to its hosts. I: The relative importance of sight, exhaled breadth and smell. Tropenmed. Parasit., 27, 455 - 473.

Thompson, B. H. (1976b).

Studies on the attraction of Simulium damnosum s.l. (Diptera: Simuliidae) to its hosts, II: The nature of substances on the human skin responsible for attracting olfactory stimuli. Tropenmed. Parasit., 27, 83 - 90.

Thompson, B. H. (1977).

Studies on the attraction of Simulium damnosum s.l. (Diptera: Simuliidae) to its hosts. III: Experiments with animal-baited traps. Tropenmed. Parasit., 27, 226 - 228.

Thylefors, B. (1978).

Ocular onchocerciasis, Bull. Wld. Hlth. Org., 56, 63 - 73.

Thylefors, B. and Rolland, A. (1979).

The risk of optic atrophy following Suramin treatment of ocular onchocerciasis. Bull. Wld. Hlth. Org., 57, 479 - 480.

Uchay, O. (1982).

The state of onchocerciasis in some Northern States of Nigeria (A comparative study of the situation in 1977 and 1981). Proceedings of the First National Conference of Onchocerciasis Kaduna, Nigeria, September, 1982; 29 pp

Undeen, A. H. and Berl, D. (1979).

Laboratory studies on the effectiveness of Bacillus thuringiensis var israelensis de Barjac against Simulium damnosum (Diptera: Simuliidae) larvae. Mosquito News 39, 742 - 745 (Quoted by Nolan, R. A. 1981).

Vajime, C. G. (1982).

The socio-economic effect of onchocerciasis in Nigeria: A review. Ent. Soc. Nig. 26, 30 - 35.

Vajime, C. G. and Dunbar, R. W. (1975).

Chromosomal identification of eight species of the subgenus Edwardsellum near and including Simulium (Edwardsellum) damnosum Theobald (Diptera: Simuliidae). Tropenmed. Parasit., 26, 111 - 138.

Vioukov, V. N., Prasertphon, S. and Knudsen, A.P. (1982).
Distribution of Simulium species in Nigeria with some remarks on their biology. Proceedings of the First National Conference on Onchocerciasis, Kaduna, Nigeria. Sept. 1982; 9pp.

Walsh, J. F. (1972).
Blackflies entering vehicles in Northern Nigeria. Trans. Roy. Soc. Trop. Med. Hyg., 66, 803 - 804.

Walsh, J. F., Davies, J. B. and Cliff, B. (1981).
"World Health Organization onchocerciasis control programme in the Volta River Basin". In: Blackflies, the future for biological methods in integrated control, (Laird, M. edition), Academic Press, London 85 - 103.

Walsh, J. F., Davies, J. B., Le Berre, R. and Garms, R. (1978).
Standardization of criteria for assessing the effect of Simulium control in onchocerciasis control programmes. Trans. Roy. Soc. Trop. Med. Hyg., 72, 675 - 676.

Wegesa, P. (1967).
Simulium vorax pomeroy; a potential vector of Onchocerca volvulus. Ann. Trop. Med. Parasit., 61, 89 - 92.

Wegese, P. (1970).

Simulium nyasalandicum (Amani form) and Simulium adersi, two new potential vectors of Onchocerca volvulus in the Eastern Usambaras, Northern Tanzania. E. Afr. Med. J., 47, 1 - 4.

Wenk, P. (1981).

'Bionomics of Adult Blackflies', In: Blackflies: the future for biological methods in integrated control. (Laird, M. edition), Academic Press, London, 259 - 279 pp.

APPENDIX 1:

PRELIMINARY SURVEY

Site	Date	River	General Location	Collections
1	25 August, 1983	Assob (near Assob falls)	Upper Plateau; SW, Jos	-
	3 November, 1983	"	"	*S. hargreavesi*; *S. vorax*; *S. cervicornutum* *S. damnosum* s.l. larvae
2	3 November, 1983	Assob (at Angwan Doka)	"	*S. damnosum* s.l.; *S. adersi* larvae and adult *S. damnosum* s.l.
3	13 September, 1983	Zagun (at Zagun village)	Upper Plateau; NW, Jos	*S.hargreavesi* larvae
4	2 November, 1983	Ribon (at Maijuju village)	Upper Plateau; E. Jos	-
5	14 November, 1983	Gada (at Gada village)	Upper Plateau; NE, Jos	*S. hargreavesi* larvae
6	20 September, 1983	Galma (near Kudaru village)	Lower Plateau; N, Jos	*S.damnosum* s.l. larvae, pupae and adults
7	27 September, 1983	Korun (at Kagoro)	Lower Plateau; NE, Kafanchan	*S. hargreavesi* larvae
8	10 May, 1984	Kogun (at Dalle)	Lower Plateau; S, Kafanchan	*S. damnosum* s.l. larvae pupae and adults
9	13 December, 1983	Mafara (at Mafara village)	Lower Plateau; NW, Jos	*S. damnosum* s.l.; *S.hargreavesi*; *S. vorax* larvae
10	27 April, 1984	Gurara (at Cantan village)	Lower Plateau; NW, Kafanchan	-
11	12 May, 1984	Sarkin Pawa (at Iri Station)	Lower Plateau; SE, Kaduna	-
12	16 May, 1984	Mada (Akwanga-Keffi Road)	Lower Plateau; W, Akwanga	-

N — North E — East

W — West S — South

APPENDIX 2: Showing the (values for the whole fly population) daily and monthly biting densities, infective biting density and transmission potential (June - August).

Symbol	Parameter	Derivation	Period of Investigation			
			June	July	August	Tota
a	Total no. of flies caught and dissected	-	161	138	191	490
b	Total no. of flies parous	-	64	72	90	226
c	Total no. of flies infected (°/o)	-	8(12.5)	5(6.9)	9(10.0)	22(9.7)
d	Total no. of flies infective	-	7	4	8	19
e	Total no. of parous flies on 3rd or subsequent bloodmeal (potentially infective)	$\frac{bd}{c}$	56	58	80	194
f	Total no. of flies/man/day (daily biting density)	$\frac{a}{\bar{x}^{\#}}$	54	35	48	
g	Total no. of flies/man/period (monthly biting density)	fy**	1620	1065	1488	4193
h	Total no. of infective flies/man/day (daily infective biting density)	$\frac{d}{\bar{x}^{\#}}$	2	1	2	
i	Total no. of infective flies/man/period (monthly infective biting density)	hy**	60	31	62	153
j	Total no. of infective larvae (in head region only)	-	11	8	14	33
k	$^{M}\bar{A}$ no. of infective larvae/infective fly (larvae in head region only)	j/d	2	2	2	
l	Total no. of infective larvae/man/day (daily transmission potential)	kh	4	2	4	
m	Total no. of infective larvae/man/period (monthly transmission potential)	Walsh, *et al* (1978)	110	62	109	281

$^{M}\bar{A}$=Arithmetic mean #No. of days catches were made June, 3; July, 4; August, 4.

**No. of days in the respective months June, 30; July, 31; August, 31.

Percentage (°/o) based on total number of parous flies (symbol b).

APPENDIX 2; Cont. (October - December).

Symbol	Parameter	Derivation	Period of Investigation Oct.	Nov.	Dec.	Total
a	Total no. of flies caught and dissected	-	102	71	25	198
b	Total no. of flies parous	-	37	30	10	77
c	Total no. of flies infected (°/o)	-	6(16.2)	2(6.6)	0(0.0)	8(10.4)
d	Total no. of flies infective	-	6	1	0	7
e	Total no. of parous flies on 3rd or subsequent bloodmeal (potentially infective)	$\frac{bd}{c}$	37	15	0	52
f	Total no. of flies/man/day (daily biting density)	$\frac{a}{x^*}$	26	18	6	
g	Total no. of flies/man/period (monthly biting density)	fy^{**}	806	540	186	1532
h	Total no. of infective/flies/man/day (daily infective biting density)	$\frac{d}{x^*}$	2	0.3	0	
i	Total no. of infective flies/man/period (monthly infective biting density)	hy^{**}	62	9	0	71
j	Total no. of infective larvae (in head region only)	-	3	2	0	5
k	^{M}A no. of infective larvae/infective fly (larvae in head region only)	j/d	1	2	0	
l	Total no. of infective larvae/man/day (daily transmission potential)	kh	2	0.6	0	
m	Total no. of infective larvae/man/period (monthly transmission potential)	Walsh, et al (1978)	23	15	0	38

^{M}A = Arithmetic mean. *No. of days catches were made October, 4; Nov., 4; December, 4

**No. of days in the respective months October, 31; November, 30; December, 31.

Percentage (°/o) based on total number of parous flies (symbol b).

Appendix 3: Showing calculation of transmission potential as standardised by Walsh *et al*, (1978).

Monthly Transmission potential (MTP)

$$MTP = \frac{\text{No. of days in the month X No. of infective larvae}}{\text{No. of days worked}}$$

$$X \frac{\text{No. of flies caught}}{\text{No. of flies dissected}}$$

For June: $MTP = \frac{30 \times 11}{3} \times \frac{161}{161} = 110$

For July: $MTP = \frac{31 \times 8}{4} \times \frac{138}{138} = 62$

For August: $MTP = \frac{31 \times 14}{4} \times \frac{191}{191} = 109$

For October: $MTP = \frac{31 \times 3}{4} \times \frac{102}{102} = 23$

For November: $MTP = \frac{30 \times 2}{4} \times \frac{71}{71} = 15$

For December: $MTP = \frac{31 \times 0}{4} \times \frac{25}{25} = 0$

APPENDIX 4: Results of hourly catches of *S. damnosum* s.l. and age distribution (June - August).

Time (hour)	JUNE: No. of flies caught				JULY: No. of flies caught				AUGUST: No. of Flies caught				JUNE - AUGUST: No. of flies caught.			
	Total (P+N)	P	N	Average (P+N)	Total (P+N)	P	N	Average (P+N)	Total (P+N)	P	N	Average (P+N)	Total (P+N)	P	N	Average (P+N)
7-8	5	1	4	2	5	0	5	1	7	1	6	2	17	2	15	2
8-9	8	2	6	3	9	3	6	2	9	3	6	2	26	8	18	2
9-10	13	5	8	4	12	4	8	3	11	4	7	3	36	13	23	3
10-11	19	11	8	6	15	7	8	4	11	5	6	3	45	23	22	4
11-12	19	9	10	6	16	12	4	4	15	8	7	4	50	29	21	5
12-13	21	10	11	7	20	16	4	5	23	13	10	6	64	39	25	6
13-14	22	8	14	7	18	12	6	5	29	20	9	7	69	40	29	6
14-15	21	6	15	7	13	6	7	3	27	16	11	7	61	28	33	6
15-16	16	6	10	5	13	8	5	3	29	15	14	7	58	29	29	5
16-17	11	4	7	4	11	2	9	3	17	3	14	4	39	9	30	4
17-18	6	2	4	2	6	2	4	2	13	2	11	3	25	6	19	2
Total (7-18)	161	64	97	54	138	72	66	35	191	90	101	48	490	226	264	45

P = Parous Flies   N = Nulliparous flies