OBSERVATIONS ON THE ENDEMICITY OF PLAGUE IN TANZANIA

BY

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Errata

A check of the rodent material at the British Museum (Natural History) has necessitated the following corrections:-

For *Lophuromys flavopunctatus*
read *Lophuromys sikapusi*.

For *Tatera leucogaster*
read *Tatera inclusa*.

For *Praomys morio*
read *Aethomys chrysophilus*.

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APPROVED STATEMENT AS TO SCOPE AND METHOD OF TREATMENT OF THESIS.

Tanzania is one of the countries in Africa where plague is endemic. The present study is designed to fill some of the gaps in the existing knowledge regarding the nature of this endemicity:-

Scope:-

A comprehensive and comparative study of domestic and field rodents and their flea fauna in two plague and two non-plague areas in Tanzania; including a historical introduction and a consideration of the climatic, seasonal, human occupational and other geographical factors in the places of study.

Method:-

Field Work: - Rodents caught in houses and in the field with aid of appropriate baited 'live' traps. Preliminary observations on these carried out in field laboratory. Fleas (and other ectoparasites) collected from rodents and preserved in spirit. Paper-disc blood

samples for plague antibody serological tests collected from rodents. Preserved skins and skulls of representative samples of rodents prepared. Field materials sent to Central Laboratory, Dar es Salaam School of Medicine.

In Central Laboratory: - Field materials processed and studied; rodents and fleas identified. Representative specimens of rodents and fleas sent away (British Museum, Natural History & Medical Research Laboratory, Nairobi, Kenya) for confirmation of identification as necessary. Paper-disc blood specimens sent to George Williams Hooper Foundation, University of California for plague antibody serological tests.

A B S T R A C T.

A historical introduction of plague as a world disease is given including a detailed review of plague outbreaks in Tanzania during the last 70 years. The main foci of endemic plague are described together with the early methods of plague control that were employed.

Altogether 2,507 rodents of the family MURIDAE belonging to 13 species were caught in houses and in the field in selected plague and non-plague areas using baited live traps. These rodents were subjected to detailed studies of their taxonomy, body measurements and flea-infestations. Paper-disc blood samples were collected from most of the rodents and sent for serological tests for plague antibodies. A total of 5,522 fleas belonging to 4 families and 10 species were collected from the rodents.

The main rodent species are discussed in regard to their body measurements, mammary formulae, breeding, habitat, habits, flea ectoparasites, role in plague transmission and results of serological tests for plague antibodies.

The field rodents of the plague areas and their flea fauna were much richer in variety than those of the non-plague areas and the flea indices of such rodents were much higher in the former than in the latter areas.

The most important rodent hosts were Rattus rattus in the domestic environment and Mastomys coucha and Arvicanthis abyssinicus in the field environment. The most important flea vectors in both environments were Xenopsylla brasiliensis and Xenopsylla cheopis. The wild rodent flea Dinopsyllus lypusus was also of some considerable importance in the field environment.

The rodents found positive for plague antibodies were Mastomys coucha, Arvicanthis abyssinicus, Praomys morio and Grammomys dolichurus.

An important factor in the maintenance of plague endemicity is a low standard of housing and sanitation which facilitates close contact between man and domestic rats and between domestic and field rats.

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HISTORICAL INTRODUCTION.

PLAGUE AS A WORLD DISEASE:

Plague is a disease of great antiquity and through the ages it has been the cause of great calamities and much worry and superstition among mankind. The discovery and application of modern antibiotics such as streptomycin and of the sulphonamide drugs to the treatment of plague and of modern insecticides to its control have reduced the importance of plague as a human disease very considerably. Thus only a consideration of its history can give some idea of the great havoc it caused to human society from very early times.

It is now generally accepted that the earliest recorded reference to human plague concerns an epidemic among the Philistines during their war with the Israelites in 1320 B.C. There are several mentions in the Bible about this outbreak, the most often quoted of which is "But the hand of the Lord was heavy upon them of Ashdod and he destroyed them and smote them with emerods even Ashdod and the coasts thereof" - (1 Samuel V; 6). The Bible speaks of this outbreak as having been characterised by the appearance of "emerods in their secret parts."

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Many recent writers including Shrewsbury (1949) and Girard (1950) have questioned this interpretation of the biblical statement and have maintained that the word 'emerods' referred to haemorrhoids. Others however including MacArthur (1952) consider that the statement definitely referred to bubonic plague.

Wu Lien-teh et al (1936) refers to the writings of Rufus (about 100 A.D.) which mention the occurrence of fatal bubonic plague in Libya and in Syria as far back as the end of the third century B.C.

The Original Home of Plague:-

The Israelites believed that the original home of plague was Egypt and several times in the Bible the disease is referred to as the "botch of Egypt: "The Lord will smite thee with the botch of Egypt, and with the emerods and with the scab, and with the itch whereof thou canst not be healed". - (Deut. XXVIII. 27). The word 'botch' in Old English means tumour or bubo. "So shall it be with the men that set their faces to go to Egypt to sojourn there; they shall die by the sword, by the famine and by the pestilence, and none of them shall remain or escape from the evil that I will bring upon them." - (Jer; XLII; 17).

3.....

Notwithstanding the biblical view it is now generally conceded that plague did not originate in Egypt but was introduced there from abroad. Some authorities believe that the original home of plague was Central Africa. The majority however including the famous Chinese plague expert Wu Lien-teh (1936) are of the opinion that the original home of plague was a group of endemic foci in the Central Asiatic Plateau. This area included Chinese Turkistan, Russian Turkistan, Inner and Outer Mongolia, Transbaikalia, Kurdistan and the foothills of the Himalayas in Northern India. The Central African focus though believed to have been established in very ancient times is regarded as having been an off-shoot of the Central Asiatic one.

The Role of Rodents:-

The biblical account of the plague outbreak among the Philistines in 1320 B.C. also represents the first historical record associating human plague epidemics with rat plague epizootics. When restoring the Ark they had robbed from Canaan the Philistines are said to have made offerings to the Lord of Israel of the golden images of their tumours and of the mice that "marred the land." Early Indian and Chinese writings refer to the connection between human plague and rat plague.

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Thus Liston (1924) quotes a sacred Hindu book the "Bhagavata Purana" written centuries ago in Sanskrit which warned house holders in Hindustan to leave their homes as soon as rats fell from the roof and died. The inhabitants of Transbaikalia and Inner and Outer Mongolia in the Central Asiatic Plateau had for centuries realised the occurrence of a periodic fatal infection among the tarabagans (Siberian marmots) which could cause epidemics in humans and had taken many precautions to protect themselves against the danger; those who hunted these animals for their fur are said to have always avoided the sick ones.

A Chinese writer - Shih Tao nan (1765-1792) composed a poem - Tien Yu Chi about a plague epidemic at Chaochow in the Yunnan Province in 1792. This poem a part of which called "Death of Rats" is quoted below, shows quite clearly that the connection between human plague epidemics and rat plague epizootics was abundantly realised and also gives some indication of the great misery caused to human society by this dreadful disease:-

5.....

"Dead rats in the east,
Dead rats in the west!
As if they were tigers,
Indeed are the people scared.
Few days following the death of the rats,
Men pass away like falling walls!
Deaths in the day are numberless,
The hazy sun is covered by sombre clouds.
While three men are walking together,
Two drop dead within ten steps!
People die in the night,
Nobody dares weep over the dead!
The coming of the devil of plague,
Suddenly makes the lamp dim,
Then it is blown out,
Leaving man, ghost and corpse in the dark room.
The crows caw incessantly,
The dogs howl bitterly!
Man and ghost are as one,
While a spirit is taken for a human being!
The Land is filled with human bones
There in the field are crops
To be reaped by none;
And the officials collect no tax!

6.....

I hope to ride in a fairy dragon
To see God and goddess in heaven,
Begging them to spread heavenly milk,
and make the dead come to life again."

The composer himself died of pneumonic plague almost immediately after writing this poem. - (Wu Lien-teh, 1936 page 12).

However it was not until 1894 that bacteriological evidence of plague in rodents and in the human body was established by the Japanese and French workers Kitasato and Jersin respectively.

On June 23rd 1894 Jersin put the following entry in his diary:- ..."I search and find the organism (Pasteurella pestis) in the corpses of dead rats, and there are many throughout the city..." - (Wu Lien-teh - 1936 page 25).

It is now well established that certain species of wild rodents are the primary reservoirs of plague in most endemic areas.

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The infection is maintained in these rodents in an enzootic form but occasionally flares up as an epizootic and spreads to involve other susceptible wild rodents and domestic rats and mice. Man usually gets the infection from the latter. Among the factors favouring the occurrence of an epizootic are an increase in the population of the wild rodent reservoirs and other susceptible rodents and an increase in the flea index of these rodents.

The Role of Fleas:-

Although in many countries where plague was endemic including India and China there was a long established belief relating to the connection between rat epizootics and human plague outbreaks, the mechanism for the transmission of the disease from rodents to humans was not established until sometime after the discovery of the causative organism - P. pestis in 1894. It had early been realised that a bubonic plague patient was of negligible danger to his close associates provided the infection did not invade the lungs to cause pneumonic plague.

8.....

Ogata (1897) on epidemiological grounds came to the conclusion that the agent of transmission of the plague bacillus was an insect, most probably a flea. He expressed the opinion that "one should pay attention to insects like fleas for as the rats become cold after death they leave their host and may transmit the pest virus direct to man". He was able to infect mice experimentally with plague by injecting them with an emulsion of crushed fleas from a plague-infected rat. Ogata's findings were confirmed by those of Simond (1898), Tidewell (1900, 1903), Verjbitzki (1904) and Thomson (1906).

Liston (1905) established the fact that although different species of fleas had preferences for certain species of hosts, under conditions of starvation, or when given the opportunity, they could quite readily bite other hosts i.e. that fleas were not very strictly host-specific. Our present state of knowledge concerning the epidemiology of plague owes much to the work of the Plague Research Commission which began its work in Bombay in 1905 under the direction of Martin, Lamb, Liston, Petric and Rowland. - (Wu Lien-teh - 1936 page 262).

9.....

It has been shown by many workers including Girard (1936, 1937, 1940, 1943) Robio (1937) and Davis (1953, 1964) that some fleas e.g. Xenopsylla cheopis and Xenopsylla philoxera can harbour P. pestis and remain infective for several months in burrows that have been vacated by rodents. Such fleas are thus not only vectors of plague but also reservoirs of the infection which help in its perpetuation.

The Spread of Plague - Plague pandemics:-

It is believed that from its original home in the Central Asiatic Plateau plague has at different times in history and under different circumstances spread to other parts of the world in the form of pandemics. Among the factors responsible for such pandemics have been wars, commercial traffic and pilgrimage. The first places to be affected by such pandemics were usually commercial centres especially sea ports. From these centres the infection spread along commercial traffic routes to cover vast areas of the countryside. Depending on the availability of suitable rodent reservoirs and efficient flea vectors when the pandemic subsided pockets of residual infection among such rodents were left behind in different parts of the world especially in rural areas.

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These pockets of residual infection became foci of endemic plague in the countries concerned. Such foci of endemic plague served as starting points of localised plague epidemics within a country or region. Available records show that early plague pandemics were restricted to Asia, North Africa, East-Central Africa and Europe. Other parts of the world - South Africa, West Africa, the Phillipines and the Americans were invaded much later.

The first plague pandemic of which there are any reliable records occurred in the year 542 A.D. during the time of the Emperor Justinian and lasted for about 60 years - (Wu Lien-teh - 1936). This pandemic is said to have started in Pelusium in Lower Egypt and to have gradually spread to "the ends of the inhabitable world" - (Hirsch, 1883). Some contemporary writers including Evagrius believed that this outbreak had come from Ethiopia, thus inferring a Central African origin of the pandemic. The pandemic started first in sea ports and spread inland eventually reaching "even the most remote villages" - (Gibbon, 1781). It was estimated that this pandemic killed a total of 100 million people and was said by chroniclers of the time

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to have depopulated towns, to have turned the country into a desert and to have made the habitations of men to become the haunts of wild beasts. It was believed to have been one of the worst calamities that ever befell mankind.

The second recorded plague pandemic started in the 14th Century and came to be known as the "Black Death". It is believed that this pandemic originated in Central Asia from which it spread to China, India, Middle East and Europe. This pandemic is said to have killed off many millions of people including an estimated 25 million in Europe alone. In Britain it is said to have reduced the population by a half to two thirds - (MacArthur 1926). During the Black Death pandemic plague infection became established and entrenched in the rodent population of many countries in Europe and elsewhere. These foci of endemic plague became the sources of localised epidemics for centuries following the Black Death. However, during the 17th Century a general decline set in and by 1841 the whole of Europe became plague-free. After this general decline plague remained endemic in its original home in the Central Asiatic plateau which was to serve as a starting point for yet another pandemic.

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The last plague pandemic again originated from the Central Asiatic plateau focus. It started in the middle part of the 19th Century and gradually spread westwards, eastwards and southwards reaching Hong Kong in 1894. From Hong Kong the pandemic spread to the rest of the world except Europe and Australia. This spread was greatly facilitated by the greatly improved means of transport of the time especially the steamship and the railway train as compared to the small sailing craft and trade caravans of earlier times. Many countries including the Americas, South Africa, West Africa, the Phillipines and many of the Pacific islands came to experience plague for the first time during this pandemic which thus became the most widespread of all pandemics hitherto. Although there has been a general decline of this last pandemic, sporadic outbreaks originating from endemic foci continue to occur in many parts of the world including Tanzania. One of the most interesting features of the last plague pandemic is that Europe which in earlier pandemics suffered the most devastating epidemics was spared.

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Probable reasons for the disappearance of Plague from Europe:-

Several theories have been put forward by various authors to explain why after the Black Death pandemic Europe remained free from endemic plague. The earliest theory regarding the disappearance of plague from Europe ascribes this happening to progress in civilisation which led to a higher standard of hygiene and sanitation as well as to prophylactic measures. This theory is still upheld by many authorities but others have advanced other theories:

Simpson (1905) was of the opinion that the disappearance of plague from Europe was due to the abandonment in the early part of the 17th century of the Mediterranean as the centre of commerce for Europe. This resulted into the shutting up of the Levant as the high way for the conveyance of the produce of the East to the West and the transfer of commercial activity to Amsterdam and London whose chief connection with the East was by sea and not by land. This change meant the avoidance of the close connection between Europe and the endemic areas of plague of Central and Western Asia.

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Another theory maintains that the regression of plague from Europe was due to the replacement of the black rat Rattus rattus which lives in close association with man by the brown or sewer rat Rattus norvegicus which is, owing to its habits, a less efficient reservoir of plague. Thus Liston (1904) stated that "the disappearance of plague from Europe in the 17th and 18th centuries coincided in the main, in point of time, with the appearance of the sewer rat and the disappearance of the house rat." He believed this change to have come about as a result of the changes in the habit of men in Europe at the time which led to the exclusion of rats from human dwellings, thus favouring the substitution of one species of rat by another.

Discussing these theories Wu Lien-teh (1936) was of the opinion that none of them offered by itself a fully satisfactory explanation of the matter. He put forward the argument that the gradual disappearance of plague from Europe was not due to any extrinsic obstacles preventing its spread but to the well-known natural law of the rise and fall of epidemics which operated in Europe and elsewhere at different times.

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The present pandemic which started in Central Asia in the middle of the last century has been in the process of declining for the last 40 years following this natural law. Thus the three theories mentioned above purporting to explain the causes for the disappearance of plague from Europe during the last century can at best only be regarded as subsidiary to this natural law. However a general progress in civilisation leading to a better standard of living and consequently less intimate contact with rats and fleas has been the most probable cause for the failure of plague to regain a strong foothold in Europe after the middle of the 19th Century. This progress in civilisation came into full force not while plague was still present in Europe but after it had disappeared. The situation can therefore be summed up thus: Plague disappeared from Europe in the first place mainly as a result of a general decline of the pandemic and following this decline a general progress in civilisation leading to a better standard of living of the people prevented it from re-establishing itself on a firm basis.

16.....

The History of Plague in East Africa:-

It is now generally accepted that the Central African focus of endemic plague though most probably secondary to and originating from the Central Asiatic one was of very long standing (Wu Lien-teh - 1936). Roberts (1935) has discussed the question of the origin of plague in East Africa at some considerable length. Ethiopia is known to have experienced plague from very early times. Evagrius, a citizen of Antioch (mentioned by Wu Lien-teh - 1936) contended that the plague pandemic of the Justinian time originated from Ethiopia. The ancient Kingdom of Ethiopia included modern upper Egypt, Sudan and Abyssinia which border on Uganda and Kenya. Trade connections by caravans between Egypt and East Africa based on slaves, ivory, gold, gum ebony and ostrich feathers from East Africa and linen and glass goods from Egypt was established from very ancient times. The routes used by these trade caravans were by the course of the river Nile and through the Rift Valley. Abyssinia served as the main distributing centre of East African slaves by the land route. Most of the slaves were sent to various parts of Arabia where plague had always been known to be endemic. Bearing all these facts in mind the contention of Roberts (1935) and others that the endemicity of plague in East Africa is of very long standing would seem plausible.

17.....

The Baganda and Luo tribes who live on the northern shores of Lake Victoria in Uganda and Kenya respectively have been acquainted with plague for a very long time. They are supposed to have imported plague into their respective areas when they migrated from the Acholi country in the North during the middle of the last century. The Kavirondo and the Eastern Buganda districts were extensively used as sources of slaves by Arab slave traders from the coast. The slave caravan routes to and from these areas passed through Kenya but mostly through central mainland Tanzania. These slave caravan routes were also used for carrying out raids in the interior in times of war and later by Mohammedan pilgrims (to Mecca) who had settled in the interior of the country including places where plague was endemic. It is most probably through these caravan routes that plague came to be introduced into many parts of mainland Tanzania. Where conditions were suitable as regards rodent reservoirs, flea vectors and favourable climatic conditions endemic foci of plague came to be established in various places and these served as starting points of localised epidemics.

18.....

Uganda: - In Uganda the first British and French missionaries are known to have encountered plague when they entered the country in 1877 and 1879 respectively (Roberts - 1935). The Reverend A. G. Ashe met cases of plague when he was in Uganda between 1883 and 1886. In his book "Two Kings of Uganda" he reports that small-pox and 'a kind of black death' which the Baganda called 'kampuli' from time to time decimated the population of Buganda. Archdeacon R. H. Walker first saw cases of 'kampuli' (plague) on the island of Barungu 7 miles from Kampala in 1889. In 1883 there was an outbreak of plague on the hill of Rubaga on the outskirts of Kampala which led to the whole hill being abandoned. It has been claimed that plague was imported from India into Uganda during the construction of the Kenya/Uganda Railway (1896-1901) but in view of what has been said above it would appear that the disease had been endemic in Uganda long before then. As soon as observations became possible and after the opening up of the interior of the country to effective civil administration in modern times foci of endemic plague of long standing were discovered. In 1893 and 1894 the White Fathers abandoned their station at Bikira in Buddu for 4 years due to a plague outbreak and in 1897 cases of plague were treated at Sir Albert Cook's hospital at Mengo in Kampala.

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Simpson (1914) expressed the opinion that plague had existed in Uganda for many years and possibly for ages before the country became a British Protectorate in 1894. From 1903-1908 most of the ports on Lake Victoria became involved and by 1906 the infection had been so entrenched that from that date onwards plague has been reported from the country in most of the years. Hopkins (1949) reported that the endemic foci from which outbreaks of plague started in Uganda were invariably situated in rural localities and not in towns.

Kenya: - The earliest outbreak of plague on record in the interior of Kenya was the Nairobi epidemic of 1902. The origin of this epidemic has been discussed by Roberts (1935). It was claimed that the disease was imported from Uganda or from India via Mombasa. But both these alternatives are untenable since the railway line through which the infection could have been introduced from upcountry had only reached Lake Victoria in the later half of 1901 and at that time the country between Kampala and Nairobi was free from plague epidemics as was the port of Kisumu. The port of Mombasa had been free from plague for years and remained so until 1912.

20.....

Roberts was of the opinion that the epidemic originated from an endemic focus in rural areas in the hinterland of Nairobi. This view is supported by subsequent epidemics in the city such as that of 1930. From 1906 onwards plague spread in Kenya but the incidence remained low until 1941 when it suddenly went up for two years before it fell again. In Kenya as in Uganda the endemic foci of plague are in rural areas.

PLAGUE IN TANZANIA:

It is most probable that plague was introduced into Tanganyika from endemic foci in Uganda and Kenya through the old slave and trade caravan routes. It is known that these caravans passed through Bukoba, Mwanza, Tabora, Singida, Masailand, Kondoa, Dodoma and Mpwapwa to the coast. Some passed through Kilimanjaro which was also an important source of slaves. Many of these places have experienced plague epidemics at one time or another and some of them, namely: Mwanza, Singida and Kilimanjaro are important foci of endemic plague to the present day.

21.....

Right from the time of early German Administration to the present day plague has ranked as an important epidemic disease in several parts of mainland Tanzania.

Except where otherwise stated the information given hereunder regarding the history of plague in Tanzania was compiled from three main sources: "Medizinal Berichte uber die Deutschen Schutzgebiete" (Medical Reports of the German Protectorates) for the years 1903-1911, Annual Medical Reports of Tanganyika for the years 1918-1965 and official files and documents under the custody of the Ministry of Health and the National Archives, Tanzania.

The Bukoba Focus: (includes Bukoba District).

Robert Koch and M. Zupitsa discovered a focus of endemic plague in the Kiziba Chiefdom of Bukoba in 1897. This was the first plague focus to be known to the Germans in German East Africa. The focus extended on both sides of the Kagera river; in the north it was continuous with the Uganda plague focus. In 1903 Feldmann reporting on plague at Kiziba stated that the disease had been introduced into the country 15 years previously (1888) from Uganda.

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Since Kiziba lies near the border with the Buddu locality of Uganda where plague was known to be endemic this view was a logical one. In 1902 there was an outbreak at Bukoba township and there were sporadic outbreaks in 1903. From 1903 onwards no plague outbraks were reported from this focus. However in 1906 acting on the advice of Robert Koch, Fieldmann proved the presence of chronic plague in rats at Kiziba by animal inoculation.

Accoording to Fieldmann the local people of Bukoba knew something about plague. They were aware of the fact that human epidemics were preceded by rat epizootics and had developed some protective and preventive measures. When an outbreak occurred in a village, the villagers including the sick if possible, abandoned their homes and built new ones elsewhere. The sick were strictly isolated but one of the relatives always volunteered to look after them. Plague epidemics were accompanied by much superstition which fact was taken advantage of by the witch doctors. But neither the Baganda nor the Waziba (inhabitants of Kiziba) knew any specific treatment for plague. They used various purgatives and tried to soften or open up the buboes by different methods.

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The localities in which the plague outbreaks occurred were: Kiziba and Bukoba.

The Iringa Focus: (includes Iringa and Njombe Districts).

Simpson (1914) in his classical report "Sanitary Matters in the East African Protectorate" traces back the history of plague among the Wahehe to 1886 when it was introduced into Iringa from the North during an inter-tribal war. From 1886-1889 the disease was confined to a small area - Image, about 50 miles north of Iringa township but it reached Iringa in 1889 when a serious outbreak occurred among the Wahehe killing a large number of people including 50 at Iringa township. In 1891 the epidemic spread southwards towards Ubena country and caused a serious outbreak there during a year of unusually heavy rains (1893/94).

In 1903/04 Griesert reported that plague was endemic in the Uhehe Highlands and that it was present at Iringa and at Tosamaganga. He diagnosed the disease bacteriologically in bubonic aspirations, splenic smears and sputum and also found P. pestis in dead rats from the houses of plague cases.

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The Wahehe were well acquainted with plague and called the disease "Chambafu"*. According to them death occurred 3 to 4 days after the onset of the attack and outbreaks were preceded by the death of large numbers of rats. They also knew that in their country outbreaks of plague occurred during the rainy season, i.e. from October to April. This was later proved by Griesert to be correct. Mkwawa the famous Chief of the Wahehe and his 'jumbes' (headmen) introduced several effective preventive and control measures against plague which according to Griesert limited the outbreaks to sporadic cases only. The death of large numbers of rats was to be immediately reported to Government; plague patients had to be isolated to huts built in the bush away from the villages, as was the case with small-pox; the relatives who looked after the sick lived in separate huts in the isolation camp and were only allowed to return to the village after a month; the local people left their houses as soon as dead rats were found.

*The German investigators spelt the word "Kyambafu" but the correct spelling is "Chambafu".

These control measures were supplemented by others introduced by the German Administration: The bodies of plague victims were at first burnt but owing to the Wahehe's objection to this practice it was abandoned and deep burial was substituted for burning. All plague cases had to be reported to Government; anti-rat measures were introduced and a small reward of money was given for each rat killed. Owing to the anti-rat campaigns organised by Mkwawa and his 'jumbes' in 1903/04 at Iringa and environs, about 100,000 rats were killed. The dead rats were burnt and the hands of the collectors were washed in mercuric chloride. The huts where plague cases had occurred had their roofs removed to expose the interior to sunlight and those in which cases had occurred repeatedly were completely burnt down. At Iringa it was compulsory for all houses to have windows in order to make it easier to find rats.

In the 1903/04 epidemic two German missionary sisters at Tosamaganga who had been in contact with a pneumonic plague patient were among the victims who died of plague.

In 1904/05 the epidemic at Iringa died down but sporadic cases continued to occur at Tosamaganga and at Ilembula in Ubena.

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Griesert who was stationed at Iringa introduced anti-plague inoculation and immunised 1,500 people including 3 German soldiers.

The Wabena who lived in Ubena, South of Iringa also knew something about plague and called it "Pambafu".

In 1905/06 Senior Staff Surgeon Zupitza was assigned to a special Plague and Coast Fever campaign based at Iringa. The 'Maji Maji' uprising took place at this time. Zupitza reported that the great uprising had disrupted all control measures and that it was not possible to get enough information about plague either because the attention of the local people was directed towards the war or because they deliberately withheld information from the authorities. Many cases of bubonic plague were reported from Southern Ubena in 1905/06 and abnormally heavy rains in Uhehe were said to have precipitated an outbreak which caused a few deaths. Zupitza expressed the opinion that an increase in the number of rats in houses due to the heavy rains driving them indoors and a breakdown in the rat-catching campaign due to lack of pressure from the authorities were among the factors contributing towards this outbreak.

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In 1912 a small outbreak at Ilembula in Ubena killed off 19 people.

During the British Administration sporadic outbreaks of plague were reported from Iringa and environs in 1920, 1928, 1933, 1935, 1936 and 1937. From 1937 to the present (1968) the whole of this once active focus has remained plague-free.

During the plague epidemics in the Iringa Focus outbreaks occurred in the following localities:-

Iringa District:

Iringa

Image

Tosamaganga

Mlolo

Kigonziro.

Njombe District:

Ilembula.

28.....

The Mwanza/Shirati Focus: (includes Mwanza, North Mara, Ukerewe, Musoma, Maswa, Shinyanga and Nzega Districts).

In 1901, 3 cases of plague were reported from Shirati. It was believed that the infection had been introduced from British East Africa (Kenya). In 1906/07, 6 fatal cases of plague occurred in a British steamer at Mwanza. In 1908 the Governor of British East Africa wrote to the Governor of German East Africa (Tanganyika) warning him of an outbreak of plague at Kisumu. In 1909/10 a vigorous anti-rat campaign under Dr. Lurz was introduced at Mwanza and Shirati using bait recommended by Robert Koch to prevent the importation of plague from Kisumu. In spite of this a serious outbreak believed to have originated from Kenya occurred at Mwanza causing 132 cases. Rat epizootics were observed both before and during the human epidemic. Dr. Weck based in Dar es Salaam went up with his mobile laboratory to investigate the situation. He identified 'Mus rattus' (Rattus rattus) among the rats and 'Pullex cheopis' (Xenopsylla cheopis) and 'Sarcopsylla gallinacea' (Echidnophaga gallinacea) among the fleas. From October 1910 to March 1911 there were outbreaks at Mwanza and at Guta on the Speke gulf and 13 people died of plague. Dr. Manteufel was sent up from Dar es Salaam to investigate.

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He reported that plague was most probably introduced from Port Florence (Kisumu) where rat plague was endemic.

The human epidemics at Mwanza and environs took place concurrently with rat epizootics and among 370 rats examined in 1911, 5 were found to be positive for plague. Infected rats were found both from Mwanza township and from the surrounding villages. Due to the vigorous anti-rat campaign introduced by Lurz in which rat catchers were paid 1 - 2 'hellers' for each rat caught, 197,783 rats were caught in 4 months, which, according to Manteufel, was more than the total number of rats caught in a full year in Bombay. Out of 1,161 rats examined, Manteufel reported that 998 were '<u>Mus decumanus</u>' (<u>Rattus norvegicus</u>) and 46 were 'another variety of the same species'. Of the rest, 97 were 'yellow brownish' rats and 20 were 'elephant-trunk' rats. "<u>Mus rattus</u>" (<u>Rattus rattus</u>) was said to be absent. He wrote: "It is remarkable that the black rat (<u>Mus rattus</u>) which plays an important part in transmission and which lives in human dwellings was missing. But there were many nests of the 'wondering rat' in the houses of natives and Indians especially in thatched roofs and floors. But the majority of rats have nests in the field and come under special circumstances into houses to collect food or to build nests.

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One can say that the rat problem originates from the field. To control them one has to concentrate on the periphery of the town. The finding of plague rats in the town provides evidence that diseased rats do migrate into the town." Lurz found that of the fleas collected off rats 87% were Xenopsylla cheopis.

Manteufel was of the opinion that human plague epidemics in Mwanza were of a mild form similar to those in the Central African focus at Buddu in Uganda and those at Kiziba in the Bukoba District. He advised that the endemic area of plague was wide and that the whole shore of Lake Victoria should be regarded as plague-infested. However as it was not practically possible to control plague in the Mwanza township as well as in the surrounding rural areas he recommended that anti-rat measures should be confined to the township area. In 1913, there was a small outbreak of plague at Bukwimba and Shirati.

Mwanza and environs continued to have sporadic outbreaks of plague throughout most of the period of British Administration and the last serious outbreaks was in 1951. During an epidemic in 1925 it was alleged that the infection had originated from Shirati and had been brought to Mwanza by the way of infected

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fleas and rats in hides and other merchanidse. It was recommended that as Mwanza was to be a future railway terminus precautions should be taken to protect Mwanza and to prevent the spread of plague from there to other parts of the country. Such precautions were to include the rat-proofing of Produce and Hide stores at Mwanza, Tabora and Dar es Salaam. An examination of rats caught at Mwanza in 1928 revealed that 42.23% were Rattus rattus, 46.16% were R. norvegicus and 11.61% were Arvicanthis abyssinicus.

Plague outbreaks have occurred in the following localities in this focus:-

Mwanza District:

Mwanza, Nyambiti

Bukwimba, Igalukiro

Nassa.

North Mara District:

Shirati.

Ukerewe District:

Ukerewe Island.

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Musoma District:

Musoma.

Maswa District:

Maswa.

Shinyanga District:

Shinyanga

Jawe.

Nzega District:

Nzega

Sungwizi

Ndala.

The Singida/Mbulu/Kondoa Focus: (includes Singida, Iramba, Manyoni, Mbulu and Kondoa Districts).

Plague is said to have been present at Singida as far back as 1918 and up to 1920 cases of an illness 'extra-ordinarily similar to plague in symptomatology' continued to be reported from Singida and Mbulu. In 1920 there were 93 fatal cases of suspected plague at Singida.

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In 1921 spleen smears from a patient that died at Singida hospital were sent to the Pathology Laboratory in Dar-es-Salaam and Dr. Butler, Director of the Central Pathology Laboratory reported 'classical' P. pestis. In the same year a total of 149 people died of plague at Singida and in its environs. Anti-rat measures instituted in 1921 resulted into the killing of 831,953 rats in that year. Following the German method a reward of 1 cent per rat was given to the rat catchers. The anti-rat measures were supplemented by innoculation with Haffkine's vaccine and a total of 14,000 inhabitants were inoculated.

From the early days of plague at Singida it was realised that the insanitary conditions in which the local people lived in their 'matembe' dwellings contributed greatly to the transmission of plague. Commenting on this aspect of the problem in the Tanganyika Annual Medical Report for 1923 it is stated: "The natives in this district live under the worst possible conditions. They do not build the ordinary type of hut thatched with grass which can be unroofed easily and the interior exposed to sunlight. The native dwellings are roofed with beaten earth and are occupied by human beings, cattle and goats; they are also used as grain stores.

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Efforts have been made for years, both by the German and British Administrative Officers, to induce these natives to improve the sanitary conditions under which they live, but with little success. No great improvement can be expected in the immediate future, and it appears possible that this district will remain an endemic plague area."

This statement made 45 years ago still remains essentially true in most rural villages in Singida today. It is not surprising therefore that throughout the years Singida has been one of the most important plague areas in the country.

In the 1948 Annual Medical Report it was stated by the Senior Pathologist that Rattus rattus was considered to be the principal reservoir, and that the prominent flea vector was Xenopsylla brasiliensis and in 1951 the following remark was made: "the link between rodent plague and human plague is defective sanitation and low standards of rural and urban housing. So long as these conditions persist where sylvatic plague remains uncontrolled plague epidemics will periodically recur."

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In 1917 the Assistant Political Officer stationed at Mbulu reported that people were dying of plague in his area. Although there had been no bacteriological confirmation it was stated that plague had been present in the area since 1904. In 1924, 17 fatal cases of plague were reported from Mbulu and 7,200 people were inoculated against plague. In 1939 Pasteurella pestis was isolated from the bone marrow of a rat from Mbulu. This area has had sporadic outbreaks of plague through the years and remains an active endemic centre.

The Kondoa District which borders on the Singida and Mbulu Districts has had sporadic cases of plague since 1910. In 1923 there was a short-lived plague epidemic in two neighbouring villages - Kiniassi and Maloya about 40 miles North-East of Kondoa during which 16 people died within two weeks. This plague area is not as important as those of Singida and Mbulu.

The following localities in this focus have had plague outbreaks:-

Singida District:

Singida, Ihanja and Ilongero.

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Iramba District:

Sekenke

Shelui

Tintigula

Mkalama

Kironda

Kiselelo.

Manyoni District:

Manyoni.

Mbulu District:

Mbulu

Basoto.

Kondoa District:

Kondoa

Kiniassi

Maloya.

The Kilimanjaro/Pare Focus: (includes Moshi and Pare Districts).

The first recorded outbreak of plague in this region was the one that occurred in the Rombo Division, East Kilimanjaro in 1912 and reported by Richard Lurz (1913).

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Although plague had never before been medically diagnosed in this area, a Roman Catholic priest stationed at Rombo reported that there had been an outbreak there in the Gasseni location in 1898 and at Taveta on the border with Kenya in 1897. In March 1912 during the long rains which coincided with a spell of cold weather a plague epidemic started at the locations of Gasseni and Usseri Kwa Demassi killing off many people. Dr. Wunn, who was Medical Officer at Moshi went to investigate and arrived at Rombo at the end of March. He reported that between March 15th and April 14th a total of 66 people died of pneumonic and 3 of bubonic plague in the two locations. The incubation period was found to be 1 - 3 days, the duration of the disease one day and the mortality 100%. He diagnosed human plague both clinically and bacteriologically. Dr. Lurz was sent by the Imperial German Government to organise plague control measures and he arrived at Rombo in April 1912.

Lurz found that whereas rats were abundant in the rest of Rombo they were few in the locations of Gasseni, Usseri Kwa Demassi and Usseri Kwa Ushive. No plague epizootics had been observed in rats prior to the outbreak of the epidemic.

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Of the rats caught in human dwellings most were 'Pelomys fallax irridescens.' Heller (identified at the Royal Zoological Museum in Berlin). There were also a few specimens of 'Arvicanthis pumilio masaicus', (possibly Arvicanthis abyssinicus), 'Lophuromys aquilis', 'Saccostomus sp.' and 'Eliomys (Graphiurus) aff. raptor Dollm'. The field rats caught in the surrounding bush included 'Mus (Thamnomys) aff-dolichurus' and, the mole rat Tachyoryctes daemon. Spleen smears of the rats caught in houses and in the field were examined for Pasteurella pestis. Of 2,893 specimens of the genus 'Pelomys' and 3,294 of the genus 'Thamnomys' (Grammomys), 36 (0.89%) and 3 (0.09%) respectively were found to be positive. No positive rats were found outside the plague-infested localities. Lurz attributed the scarcity of rodents in these localities to the long presence of rodent plague which had kept their numbers down.

Commenting on the rats caught in houses and in the field by Lurz, Guggisburg (1967) was of the opinion that according to the description and measurements given what Lurz called "Pelomys fallax" was the multi-mammate rat Mastomys coucha which is one of the commonest field rats in East Africa and which has semi-domestic tendencies.

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Since P. fallax is not known to enter houses Guggisburg's view seems correct.

Lurz also examined fleas caught from man, rats and dogs and out of 127 such fleas 40 were "Laemopsylla cheopis" (Xenopsylla cheopis), 40 were "Sarcopsylla gallinacea" (Echidnophaga gallinacea, 34 were "Ctenocephalus canis" (possibly Ctenocephal ides felis strongylus), 9 "Ctenopsylla musculi" (Leptopsylla segnis), 3 Pullex irritans and 1 "Ceratophyllus fasciatus" (Nosopsyllus-fasciatus).

Animal inoculation tests using guinea pigs and mole rats (genus 'Tachyoriotes') and sputum from plague patients or spleen of plague infected rodents confirmed the presence of plague.

The control measures adopted to deal with the situation were:-

1. A vigorous and thorough anti-rat campaign; a total of 30,654 rats and mice were killed in 9½ weeks.
2. The huts of those who had died of plague were burnt down.

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3. The sick were isolated and a strict quarantine was imposed on the movement of people to and from the plague-infested villages.

The effectiveness of these measures was reflected in a rapid decline of human plague cases.

After this epidemic no more cases of plague were reported from the Kilimanjaro area until 1956 when 3 cases of plague with one death occurred in the labour lines of an estate in West Kilimanjaro. Anti-plague measures consisting mainly of insecticide dusting of the houses were instituted promptly and the outbreak did not spread beyond the labour camp. It is believed that the infection was brought into the area by an immigrant labourer.

In 1957 three cases of plague with 2 deaths (not bacteriologically confirmed) were reported from Mashati in the Rombo Division of Moshi. In 1962 nine cases of plague with 3 deaths occurred in the Usseri location of Rombo Division in the villages of Mashati and Mrao and in 1963 there were 4 fatal cases of suspected plague in the same location.

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The occurrence of plague in Rombo about 45 years after it was last reported there is interesting and serves as a warning against complacency. Since these outbreaks were isolated and confined to small localities, they can only be regarded as having originated locally. It is clear from this therefore that in an endemic area plague can remain latent and smouldering in wild rodent reservoirs for very long periods and that when the right conditions occur human epidemics will break out. It would follow from this that all the places where plague was once endemic, including those like Kiziba in Bukoba where the last human outbreak occurred so many years ago, must be regarded as potentially endemic areas of plague.

In the middle of November 1951 the District Commissioner of Same (Pare) reported an epidemic outbreak at Suji on the South Pare mountains during which 16 people had died within 3 weeks. Because this was the first outbreak of plague that had ever been reported from the area it took sometime before the disease was diagnosed as such. The medical officer who first went to investigate thought that the epidemic was due to influenza precipitated by a spell of wet and cold weather.

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At Suji and Makanya 10 inches of rain fell in the months of October and November as compared to the normal average of 1 - 1.5 inches. By the end of the epidemic in January 1952 a total of 171 cases and 27 deaths had been reported from Suji, Makanya and Gonja divisions.

As soon as the diagnosis of plague was established prompt control measures were introduced. These included the use of anti-plague vaccine (a total of 45,000 people were inoculated), the dusting of all dwelling houses with Gammexane and strict quarantine on the movement of people and all forms of tranport to and from the affected areas. Barium carbonate was used as a rodenticide but its effectiveness was not very encouraging and in the later stages of the campaign it was found better to concentrate on anti-flea measures by insecticide dusting. The very low mortality was attributed to the drammatic effect of streptomycin which was used to treat plague cases for the first time in the country.

Sporadic cases of plague were reported from Chome in 1956 and 1957 and suspected, but not confirmed cases were reported in 1958.

In 1963 a few doubtful cases were reported from Chome and from January to April 1964 there was a wide-spread plague epidemic at Chome and Vuhdee involving 513 cases and 11 deaths. The latter epidemic was preceded by a rodent epizootic and like the one of 1951 was quickly brought under control by the liberal use of Gammexane dusting and by effective quarantine and control of the movement of the people. Instead of protective inoculation with anti-plague vaccine sulphonamides were administered to the population at risk. Once again the very high efficacy of streptomycin treatment was reflected in the very low mortality.

In both the 1951 and 1964 epidemics, most of the cases were children and adolescents.

The origin of the plague outbreaks in Pare has not been elucidated. It has been suggested that the Pare epidemic of 1951 could have originated from Singida or Mbulu by way of people or wild rodent reservoirs since these well known areas of endemic plague were experiencing plague epidemics at the time. However no epizootics among wild rodents had been noticed and there had been no outbreaks in the towns or settlements lying on the route between Pare and Singida or Mbulu.

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The similarity of the rodent and flea fauna of Singida (a plague area of long standing) and Pare (see below) makes one wonder why no plague outbreaks had been reported from Pare before 1951. As has already been stated in the neighbouring area of East Kilimanjaro which is only a matter of some 60 miles away, plague outbreaks have been recorded as early as 1912. The tendency of these outbreaks to occur sometimes at long intervals, e.g. 45 years at Rombo, cast some doubt as to whether the 1951 epidemic really represented the first outbreak of plague in Pare. Is it possible that this plague area is just as old as the others but that prior to 1951 for a period extending beyond written records and living memory it was dormant owing to the lack of the right combination of circumstances to set it aflame? An attempt to get an answer to this question from old people in the area yielded no satisfactory explanation.

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During the plague epidemics outbreaks have occurred in the following localities in this focus:-

Moshi District:

Ngasseni

Usseri

Mashati

Mrao

Kisale

West Kilimanjaro.

Pare District:

Chome

Suji

Vudee

Makanya

Gonja.

Records of Plague in other parts of Tanzania:-

Dar es Salaam: - Owing to an outbreak of plague in Zanzibar in August 1905 strict control measures were put into operation to protect Dar es Salaam which was in continuous contact with Zanzibar, especially through dhow traffic.

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These measures were thought to be especially necessary since there were many German warships and troops on the harbour which had been called up to suppress the Maji Maji uprising. The control measures adopted consisted of strict quarantine including the isolation of passengers that had come by sea from Zanzibar, claytonisation of dhows, ships and other sea-going vessels from Zanzibar and vigorous anti-rat measures. The rats were caught mainly by trapping and were examined for plague infection. These measures proved to be adequate and successful and only 1 case of plague was reported during the year. No cases of plague were reported in 1906 and in 1907 the quarantine measures were lifted but other control measures were continued. These included the trapping of rats and their laboratory examination for plague infection and the inspection of ships and dhows coming into Dar es Salaam harbour from Zanzibar and elsewhere.

In spite of these measures an outbreak of plague occurred in Dar es Salaam in 1908. The disease was immediately recognised in the plague Investigation Centre which consisted of one fully equiped laboratory and three mobile field laboratories. During this outbreak 12 cases including 6 deaths were isolated at the Sewa Hadji Hospital in Dar es Salaam.

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At the beginning of the epidemic in October 1908, 657 rats were examined in Dar es Salaam for plague at the Plague Investigation Centre and 7.9% were found positive.

The chief control measures taken against this outbreak were isolation of cases, careful burial of the dead in sealed coffins, disinfection of dwelling houses, surveillance of contacts and stringent rat control measures including claytonisation of drainage canals using sulphur. This epidemic lasted for 3 months and the last case was reported on 8th January, 1909.

After this outbreak Dar es Salaam remained free of plague until 1911. In that year a man who had just returned to the capital from Zanzibar via Bagamoyo died of pneumonic plague and a few weeks later another person died of bubonic plague. It was reported at that time that there were rat epizootics all along the coast from Tanga to Lindi. An inspection of the steamer Sultani of the German East African Line, which had called on all the ports and was lying in the harbour at Dar es Salaam revealed dead plague-infected rats. The ship was at once placed under quarantine and the passengers and crew were placed under surveilance.

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After claytonisation of the ship 262 heavily infected rats were found.

Another small outbreak of plague occurred in Dar-es-Salaam in 1914 after which date there have been no more local outbreaks to date. In September 1965 a patient died of bubonic plague at Muhimbili Hospital, Dar es Salaam but the deceased had arrived from upcountry a few days before his admission to hospital. He had on his way to Dar-es-Salaam visited Manyoni in the Singida Region where plague was known to be endemic and it was thought most probable that the infection had been contracted from there.

Lindi: - There was a small outbreak of human plague preceded by a rat epizootic at Lindi in 1910 during which 3 people died. This outbreak was thoroughly investigated by Manteufel (1911) who had the following to say:-

"The first signs of the disease were noticed in a child at 9.00 a.m. and he died at 11.00 p.m. No rats were found in the house but a cage with 2 guinea-pigs was placed in the house. One of the guinea-pigs died after 3 days and the other after 5 days, both from plague.

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520 rats were examined and 26 (5%) were found positive; later the infection rate in rats rose to 14%. Only 3 cases of human plague were observed in spite of the fact that the weather was favourable for transmission and the hygienic condition of the town was very poor."

Among 456 rats collected from Lindi by Manteufel:-

245 were "grey rats" - "Mus decumanus" (Rattus norvegicus).

190 were "black rats" - "Mus rattus" (Rattus rattus).

21 were mice -"Mus musculus"

Of the 26 infected rats found, 19 were Mus decumanus, 3 were Mus rattus and 4 were Mus musculus.

Concerning the rat epizootic at Lindi Manteufel made the following remarks:-

"The infected rats from the houses where the epizootic started were all grey rats.

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22 of the 26 infected rats were females; the normal sex ratio in the population was 1.9 females: 1 male. There were very few fleas on healthy rats - 1-2 per rat and plenty of fleas on infected rats. Among 100 fleas from the plague-infected rats 63 were Laemopsylla cheopis (Xenopsylla cheopis), 34 were Sarcopsylla gallinacea (Echidnophaga gallinacea) and 3 were not identified. On one of the guinea pigs put in a house as a flea-trap 4 fleas were found, all Laemopsylla cheopis."

Bagamoyo: - In 1911 3 people died of plague at Bagamoyo, 25 miles North of Dar es Salaam.

Zanzibar: - The island of Zanzibar experienced a plague outbreak supposedly originating from India, in 1905.

Mpwapwa: - Sporadic outbreaks of plague were reported from Mpwapwa between 1900 and 1905 but this place has never been an important plague area.

Dodoma: - A few cases of plague were reported from Dodoma in 1927. It was believed that the infection originated from the Singida plague area which was experiencing a small plague epidemic at the same time.

Tabora: - During a wide-spread and serious plague epidemic in the Mwanza/Shirati Focus in 1931 a few cases were reported from Tabora township.

Kigoma and Ujiji: - In 1914 two fatal cases of plague were reported from Kigoma and Ujiji on the shores of Lake Tanganyika. It was believed that the infection had been introduced from Dar es Salaam through railway traffic.

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Masailand: - In 1923, forty people died of suspected pneumonic plague at Oldonyo, Kisale - a Masai village about 50 miles South-West of Arusha.

The geographical distribution of endemic plague in Tanzania is shown in figure 1.

A summary of the recorded outbreaks of plague in Tanzania for the last 70 years showing the Regions, Districts and localities in which they occurred together with the reported number of cases and deaths is shown in Table I. It was not always possible to get from official records all the details about the localities of occurrence and the number of cases and deaths.

TABLE I.

Recorded outbreaks of Plague in Tanzania from 1897 - 1967.

YEAR	REGION	DISTRICT	LOCALITIES	NO. OF CASES	NO. OF DEATHS
1897	West Lake	Bukoba	Bukoba, Kisiba	-	-
1900	Dodoma	Mpwapwa	On border with Iringa District	-	40
1901/02	West Lake Mara	Bukoba North Mara	Bukoba Shirati	17	5
1903/04	West Lake Dodoma Iringa	Bukoba Mpwapwa Iringa	Kisiba Mpwapwa Iringa and Tosamaganga	- - -	- - -
1904/05	Iringa " Coast	Iringa Njombe Kisarawe	Tosamaganga Ilembula Dar es Salaam	- - 1	- - 1

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TABLE I (CONTINUED):

YEAR	REGION	DISTRICT	LOCALITIES	NO. OF CASES	NO. OF DEATHS
1905/06	Iringa	Iringa	Iringa	-	-
	"	Njombe	Ilembula	-	-
	Mwanza	Mwanza	Mwanza	-	6
1908/09	Coast	Kisarawe	Dar es Salaam	12	6
1909/10	Mwanza	Mwanza	Mwanza	132	-
	Mara	North Mara	Shirati		
	Dodoma	Kondoa	Kondoa	-	-
1910/11	Mtwara	Lindi	Lindi	-	3
	Mwanza	Mwanza	Mwanza	17	15
	Coast	Kisarawe	Dar es Salaam	-	-
	"	Bagamoyo	Bagamoyo	-	-
1912	Kilimanjaro	Moshi	Gasseni Usseri	69	69

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TABLE I (CONTINUED):

YEAR	REGION	DISTRICT	LOCALITIES	NO. OF CASES	NO. OF DEATHS
1914	Kigoma	Kigoma	Kigoma, Ujiji	2	2
	Coast	Kisarawe	Dar es Salaam	-	-
1920	Singida	Singida	Singida)	124	124
	Mara	North Mara	Shirati)		
1921	Singida	Singida	Ihanja)	150	150
	"	Iramba	Mkalama)		
	Dodoma	Kondoa	Kondoa	-	-
	Mara	North Mara	Shirati	-	-
1922	Singida	Singida	Singida)	30	25
	Mara	Musoma	Musoma)		
	Mwanza	Ukerewe	Ukerewe)		
	Shinyanga	Shinyanga	Shinyanga)		
1923	Singida	Singida	Singida)	39	26
	"	Manyoni	Manyoni)		
	Dodoma	Kondoa	Kondoa)		
	Mwanza	Mwanza	Mwanza)		

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TABLE I (CONTINUED):

YEAR	REGION	DISTRICT	LOCALITIES	NO. OF CASES	NO. OF DEATHS
1924	Arusha Singida Mara	Mbulu Singida Musoma	Mbulu Singida Musoma	42	35
1925	Arusha Mara	Mbulu Musoma	Mbulu Musoma	44	27
1926	Mara	North Mara	Shirati	6	6
1927	Singida Mara Dodoma	Singida Musoma Dodoma	Singida Musoma Dodoma	13	10
1928	Iringa Mara Singida	Iringa Musoma Manyoni	Image Musoma Kisigo	43	42
1930	Arusha	Mbulu	Mbulu	15	15

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TABLE I (CONTINUED):

YEAR	REGION	DISTRICT	LOCALITIES	NO. OF CASES	NO. OF DEATHS
1931	Shinyanga	Shinyanga	Shinyanga, Jawa	238	172
	Shinyanga	Maswa	Maswa		
	Tabora	Tabora	Tabora		
	Tabora	Nzega	Nzega, Ndala Sungwisi		
1932	Arusha	Mbulu	Mbulu	12	10
	Shinyanga	Shinyanga	Shinyanga		
1933	Arusha	Mbulu	Mbulu	9	5
	Iringa	Iringa	Iringa		
1936	Iringa	Iringa	Mlolo	16	9
	Shinyanga	Maswa	Maswa		
1937	Singida	Singida	Singida	135	66
	Mwanza	Mwanza	Mwanza		
	Shinyanga	Maswa	Maswa		
	Iringa	Iringa	Iringa		

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TABLE I (CONTINUED):

YEAR	REGION	DISTRICT	LOCALITIES	NO. OF CASES	NO. OF DEATHS
1938	Arusha	Mbulu	Mbulu	3	-
1941	Arusha	Mbulu	Mbulu	2	2
1948	Singida	Iramba	Shelui, Sekenke, Kironda, Tintigula, Kiselelo, Matulutulu	312	178
1949	Singida	Singida	Singida	18	14
1951	Mwanza	Mwanza	Nassa, Nyambiti Igalukiro	263	40
	Kilimanjaro	Pare	Suji, Makanya		
	Arusha	Mbulu	Basoto		

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TABLE I (CONTINUED):

YEAR	REGION	DISTRICT	LOCALITIES	NO. OF CASES	NO. OF DEATHS
1952	Kilimanjaro	Pare	Suji, Chome, Vudee	573	100
	Arusha	Mbulu	Mbulu		
	Singida	Singida	Singida		
1953	Arusha	Mbulu	Mbulu	12	3
1956	Kilimanjaro	Moshi	West Kilimanjaro	5	-
	Kilimanjaro	Pare	Chome, Vudee		
1957	Kilimanjaro	Moshi	Rombo	5	-
	Kilimanjaro	Pare	Chome		
1962	Kilimanjaro	Moshi	Usseri, Mashati	15	5
	Singida	Singida	Ihanja, Kikomango		

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TABLE I (CONTINUED):

YEAR	REGION	DISTRICT	LOCALITIES	NO. OF CASES	NO. OF DEATHS
1963	Kilimanjaro Kilimanjaro Singida	Moshi Pare Singida	Usseri Chome Singida	8	4
1964	Kilimanjaro	Pare	Chome, Vudee	513	11
1965*	(Coast)		(Dar-es-Salaam)	1	1

*This one fatal case which was reported in Dar es Salaam had been contracted upcountry.

There were no outbreaks in the years that are not shown in the Table.

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Present State of Knowledge regarding the Nature of Plague Endemicity in Tanzania:-

Most of the early work on plague in Tanzania was concerned with the immediate problem of the control and prevention of plague epidemics. At first the greatest emphasis was laid on the destruction and control of domestic rats which were the immediate reservoirs of the disease. Some of the early German workers notably Lurz and Manteufel accomplished a considerable amount of work on plague in domestic and field rodents in some of the plague areas in Tanzania and also studied domestic rodent fleas.

With the discovery of modern insecticides and antibiotic and sulphonamide drugs the emphasis on plague control has shifted from rodent control to flea control and protective and curative treatment with drugs. This has tended to make the need for detailed studies of the rodents and fleas concerned with plague transmission less urgent.

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Halcrow (1958 and personal communication) carried out some observations on rodents and fleas in a few localities in Tanzania but left the country soon after starting this work. Hubbard (1963) made some extensive collections of field rodents and their fleas in North-East Tanzania. However, a detailed study of both domestic and field rodents and their flea fauna in plague and non-plague areas is considered a necessary pre-requisite for a full understanding of the true nature of plague endemicity in Tanzania. It is hoped that the present study will make some contribution towards that end.

MATERIALS AND METHODS OF INVESTIGATION.

AREAS OF STUDY:

In order to obtain useful scientific information on the nature of plague endemicity in Tanzania it was decided to carry out a detailed study of domestic and field rodents and their flea fauna in selected plague and non-plague areas in the country. Thus two plague areas, i.e. areas in which plague was known to be endemic and two non-plague areas, i.e. areas which were known to be free from endemic plague were selected for such a study.

The two plague areas selected were both centres of active plague foci, i.e. places where plague outbreaks had occurred in the past few years. One of these areas was Singida where endemic plague had been known to exist for a long time and the other was South Pare where so far as written records went, plague endemicity was comparatively new.

One of the non-plague areas chosen was Dar es Salaam which though free from endemic plague was known to have experienced plague outbreaks in the past; these outbreaks having been introduced from abroad.

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The other non-plague area selected was Morogoro where there had never been any recorded plague outbreak.

Singida:-

The Singida plague area is an old one and plague is said to have been present there since 1918. Since the old trade route to the coast from the Lake Victoria region and from Kenya and Uganda passed through Singida it is possible that this endemic area was established much earlier than written records would suggest. The plague focus of which Singida is one of the centres is situated in the Central Plateau of the country and extends northwards to Mbulu, eastwards to Kondoa Irangi and southwards to Manyoni. It is one of the most important foci of endemic plague in the country and since 1921 when the presence of the disease was proved microscopically outbreaks have occurred there more or less continuously to the present time.

Climate: - Singida lies on the Iramba Plateau which is part of the Central Plateau of Tanzania. It is about 5,000 feet above sea level and is situated near the western escarpment of the eastern branch of the Great Rift Valley.

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The climate is similar to that of the rest of the Central Plateau, i.e. a tropical climate modified in places by the altitude.

The maximum shade temperature is of the order of 32°C. (90°F) and is experienced from November to January and the minimum is about 13°C. (55°F) and occurs between June and July.

In the Iramba plateau there is only one dry and one rainy season. The dry season extends from June to November and the rainy season from December to May. Most of the rain falls in the first four months of the year. The average annual rainfall is about 22.0".

Vegetation: - The vegetation around Singida is mostly open grasslands with scattered low trees and patches of thorny bush in places. In the deep valleys and on higher ground the 'miombo' type of forest is found.

Occupation: - The people who live around Singida are the Wanyiramba. Some members of the adjacent tribe - Wanyaturu also live in Singida.

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The chief means of livelihood is agriculture on a subsistence scale and animal husbandry. The chief food crops grown are millets, maize, beans and some rice. Cotton is grown as a cash crop and large herds of cattle, sheep and goats are kept.

Standard of housing: - Except in towns and near mission centres the general standard of housing is very low. Most of the people in the villages live in the 'tembe' type of hut. The average type of tembe is a windowless rectangular structure about 30 m. long, 10 m. wide and about 1.5 m. high with a wall and roof construction of wattle and daub. Such a house is partitioned into several compartments to house humans, sheep, goats, chickens and sometimes young calves. Very often several tembes are built close together to house a whole clan in the same compound which would also include an enclosure for the clan's cattle. Both the inside and the surroundings of the tembes are in most cases of a very low hygienic standard. The floors are of bare earth but sometimes they are covered with a type of mat or loose hay. In the surroundings of the tembes may be maize or millet shambas or just bush.

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The flat roofs of the tembes are used for storing grain (maize or millet). The tembe is thus a very suitable place for rats (the walls, floors and the roofs) and for fleas (the loose earth floor, mat or hay). Man therefore lives in close association not only with domestic rats and their fleas but also with field rodents in the surrounding bush or shamba.

South Pare:-

The South Pare Mountain plague area is, so far as written records are concerned, the most recent one. The first plague outbreak in the area occurred in 1951 and since then sporadic outbreaks have recurred to the present time. The latest outbreak in the area was in 1964. This endemic area is centred around Suji, Chome and Vudee locations with an altitude of about 6,000 feet. But Makanya on the foot-hills with an altitude of about 4,000 feet was also involved in the first plague outbreak in the area in 1951.

Climate: - The weather on the mountain is pleasant with a temperature range between 30°C. (88°F) in January and 15°C. (60°F) in July.

On the plains the respective range is 35°C. in December-January and 20°C. in July-August.

The average annual rainfall over the South Pare Mountain plague area is of the order of 30". Most of the rain falls between March and May but there is a shorter rainy season between November and December. The wind-swept Makanya plain is a semi-desert area with an average annual rainfall of about 15" which falls mostly during the March-May rainy season.

Vegetation: - The mountain tops are covered with thick tropical forests. But the inhabited mountain slopes have been cleared of the original montane type of grass-land vegetation with scattered trees and are intensely cultivated. The valleys which are also intensely cultivated are partly swamps and partly montane grass-lands.

The plains around Makanya have a scrub type of vegetation except in swamps.

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In the more backward villages on the mountains and also on the plains around Makanya especially among the cattle keeping communities the dwelling houses are simple huts constructed of wattle and daub and roofed with grass. In such places the standard of hygiene is low and man lives in close association with domestic rats and their fleas and also with the surrounding bush and its rodent fauna.

Dar es Salaam:-

Dar es Salaam is the capital of the country and has been an international port since the 15th century. In the early part of this century plague was imported by sea into Dar es Salaam but because it did not gain any strong foothold it has never been endemic. Since the capital has for a long time been connected by communication lines with endemic areas in the interior, the danger has always been present of plague being introduced into Dar es Salaam. However, surprisingly few such introductions have occurred to date. In September 1965 a patient who had travelled from Mwanza and stopped at Manyoni died of plague at Muhimbili Hospital in Dar es Salaam.

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The present investigations were carried out in the city and its surroundings to a distance of about 15 miles.

Climate: - Being on the coast Dar es Salaam has a warm and humid climate. The temperature ranges from 20°C. (78°F) in July to 38°C. (100°F) in January. The average annual rainfall is about 45" falling in two seasons. The long rains are from about mid-March to end of May and the short rains from December to January.

Vegetation: - Much of the land around Dar es Salaam is swampy and the soil is sandy. The vegetation is mainly tropical grassland mixed with a low type of bush on higher ground.

Occupation: - There is much cultivation of coconuts, cashew nuts, rice, cassava and some maize and cotton by both the indigenous Wazaramo and immigrants from all over Tanzania. The majority of people who live in the City of Dar es Salaam work on paid employment.

Standard of housing: - The standard of housing in the villages on the outskirts of Dar es Salaam City is not very high. Most of the houses in such villages are rectangular structures of wattle and daub and thatched with woven coconut leaves. In most cases they have no cemented floors.

Morogoro:-

Morogoro is situated at the foot of the Uluguru Mountains and is 120 miles west of Dar es Salaam. The investigations were confined to the township and its immediate hinterland. The town is an old one and has been linked to the capital Dar es Salaam by rail since 1908. It is an important station on the highways from the East to the West and from the North to the South. In spite of what would appear to be a favourable position from the point of view of plague introduction, Morogoro has remained free of plague so far as it is known, all the time.

Climate: - Morogoro is about 1,600 feet above sea level and has a tropical type of climate with a rainfall of 35" - 45" annually which falls in two rainy seasons as in Dar es Salaam. The hottest part of the year is from December to February with the temperature reaching about 35°C. (95°F) in January and the coolest in July/August when the temperature falls to about 18°C. (65°F).

Vegetation: - The country around Morogoro is intensely cultivated for sisal and there is not much of the original vegetation left.

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Tropical Forest vegetation is found on the mountains and tropical grassland vegetation on the uncultivated parts of the plains. The 'miombo' type of forest is found over most of the drier parts of the plains and on the lower slopes of the mountains.

Occupation: - The rich red soil supports not only sisal which is grown by large estates on a commercial scale but also maize, millets, beans, vegetables and cotton. Rice and sugar cane are grown in the swamps and river valleys. The indigenous people are the Waluguru who have come down from the mountains to seek easier livelihood from the fertile plains or from paid employment. People of many different tribes are employed in the sisal estates.

Standard of housing: - The standard of housing in the villages and in the suburbs of Morogoro township is not high. The wattle and daub type of hut is common although bricks and corrugated iron sheets are being increasingly used.

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In the villages some of the people keep large numbers of goats but in most cases these live in separate enclosures aside from human living quarters. In many homes in the villages grain (maize, millet, rice) is stored in the house.

FIELD WORK:

The field work involved the catching of live rodents in houses and in the field, the collection of flea and other ectoparasites from the rodents and the processing of the rodent and flea materials.

In the plague areas the field observations were carried out in the form of two extensive surveys in each area, one during the cool and another during the hot season of the year. Each of these surveys lasted about a month and involved intensive work. These field surveys were carried out with the help of one experienced Entomology Laboratory Technician, two laboratory attendants, one Health Inspector or Assistant Health Inspector, a driver and two local helpers. A long wheel-base Land Rover was the chief means of transport used.

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During such a field survey much rodent and flea materials were collected which took a few months to sort out in the central laboratory.

In the non-plague areas which were nearer the base of operation the field observations were carried out less intensively but over a longer period of about a year.

Organisation of field work:-

In carrying out a survey in an area the work was done systematically spending a few days of trapping in each main village and the surrounding countryside.

In order to facilitate the easy collection of rodents and to minimise losses of traps the houses and fields in a village where rodents were to be trapped were divided into sections each of which was allocated to one worker who had a known number of traps assigned to him. This worker was responsible for the trapping and collection of rodents from his section and for bringing the rodents to the field laboratory for processing.

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Each field worker had to record the number of houses in his section, the number of traps he placed in each house, the position of the traps in the house, the type of bait he used in each trap and the type of house in which the traps were placed. For field trapping his field notebook would have a sketch map of the section where the traps were laid showing the position of each trap. At the close of the field survey in an area each worker was required to account for all the traps originally assigned to him. After some initial supervision it was found that this system worked well and during the four year investigation only about 5% of the traps were lost.

Precautions against plague infection:-

At first it was thought necessary to immunise all the field workers including the author with plague vaccine. Medical advice however was against this. Their argument was that the plague vaccine was not very effective and that during the off-season the chances of getting infected were remote. However the vaccine and plague treatment drugs were kept handy in the nearest hospital to where the field work was being carried out.

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In addition the field laboratory and the camp or rest house were dusted with 10% D.D.T. powder once a week; the insides of the knee-high rubber boots that were worn over trousers in the field were also dusted with the insecticide powder. These precautions together with the ordinary daily cleaning of the field laboratory and the camp were regarded as adequate. It was satisfying that the field work was concluded without a single incident.

The Traps:-

Since fleas abandon the dead bodies of their rodent hosts soon after the death of the latter it was necessary that live traps should be used. The traps used in the field work were of two types:-

Cage traps: - Two varieties of cage traps were used - the "Drop-Door" and the "False-Bottom" wire cage traps. The "Drop-Door" trap (fig.2) was the standard cage trap stocked by the Tanzania Government Stores. It was cuboid in shape, measured 50 cm. x 15 cm. x 15 cm. and was made of a network of stout galvanised steel wire (gage No. 16) spaced at about 1.5 cm. intervals.

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One end of the trap which was the 'drop-door' had a spring hinge which when set was connected to a trigger mechanism. The rodent got trapped on trying to eat the bait which was attached by means of a hook to the trigger mechanism. This trap was found to be capable of holding any ordinary-sized domestic or field rodent in comfort. However it was found that very small species like Mus musculus, Acomys wilsoni and young Mustomys coucha could squeeze their way to freedom through the gaps in the network. Being collapsible and tougher this trap was found more suitable and was used more extensively than the "False-Bottom" variety. It was found to be particularly useful for catching large domestic and field rodents. Usually only one rodent was caught in one trap but quite often, where there were many rats, more than one and sometimes a whole family of rats was caught in a single trap.

The "False-Bottom" cage trap (fig.3) was bee-hive in shape and measured about 40 cm. in length and about 16 cm. in height. It was made of a network of galvanised steel wire (gage 17) spaced at intervals of about 1 cm.

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The funnel-shaped inlet for the rodent was situated at one end and led on to a flat metal platform which was kept in position by a lever. The rodent got trapped by walking on to the platform and dropping into the trap chamber where the bait was placed. This trap was used for catching medium and large-sized domestic and field rodents but was not as efficient as the "Drop-Door" trap. Occasionally however under conditions of high infestation a large number of rodents (up to 11 at one time) were caught in one trap. It was found that the wire used for its construction was not strong enough to prevent determined rodents including large ones from squeezing themselves out in the gaps.

The Chauvancy Trap: - This small mammal trap made for the "MUSEUM NATIONAL D HISTOIRE NATURELLE DE PARIS" on a patent of "CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE" was found to be most handy for field rodents and for small domestic mice such as Mus musculis. The details of the trap are shown in figure 4. The essential part of the trap is a cadmium-steel, stainless spring ring with a flapping door.

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It can be fitted to all metallic boxes or cans of about 10 cm. diameter. The great advantage of this type of trap was that many could be packed in a relatively small space and the metal holders could be discarded after use. Various types of empty food and drug tins were found to be suitable for use with these traps. When used in the field it was found advisable to have the closed end of the can perforated to allow for ventilation; otherwise on a hot day, the animal caught died of heat exhaustion.

Although this type of trap was found to be suitable for catching many types of field rats including fully grown Tatera - it did not work so well with the common domestic rats Rattus rattus and R. norvegicus regardless of their sizes. This was thought to be due to the great suspicion which these domestic rats have for strange objects. However the semi-domestic field mouse Mastomys coucha and the house mouse Mus musculus were easily caught inside houses using this type of trap.

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Bait:-

Many types of bait were used - green and dry maize, fresh and dry cassava, sweet potatoes, ripe bananas, ground nuts, coconuts, carrots, dried and fried fish, fried and boiled beef, and various types of bread. In addition some enthusiastic house holders added other things to the baited traps in an attempt to make them more attractive. These were in the nature of various types of cooked foodstuff - rice, 'ugali', bananas, sweet potatoes, Irish potatoes, fish, meat, etc.

It was found that both for domestic and field rodents the cereal type of bait, especially maize, was most attractive followed by roots and nuts (cassava, potatoes, coconuts, ground nuts) and then by fruits. Meat and fish of whatever description was not found to be attractive, especially with field rodents. This comparative attractiveness of different types of bait was found to be practically the same for all the rodents caught. There did not seem to be any correlation between the smell (from the human point of view) and the attractiveness of the bait. When strongly smelling fish or dried meat and maize were used as bait in the same house and at the same time it was found that the latter was more attractive than the former.

The Trapping of Rodents:-

Before the traps were laid out the houses in the villages and the fields and cultivated shambas around the villages were quickly surveyed to determine the most likely places. In preliminary observations in Dar es Salaam and Morogoro it had been found that "low standard" houses, i.e. huts built of wattle and daub and having earth floors were most attractive to rats. A thatched roof seemed an added attraction but the most important deciding factors were mud walls and earth floors. During trapping therefore attention was concentrated on the "low standard" type of house. But "better standard" houses, i.e. houses with cemented floors, concrete or concrete-plastered walls and corrugated iron or tile roofs were also searched for rats especially if the owners complained of rat infestations.

In houses the baited traps were placed out of the reach of children in dark corners, under beds, behind furniture, by rat burrows and in rat runways. Traps were also laid in outbuildings, e.g. grain stores and kitchens. The house owners were requested not to interfere with the traps and not to kill the rats when caught.

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Usually house trapping was carried out in the afternoon and the rodents collected the following morning. During collection the traps that had no catch were examined and if necessary rebaited and their positions changed.

In the field the baited traps were placed in rodent runs and by rodent burrows. Care was taken where possible to conceal the traps under the cover of grass or low bush. Where such a natural cover did not exist some grass or leaves were used to conceal the traps. The concealing of the traps was done not only to counteract the suspicion of the rodents and to reduce their exposure to the heat of the day but also to minimise the loss of traps through theft by passers-by especially children. Field trapping was usually carried out in the mid-morning and late afternoon and the rodents collected in the late afternoon and early morning. The same procedure was adopted regarding the rebaiting of traps and the changing of their positions as in the case of house trapping.

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PROCESSING OF RODENTS AND THEIR FLEAS:

The rodents collected from houses and from the field were sent to the field laboratory and transferred one at a time from the traps into a clean specially constructed wooden box (15 cm. x 15 cm. x 15 cm.) with a sliding top. The animal was given a serial number which was recorded before it was killed with chloroform contained in cotton wool. After death, which took 5 - 10 minutes the animal was placed on a white enamel tray (30 cm. x 26 cm. x 5 cm.) and the following processes were carried out:-

Collection of Fleas and other Ectoparasites:-

It was found that the process of killing the rodents when properly carried out also killed the ectoparasites. Using a small brush all the ectoparasites were removed from the dead animal onto the tray. The stick-tight fleas were removed gently with a fine pair of forceps. Any parasites that had fallen from the rodent during the process of killing into the killing box were also placed in the white basin. The ectoparasites were placed in 6 ml. bottles containing 70% alcohol. Separate bottles were used for fleas, ticks, mites and lice.

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The bottle was then labelled with the serial number of the rodent from which the ectoparasites were collected and kept for subsequent identification of the ectoparasites.

Measurements of the Rodents:-

After the ectoparasites had been removed and preserved the relevant identification measurements of all adult rodent specimens were taken. These were weight (in gm.), length of head and body excluding the tail, length of tail, length of hind foot and length of ear (in mm.). Besides these measurements a note was taken of the sex, mammary formula and species (if known) of the rodent and the weather condition at the time of collection.

The size of litter of the Rodents:-

In order to get some idea of the size of litter of the rodents caught those females found by visual inspection to be at an advanced stage of pregnancy were opened up after all the measurements had been taken and the number of foeti in both uteri counted.

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Collection of Blood Samples for Plague Anti-body Serological Tests:-

After all the above processes had been completed the chest of the animal was cut open and two discs of adsorbent paper were soaked with blood from the chest cavity. The adsorbent paper discs 0.5 in. (12.7 mm.) in diameter were of the type used for the assay of antibiotic substances (Carl Schleicher and Schuell Co., Keene, New Hampshire). The blood-soaked discs were allowed to dry away from dust and direct sunlight. After complete drying which took about 24 hours the discs were labelled with the serial numbers of the respective rodent from which the blood was obtained, and mailed off to Dr. F.K. Meyer of the George Williams Hooper Foundation, University of California for serological tests for plague antibodies.

Identification of the Rodents:-

The common rodents were identified in the field. Those whose identity could not be ascertained in the field were preserved as stuffed skins and skulls following the method of Setzer (1963) and sent to the Central Laboratory for closer examination.

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The preserved specimens of those rodents which could not be identified were sent to the Medical Research Laboratory, Nairobi, Kenya and to the British Museum of Natural History for expert identification.

Identification of the Fleas:-

All the fleas collected in the field were sent to the Central Laboratory in Dar es Salaam for identification. Most of the material was identified by examining the preserved specimen in a drop of water on a slide under a cover slip with the low power of a microscope.

It was found that for the female the spermatheca could easily be seen in most of the specimens when the flea was placed on the slide with its right side uppermost. It was sometimes necessary to apply slight pressure with a dissecting needle on the cover slip to reveal the spermatheca. For very dark specimens it was found necessary to prepare permanent preparations of the fleas. The method adopted was essentially that of Matheson (1950).

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Those flea specimens which could not be identified with certainty were sent to F.G.A.M. Smit of the British Museum of Natural History for expert identification.

The results of these investigations are summarised in Tables II - VII.

THE RODENTS:

In Tables II and III the taxonomic status, numbers collected, relative abundance and sex of the rodents caught in houses and in the field in the four areas of investigation are given. Altogether 1,164 rodents were caught in houses and 1,343 were collected in the field.

An examination of Table II shows that the black rat Rattus rattus was the commonest and most abundant rodent in houses in all the areas investigated. The multi-mammate rat Mastomys coucha was found in houses in both the plague and the non-plague areas but the numbers caught were negligible in all the areas except in Singida where it formed 16% of the total catch from houses. The brown rat R. norvegicus and the pygmy mouse Mus musculus were caught in houses in Dar es Salaam only where they formed 26% and 19% of the total house catch respectively.

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One specimen of the garbil Tatera robusta, a typical wild rodent was caught in a 'tembe' type of hut at Singida.

As shown in Table III the field rodent fauna of the two plague areas was much richer in variety than that of the two non-plague areas. Thus whereas ten genera of rodents were collected from the former areas only half as many were obtained from the latter areas. It is noteworthy too that all but one (Lemniscomys) of the genera caught in the field in the non-plague areas were also found in the plague areas while six genera found in the latter areas were not recorded in the former. It is clear from Table III that M. coucha was the most common and most abundant field rodent in all the areas of investigation. In the plague areas the unstriped grass mouse Arvicanthis abyssinicus was second in abundance to M. coucha and formed 31% of the total catch from the field in both areas.

The arithmetic means and range of the standard body-measurements of adult (mature) males and females of all the species of rodents collected in houses and in the field in all the areas including their weights and the

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mammary formulae of the females are shown in Table IV. Mature females were identified by the perforate vagina and mature males by the presence of clearly visible tubules through the shiny skin of the testes (see Fehn and Kinney, 1949). For those species of which only a few specimens were collected these measurements have been given only for the sake of completeness, it being understood that they would have much less meaning in these cases than in those in which significantly large numbers of both sexes were caught. The table shows that in the domestic rats Rattus rattus and Rattus norvegicus the male attains a larger body size than the female. This however was not always the case with field rodents. In Mastomys coucha and Arvicanthis abyssinicus for example there was not much difference between the sexes in this respect.

FLEA INFESTATION:

The species of fleas collected are listed below according to the classification of DeMeillon et al (1961):-

FAMILY	SUB-FAMILY	Genus & Species.
PULICIDAE	XENOPSYLLINAE	Xenopsylla brasiliensis
		Xenopsylla cheopis
		Xenopsylla debilis
	PULICINAE	Echidnophaga gallinacea
	ARCHAEOPSYLLINAE	Ctenocephalides felis strongylus

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FAMILY	SUB-FAMILY	Genus & Species.
CERATOPHYLLIDAE	CERATOPHYLLINAE	Nosopsyllus fasciatus
LEPTOPSYLLIDAE	-	Leptopsylla aethiopica
HYSTRICHOPSYLLIDAE	DINOPSYLLINAE	Dinopsyllus lypusus
	CTENOPHTHALMINAE	Ctenophthalmus calceatus.

The details of the flea-fauna including the extent and degree of flea infestation (as indicated by the percentage of rodents infested and by the flea indices respectively) of the rodents caught in houses and in the field are shown in Tables V and VI.

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A total of 2,547 fleas was obtained from rodents caught in houses and of 2,975 from rodents caught in the field. These two tables show that the extent and degree of flea infestation of both domestic and field rodents was higher in plague than in non-plague areas. In Table V the extent of flea infestation and the highest number of fleas found on a rodent have been given only in regard to Xenopsylla fleas since these are known to be the fleas of importance in the transmission of plague from domestic rats to man. In Table VI however these measurements have been given in regard to all types of fleas found on field rodents.

The domestic fleas X. brasiliensis and X. cheopis formed the greater bulk of the fleas collected from rodents caught in houses in all the areas. The former flea was in all cases more abundant than the latter of which only comparatively small numbers were collected in the plague areas. These two same species together were also the most abundant fleas of the two commonest field rodents M. coucha and A. abyssinicus. However, whereas X. brasiliensis was more abundant on M. coucha than X. cheopis the latter flea was by far the more abundant of the two in the case of A. abyssinicus.

The flea-fauna of wild rodents was much richer in variety in the plague areas than in the non-plague areas. Of the typical field rodent fleas D. lypusus was the most common and occurred in both plague areas while L. aethiopicus, C. calceatus and N. fasciatus were only found on the highlands of the South Pare area. X. debilis was mainly found on the gerbils T. robusta and T. leucogaster.

An analysis of the flea indices according to the seasons of the year in which the rodents were caught revealed no consistent pattern and gave the general impression that these indices did not vary to any considerable extent from one season to another. The constancy of the micro-climatic conditions of rodent burrows (see Ingram, 1927; Buxton, 1933; George and Webster, 1934) together with the constant body temperature which rodents have (in common with other mammals) afford the most probable explanation for this observation.

TESTS FOR PLAGUE ANTIBODIES:

The results of serological tests for plague antibodies carried out by Dr. K. F. Meyer of the George Williams Hooper Foundation, University of California using the paper disc method described by Trainer et al (1963) are shown in Table VII. Since this aspect of the investigation was adopted some time after the work had begun only some of the rodents caught were tested. These included all the rodents caught in the two plague areas and 136 rodents caught in one of the non-plague areas (Dar-es-Salaam).

Of a total of 1,310 rodents tested from the plague areas 12 were found to be positive for plague antibodies. All the positive specimens were caught in the field and belonged to four species - M. coucha (5), A. abyssinicus (5), G. dolichurus (1) and P. morio (1). The numbers found positive were small possibly due to the fact that the rodents were caught during the plague off-seasons. It is however believed that these positives indicate the species of rodents which play an important part as reservoirs of plague in the endemic areas.

DISCUSSION.

DOMESTIC RODENTS AND THEIR FLEAS:

The term "domestic rodent" is here used to mean the typical house rats R. rattus and R. norvegicus and the pygmy mouse Mus musculus. The multimammate rat M. coucha believed to have once been the house rat of East Africa has now largely ceased to play this role having to a great extent been ousted from houses by R. rattus.

Rattus rattus:-

This domestic rodent which is commonly known as the black rat or roof rat is now the commonest house rat in Tanzania. Hopkins (1949) gives the opinion, with reason, that R. rattus was introduced into the inland areas of Kenya and Uganda early in the present century by the Kenya and Uganda Railways (1896 - 1901). It is probable that this rodent was introduced into the interior of Tanzania at about the same time via Kenya and Uganda and by the Central and Tanga Railways which were also built early in the century.

The predominance of Rattus rattus in houses in all the areas investigated indicates that this rodent has to a large measure successfully replaced Mastomys coucha as the domestic rat of Tanzania.

There are three main colour varieties of R. rattus all of which are found in East Africa (Schwarz, 1935). These colour forms which have been regarded by some workers as sub-species are:-

i) Rattus rattus rattus which is black or slate-coloured on both back and belly.

ii) Rattus rattus alexandrinus which has a tawny back and a greyish-white belly.

iii) Rattus rattus frugivorus which has a tawny back and a white or lemon-coloured belly. (Fehn and Kinney - 1949).

It is now held by many experienced workers that all these varieties are not true sub-species but colour forms of Rattus rattus - Jorge (1928), Webster (1933) Ellerman

and Morrison-Scott (1951). This view has been adopted in the present work.

Body Measurements: - The standard body measurements and weight of adults are shown in Table IV. The general conclusion that can be drawn from these measurements is that the male attains a larger body size (as judged by the maxima of the measurements) than the female and reaches maturity at a smaller body size and possibly younger age.

Mammary formula: - Although the typical mammary formula of 2 - 3 = 10 shown in Table IV for this species was found in the majority (61.7%) of the adult females collected, a considerable proportion (37.5%) had an extra mammy on one or both sides of the thorax making the total number of mammies 11 - 12. Two individuals had the mammary formula 3 - 2 = 10, unusual in this species and one individual specimen had an extra mammy on one side of the abdomen.

Breeding: - Breeding did not appear to be markedly seasonal although it was more intense during the time of harvest of the locally grown grain particularly maize and millet. Altogether 39 females were found to be at an advanced stage of pregnancy. The distribution of foeti in the two uteri was more often than not uneven, sometimes grossly so. In four of the cases for example all the foeti were in the one uterus while the other was empty, and in another case with 10 foeti, 7 were in the one uterus and 3 in the other. The average number of foeti in a pregnant female was 6 and the maximum 10.

Habitat: - This rat was found to be mainly commensal in houses, godowns, granaries, etc. No specimens were caught from outside. It lived mainly in nests, in the roofs of thatched houses, in ceilings and also in burrows in earth floors and walls.

Hopkins (1949) states that Rattus rattus is a poor burrower but that it sometimes lives in burrows made by Mastomys coucha. He doubts whether this rodent ever makes its own burrows and expresses the opinion that it nests by

preference in the roofs of "huts" i.e. dwellings built of mud and wattle usually with thatched roofs and almost always with earth floors. It has been stated by Wu Lien-teh (1936) that in India Rattus rattus were seen to dig in soft materials like earthen floors and walls and Milmore (1943) and Peralio (1943) have found that in the U.S.A. these rodents dig under-ground shelters. Pollitzer (1954) states that one reason why R. rattus prefers to shelter in upper parts of buildings is to keep out of the way of Norway rats (R. norvegicus) living in the same premises in under-ground burrows or on the ground floor; in the absence of R. norvegicus, R. rattus may live on the ground floors or even under-ground. Girard (1937) found that in Madagascar where R. norvegicus were absent R. rattus inhabited the sewers in their place. During the course of the present work considerable numbers of R. rattus were found living in burrows in earth floors and mud walls of dwellings. In Dar es Salaam and Morogoro where the houses from which rats were caught were classified as "low standard" or "better standard" corresponding very nearly to Hopkin's "huts" and "permanent buildings" respectively, it was

found that about 80% of R. rattus were caught in the "low standard" and about 20% in the "better standard" type of house.

Habits: - Rattus rattus was found to be communal to some extent and sometimes a whole family group comprising several adult males and females was caught in the same trap. Although the species would feed on practically any kind of food when used as bait it was found that cereals and cereal products - maize, millet, bread, buns, etc. were definitely more attractive than other kinds of food.

The fleas of Rattus rattus: - The fleas collected from Rattus rattus in all the four areas are shown in Table V. The 1,688 fleas collected from 816 rodents of this species were distributed as shown in Table VIII.

Table VIII.

Fleas of Rattus rattus.

Species	Number collected	% of collection
Xenopsylla brasiliensis	988	58.6
Xenopsylla cheopis	335	19.9
Echidnophaga gallinacea	321	19.0
Ctenocephallides felis	10	0.6
Leptopsylla aethiopica	26	1.4
Xenopsylla debilis	6	0.4
Dinopsyllus lypusus	2	0.1

The first three species - X. brasiliensis, X. cheopis and E. gallinacea were found in all the areas. The chick flea E. gallinacea was only found in considerable numbers in Dar es Salaam where it formed 47% of all the fleas collected from Rattus rattus in that area. The presence of this flea in houses is governed more by the presence of chickens than by the presence of rats. However since

it has been shown to be capable of transmitting the plague bacterium Pasteurella pestis - Wheeler et al (1941) and Burroughs (1947), its presence in houses cannot be ignored. The cat flea Ctenocephalides felis was found on R. rattus in three of the areas but the numbers collected were negligible. In reviewing the experimental evidence for and against incriminating the common cat and dog fleas C. felis felis and C. canis as vectors of bubonic plague Pollitzer (1954) came to the conclusion that these fleas did not play any important role in the transmission of plague under natural conditions.

The last three species of fleas found on R. rattus - Leptopsylla aethiopica, Xenopsylla debilis and Dinopsyllus lypusus which are fleas of field rodents were only found in the plague areas. Although the numbers collected were small they indicate the close connection that exists between domestic and field rodents in the endemic areas of plague. The exchange of fleas between field and domestic rodent provides an important link between sylvatic plague on the one hand and domestic rodent plague and human plague on the other.

Hopkins (1949) states that the relative frequency of such a flea exchange indicates the degree to which contact between the two types of rodents takes place. Fox (1909), McCoy and Mitzmain (1911), Prince (1943) and Meyer and Holdenried (1949) found that fleas of the ground squirrel (Citellus) commonly occurred on rats in endemic areas of plague in the U.S.A.

The typical domestic rodent fleas Xenopsylla brasiliensis and X. cheopis together formed nearly 80% of all the fleas found on Rattus rattus. X. brasiliensis was numerically the more important of the two species and formed nearly 60% of the total fleas found on this rodent when all the areas are considered together.

In the two plague areas which were mostly rural in nature with a preponderance of "low standard" houses X. brasiliensis accounted for nearly all the Xenopsylla fleas found on R. rattus and was in both areas over 20 times more numerous than X. cheopis. In the two non-plague areas where urban conditions prevailed and

where a considerable number of houses were of a "better standard" type, the proportion of X. cheopis was much higher. Roberts (1936 and 1950) attributed the greater abundance of X. brasiliensis over X. cheopis on Rattus rattus to a difference in the habits of the two fleas. He stated that X. cheopis mainly infested rodents living underground in permanent houses whereas X. brasiliensis mainly infested rodents which sheltered in thatched roofs of rural buildings. These observations were supported by those of Symes and Roberts (1936) and Cormack (1936). The fact that in Dar es Salaam most of the R. rattus specimens with X. cheopis were caught in houses, shops, godowns in the centre of the city and most of those with X. brasiliensis were caught in huts on the periphery and outside of the city would seem to lend some support to this statement. It should be stated however that some rodents of this species with X. brasiliensis were found living in underground burrows.

The Role of Rattus rattus in the transmission of human plague: - Hopkins (1949) stated: "there is no possible doubt that R. rattus is the principal rodent-vector

of plague in Uganda at the present day." He found that there was no area in Uganda in which plague was endemic in the absence of this rat. Roberts (1950) claimed that R. rattus was the only rodent involved in plague transmission in Kenya. Pollitzer (1954) stated that Rattus rattus alexandrinus appeared to be the only rodent playing a causative role in plague outbreaks in Tanganyika.

Although the above statements particularly that of Roberts would in the light of present day knowledge appear to be somewhat exaggerated, there is no doubt that in human plague outbreaks R. rattus plays a central role.

It would appear that the reasons why R. rattus plays such a key role in the transmission of human plague in Tanzania are three-fold: it is the rodent living in closest association with man being in most areas practically the only rodent living in human dwellings; it is highly susceptible to plague infections; its main flea ectoparasites X. brasiliensis and X. cheopis are known to be efficient vectors of plague (Pollitzer - 1954).

Tests for plague antibodies in Rattus rattus: - Blood samples from 318 rats of the species Rattus rattus were tested for plague antibodies by the paper disc method; none was found to be positive although 203 of the specimens were obtained from plague areas (Table VII). Since these specimens were collected during the off-season of plague the negative result is not very surprising. It should be pointed out however that Meyer (1964) found 14% of 646 sera specimens from R. rattus in Kenya positive for plague antibodies but in this case the tests were carried out on sera specimens and not on dried up blood on filter paper discs.

Rattus norvegicus:-

The Norway rat or brown rat or sewer rat as it is sometimes called, was only found in Dar es Salaam. Swynnerton (1951) shows that R. norvegicus has been recorded at Pangani, Bagamoyo and Kimbande (Songea) in Mainland Tanzania. Halcrow (unpublished report) states that R. norvegicus has not been recorded at Tanga.

Manteufel (1910/11) reported that of 1,161 rats examined at Mwanza 998 (86%) were 'Mus documanus' (Rattus norvegicus) and that R. rattus was absent from the area. However in the Tanganyika Annual Medical Report for 1928 it is stated that among the rats caught in houses at Mwanza that year 46.16% were R. norvegicus, 42.23% were R. rattus and 11.61% were Arvicanthis abyssinicus. It would seem from the two statements that R. norvegicus was being replaced by R. rattus at Mwanza.

R. norvegicus would thus seem to have a sporadic distribution in Mainland Tanzania and to be mostly found along the coast. Its presence at Mwanza has not been checked in recent years. This patchy distribution would seem to indicate that this rodent has not been very successful in establishing itself. In Dar es Salaam its presence was confined to the central commercial part of the city.

Body Measurements: - Table IV shows that the adult male R. norvegicus attains a larger body size and heavier weight than the adult female. The heaviest male caught

weighed 552 gm. and the heaviest female 359 gm. As in R. rattus males of R. norvegicus seemed to reach sexual maturity at an earlier age (smaller body size) than females.

Mammary formula: - The mammary formula shown by the 88 adult females examined was 2 - 3 = 12 typical of this species. No anomalies were found in regard to this characteristic.

Breeding: - No marked seasonal differences in breeding activity were noted. Of the 12 females found to be at an advanced stage of pregnancy an average of 8 developed foeti was recorded. The maximum number of foeti found in a female was 10. The distribution of young in the two uteri was uneven in most cases.

Habitat: - R. norvegicus was caught in buildings in the central part of the city of Dar es Salaam. Most of the rodents were caught in "low standard" type houses and in permanent houses which were in delapidated conditions with a low standard of sanitation. These rats

were also found to inhabit stores, kitchens, shops, etc. especially if these were in a poor standard of cleanliness. All the specimens were caught by placing baited traps on the ground floor next to their burrows or in their runs; none were caught in traps placed in the attic. This was in agreement with the common experience that R. norvegicus as a rule prefers to live underground.

Habits: - It has been pointed out by many workers including Pollitzer (1954) that the feeding habits of R. norvegicus are more catholic than those of R. rattus. Thus the former rat can subsist on any type of nourishment available including garbage heaps, sewers, etc. This might explain why in the present work they were found in delapidated houses and buildings with a low standard of sanitation. Judging from the attractiveness of the different types of bait that were used the food preferences of R. norvegicus were similar to those of R. rattus.

Fleas of Rattus norvegicus: - The 738 fleas found on 187 rodents of this species were distributed as shown in Table IX.

Table IX.

Fleas of Rattus norvegicus.

Species	Number collected	% of collection
Echidnophaga gallinacea	410	56
Xenopsylla cheopis	324	44
Ctenocephalides felis	4	1

It is interesting that not a single specimen of Xenopsylla brasiliensis was found infesting this type of rat. Phipps (1949) in an unpublished report on "Identification of Rat Fleas in Dar es Salaam" found that most of the fleas collected from Rattus norvegicus were Echidnophaga gallinacea and Xenopsylla cheopis. However he reported finding two male specimens of X. brasiliensis (one of which he marked 'doubtful') on this rat.

The Role of Rattus norvegicus in the transmission of human plague: - Wu-Lien-teh et al (1936) stated emphatically that "R. norvegicus and R. rattus are equally susceptible to plague infection and, whenever occurring by themselves, equally able to act as reservoirs of the virus."

In Tanzania where this rodent is not widely distributed it cannot be regarded as playing any important role in the transmission of plague except perhaps at Mwanza.

Tests for plague antibodies in R. norvegicus: - No specimens of R. norvegicus were tested for plague antibodies.

Mus musculus:-

This tiny mouse is commonly known as the Common House Mouse or the Pygmy Mouse. Miller (1912), Ellerman (1941), Hill and Carter (1941) and Swynnerton (1951) regard Mus and Leggada as synonyms which view is contrary to that of Thomas (1919) who considered the two as distinct natural groups.

This species was only caught in houses in Dar-es-Salaam (Table II) and 18 specimens were caught outside in the vicinity of houses at Chome in the South Pare area (Table III).

Body Measurements: - There was not much difference in size between males and females of this species (Table IV).

Mammary Formula: - All the 49 adult females examined had the mammary formula typical of this species 3 - 2 = 10.

Breeding: - The breeding activity of this rodent showed no seasonal fluctuations. A total of 9 females at an advanced stage of pregnancy was collected. The average number of foeti in the two uteri was 4 and the maximum 6. The distribution of the foeti in the two uteri was not even.

Habitat: - Although this rodent usually lives indoors it was often seen foraging out of doors in the vicinity of houses. The 18 specimens collected from

the Pare area were all caught in Chauvancy traps placed in the open near houses. It lives in burrows in earth floors and mud walls. In many places it was found occupying the same premises as Rattus rattus.

Habits: - Of the three common species of domestic rodents M. musculus seemed to be the least shy. Several times members of this species were observed, in their foraging activity, to approach from underneath beds or from behind furniture in houses to within a few inches of places where people were sitting. M. musculus also seemed to be the cleanest of the three domestic rodent species; it was mostly caught in clean environments free of rubbish and other kinds of accumulations. This would seem to be reflected in the very low flea index characteristic of this species (see below).

The fleas of Mus musculus: - Only 8 fleas were collected off 132 M. musculus caught in Dar es Salaam giving the negligible flea index of 0.06 (Table V). The 8 fleas were X. cheopis (7) and E. gallinacea (1).

The Role of Mus musculus in the transmission of human plague: - Commenting on plague in the Cape Province of South Africa Davis (1943) attributed the low incidence in the Central and Western Karroo areas to the fact that Mus musculus was the only commensal rodent present, R. rattus and M. coucha being absent. He pointed out that human infections in these areas were mostly spread by means of a direct contact with wild rodents or their fleas.

Pollitzer (1954) expressed the opinion that though M. musculus was often found infected during the course of rat epizootics, it was usually a victim of the disease rather than an agent in its transmission. He attributed this to two facts:-

i) These rodents were often less susceptible to plague infections than the rats.

ii) The flea index of the mice was considerably lower than that of the rats.

The second explanation is supported by the findings of the present investigation. However it has been shown by several workers including Herivaux and Toumanoff (1948) and Girard (1937) that this rodent may sometimes play an important role in plague especially when infested with efficient flea vectors like X. cheopis.

Tests for plague antibodies in Mus musculis: - All the 18 specimens tested from the South Pare plague area were negative for plague antibodies.

FIELD RODENTS AND THEIR FLEAS:

All the species of field rodents collected in all the areas of study are shown collectively in the order of their numerical importance in Table X.

Table X.

Relative Abundance of Field Rodent Species from all the Areas combined.

Species	Total number collected from all areas.	% of total collection from all areas
Mastomys coucha	770	58
Arvicanthis abyssinicus	339	26
Tatera robusta	99	7
Praomys moris	23	2
Lemniscomys griselda	22	2
Grammomys dolichurus	18	1
Acomys wilsoni	16	1
Pelomys fallax	16	1
Tatera leucogaster	16	1
Lophuromys flavopunctatus	14	-
Praomys jacksoni	3	-

Mus musculus of which 18 specimens were caught outside from the Pare area is not considered under this section as this species is regarded as a 'domestic' rodent and has been considered with the other domestic rodents.

Mastomys coucha:-

Synonyms: Rattus natalensis, Mus coucha, Mus natalensis.

This species which formed more than half of the total field catch in both the plague and the non-plague areas is commonly called the multimammate rat or the shamba rat.

Mention has already been made of the tendency of this rodent to enter houses and of the fact that in one of the plague areas 16% of all the rodents caught in houses belonged to this species. Hopkins (1949) has expressed the opinion that before Rattus rattus came to Uganda Rattus coucha (Mastomys coucha) was the house rat of the whole of Uganda and that it was still abundant in all the areas to which Rattus rattus had not penetrated. Pollitzer (1954) pointed out that in the Lake Albert and Lake Edward foci of plague in Congo M. coucha formed 98% and 32% respectively of the rodents found in human

habitations. Ansell (1960) reported that M. coucha was the common house rat of Northern Rhodesia (now Zambia).

Body Measurements: - There does not seem to be much difference in size between the sexes (Table IV).

Mammary formula: - The mammies were arranged on either side of the thorax and abdomen in a single unbroken line. The number of mammies on one side varied from 7 - 11 giving a total of 14 - 22 mammies. Ansell (1960) made a similar observation on this species in Zambia.

Breeding: - Breeding was found to take place the whole year round but tended to increase in intensity during and soon after the harvest of cereals. M. coucha was found to be a very fertile rodent producing many young per litter. An average of 11 foeti was found during the examination of 20 females which were at an advanced stage of pregnancy. The maximum number of foeti found in both uteri of a female was 17 and the minimum 8. This great fecundity is believed to be one of the factors accounting for the great abundance and ubiquity of this rodent all over the country.

Habitat: - This rodent lives mainly in the field around villages and in 'shambas' (cultivated fields) away from the villages. It is a burrowing animal.

Habits: - The semi-domestic habits of this species has already been referred to. It seems to be a very adaptable rodent which can thrive just as well in human habitations, in the 'shambas' around villages or in fields away from human dwellings. Neither does it seem to be very selective in its feeding habits. The places from which it was caught included shambas of rice, maize, millet, cassava, sweet potatoes, sugar-cane and open fields containing nothing but grass, apparently thriving quite well on the latter. It would appear certain that the great adaptability possessed by this rodent both in regard to habitat and diet is another contributory factor in its great success in colonising different types of environments. It was found to be just as abundant at sea level in the Dar es Salaam area as at 6,000 ft. in the Chome/Suji area of South Pare.

The fleas of Mastomys coucha: - A total of 1,323 fleas was collected from M. coucha caught in houses and in the field (Tables V & VI). The distribution of these fleas according to species is shown in Table XI.

Table XI.

Fleas of Mastomys coucha.

Species	Number collected	% of collection
Xenopsylla brasiliensis	776	59
Dinopsylla lypusus	225	17
Xenopsylla cheopis	196	15
Xenopsylla debilis	43	3
Leptopsylla aethiopica	42	3
Ctenophthalmus calceatus	36	3
Nosopsyllus fasciatus	3	-
Ctenocephalides felis	2	-

The most important points of interest in regard to the flea fauna of Mastomys coucha as observed during the course of this investigation are:-

i) In the non-plague areas the flea infestation of this rodent was almost negligible. In the plague areas on the other hand the flea index was high and the flea fauna rich.

ii) A high proportion of the fleas infesting this rodent in plague areas was composed of the common domestic rodent fleas Xenopsylla brasiliensis and Xenopsylla cheopis which formed nearly 75% of all the fleas collected from this rodent. This is an indicator of the close relationship in which M. coucha lives with R. rattus even in those areas in which the former rodent was not found to live in houses to any appreciable extent. This relationship between the two rodents which enables the exchange of fleas between them is of vital importance in the conveyance of plague from wild rodents to domestic rodents and to man - Davis (1964).

iii) About 25% of the fleas found on M. coucha in the plague areas were typical wild rodent fleas. Most of these were also found on other wild rodents like Arvicanthis abyssinicus and Tatera robusta. The sharing of fleas with wild rodents again shows that M. coucha lives in close association with such rodents.

It is clear therefore that in the endemic areas of plague in Tanzania M. coucha plays the role of an intermediary between wild rodents and domestic rodents.

Dinopsyllus lypusus numerically the most important wild rodent flea found on M. coucha is known to be a vector of plague in Central Africa. Thus Heisch (1952) found a pool of fleas of this species collected from an Arvicanthis burrow in Kenya to be positive for P. pestis. The other wild rodent fleas collected off M. coucha i.e. Leptopsylla aethiopica and Ctenophthalmus calceatus which were only found in the highland areas of South Pare (at Chome and Suji) are not regarded as important since only

small numbers were found. It should be noted however that Devignat - (quoted by Pollitzer, 1954) was able to infect guinea-pigs by inoculating them with a suspension of pools of L. aethiopica.

The role of Mastomys coucha in the transmission of plague: - Vincke and Devignat (1937) pointed out that in the Lake Albert plague focus of Congo the disease occurred where Rattus coucha ugandae (M. coucha) was the principal if not the only reservoir of the disease and where R. rattus was absent. While considering the role of Mastomys coucha in plague in Uganda, Hopkins (1949) came to the conclusion that before the arrival of R. rattus early in the century M. coucha was responsible for carrying plague and that it was probably still playing a minor role in the spread of plague in that country. Davis (1948, 1964) has pointed out that in the endemic areas of South Africa M. coucha is the intermediary between primary gerbil reservoirs and man. Heisch (1952) during a study of wild rodent reservoirs of plague in the Rongai endemic area of Kenya proved the presence of

P. pestis in M. coucha.

Test for plague antibodies in M. coucha: - A total of 603 rodents of this species collected in the two plague areas were tested for plague antibodies and 5 were found to be positive (Table VIII). The presence of plague antibodies in the blood of this rodent during the off-season of plague suggests that it probably acts as a reservoir of plague.

Arvicanthis abyssinicus:-

Ellermann et al (1953) regards A. abyssinicus as being conspecific with A. niloticus. However Hopkins (unpublished manuscript quoted by Ansell, 1960) claimed to have found the two to be sympatric in Uganda, the shorter tailed being A. abyssinicus.

This rodent is commonly known as the unstriped grass mouse. It is sometimes confused with Pelomys fallax where the two occur together but they can easily be distinguished from one another by the fact that the latter

rodent has the upper incissors grooved, the tail always longer than the head and body and the hairs around the base of the tail with an orange irridescent colour.

This species was the second most abundant rodent found in the field in the plague areas investigated forming 25% of all the rodents collected.

Body measurements: - There is not much difference in size between male and female A. abyssinicus (Table IV).

Mammary formula: - The 116 females of this species examined had the mammary formula 2 - 2 = 8 typical of this species.

Breeding: - Breeding was not found to be seasonal. The average number of fully developed foeti found in 11 females at an advanced stage of pregnancy was 5, the maximum 6. The distribution of foeti in the two uteri was uneven.

Habitat: - This rodent was not found in the two non-plague areas investigated. It seemed to be absent from the coastal lowlands for quite some distance inland (it was absent from Morogoro situated about 120 miles from the coast). Apart from this restriction it was widely distributed in the interior of the country. Swynnerton (1951) recorded it from most parts of the interior of Mainland Tanzania. Hopkins (1949) stated that Arvicanthis formed a large portion of the field rat population in all parts of Uganda but that it seemed not to occur at high elevations and in forests. Ansell (1960) described it as having a very patchy distribution in Zambia.

A. abyssinicus like M. coucha lives in burrows in grasslands and in cultivated 'shambas'. In the plague areas these two rodents were caught in the same habitat.

Habits: - A. abyssinicus is diurnal (Ansell, 1960) and has semi-domestic tendencies. Hopkins (1949) stated that though not truly a domestic rat Arvicanthis was very common in the neighbourhood of dwellings and often foraged for

food in huts. He found that in those places where R. rattus did not occur e.g. the Mubende District of Uganda Arvicanthis entered dwellings to a much greater extent than in those areas where R. rattus was established. Pollitzer (1954) reported that in the Lake Albert and Lake Edward plague foci of Congo A. abyssinicus was regularly caught indoors and formed 14% of the rodents found in huts in the latter focus. During the present work although this rodent was found in very close proximity to human dwellings (sometimes its burrows were found only a few inches from the outside walls of huts) no specimens were caught indoors.

The food habits of this rodent were found to be very similar to those of M. coucha - mostly cereals and young grass stems.

The fleas of Arvicanthis abyssinicus: - The 1,329 fleas collected from the 339 rodents of this species in the two plague areas were distributed as shown in Table XII.

Table XII.

Fleas of Arvicanthis abyssinicus.

Species	Number collected	% of collection
Xenopsylla cheopis	1,056	80
Xenopsylla brasiliensis	110	8
Dinopsylla lypusus	72	5
Ctenophthalmus calceatus	83	6
Xenopsylla debilis	4	-
Ctenocephalides felis	3	-
Echidnophaga gallinacea	1	-

Generally speaking the flea fauna of A. abyssinicus appeared similar to that of M. coucha in as much as the bulk of it (nearly 90%) was composed of the common domestic rodent fleas X. cheopis and X. brasiliensis.

It is interesting however that whereas in the case of *M. coucha*, *X. brasiliensis* outnumbered *X. cheopis* by about 4 times, in the case of *A. abyssinicus*, *X. cheopis* was nearly 10 times more numerous than X. brasiliensis. *Ctenophthalmus calceatus* was only found in the highland areas of South Pare (Chome and Suji).

Hopkins (1949) commenting on the fleas of *Arvicanthis* in Uganda reported that the normal flea-fauna of this rodent was almost exclusively of the genera *Dinopsyllus* and *Ctenophthalmus*.

The role of Arvicanthis abyssinicus in the transmission of plague: - *A. abyssinicus* was found to be naturally infected with plague in the Rongai area of Kenya by Heisch (1952) and Pollitzer (1954) reported that this rodent was one of several wild rodent species found naturally infected with plague in Congo.

The similarities of habitats and habits, food requirements and flea-fauna between *M. coucha* and *A. abyssinicus* would suggest strongly that these two rodents play a similar role in the transmission of plague.

Tests for plague antibodies in A. abyssinicus: - Of the 339 rodents of this species tested for plague antibodies, 5 were found positive.

Tatera robusta:-

This species was found in the two plague areas and in one of the non-plague areas (Morogoro). Altogether 99 rodents of this species were collected in the three areas; one of these was caught inside a house at Singida.

Body Measurements: - The body measurements for this species show that the male attains a larger body size than the female (Table IV).

Mammary formula: - The 48 females examined had the mammary formula 2 - 2 - 8 typical of this species.

Breeding: - Three females which were found pregnant had 3, 5 and 6 foeti respectively.

Habitat: - This rodent was found to live in burrows in open bush country with scattered low trees and shrubs and with little undergrowth. It favoured places which were adjacent to open grasslands or cultivated shambas. It was sometimes caught in the vicinity of anthills.

Habits: - T. robusta was found to be mainly nocturnal in habit. Most specimens were caught with a cereal type of bait. Hopkins (1949) reported that two species of gerbils - Tatera liodon and Taterillus emini were sometimes, but not commonly captured in huts in Uganda. During the course of the present work one specimen of T. robusta was caught in a "tembe" type of hut at Singida.

The fleas of Tatera robusta: - Altogether 198 fleas were collected from the 99 rodents of this species caught in the field. The species distribution of the fleas was as shown in Table XIII.

Table XIII.

Fleas of Tatera robusta.

Species	Number collected	% of collection
Xenopsylla debilis	152	77
Xenopsylla cheopis	24	12
Xenopsylla brasiliensis	18	9
Dinopsylla lypusus	4	2

Thus the bulk of the flea-fauna of this rodent was composed of X. debilis described by Jordan (1925). This flea is a specific ectoparasite of gerbils and has been recorded in the Kilimanjaro, areas of Tansania - Smit (personal communication).

The fact that all the flea species found on T. robusta were also found on the two commonest field rodents in the plague areas i.e. M. coucha and A. abyssinicus indicates that these three rodent species

live in close association with one another. Since M. coucha and A. abyssinicus also live in close association and share fleas with domestic rats it would seem that these two rodents can serve as a link connecting the wild rodent T. robusta with the domestic rat R. rattus.

The role of Tatera robusta in the transmission of plague: - Davis (1948, 1953 and 1964) has established that in South Africa two species of gerbils Tatera brantsi and Desmodillus auricularis together with their respective fleas Xenopsylla philoxera and X. piriei form the primary plague reservoirs in the endemic plague areas of that country and that the multimammate mouse R. natalensis (Mastomys coucha) acts as a link between these gerbils and the domestic Rattus rattus. So well established is this picture of the nature of plague endemicity in South Africa that in attempting to study the same problem in other parts of Africa where these types of rodents occur one is greatly tempted to look for a similar explanation.

Thornton (1930) expressed the belief that gerbils were important in plague transmission in Uganda. However, Hopkins (1949) disagreed with this belief on the grounds that according to his own observations the flea of the local gerbils X. nubicus (an efficient vector of plague in West Africa) was rare or absent in the plague areas of Uganda.

According to the present observations the flea-fauna of T. robusta was very similar to that of M. coucha and A. abyssinicus, the two field rodents which have semi-domestic tendencies. This similarity of flea-fauna would seem to suggest that the three rodents meet freely in the field and exchange fleas. The occurrence of domestic rat fleas on T. robusta strengthens the belief that such a link exists. If it could be proved therefore that T. robusta was a plague reservoir in those endemic areas where it occurs a similar picture to that occurring in South Africa would emerge. Such a proof however has not been obtained from the present work. Of 71 rodents of this species subjected to the paper-disc serological test for plague antibodies none was found positive.

However as the samples were collected during the plague off-season and as the number was small not much emphasis can be placed on the negative results.

It should also be pointed out that in the South Pare plague focus Tatera seemed to be absent from the highland areas of Chome and Suji where plague outbreaks have been more frequent than in the lowland area around Makanya where T. robusta was present.

It could therefore be concluded that although Tatera robusta might be playing a role in plague transmission and maintenance in those endemic areas of Tanzania where it occurs, plague endemicity could be maintained without its presence.

Praomys morio:-

P. morio and P. jacksoni, have been regarded by some workers to be conspecific, but many authorities regard the two as separate species - Ansell (1960).

This rodent was caught in the Singida area only. It is a medium-sized rodent, light brown in colour and is somewhat similar in appearance to the gerbil T. robusta. The two rodents can however be distinguished by the fact that whereas the upper incisors of T. robusta are distinctly grooved those of P. morio are not.

Body measurements: - The adult male attained a larger body size than the female. As the measurements for this species shown on Table IV were based on 8 adult males and 13 adult females only, not much conclusion can be derived from them.

Mammary formula: - All the 13 female specimens had the mammary formula 1 - 2 = 6 typical of this species.

Breeding: - None of the female specimens caught was found to be pregnant.

Habitat: - This rodent was caught in habitats similar to those in which T. robusta was found but seemed to prefer more undergrowth vegetation provided by grass.

Habits: - Not much is known about the habits of this rodent. Ansell (1960) describing P. jacksoni in Zambia reported that it was partly diurnal and definitely nocturnal and that its diet was presumably mostly vegetarian but also insects. During the present work most specimens were caught using a cereal type of bait especially maize.

The fleas of P. morio: - This rodent had a comparatively high flea index of 6.7 (Table VI). The species distribution of the 155 fleas collected off 23 P. morio specimens was as shown in Table XIV.

Table XIV.

Fleas of Praomys morio.

Species	Number collected	% of collection
X. brasiliensis	137	88
X. cheopis	11	7
D. lypusus	6	4
X. debilis	1	1

This kind of flea-fauna is very similar to that of M. coucha and also resembled that of A. abyssinicus and T. robusta. It indicates that all these rodents share fleas to a greater or lesser degree.

The role of P. morio in the transmission of plague:- The facts that one of the 23 specimens of this rodent was found positive for plague antibodies (Table VII), that its flea-fauna included efficient vectors of plague and that it harboured the same species of fleas as M. coucha, A. abyssinicus and R. rattus suggest the possibility of its involvement in plague transmission and perhaps maintenance in those areas where it occurs. However the small numbers collected would seem to suggest that it was not a very common rodent and this factor alone would tend to limit its role as a plague host.

Other Field Rodents:-

Lemniscomys griselda: - This rodent is commonly known as the single-striped grass mouse. During the present work it was caught in the Morogoro area (Table III). Only one flea L.aethiopica was collected from this rodent (Table VI).

Grammomys dolichurus: - Only 18 specimens of this tree rat were caught; one in the Singida area and 17 in the South Pare area (Table III). It is interesting that the one specimen caught in the Singida area which had only one flea (E. gallinacea) on it was found to be positive for plague antibodies. In the South Pare area this rodent was infested with typical wild rodent fleas L. aethiopica, D. lypusus and C. calceatus (Table VI).

Tatera leucogaster: - All the 16 rodents of this species were caught in the Dar es Salaam area (Table III). The flea-fauna consisted mostly of the gerbil flea X. debilis but a few specimens of X. brasiliensis were also found (Table VI).

Acomys wilsoni: - Only 16 specimens of this tiny Spiny Mouse were caught - one in the Morogoro area and 15 in the South Pare area at Makanya (Table III). It had a scanty flea-fauna composed largely of X. cheopis.

It is interesting that Meyer (1964) found 13 out of 18 specimens of Acomys sp. from Kenya positive for plague antibodies.

Pelomys fallax: - Of the 16 specimens of this rodent collected during the course of this work 2 were found in the Dar es Salaam area and 14 were collected at Chome in the South Pare area (Table III). In the latter area this rodent was infested with the wild rodent fleas Ctenophthalmus calceatus, Dinopsyllus lypusus and Leptopsylla aethiopica (Table VI).

Lophuromys flavopunctatus: - All of the 4 specimens were caught at Chome in the South Pare plague area (Table III). A single specimen of the flea D. lypusus was found on one of these rodents (Table VI).

Praomys jacksoni: - Only 3 specimens of this rodent were collected in the mountainous area of South Pare - Chome and Suji (Table III).

SUMMARY AND CONCLUSION.

It is probable that endemic plague in East Africa is of long standing. In Tanzania the disease was probably introduced from endemic areas in Uganda and Kenya through slave-trade caravans.

The indigenous people in many endemic areas including the Baganda of Uganda, the Luo of Kenya and the Wahaya and the Wahehe of Tanzania were found by early European investigators to be familiar with plague and some had vernacular names for the disease. They knew for instance of the connection between plague epizootics in rats and human plague epidemics and of the fact that the former usually preceded the latter. Some of these tribes like the Wahehe had through their own ingenuity and experience devised elaborate methods of plague control which included the destruction of rats, the isolation of the sick, the abandonment and/or destruction of huts in which plague outbreaks had occurred and restriction on the movement of the people from infected to uninfected areas. No tribe however knew any specific remedy for plague.

The earliest recorded foci of endemic plague in Tanzania were those of Kiziba in Bukoba, Shirati in Mwanza, Iringa in Uhehe and Rombo in East Kilimanjaro which were all discovered between 1897 and 1912. These foci were followed by those of Mbulu, Kondoa and Singida discovered between 1917 and 1920. The most recently discovered plague focus in the country is that of South Pare which was first reported in 1951. Two of these foci - that of Kiziba and that of Iringa are now dormant, the last human plague outbreak having occurred in the former focus in 1903 and in the latter one in 1937. It is interesting that in the Rombo Division of Kilimanjaro after the human plague epidemic of 1912 no plague outbreak was reported among the human population of the area until 1957. This tendency of endemic plague to keep smouldering among the rodent reservoirs and to flare up as a human epidemic when the right combination of favourable conditions for its transmission occur should serve as a warning against regarding those foci which are now quiescent with complacency.

The conditions which seem to favour plague endemicity in Tanzania as elsewhere are four-fold:-

1. A suitable climate for plague transmission and maintenance provided by moderately damp and cool conditions for the greater part of the year. Such climatic conditions would be necessary for the continuous breeding of fleas in rat-burrows and for their wandering from them (Sharif, 1951). Many places in the Central Plateau and the Highlands of Tanzania between about 4,000 and 6,000 ft. with an annual rainfall of 20 - 45" provide such climatic conditions and the endemic plague foci of the country are situated in such places. In the coastal areas where the climate is hot and humid for the greater part of the year the conditions are not suitable for plague endemicity. Thus although many coastal towns including Dar es Salaam, Lindi, Bagamoyo and the island of Zanzibar experienced plague in the past which was introduced from abroad through sea traffic, the disease never gained a foot-hold and plague endemicity was never established.

2. Suitable rodent hosts and reservoirs of plague. In Tanzania these include Rattus rattus and to some extent Mastomys coucha in the domestic environment and M. coucha and Arvicanthis abyssinicus in the field environment.

In addition to these three main rodent species it is possible that such other species as Tatera robusta, Praomys morio and Grammomys dolichurus play a part in plague perpetuation in the endemic areas where they occur.

3. Efficient flea vectors:- It is evident from the present observations that the most important rodent fleas both in the domestic and the field environments in the endemic plague areas of Tanzania are Xenopsylla cheopis and X. brasiliensis which are known to be efficient plague vectors. These two fleas were not only common and abundant in domestic rodents but they occurred very commonly in all the main species of field rodents caught.

The most striking difference between the plague and the non-plague areas investigated was in respect of the flea indices of the field rodents. Thus whereas such indices were high in the plague areas they were generally very low in the non-plague areas.

The most commonly occurring field-rodent flea was Dinopsyllus lypusus which was mostly found on M. coucha and Arvicanthis abyssinicus. This very large flea is known to be an efficient vector of plague amongst field rodents in the Lake Albert plague focus of Congo - (Devignat, 1946). The other field-rodent fleas found in the endemic areas were Xenopsylla debilis of gerbils which was mainly obtained from Tatera robusta and Ctenophthalmus calceatus and Leptopsylla aethiopica which were found mostly on M. coucha and A. abyssinicus on the highland areas of South Pare.

Although the above three conditions would be sufficient for the establishment and maintenance of enzootic plague in rodents, a fourth factor would be necessary before man

could become actively involved, i.e. before endemic plague could be well established:-

4. Close association between man and rats: - This condition is brought about by a low standard of housing and sanitation which are favourable for rat and flea-infestations. The close proximity between man on the one hand and domestic rats and their fleas on the other enables easy transmission of plague from rats to man through the agency of rat fleas.

In many rural areas in Tanzania most houses are of a low standard. Such houses have insanitary and 'bush' surroundings which environments are favourable breeding places of field rodents and suitable foraging grounds for domestic rodents. Such surroundings therefore are convenient meeting places of domestic and wild rodents and it is mainly here that transmission of plague from field to domestic rodents takes place.

The finding of Tatera robusta, a typical wild rodent in a human dwelling in the Singida area emphasises the fact that where man lives so close to the bush in low standard dwellings and under insanitary conditions, plague can be brought into the domestic environment directly from the field without the intervention of domestic rodents.

Experience has shown that much can be done to control plague epidemics in endemic areas by the use of various methods including the application of insecticides against fleas and rodenticides against rodents, the early reporting of cases (or suspected cases) of plague and efficient quarantine measures during outbreaks. However it would seem that the final eradication of human plague in endemic areas would depend to a large measure on a general improvement in the standard of living, especially of housing of the people. Only by this means can the contact between man and rats and their fleas be broken. Once this is achieved, plague would be mostly confined to the wild environment to which it naturally belongs.

TABLE II.

1,164 RODENTS CAUGHT IN HOUSES.

AREA	FAMILY OF RODENT	SUB-FAMILY	GENUS	SPECIES	NOS. COLLECTED		
					Males	Females	To
Dar es Salaam	Muridae	Murinae	Rattus	rattus	177	213	3
	"	"	"	norvegicus	74	113	1
	"	"	Mus	musculus	65	67	1
	"	"	Mastomys	coucha	0	1	
Morogoro	"	"	Rattus	rattus	91	132	2
	"	"	Mastomys	coucha	1	1	
Singida	"	"	Rattus	rattus	51	72	1
	"	"	Mastomys	coucha	10	13	
	"	Gerbillinae*	Tatera	robusta	0	1	
South Pare	"	Murinae	Rattus	rattus	27	53	8
	"	"	Mastomys	coucha	0	2	

*This typical wild rodent was found in a 'tembe' type of house surrounded

TABLE III.

1,343 RODENTS CAUGHT IN THE FIELD.

AREA	FAMILY OF RODENT	SUB-FAMILY	GENUS	SPECIES	NOS. CAUGHT		
					Males	Females	Tota
Dar es Salaam	Muridae	Murinae	Mastomys	coucha	59	42	101
	"	"	Pelomys	fallax	1	1	2
	"	Gerbillinae	Tatera	leucogaster	5	11	16
Morogoro	"	Murinae	Mastomys	coucha	52	39	91
	"	"	Lemniscomys	griselda	13	9	22
	"	"	Acomys	wilsoni	1	0	1
	"	Gerbillinae	Tatera	robusta	18	10	28
Singida	"	Murinae	Mastomys	coucha	159	116	275
	"	"	Arvicanthis	abyssinicus	92	74	166
	"	"	Praomys	morio	8	15	23
	"	"	Grammomys	dolichurus	0	1	1
	"	Gerbillinae	Tatera	robusta	31	33	64

TABLE III (CONTINUED).

AREA	FAMILY OF RODENT	SUB-FAMILY	GENUS	SPECIES	NOS. CAUGHT		
					Males	Females	Total
South Pare	Muridae	Murinae	Mastomys	coucha	155	148	303
	"	"	Arvicanthis	abyssinicas	101	72	173
	"	"	Grammomys	dolichurus	15	2	17
	"	"	Mus	musculus	6	12	18
	"	"	Acomys	wilsoni	8	7	15
	"	"	Pelomys	fallax	10	4	14
	"	"	Lophuromys	flavopunctatus	1	3	4
		"	Praomys	jacksoni	0	3	3
	"	Gerbillinae	Tatera	robusta	3	3	6

TABLE IV.

BODY MEASUREMENTS OF 1,906 ADULT RODENTS CAUGHT IN HOUSES AND IN THE FIELD.

RODENT SPECIES	SEX	NUMBER COLLE-CTED	HEAD & BODY LENGTH (MM.)		TAIL LENGTH (MM.)		HIND FOOT LENGTH (MM.)		EAR LENGTH (MM.)		WEIG (GM
			Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Rattus rattus	M F	311 393	153 155	121-189 123-184	187 187	145-238 140-229	32 31	25-37 26-36	22 22	18-26 18-26	102.5 100.7
Rattus norvegicus	M F	61 88	205 203	135-253 155-233	193 187	130-248 145-219	43 43	37-50 35-46	21 20	17-26 17-25	236.8 216.6
Mus musculus	M F	49 47	71 74	60-82 61-84	79 81	62-99 61-98	16 17	14-18 12-19	12 12	10-14 10-14	12.6 13.6
Mastomys coucha	M F	315 160	115 116	100-148 100-140	109 109	90-148 87-137	23 23	19-29 20-26	18 18	15-21 15-21	43.2 39.2

TABLE IV (CONTINUED).

RODENT SPECIES	SEX	NUMBER COLLECTED	HEAD & BODY LENGTH (MM.)		TAIL LENGTH (MM.)		HIND FOOT LENGTH (MM.)		EAR LENGTH (MM.)		WE
			Mean	Range	Mean	Range	Mean	Range	Mean	Range	Me
Arvicanthis abyssinicus	M F	159 116	127 125	111-158 110-150	108 105	78-145 81-128	28 28	25-33 22-32	17 17	15-20 15-21	68. 63.
Tatera robusta	M F	51 48	143 139	116-179 113-157	178 182	131-208 122-203	37 37	23-43 26-41	21 22	18-23 17-28	85. 77.
Tatera leucogaster	M F	3 7	124 140	109-137 124-150	148 156	124-164 144-165	37 38	35-38 36-39	20 21	20-20 20-22	71.6 92.3
Praomys morio	M F	8 13	137 133	132-142 120-150	163 158	143-175 145-185	30 30	28-31 29-31	20 20	19-22 19-22	77.2 64.5
Lemniscomys griselda	M F	13 9	130 122	116-147 111-130	152 136	134-166 128-146	28 25	23-34 23-27	18 18	14-20 16-19	62.2 53.3

TABLE IV (CONTINUED).

RODENT SPECIES	SEX	NUMBER COLLECTED	HEAD & BODY LENGTH (MM.)		TAIL LENGTH (MM.)		HIND FOOT LENGTH (MM.)		EAR LENGTH (MM.)		
			Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Grammomys dolichurus	M F	15 3	109 98	95-117 92-104	154 155	126-173 146-160	25 23	22-28 22-23	18 17	16-19 17-18	35.7 27.9
Pelomys fallax	M F	10 5	145 141	133-160 120-157	152 152	138-167 141-170	33 34	31-34 33-35	18 19	17-20 17-20	93.2 85.9
Acomys wilsoni	M F	9 7	85 85	75-91 73-93	51 51	44-57 48-56	14 14	13-16 14-15	14 14	13-15 14-15	19.9 22.4
Lophuromys flavopunctatus	M F	1 3	(1 2 9) 120	117-124	(7 0) 75	72-78	(2 4) 25	24-25	(2 0) 19	18-20	(6 50.1
Praomys jacksoni	M F	0 3	- 95	- 92-101	- 125	- 122-128	- 24	- 23-24	- 21	- 20-22	- 21.5

TABLE V.

2,547 FLEAS FROM RODENTS COLLECTED IN HOUSES.

AREA	RODENT HOST	NO. OF RODENTS	TOTAL NO. OF FLEAS	FLEAS					SPECIFIC FLEA INDEX	TOTAL FLEA INDEX
				Species		M	F	Total	% of Total Collection	
Dar es Salaam	Rattus rattus	390	343	X. brasiliensis		77	54	131	38	0.34	
				X. cheopis		34	10	44	13	0.14	0.88
				E. gallinacea		31	129	160	47	0.41	
				C. felis		2	6	8	2	0.02	
Morogoro	"	223	624	X. brasiliensis		125	203	328	53	1.47	
				X. cheopis		160	108	268	43	1.20	2.80
				E. gallinacea		7	20	27	4	0.12	
				C. felis		0	1	1	-	-	
Singida	"	123	434	X. brasiliensis		141	150	291	67	2.36	
				X. cheopis		8	5	13	3	0.11	
				X. debilis		0	6	6	1	0.05	3.53
				E. gallinacea		15	108	123	28	1.00	

TABLE V (CONTINUED).

AREA	RODENT HOST	NO. OF RODENTS	TOTAL NO. OF FLEAS	FLEAS					SPECIFIC FLEA INDEX	TOTAL FLEA INDEX
				Species	M	F	Total	% of Total Collection		
South Pare	Rattus rattus	80	287	X. brasiliensis	134	104	238	83	2.97	
				X. cheopis	3	7	10	4	0.13	
				L. aethiopica	14	12	26	9	0.33	3.59
				E. gallinacea	1	10	11	4	0.14	
				D. lypusus	1	1	2	1	0.02	
Dar es Salaam	Mustomys coucha	1	0	-	0	0	0	0	0	0
Morogoro	"	2	2	X. cheopis	2	0	2	(100)	1.00	1.00
Singida	"	23	109	X. brasiliensis	76	32	108	99	4.70	
				D. lypusus	0	1	1	1	0.04	4.74
South Pare	"	2	1	C. calceatus	0	1	1	(100)	0.50	0.50

TABLE V (CONTINUED).

AREA	RODENT HOST	NO. OF RODENTS	TOTAL NO. OF FLEAS	FLEAS					SPECIFIC FLEA INDEX	TOTAL FLEA INDEX	% RO WI FL
				Species	M	F	Total	% of Total Collection			
Dar es Salaam	Rattus norvegicus	187	738	X. cheopis	205	119	324	44	1.73		
				E. gallinacea	46	364	410	56	2.20	3.95	
				C. felis	0	4	4	1	0.02		
Dar es Salaam	Mus musculus	132	8	X. cheopis	5	2	7	(88)	0.05	0.06	
				E. gallinacea	1	0	1	(12)	0.01		
Singida	Tatera robusta	1	1	X. brasiliensis	0	1	1	(100)	1.00	1.00	(1

TABLE VI.

2,975 FLEAS FROM RODENTS CAUGHT IN THE FIELD.

AREA	RODENT HOST	NO. OF RODENTS	TOTAL NO. OF FLEAS	FLEAS					SPECIFIC FLEA INDEX
				Species	M	F	Total	% of Total Collection	
Dar es Salaam	Mastomys coucha	101	8	X. brasiliensis	4	3	7	(88)	0.07
				C. felis	0	1	1	(12)	0.01
Morogoro	"	91	1	X. brasiliensis	1	0	1	(100)	0.01
Singida	"	275	862	X. brasiliensis	344	213	557	65	2.03
				X. cheopis	55	79	134	16	0.49
				D. lypusus	73	58	131	15	0.48
				X. debilis	13	27	40	5	0.15

TABLE VI (CONTINUED).

AREA	RODENT HOST	NO. OF RODENTS	TOTAL NO. OF FLEAS	FLEAS					SPECIFIC FLEA INDEX	TOT FLE INDI
				Species	M	F	Total	% of Total Collection		
South Pare	Mastomys coucha	303	340	X. brasiliensis	52	51	103	30	0.34	
				X. cheopis	31	29	60	18	0.20	
				D. lypusus	47	46	93	27	0.31	
				L. aethiopica	15	27	42	12	0.14	1.1
				C. calceatus	17	18	35	10	0.12	
				N. fasciatus	2	1	3	1	0.01	
				X. debilis	1	2	3	1	0.01	
				C. felis	1	0	1	-	-	
Singida	Arvicanthis abyssinicus	166	815	X. brasiliensis	42	58	100	12	0.60	
				X. cheopis	259	436	695	85	4.18	
				D. lypusus	7	10	17	2	0.10	4.91
				X. debilis	9	1	1	-	0.01	
				E. gallinacea	0	1	1	-	0.01	
				C. felis	0	1	1	-	0.01	

TABLE VI (CONTINUED).

AREA	RODENT HOST	NO. OF RODENTS	TOTAL NO. OF FLEAS	FLEAS					SPECIFIC FLEA INDEX
				Species	M	F	Total	% of Total Collection	
South Pare	Arvicanthis abyssinicus	173	514	X. brasiliensis	5	5	10	2	0.06
				X. cheopis	122	239	361	70	2.08
				D. lypusus	30	25	55	11	0.32
				C. calceatus	30	53	83	16	0.48
				X. debilis	1	2	3	1	0.02
				C. felis	1	1	2	-	0.01
Dar es Salaam	Tatera leucogaster	16	28	X. brasilienis	0	2	2	7	0.13
				X. debilis	13	13	26	93	1.62
Morogoro	Tatera robusta	28	15	X. brasiliensis	2	2	4	27	0.14
				X. cheopis	10	1	11	73	0.39

TABLE VI (CONTINUED).

AREA	RODENT HOST	NO. OF RODENTS	TOTAL NO. OF FLEAS	FLEAS					SPECIFIC FLEA INDEX	TOTAL FLEA INDEX
				Species	M	F	Total	% of Total Collection		
Singida	Tatera robusta	64	114	X. brasiliensis	2	11	13	11	0.20	
				X. cheopis	10	3	13	11	0.20	1.78
				X. debilis	27	57	84	74	1.31	
				D. lypusus	2	2	4	4	0.06	
South Pare	"	6	68	X. debilis	40	28	68	100	11.33	11.33
Singida	Grammomys dolichurus	1	1	E. gallinacea	0	1	1	(100)	1.00	1.00
South Pare	"	17	20	L. aethiopica	3	11	14	70	0.82	
				D. lypusus	0	3	3	15	0.18	1.18
				C. calceatus	0	2	2	10	0.12	
Dar es Salaam	Pelomys fallax	2	0	-	0	0	0	0	0	0

AREA	RODENT HOST	NO. OF RODENTS	TOTAL NO. OF FLEAS	FLEAS					SPECIFIC FLEA INDEX	TOTAL FLEA INDEX
				Species	M	F	Total	% of Total Collection		
South Pare	Pelomys fallax	14	21	C. calceatus	7	8	15	71	1.07	
				D. lypusus	2	2	4	19	0.29	1.50
				L. aethiopica	1	1	2	10	0.14	
Morogoro	Acomys wilsoni	1	0	-	0	0	0	0	0	0
South Pare	"	15	9	X. cheopis	5	3	8	89	0.53	0.60
Singida	Praomys morio	23	155	X. brasiliensis	76	61	137	88	5.96	
				X. cheopis	4	7	11	7	0.48	6.74
				D. lypusus	3	3	6	4	0.26	
				X. debilis	1	0	1	1	0.04	
Morogoro	Lemniscomys griselda	22	1	L. aethiopica	0	1	1	(100)	0.05	0.05
South Pare	Lophuromys sikapusi	4	1	D. lypusus	1	0	1	(100)	0.25	0.25

TABLE VII.

RESULTS OF SEROLOGICAL TESTS FOR PLAGUE ANTIBODIES ON 1,446 R

AREA	RODENT SPECIES	NO. TESTED	NO. POSITIVE	LOCALITY FROM WHI POSITIVE SPECIMEN WERE FOUND
Dar es Salaam	R. rattus	115	Nil	-
	M. coucha	7	Nil	-
	T. lecogaster	13	Nil	-
	P. fallax	1	Nil	-
Singida	R. rattus	123	Nil	-
	M. coucha	298	2	Singida, Ilongero
	A. abyssinicus	166	4	Singida, Manyoni
	T. robusta	65	Nil	-
	P. morio	23	1	Singida
	C. dolichurus	1	1	Shelui

*This was imported plague and never got entrenched in the local rodents of th
to establish endemicity.

TABLE VII (CONTINUED).

AREA	RODENT SPECIES	NO. TESTED	NO. POSITIVE	LOCALITY FROM WHICH POSITIVE SPECIMENS WERE FOUND
South Pare	R. rattus	80	Nil	-
	M. coucha	305	3	[illegible], Makanya
	A. abyssinicus	173	1	[illegible]anya
	M. musculis	18	Nil	-
	G. dolichurus	17	Nil	-
	A. wilsoni	15	Nil	-
	P. fallax	14	Nil	-
	T. robusta	6	Nil	-
	L. flavopunctatus	4	Nil.	-
	P. jacksoni	3	NIL	-

Fig. 1

DISTRIBUTION OF PLAGUE IN TANZANIA.

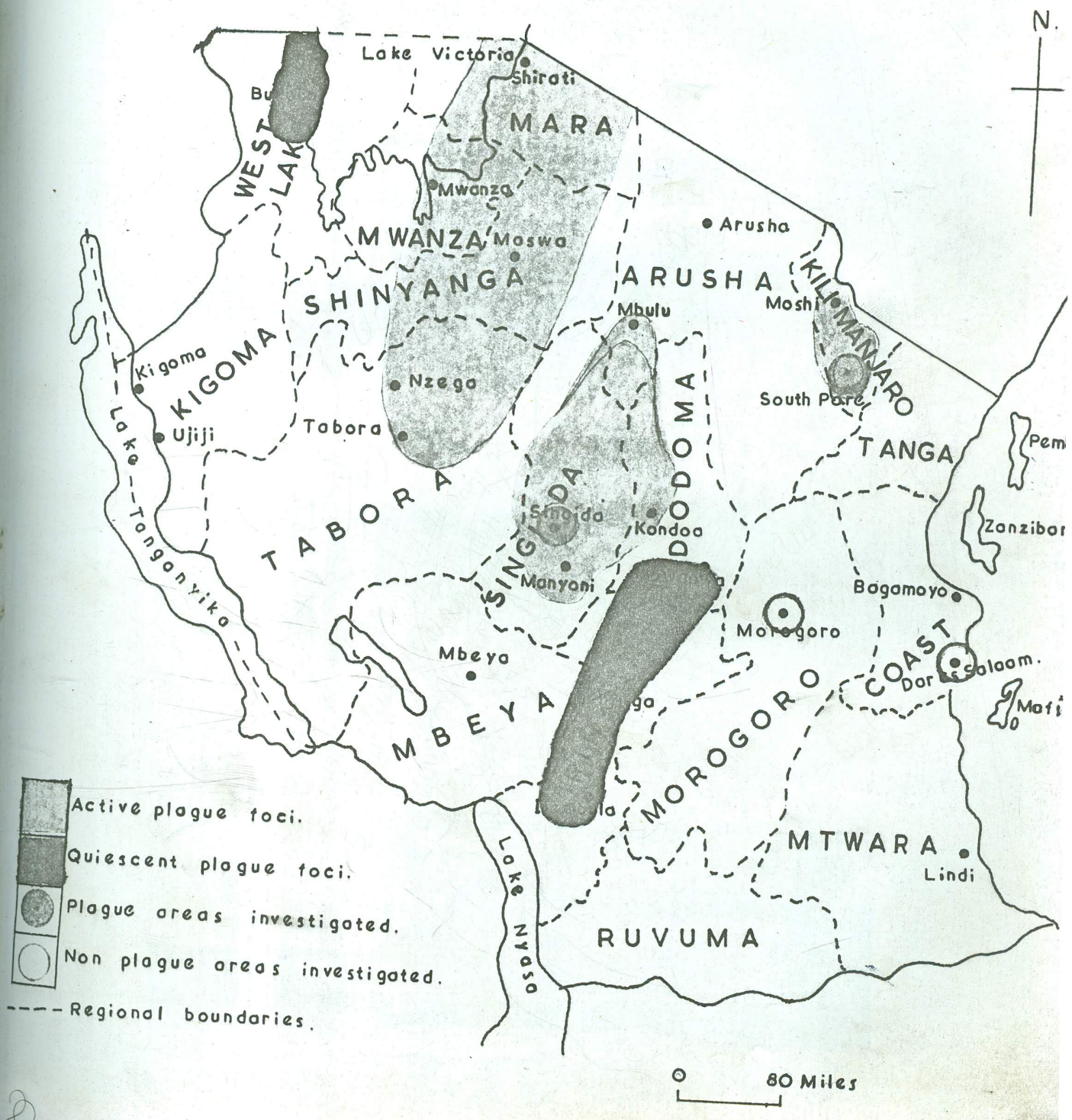
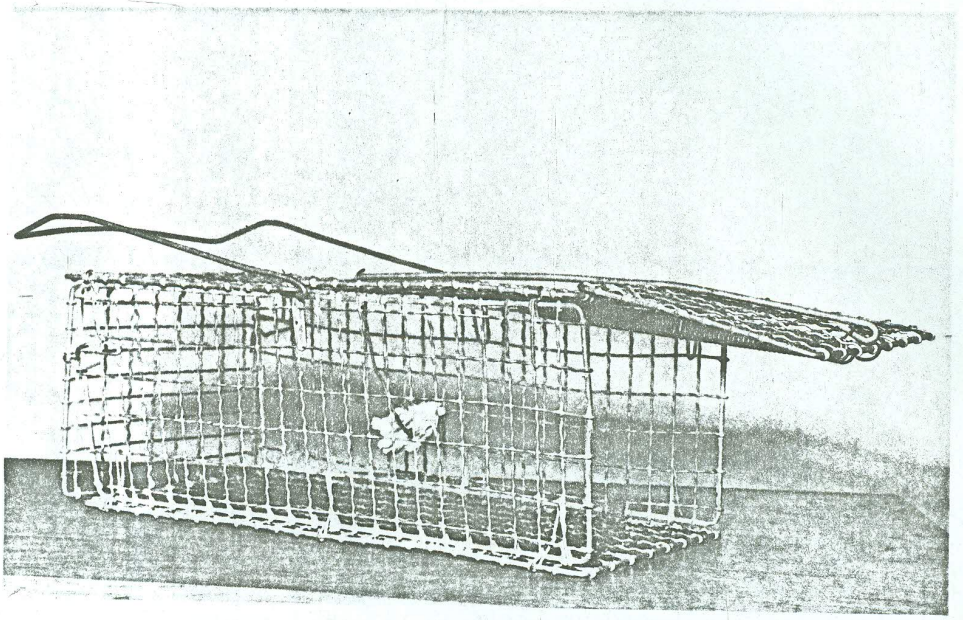


Fig. 2

A. The "Drop-Door" Cage Trap in the 'set' position



B. The "Drop-Door" Cage Trap with catch

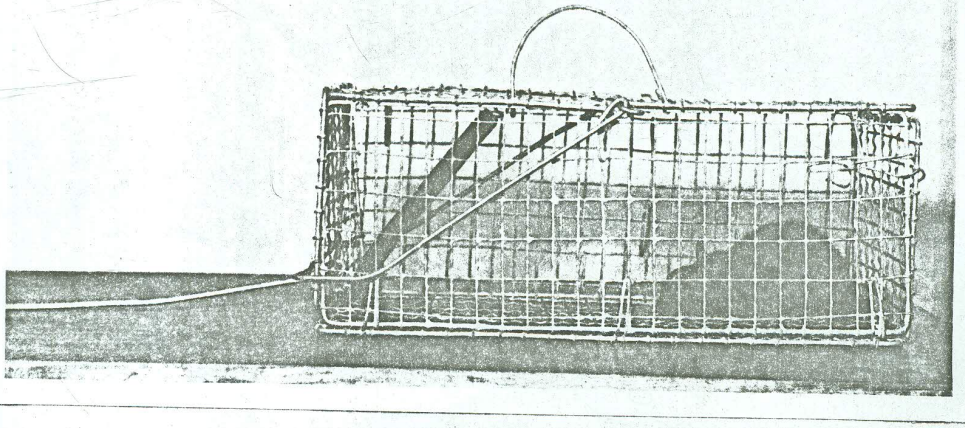


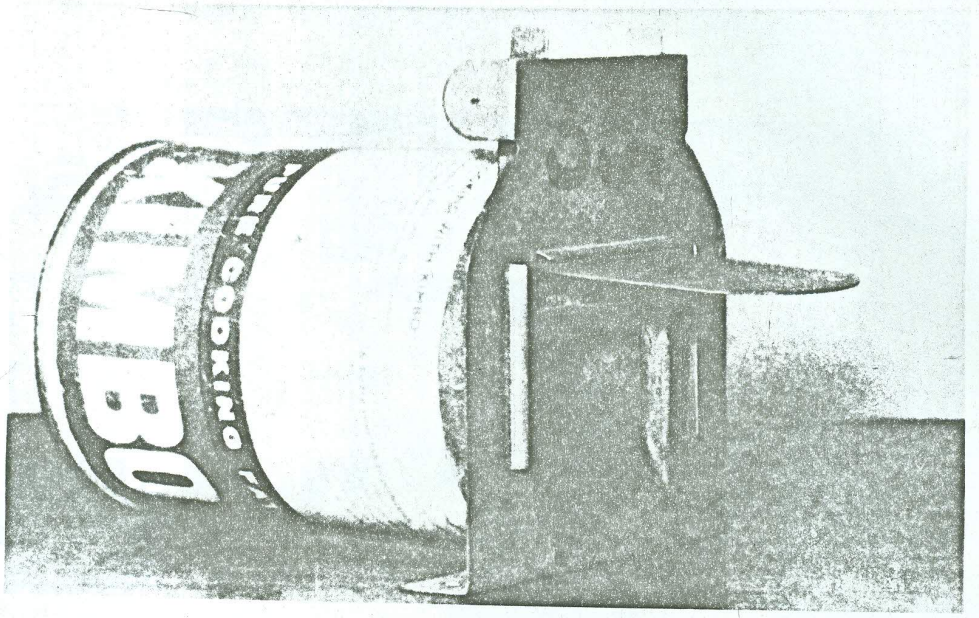
Fig. 3

The "False-Bottom" Cage Trap with catch

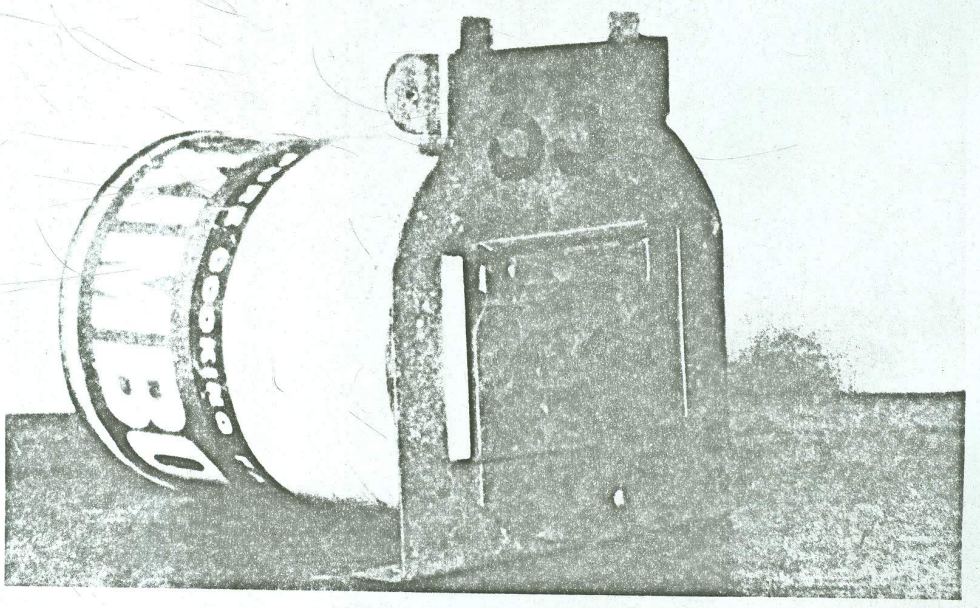


Fig. 4

A. The Chauvancy Trap in the 'set' position



B. The Chauvancy Trap with catch inside



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APPENDICES

Reprints of Previous Published Work

1. Wilson, D. Bagster and Msangi, A.S. (1955). An Estimate of the Reliability of Dipping for Mosquito Larvae. E. Afr. med. J. 32, 37.

   Candidate's contribution: carried out all the laboratory and field work.

2. Msangi, A.S. (1956). Cetyl Alcohol and Larval Mosquito Control. E. Afr. med. J. 33, 353.

3. Maclean, G., Webbe, G. and Msangi, A.S. (1958). A Report on a Bilharzia and Molluscan Survey in the Tanga District of Tanganyika. E. Afr. med. J. 35, 7.

   Candidate's contribution: participated in all the field surveys.

4. Webbe, G. and Msangi, A.S. (1958). Observations on Three Species of Bulinus on the East Coast of Africa. Ann. trop. Med. Parasit. 52, 302.

   Candidate's contribution: participated in all the field and laboratory observations.

5. Msangi, A.S. (1959). The Value of a Spreading Agent on Larvicidal Formulations containing D.D.T. Bull. Wld Hlth Org. 21, 773.

6. Msangi, A.S. (1960). Comparison of B.H.C. and D.D.T. Larvicides against Anopheles gambiae. E. Afr. med. J. 37, 776.

7. Pringle, G. and Msangi, A.S. (1961). The Experimental Study of Water Snails in a Fishpond in Tanganyika. 1. Preliminary Trial of the Method. E. Afr. med. J. 38, 275.

   Candidate's contribution: participated in all the field work.

8. Clyde, D.F. and Msangi, A.S. (1963). Malaria Distribution in Tanganyika. Part II. Tanga Region. E. Afr. med. J. 40, 71.

   Candidate's contribution: participated in the collection of data from various sources.

9. Bertram, D.S., Srivastava, S.C. and Msangi, A.S. (1964). Transmission of Plasmodium gallinaceum Brumpt to Chicks by Aedes aegypti (L.) sterilised by an Akylating Agent, Thiotepa. J. trop. Med. Hyg. 67, 51.

   Candidate's contribution: participated in the insectary and laboratory work.

10. Msangi, A.S. and Zeller, C. (1965). Investigations on the Molluscicidal Effects of the Fruits of Sapindus saponaria on the Bilharzia Vector Snail Bulinus (Physopsis) africanus. Proc. E. Afr. Acad. 3, 52.

    Candidate's contribution: participated in the planning, execution and writing up of the work.

Reprinted from

The East African Medical Journal

No. 2 *FEBRUARY, 1955* *Volume 32*

AN ESTIMATE OF THE RELIABILITY OF DIPPING FOR MOSQUITO LARVAE

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Received for Publication 12.9.54

THE standard method of larval dipping is in daily use as a means of assessing the effectiveness of larvicidal control of *Anopheles*, or of mosquitoes in general. It is commonly assumed that this method provides a true reflexion of the presence or absence of mosquito breeding, or of the degree of breeding present. But there is room for doubt as to the truth of these assumptions, and the method for the numerical study of larval populations developed by Christie (1954) gives a means of testing their reliability. This method is, in brief, to bale out all the water from a breeding place, to pass all this water through a sieve, of a mesh that is sufficiently small to retain all the larvae present, and then to count these larvae. These counts can be compared with the numbers obtained from a known number of dips, or from dipping for a known length of time.

A comparison of this sort is applicable, because of the nature of the technique, only to small water collections, but as these are the characteristic breeding places of *Anopheles gambiae*, it is particularly applicable to East African conditions, and the observations recorded in this paper provide such a comparison.

In these experiments, concrete rectangular tanks (about 10 ft. by 8 ft. in size) were used, the floors being covered with earth which was shaped into a hollow. Three such tanks were filled with water to a depth of about eight inches in the middle, and one inch at the margin. Mosquitoes were allowed to breed naturally in this water, and a close watch was kept for the appearance of fourth stage larvae. After five to six days both anopheline (mostly *A. gambiae*) and culicine fourth stage larvae were found, and the water was searched by two observers for varying periods, the number of dips and the larvae caught being recorded.

TABLE I

Larvae from spontaneous breeding.

Time spent dipping in minutes.	*Total number of dips. (A)*	*Number of positive dips. (B)*	*(B) as percentage of (A)*	*Number of larvae by dipping. (C)*	*Number of larvae by Christie's method (D)*	*(C) as percentage of (D)*
5	24	5	21	6	193	3
10	54	23	43	23	193	12
20	103	27	26	33	193	17
5	14	6	43	16	488	3
10	12	8	66	36	488	7
20	24	20	83	150	488	31
5	30	8	27	10	140	7
10	67	15	22	30	140	21
20	93	30	32	36	140	26

Table I shows that only a small percentage of the total number of larvae present is recovered by dipping. In each experiment there were considerable numbers of dips in which no larvae were found. It is clear that the chance of missing the presence of breeding is considerable, and this in spite of the comparatively small area of the water surface. Whatever the period of searching, there was no evident change in the relationship between the number of positive dips and the total number of dips made. The proportion of larvae recovered by dipping was of course directly related to the length of search.

Since the tanks used provided a very different environment from the wells that Christie used in establishing his results, it was thought desirable to check his results in the former. After filling, known numbers of insectary bred fourth stage larvae of *A. gambiae* were put into the tanks, and left for about twenty-four hours, in order to become acclimatised to the change. They were then recovered by dipping, and by Christie's method. In a preliminary investigation it had been found that, in order to recover most of the larvae even by Christie's method, certain precautions, such as that of allowing the larvae sufficient time to get acclimatised, had to be taken. Whether or not such precautions were taken, it was however always found that the relationship between the recovery by dipping and by evacuation was similar.

TABLE II

Recovery of Introduced Larvae.

Number of larvae put in	*Percentage recovered by dipping for 10 minutes*	*Percentage recovered by Christie's method*
30	20	93
25	36	84
15	47	87
20	30	100

Table II gives the results of this second series of trials, in which the average of four experiments gave a recovery by Christie's method of ninety-one per cent of the larvae introduced, whereas dipping gave a thirty-three per cent recovery only, when dipping was continued for ten minutes by two observers.

DISCUSSION

It seems to be clear enough from these experiments that the dipping method is a fallible one, even under these nearly ideal conditions for the observer, especially if the period of search is short. There was always a one in three chance of larvae being missed in any dip, and at worst they might be missed four out of five times. The method gives an inconstant reflexion of the total number of larvae present : if larvae were rare, as they may so often be in wider stretches of water, or even after the most ineffective application of larvicide, it is apparent how easily they might be missed altogether.

SUMMARY

1. The recovery of mosquito larvae from an artificial breeding tank by larval dipping was compared with the recovery obtained by totally evacuating the water and straining it.

2. It was found that never more than about one third of the larvae were recovered by dipping, and the recovery might be as low as three per cent after ten man-minutes searching.

3. It is concluded that the method of larval dipping must be an unreliable one when larvae are at all scarce, and searching is not prolonged.

Reference

Christie, M. (1954) *Ann. Trop. Med. and Parasit.* **43.** (*In press.*)

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CETYL ALCOHOL AND LARVAL MOSQUITO CONTROL

By A. S. MSANGI

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In view of the proposed large scale use of cetyl alcohol to check evaporation from dams and other reservoirs of water, it was considered desirable to find out whether this chemical had any effect on the aquatic phases of the life of mosquitoes, or whether it affected anti-larval measures. It was possible that a layer of cetyl alcohol on water might :—

(*a*) have a lethal effect on mosquito eggs, larvae or pupae.
(*b*) cause an interference with the availability of atmospheric oxygen to mosquito larvae or pupae.
(*c*) have a repellent effect on ovipositing female mosquitoes.
(*d*) interfere with the free spread of oil solutions of larvicides.

Effect on Larval Development :

Field and laboratory experiments were carried out to find the effect of cetyl alcohol on larval development.

(i) *Laboratory Experiments :*

100 second stage larvae of *Anopheles gambiae* from the insectary were placed in each of four enamel dishes (ten inches by eight inches) containing filtered tap water. An open cylinder of about two and a half inches in diameter and about two inches in height, made from plastic gauze of 18 mesh, was placed in each dish. Cetyl alcohol (0.033 gm. being the quantity used to check evaporation from a water surface of this size), 0.033 gm., 1 gm., and 2 gm. respectively was placed in the cylinders in three of the dishes. The fourth dish was used as a control. The larvae were fed on yeast suspension and their development was observed and recorded daily.

TABLE 1. Effect of Cetyl Alcohol on Larval Development*

Treatment	*No. of 2nd stage larvae used*	*Days to appearance of :*			*Pupated Per Cent*
		3rd stage larvae	*4th stage larvae*	*Pupae*	
Control	200	2	3-5	6-7	51
0.033gm. C.A.	200	2-3	4-5	6-7	43
1gm. C.A.	100	3	4	6	32
2gm. C.A.	100	2	5	7	45

**Note :* Throughout the tables C.A. has been used to mean cetyl alcohol.

(ii) *Field Experiments :*

Experiments were carried out in four earth-lined concrete tanks (ten feet by eight feet) to find out the effect of cetyl alcohol on larvae under semi-field conditions. These tanks were filled with water to a depth of about eight inches in the centre. Cetyl alcohol (1 gm. being about the quantity required to check evaporation from a water surface of this size), 1 gm., 2 gm. and 3 gm. respectively, was placed in floating cages in three of the tanks. The fourth tank was used as a control. The cages used were made from copper wire gauze of 18 mesh and were three inches in diameter. Third stage larvae of *Anopheles gambiae* were placed in each of these tanks and their development was observed.

TABLE II. EFFECT OF CETYL ALCOHOL ON LARVAE UNDER SEMI-FIELD CONDITIONS

Treatment	*No. of 3rd stage larvae*	*Duration of contact*	*Survival Per cent*
CONTROL	350	4-5 days	61
1gm. C.A.	350	4-5 days	59
2gm. C.A.	350	4-5 days	54
3gm. C.A.	350	4-5 days	40

EFFECT ON THE HATCHING OF EGGS :

Experiment (i) was repeated using about 500 eggs of *Anopheles gambiae* instead of second stage larvae. After hatching, all but 100 larvae were removed from each dish. The remaining 100 larvae in each dish were fed on yeast suspension and their development was observed and recorded daily.

TABLE III. EFFECT OF CETYL ALCOHOL ON THE HATCHING OF MOSQUITO EGGS

Treatment	*Days to appearance of*					*Pupated Per Cent*
	1st stage larvae	*2nd stage larvae*	*3rd stage larvae*	*4th stage larvae*	*Pupae*	
CONTROL	1-2	3-4	6	7-8	10-11	74
0.033gm. C.A.	2	4	6	7	10	63
0.5gm. C.A.	1	3	6	8	9	41
1gm. C.A.	1-2	3-4	6	7-8	10-11	82

The above experiments indicate that cetyl alcohol has no appreciable effect on the hatching of eggs of *Anopheles gambiae*, nor on the subsequent development of larvae from these eggs.

EFFECT OF CETYL ALCOHOL ON MALARIOL HS AS A LARVICIDE :

A surface film of cetyl alcohol has a very high crushing strength (above 35 dynes/cm.). This means that oils of high spreading pressure including Malariol HS (spreading pressure about 35 dynes/cm.), cannot spread on water bearing a surface film of cetyl alcohol. But cetyl alcohol is soluble

TABLE V. EFFECT OF CETYL ALCOHOL ON THE NATURAL BREEDING OF MOSQUITOES

Treatment	*No. of Larvae found*	
	Anophelines	*Culicines*
CONTROL	40 all stages	1 fourth stage
1gm. C.A.	27 all stages	186 all stages
2gm. C.A.	96 all stages	NIL

This experiment indicates that cetyl alcohol has no repellent effect on ovipositing female mosquitoes. The numbers of larvae recovered are not significant, since it could not be arranged for the same number of females to lay the same number of eggs in each tank. In other words the experiment could not be made quantitative.

SUMMARY AND CONCLUSIONS

The effect of cetyl alcohol on all aspects of the aquatic phases of the life of mosquitoes, and on Malariol HS on water, has been investigated. It is concluded that cetyl alcohol has a short-lived retarding effect on the free spread of Malariol HS, but that it has no appreciable effect on any of the aquatic phases of the life of mosquitoes.

ACKNOWLEDGEMENT

My thanks are due to the Director, East African Meteorological Department, for the supply of a sample of cetyl alcohol and for details of the quantities used, to Mr. M. G. Christie for his constant advice, and to the Director, East African Malaria Institute, for his constructive criticism.

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A REPORT ON A BILHARZIA AND MOLLUSCAN SURVEY IN THE TANGA DISTRICT OF TANGANYIKA
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A REPORT ON A BILHARZIA AND MOLLUSCAN SURVEY IN THE TANGA DISTRICT OF TANGANYIKA

By GEORGE MACLEAN, G. WEBBE, and A. S. MSANGI

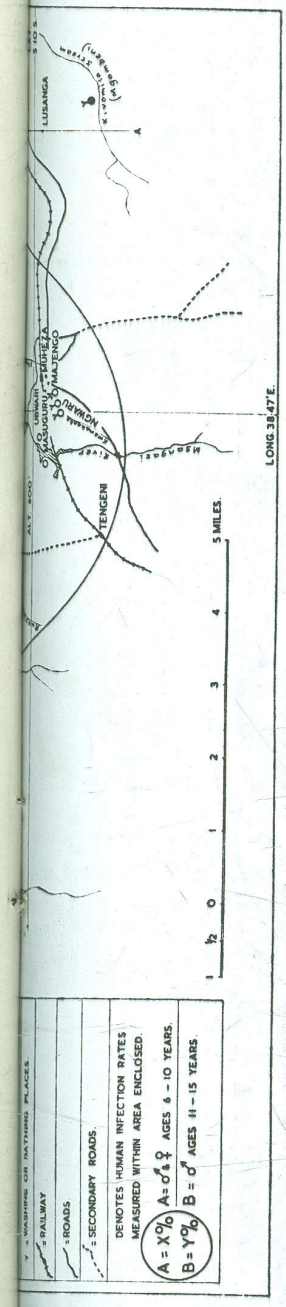
HUMAN schistosomiasis is stated to be widespread in Tanganyika but there is no record of any detailed surveys in which the incidence of infection in human beings is related to the distribution of vectors or to the cercariae which they carry. This paper records a contribution towards remedying this deficiency. The prevalence of this infection is repeatedly mentioned in the Annual Medical Reports of the Territory, and is confirmed by correspondence from the different provinces, which we have been able to study through the courtesy of the Director of Medical Services. These reports show that infection with *S. haematobium*, *S. mansoni* or both, is prevalent over large sections of every province of Tanganyika Territory. Cases of *S. japonicum* have also been reported, (four in the Annual Medical Report, 1954 and two in 1955). The Annual Medical Report for 1955 gives a total of 17,531 cases of *S. haematobium* and 3,835 of *S. mansoni*, and an additional 45 in which the species is not specified. The figures were compiled from returns received from hospitals in which a doctor is resident and it is recognised that the number can only form a fraction of the total for the whole territory.

A limited number of surveys has been carried out. One recorded in the Annual Report for 1950 showed 90·8 per cent infection rate in 196 children in a school in Northern Province. The East African Medical Survey found 12 cases of *S. mansoni* in 1,612 stools examined in two areas of the Bukoba district of Lake Province. In another part of the district none was found in 654 examinations.

Draper (personal communication) has examined the urines and stools of 1,877 persons in six areas in northern Tanganyika. He found 240 infected with *S. haematobium* and 86 with *S. mansoni*. The incidence varied considerably in the different areas. The highest he recorded in the case of both parasites was in the five to nine years age group, 53 per cent being infected with *S. haematobium* in a group of 100 in one village and 30 per cent with *S. mansoni* in a group of 40 in another village. In one village the highest incidence (19 per cent in 222 examined) was in the age group 40 years and over, while in the 15-19 age group only 14 per cent were found infected in 64 examined, in the 10-14 age group seven per cent in 94 examined, and in the five to nine age group seven per cent in 112 examined.

Examinations have been made by Government staff of groups of school children at Pongwe, Tanga district, and of schoolchildren, labourers and

AREA OF TANGA DISTRICT
SURVEYED.
KEY :-
O = PHYSOPSIS FOCUS. NO INFECTION FOUND.
● = PHYSOPSIS FOCUS. CERCARIAL SHEDDING
Y = WASHING OR BATHING PLACES.
= RAILWAY
= ROADS.
= SECONDARY ROADS.
DENOTES HUMAN INFECTION RATES MEASURED WITHIN AREA ENCLOSED.
A = X% A = ♂& ♀ AGES 6 - 10 YEARS.
B = Y% B = ♂ AGES 11 - 15 YEARS.
MARVERA
ALT. 3000'
DEREMA
AMANI
ALT. 2989'
SIGI
Sigi River
LUNGUZA
ANGEZA
MANGUBU
TONGWE
A = 80%
B = 97.3%
KIWANDA
BOMBANI
KINYANDEGE
KITOPENI
KILOMETASABA
UBEMBE
MAGILA
KIUMBA
MISONGENI
MKWAMBA
POTWE C.
KITIVO
ALT. 2908'
B = 80%
MLINGOTENI
KICHEBA
MLINGANO
A = 34.7%
NGOMENI
PONGWE
ALT. 330'
LUSANGA
LAT. 5.09'S
LONG 38.54'E
LAT. 5.10 S.
LONG 38.47'E
ALT. 600'
UBWARI
UGUIRU
MAJENGO
NDAKAU
TENGENI
1 ½ 0 1 2 3 4 5 MILES.



prisoners at Morogoro. Mozley (1938), to whose work reference is again made later on in this paper, carried out an extensive survey of schistosome vectors. In addition to these surveys, the staff of the Medical Department have, as is evident from the correspondence mentioned above, made extensive collections of suspected vector snails and have mapped out foci of schistosome infection.

The survey to be described was carried out in the Usambara foot-hills and the plains below, in the Tanga district of Tanganyika, from ten to 25 miles from the coast. The area surveyed is drained by three river systems—the Sigi, the Mkulumuzi and the Mgombeni (see map). One part of the area, the Pongwe-Ngomeni section, carries a number of pools which do not drain into any river.

The objects of the survey were:

to assess the incidence of infection with *S. haematobium* and *S. mansoni* respectively, in different places and in the different sexes and age groups;

to see whether any evidence could be found of inherited or acquired resistance to infection;

to make an estimate of the amount of disability and, if possible, of secondary disease associated with infection at different ages;

to study the distribution and behaviour of vector snails in different parts of the water systems under survey, at different times of the year;

to study the incidence of infection in snails and, as far as possible, to get the parasites identified.

METHODS

The work was carried out at hospitals (one Government and one Mission), dispensaries, schools and villages. The names, addresses, sex, and ages of the examinees were recorded, and, in some cases, the place of birth and the number of years resident at their present address as well. Urine specimens were taken without any previous exercise other than that involved in coming to the place of examination, and this might mean anything from a hundred yards to something over a mile. The specimens were taken as produced by the examinees and it was not necessarily the last part of the evacuation that was always produced. In nearly all cases the specimen was hand-centrifuged and a drop of the deposit examined under a low power, a coverslip being used only when required for better definition or higher magnification. Specimens of stools were collected in tubes, and as much as was available, up to the size of a large pea, was mixed with normal saline and broken up well with a small glass pestle. More saline was added to form a suspension which was then passed through two sieves, the mesh of the smaller of which was 100 to the linear inch. The suspension which passed through the sieves was left to sediment for at least half an hour. The supernatant fluid was next discarded and a fresh suspension was made by mixing the deposit with more normal saline. This was centrifuged and the deposit examined in the same way as in the case of the urine.

The urines were examined on the spot as soon as possible after evacuation. The stool specimens were taken to a central laboratory and examined on the same day.

HUMAN RESULTS

The Species of Schistosomes Found

Only a few *S. mansoni* were found. The remainder were all *S. haematobium* the eggs of which showed a considerable range of morphological variation. Except where otherwise stated, the text that follows refers entirely to *S. haematobium*. The findings in the case of *S. mansoni* are recorded in a separate paragraph.

Other intestinal parasites found included hookworm, roundworm, whipworm, strongyloides and another nematode, probably trichostrongylus.

The Incidence of Vesical Infection with S. haematobium in the area surveyed.

In the complete series of the main survey the urines of 3,400 persons were examined and the stools of 900 of them. In most cases not more than one specimen of urine and of stool was examined from the same individual. Both sexes were examined, and their ages ranged from under one year to over 60. Only four of the stools showed *haematobium* ova.

The results of the examinations of the 3,400 urines are shown in Table I.

TABLE I

Showing incidence of vesical infection in the complete series

Age group	*Sex*	*No. Examined*	*Ova found with or without erythrocytes. Per cent*	*Erythrocytes or ova or both found. Per cent*
All ages	Both Sexes	3,400	38·8	—
,,	Male	1,800	44·4	60·3
6-10 years	Male	682	47·1	58·4
,,	Female	402	43·2	59·7
11-15 years	Male	424	66·6	83·7
,,	Female	243	52·7	—
Over 50	Male	83	28·9	50·6
,,	Female	57	19·3	54·4
Over 55	Female	35	20·0	60·0

TABLE 2

Showing the Incidence of Vesical Infection in the two sexes by age groups

Age group (1)	Total examined			Ova found. Per cent. (with or without blood)			Erythrocytes found but no ova			Percentage in whom ova or erythrocytes found		
	M	F	Total	M	F	Total	M	F	Total	M	F	Total
Under 2 years .	12	13	25	—	7·6	4·0	1	3	4	8·3	37·7	21·7
2– 5 years .	39	37	76	—	2·6	1·3	6	10	10	15·4	29·7	14·5
6-10 ,, .	294	199	493	42·5	39·7	41·9	32	33	65	53·4	56·3	54·6
11-15 ,, .	200	173	373	57·5	50·3	54·2	46	—	—	80·0	—	—
16-20 ,, .	56	65	121	64·4	38·5	50·4	6	—	—	75·0	—	—
21-25 ,, .	7	59	66	43·0	27·1	28·8	2	—	—	71·4	—	—
26-50 ,, .	71	183	254	16·0	18·0	17·7	28	—	—	56·3	—	—
51-55 ,, .	11	10	21	—	40·0	19·0	7	—	—	63·3	—	—
Over 55 ,, .	26	17	43	19·2	17·6	18·6	7	9	16	43·1	70·6	55·8
Age not specified .	18	4	22	—	50·0	9·1	4	2	6	22·2	100·0	36·3
TOTAL . .	734	760	1494	40·3	33·0	36·6	139	57	101	59·3	—	—

Note (1) The ages are only estimates in nearly all adult cases
The young age groups are approximately accurate in most cases

This series includes immigrants into the area and some of them may possibly have been infected before their arrival, though the majority have been in the area for several years. The series also includes some who have had previous treatment, the details of which were not available to us. It was noted, however, that many of those who were stated to have had treatment were still passing ova. From the information some of them gave it was evident that recognised courses of treatment had not been completed. The population in certain villages and schools in the Mkulumuzi river system and an adjacent part of the Sigi river system is believed to be fairly stable. A number of young people leave but there is no great immigration of outsiders to take their place. Table 2 has been prepared from the results obtained in these villages and schools. Adults who were obviously immigrants, and persons who were known to have received antibilharzia treatment, have been excluded. The highest incidence is in the 11-15 age group, with a slightly higher rate in males than in females.

The rate of infection is by no means the same throughout the district. Table 3 makes a comparison between two localities, Kiwanda and Ngomeni, which are separated from each other by a large mountain.

TABLE 3

Showing the results of one urine examination of two groups of schoolchildren from two different localities

	Kiwanda		*Ngomeni*	
	6-10 yrs.	11-15 yrs.	6-10 yrs.	11-15 yrs.
Boys				
No. examined	25	35	53	1
No. showing ova	15 (60 per cent)	27	12 (22·6 per cent)	1
No. showing either ova or erythrocytes	20 (80 per cent)	31	15 (28·3 per cent)	1
Girls				
No. examined	26	2	19	1
No. showing ova	20 (76·2 per cent)	2	3 (15·8 per cent)	—
No. showing ova or erythrocytes	21 (80 per cent)	—	10 (52·6 per cent)	—

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Ngomeni	
1-10 yrs.	11-15 yrs.
53	1
12	1
22·6 per cent)	
15	1
38·3 per cent)	
19	1
3	—
15·8 per cent)	
10	—
32·6 per cent)	

DISABILITY AND SYMPTOMS

In the section on Helminthic Infestations in the Annual Report of the Medical Department of Tanganyika for 1952, it is pointed out that "no reliable facts have yet been adduced as to the effect of such infestations on health and physical efficiency". That appears to be still the position although, as pointed out in the 1955 Annual Report of the same department, there is concern about the effect that bilharzia may have on industrial undertakings, which are of growing economic importance, and on the health of people living where water conservation and irrigation projects are being developed.

Those examined in this survey did not, with the possible exception of some individuals in the older age groups, show signs of any gross disease which could be attributed to bilharzia infection. Tests for minor degrees of disablement are difficult to devise, and in this series the problem was complicated by the prevalence of other concurrent infections.

The stools of 201 cases who showed *haematobium* ova in their urine were examined and 138 (65 per cent) of them were found infected with one or more of the other helminthic parasites, some of them showing as many as four different species in the one stool slide. In a group of 111 schoolchildren who were passing *haematobium* ova, Clyde and Shute (personal communication), found 64 (57.7 per cent) of them with malaria, the main infection being *P. falciparum.*

The true incidences of the different infections were almost certainly higher than the minima quoted above, most of which are based on single examinations only, and some at least of these infections probably contributed their share to the anaemia, splenomegaly and hepatomegaly that were found.

The haemoglobin of 202 children was examined by Clyde and Shute (personal communication), using the Tallqvist method. The readings varied from 40 to 80 per cent in the bilharzia cases, but there were so few who were free from other infections that no conclusions could be drawn without applying precise therapeutic tests.

Enlargement of Spleen and Liver. 527 positive cases of both sexes were examined for splenomegaly and hepatomegaly. The results are shown in Table 4. None of the livers examined were more than four fingers' breadth below the costal margin in the region of the nipple line and one of the spleens was more than four below, and this was in the six to ten age group. (There was one infected woman not included above, whose clinical history is not available, but whose spleen was seven finger breadths below the costal margin).

Haematuria. It was exceptional to meet a positive case who did not have some degree of haematuria, and in more than a quarter of the 847 investigated the haematuria was apparent to the naked eye on centrifuging (a degree of haematuria referred to in the table as "macroscopic"). Table 5 shows the findings in the 847 cases.

TABLE 4

Showing cases in which there was well marked splenic and hepatic enlargement.

Age group	Total Examined	Liver Spleen not enlarged	Liver less than I Spleen III-IV	Liver I-II Spleen III-IV	Liver III-IV Spleen V	Liver III-IV Spleen III-IV	Liver III-IV Spleen I-II	Spleen under I
0— 2	3							
2— 5	172	1	0	0	0	0	0	0
6—10	199	60	2	13	1	3	0	2
11—15	75	92	1	7	0	4	0	1
16—20	76	57	0	2	0	2	1	0
Over 21		51	4	2	2	6	0	0

(The figures in Roman characters indicate the number of fingers' breadth (in the case of the liver taken in the region of the nipple line) below the costal margin. Cases in whom *both* spleen and liver enlargement were less than three fingers' breadth below, are not shown).

TABLE 5

...e of the mothers who ...

Showing the proportion of positive cases with haematuria. ... numbers in the fourth column are also included in the third. T... ...t of 83, age groups 0-10 years include both male and female. Those ... ...t between 11 and 50 include males only.

Age Group	Total Examined	Total with Haematuria Per Cent	"Macroscopic" Haematuria Per Cent
0-2	7	71·4	.....
2-5	8	100·0	.....
6-10	425	95·3	25·4
11-20	322	84·8	37·9
21-30	25	92·0	16·0
31-40	23	82·6	17·4
Males over 50	18	83·3	22·2
Females over 55	6	83·3	.....

Cystitis. Probably all had some degree of cystitis, but none appeared to be seriously handicapped by it, though a few had rather large numbers of white blood cells. There were no cystoscopic examinations made.

Dysuria is probably the commonest symptom that the patients complained of. The feeling is variously described as "pain", "stabbing pain", or "irritation". It seems to disappear altogether for a time and then recur. Occasionally the symptom is noticeable at the beginning of micturition, but more frequently at the end. The histories of 209 cases, 92 girls and 117 boys, between the ages of six and 20, were investigated; and the symptom was complained of in 82 (39·8 per cent) of them. It was difficult to assess its severity, but it appeared to be only slight in 28 of the total 209, moderate in 44, and severe in ten. The ten severe cases were all boys.

Dysmenorrhoea was complained of in a number of cases, but it is not an uncommon complaint among the general population from whom inquiries were made. One of the most suitable tests of its relationship with bilharzia is a therapeutic one. It is necessary to make a number of examinations, probably not less than a dozen, to exclude infection in any given case, so that a comparison between infected and non-infected cases is not practicable in a routine survey.

Child Bearing and Bilharzia.

The urines of 166 ante-natal cases were examined, and 61 of them (36·7 per cent) were passing ova. 34 more had blood in the urine. The pregnancies of 14 of the infected cases had ended before the completion of the survey. Nine of these were normal deliveries and five were abortions.

None of them received anti-bilharzia treatment. Some of the mothers who were found infected had had as many as five children living.

The Effect of Bilharzia on the Older Age groups.

As was seen earlier in the report 42 males (50.6 per cent) out of 83, over the age of 50, had ova or haematuria or both; and 21 (60 per cent) out of 35 females over the age of 55 had ova or blood or both. It was not possible to have any of the 118 cases investigated more fully but it is obviously important that a cystoscopic examination should be made of such cases.

Infection with S. mansoni.

Only seven cases were found out of 900 stools examined. None was found in the urine. Three of the cases were known to have come from Central Africa outside Tanganyika and one from the Ufipa district in South West Tanganyika.

No *Biomphalaria* was found during the snail survey.

Evidence of Immunity.

It is probable that most if not all young persons in the area are susceptible to infection if they are sufficiently exposed to it.

At Lusanga a number of schoolchildren who had previously shown no ova in their urines were re-examined towards the end of the survey and several of them were found positive. Out of a total of 75 boys between the ages of 11-15 years, 71 were passing ova, two more had haematuria and only two showed neither ova nor red blood cells. In the same area, out of 27 girls between the ages of six and ten years, 23 were passing ova, two more had haematuria and two showed neither ova nor red blood cells. Table 2 shows that 80 per cent of 200 boys in the 11-15 age group were passing ova or red blood cells or both. 17 of those passing red blood cells only have been re-examined since, and all of them were found to be passing ova.

In communities in which infection is heavy in the early years of life, there is evidence that a certain amount of immunity develops. It becomes noticeable after the second decade of life. Thus in Table 2, the incidence of infection, measured by the presence of ova only, has fallen from 50·4 per cent in the 16-20 group, and 28·8 per cent in the 21-25 group, to 17·7 per cent in the 26-50 group. (In the 26-30 group, which is not shown separately in the table, the rate was 29·3 per cent in a total of 99). The proportion having either ova or red cells remains high—56·3 per cent in men in the 26-50 group.

To complete the picture it would be necessary to know the history of individuals over a period of many years. Infection may be latent over long periods.

In the series from one village quoted above from Draper's report the picture is different; the highest incidence being in the group 40 years and over. This finding does not necessarily exclude the development of immunity in those already infected. The increase with age in the number infected may be due to opportunities for infection being infrequent for most of the population. In such a case opportunities would tend to increase with age.

On the whole the results obtained, so far as they go, are confirmation of the data collected by Newsome (1956), as evidence of resistance in man.

SNAIL SURVEY

An extensive snail survey was carried out in Tanganyika Territory, by Mozley (1938), who records that the distribution of *B.* (*Physopsis*) *globosus* was widespread in areas where the incidence of *S. haematobium* was high; and who also found *Physopsis globosus* at Pongwe and Muheza, Tanga district.

During the present survey carried out over a period of five months, (approximately 500 man-hours searching), bodies of water were searched for snails, and specimens collected for identification and for a study of cercarial shedding. Special attention was paid to places being used by local inhabitants for bathing and washing purposes. Drinking wells and also, where possible, rice fields were searched.

The following river systems were included :—

Mkulumuzi river, from head-waters for two miles below Muheza town.

Mkulumuzi tributaries: Mnyodo, Runywa, Msangazi from Muheza dam, Muheza dam, Kwamakanka.

Sigi river from Lunguza to Kiwanda.

Sigi river tributaries: Madidimo, from headwaters for three miles below Kitopeni, Lusanga, Mngeza, both from headwaters to Sigi.

Mgombeni river tributary: Kivomila near Lusanga and for two miles south-east.

Impounded waters with no drainage: dam at Mlingano, pond at Ngomeni, two ponds at Pongwe, (see Map).

Identification of Snail Material.

Snails of the genus *Bulinus* have been found at all the places shown on the map, and the following species have been identified.

B. (*Physopsis*) *nasutus* (Von Martens): At Pongwe, two foci, Ngomeni, Muheza dam, filtration plant below Muheza dam, three foci on Lusanga stream near Tongwe.

B. (*Physopsis*) *africanus ovoideus.* (Bourguignat), three foci on Runywa.

B. (*Physopsis*) *globosus* (Morelet), all other foci indicated on map. Both Wright and Verdcourt, (personal communications) consider that intermediate forms between *B.* (*Physopsis*) *globosus* and *B.* (*Physopsis*) *nasutus* exist in the area surveyed and work is in progress on the conchological and malacological aspects of this material.

TABLE 6

Snails found showing Gross Cercarial Shedding

Foci	Percentage of Snails infected	Type of Cercariae	Species of Snail
Mkulumuzi-Magila (a)*	1·5	"Mammalian type"	B. (Physopsis) globosus
,, -Magila (b)	2·4	,,	,,
,, -Mikwamba	14·2	,,	,,
Mnyodo (a)	3·1	,,	,,
,, (b)	14·2	,,	,,
Runywa (a)	8·3	,,	B. (Physopsis) africanus ovoideus
,, (b)	12·5	"Avian type"	,,
Kivomila	10·0	"Mammalian type"	B. (Physopsis) globosus
Mlingano dam	12·0	,,	,,
Ngomeni	16·0	,,	B. (Physopsis) nasutus
Pongwe (a)	7·0	"Avian type"	,,
(b)	1-69 (monthly over a year)	,,	,,

* Indicated on map

The few collections of snails made from the Kiwanda area, (one of the heaviest infected localities), shed no cercariae. The snail survey in this area was abandoned, because of floods, (approximately 40 man-hours searching only). Epidemiological consideration leaves little doubt that *B. (Physopsis) globosus* is a major vector of *S. haematobium* in this area.

Association of Bulinus snails with Human Habitation.

Blacklock and Thompson (1924), working in Sierra Leone, refer to *Bulinus* as being a sewage snail to a marked degree and observed that the *Physopsis* from water latrines were the largest and most active of all those found, as well as being the most highly infected with schistosome cercariae. According to Ransford (1948), working in East Africa, *B. (Physopsis) globosus*, required "fouling of its habitat" for its survival. Gerber (1952), working in Sierra Leone, found that *Bulinus* occurred in greatest numbers close to villages, but without association with urinary or faecal contamination. During the present survey the largest concentrations of *Bulinus* have been found at places frequented by local people for the purpose of bathing, washing clothes and household utensils, or both (see Map). The foci found on the Mkulumuzi near Magila are constantly used for bathing by the school-children. The same is true at Tongwe, Lunguza, Mngeza, and Kiwanda on the Sigi river, and in the ponds at Ngomeni and Pongwe. Only a few of the snail foci found in this survey are entirely unfrequented by man. Many parts of the uninhabited stretches of the Mkulumuzi river complex were searched and were apparently devoid of *Bulinus* snails: the same being true of similar places along the Sigi between Lunguza and Kiwanda. It may be that the relationship between *Bulinus* and fouling of its habitat is not a direct one, but rather attributable to the attraction of an increased food supply provided by the organic waste matter. One collection only of snails was

made in a rice field, near Kitopeni. No snails were found in the drinking wells examined, one collection was made, however, in the filtration plant below the dam that is the main water supply of Muheza town.

Experimental Infection of laboratory-bred Animals.

Two guinea pigs and five white mice were exposed to cercariae shed by infected *Physopsis*, from the area surveyed. The results obtained are shown in Table 7.

TABLE 7

Showing the results of exposing guinea-pigs and white mice to "Mammalian type" cercariae obtained from naturally infected Physopsis

Species of animal	Species of snail	No. of snails used	Total Cercariae applied	Days from first infection to autopsy	Result of autopsy
Guinea-pig	Physopsis globosus	2	1,000	116	No trematodes found.
,,	,,	5	2,500	123	,, ,,
White mouse	,,	2	1,000	92	,, ,,
,,	,,	1	900	94	,, ,,
,,	,,	4	1,500	86	,, ,,
,,	Physopsis nasutus	2	1,000	100	3 immature male trematodes found.
,,	Physopsis africanus ovoideus	1	800	87	No trematodes found.

DISCUSSION

The first major need in connection with the bilharzia problem of East Africa would appear to be to get an assessment of the prevalence of infection, and of the harm that it may be doing to the well-being of the people and to the economy of the country. Improvements of water supplies and extension of their utilisation must come in a country of which a large part is relatively dry and under-developed and these changes will bring with them, unless precautions are taken, an increase in bilharzia hazards which may become critically important to human welfare.

The survey described has demonstrated the prevalence of infection in a particular coastal area, but the results obtained cannot be applied generally, and more surveys in other areas and on a large scale are necessary. It has also shown that, in this area at least, there is a growing number of people who are anxious that they and their families should be protected, or be shown how to protect themselves, against infection.

The points arising out of the snail survey are discussed in another paper.

Possibilities of Extending Investigations in East Africa.

Pond B : 10 acres at highest level ; marginal vegetation composed of grasses and sedges varying in density ; on one side cleared edges with cultivated furrows ; floating vegetation composed of water-lilies and some water lettuce ; 80 per cent. of the area completely open water subject to fairly strong action by wind and waves ; snail population of *B.* (*P.*) *nasutus*. Both ponds were rich in organic matter, with soils composed of sandy clay with humus. Neither had continuous change of water by inflow or outflow. Both contained a rich fauna, including may-fly, dragon-fly and damsel-fly nymphs, bugs, water-boatmen and water beetles, leeches and earthworms, freshwater crabs and other small crustaceans, and large populations of frogs. Pond B contained a species of water tortoise and of small fish, and was frequented by domestic and wild ducks. Both ponds were visited by wild aquatic birds. Pond C : three acres at highest level ; sparse marginal vegetation composed of grasses and sedges ; some floating vegetation, composed of water-lilies only ; 95 per cent. of the area completely open water subject to strong wind and wave action ; sandy soil with humus ; rich in green algae ; moderately rich insect fauna, small crustaceans, leeches and frogs ; frequented by wild aquatic birds ; snail population of *B.* (*P.*) *globosus* Morelet and *Cleopatra ferruginea* Lea. Stream D : a small tributary of the Mkulumuzi river, with head-waters in the eastern Usambara foothills ; sluggish stream with rocky bed, small rapids and numerous sandy pools ; sparse marginal vegetation composed mainly of grasses, with sedges in places ; rich insect fauna ; snail population of *B.* (*P.*) *africanus ovoideus* Bourguignat.

CLIMATE

The area is primarily low-lying coastal plain. From November to May temperatures frequently rise above 90° F. and at night do not usually fall below 75°. During the period June-October afternoon temperatures may be as high as 75-80°, with night temperatures of the order of 65-70°. Rainfall from April to May and from October to December is associated mainly with the south-west and north-east monsoons respectively. Rainfall occurs chiefly during the night and morning, often in the form of heavy showers and sometimes as thunderstorms. Rainfall totals diminish inland, from some 45-50 inches per year on the coast to 35 inches inland in the south-east and about 40 inches inland in the north. There is a long cool season from June to September and a shorter hot one from January to March.

METHODS

Snail populations were estimated weekly in the two following ways : first, by hand-collecting for a fixed period of time, the numbers being expressed as the average number of snails collected per man-hour of searching ; secondly, by the use of snail-traps, with the numbers collected expressed as the average number of snails per trap. The traps initially used were made of palm-leaf fronds woven into rectangular mats 3 feet square, as described by Azim and Ayyed (1948). They were found, however, to deteriorate quickly, and their replacement became a problem. Traps were therefore subsequently made of bamboo canes, bound together to form rafts of the same dimensions as the palm-leaf traps. Each trap was anchored, to float horizontally in shallow water near the margin of a pond. These bamboo traps were very successful, and were used for the greater part of the observations in ponds A and B and throughout all the observations in pond C and stream D. Both methods of estimation were used in ponds A, B and C ; in stream D only the trap method was used.

TABLE II

Showing the monthly fluctuation in the numbers of *B.* (*P.*) *globosus* collected in pond C, together with the average surface temperatures and the monthly rainfall figures recorded at Mlingano. The *p*H of the water ranged from 6·7 in July, 1956, to 7·5 in October, dropping to 5·5 in March, 1957

Month	Average weekly collections of snails		Average weekly surface temperature, in degrees C., at 11.30 a.m.	Monthly rainfall, in inches
	Per man-hour search	Per bamboo trap*		
1956				
June ...	68	28	30·1	1·45
July ...	77	35	29·2	0·97
Aug. ...	89	32	27·4	0·84
Sept. ...	187	84	30·4	1·38
Oct. ...	121	48	32·0	0·78
Nov. ...	27	34	33·2	6·32
Dec. ...	4	8	30·7	2·18
1957				
Jan. ...	0	0	29·6	7·93
Feb. ...	0	0	30·7	1·32
March ...	0	0	32·5	2·79
April ...	0	0	32·1	15·25
May ...	3·6	0·4	30·2	11·06
June ...	32	18	29·8	2·01
July ...	77	52	28·5	1·16

* Five traps were placed in the pond.

The Quantitative Methods of Estimation Used

The quantitative method of measuring the density of a snail population by hand-collecting for a fixed period of time has certain merits. While it requires direct accessibility to the population, it is quick and easy to carry out. Hubendick (1956) has, however, criticized the method on the grounds of the possibility of personal variation and of difficulty in finding the snails owing to vegetation and other local conditions ; and he is of opinion

TABLE III

Showing the monthly fluctuation in the numbers of *B.* (*P.*) *africanus ovoideus* collected in stream D, together with the average surface temperatures and the monthly rainfall figures recorded at Muheza. The *p*H of the water was constant at 6·7

Month	Average weekly collections of snails per bamboo trap*	Average weekly surface temperature, in degrees C., at 2.30 p.m.	Monthly rainfall, in inches
1956			
June ...	8·6	24·4	1·35
July ...	4·8	24·0	0·94
Aug. ...	3·6	23·8	0·89
Sept. ...	3·5	25·9	1·24
Oct. ...	1·5	27·6	1·24
Nov. ...	1·0	28·8	9·11
Dec. ...	2·8	30·2	3·96
1957			
Jan. ...	9·0	30·0	4·85
Feb. ...	8·7	30·3	0·87
Mar. ...	3·0	31·5	4·04
April ...	1·3	30·7	16·96
May ...	3·7	27·8	9·9
June ...	8·3	26·1	1·75
July ...	9·4	24·2	1·48

* Five traps were placed in the stream.

TABLE IV

Showing the approximate age-composition of the snail populations in each of the four habitats, as estimated by measurement of the height of the shell from base to apex and by grouping the snails measured as follows: group 1, under 1 cm. in height; group 2, 1-1·49 cm.; group 3, 1·5 cm. and over

Month	No. of snails per cent. in each size-group											
	Pond A			Pond B			Pond C			Stream D		
	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3
1955												
Sept.	25·5	66·0	8·5	1·5	54·8	43·7	—	—	—	—	—	—
Oct.	63·5	30·5	6·0	2·4	54·0	43·6	—	—	—	—	—	—
Nov.	86·5	12·5	1·0	41·3	30·0	28·7	—	—	—	—	—	—
Dec.	60·0	33·6	6·4	38·9	47·8	13·3	—	—	—	—	—	—
1956												
Jan.	27·2	58·3	14·5	41·9	52·4	5·7	—	—	—	—	—	—
Feb.	20·8	48·0	31·2	25·3	63·7	11·0	—	—	—	—	—	—
Mar.	4·0	61·0	35·0	18·4	75·0	6·6	—	—	—	—	—	—
Apr.	1·8	50·0	48·2	14·3	64·4	21·3	—	—	—	—	—	—
May	23·5	49·2	27·3	22·1	57·2	20·7	—	—	—	—	—	—
June	7·2	55·4	37·4	14·8	47·9	37·3	34·2	60·3	5·5	54·8	43·4	1·8
July	2·0	54·0	44·0	8·3	26·9	64·8	22·5	61·8	15·7	25·6	63·9	10·5
Aug.	Dried up			5·1	32·2	62·7	13·2	57·1	29·7	17·4	78·3	4·3
Sept.	—	—	—	1·8	36·5	61·7	11·1	49·8	39·1	18·6	74·2	7·2
Oct.	—	—	—	0·4	58·2	41·4	0	36·5	63·5	0	16·7	83·3
Nov.	—	—	—	0·3	52·3	47·4	0	23·4	76·6	0	30·0	70·0
Dec.	—	—	—	0	53·1	46·9	0	17·0	83·0	12·0	25·6	62·4
1957												
Jan.	—	—	—	0	0	0	0	0	0	63·5	24·6	11·9
Feb.	—	—	—	0	2·7	97·3	0	0	0	50·0	33·6	16·4
Mar.	—	—	—	0	16·1	83·9	0	0	0	0	75·0	25·0
Apr.	—	—	—	0	21·8	78·2	0	0	0	17·5	71·3	11·2
May	—	—	—	55·4	22·3	22·3	69·2	23·7	7·1	89·1	10·9	0
June	—	—	—	53·6	44·2	2·2	68·4	31·6	0	83·6	15·1	1·3
July	—	—	—	23·1	74·8	2·1	75·5	23·8	0·7	76·7	22·1	1·2
Aug.	—	—	—	15·5	52·8	31·7	—	—	—	—	—	—

that one method is not enough for measuring snail density. Wright (1956) demonstrated the presence of a snail microhabitat on the underside of water-lily leaves, and pointed out that such microhabitats might be of considerable importance in the numerical analysis of snail populations. It was noted at the beginning of the present observations that *Bulinus* favoured the underside of water-lily leaves and that this type of vegetation assisted, rather than hindered, the collection of snails in the habitats studied.

In the present observations the results obtained by the use of the bamboo snail-traps closely paralleled those obtained by hand-collecting for a fixed period of time. While the numbers collected by the traps were smaller than those collected by hand, they served both as a useful check on the hand-collecting method and to confirm the seasonal trends of the populations studied.

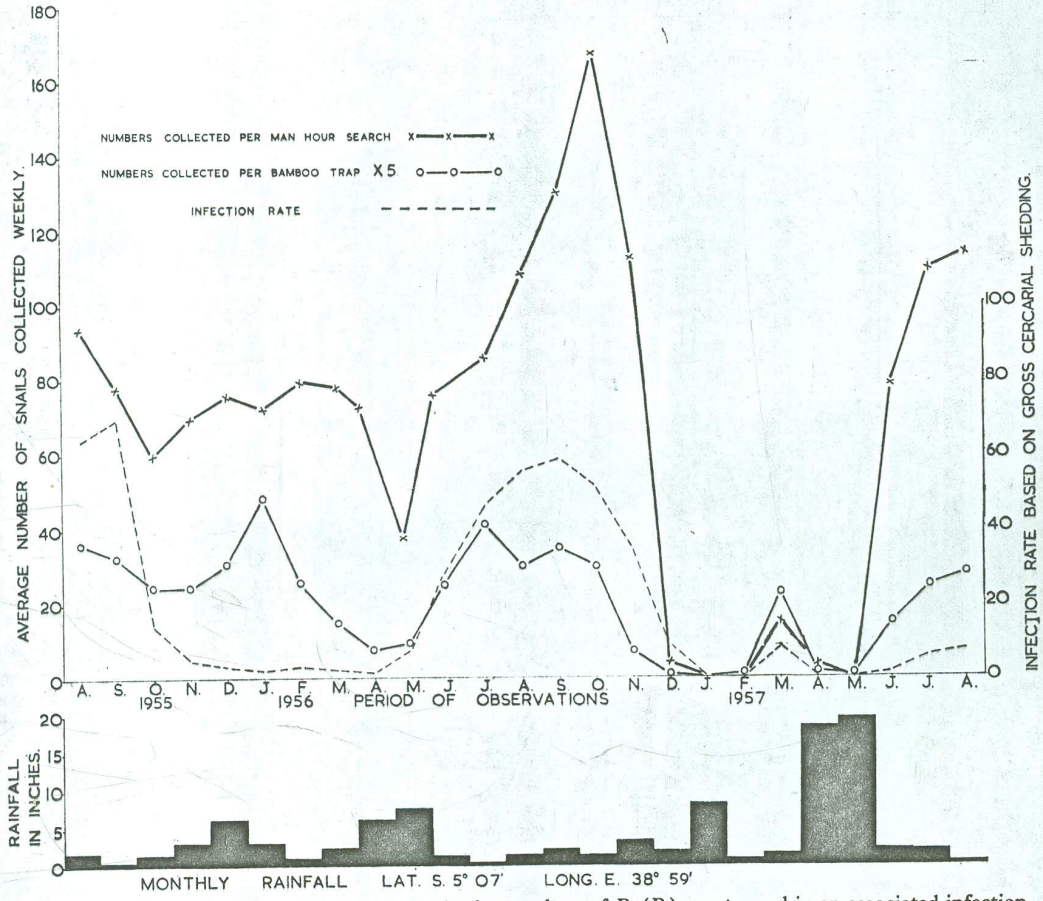


FIG. 1. Showing the monthly fluctuation in the numbers of *B.* (*P.*) *nasutus* and in an associated infection rate in pond B, and their relationship to rainfall.

RESULTS

The monthly fluctuation in the numbers of snails found in all four habitats, together with the average weekly temperatures and monthly rainfall figures, are set out in Tables I,

TABLE V

Showing the average free-calcium content of each of the four habitats, and the total chlorides estimated at different times from 1955 to 1957

Average free-calcium content, in mgm. per litre				Total chlorides, in mgm. per litre				
Pond A	Pond B	Pond C	Stream D		Pond A	Pond B	Pond C	Stream D
30	9	103	6·8	Aug. 1955	806	708	—	—
				Oct. 1956	—	—	904	—
				Dec. ,,	—	1,130	1,262	603
				Mar. 1957	—	902	1,792	—
				Apr. ,,	—	—	2,220	—
				June ,,	—	714	—	—
				July ,,	—	—	468	—

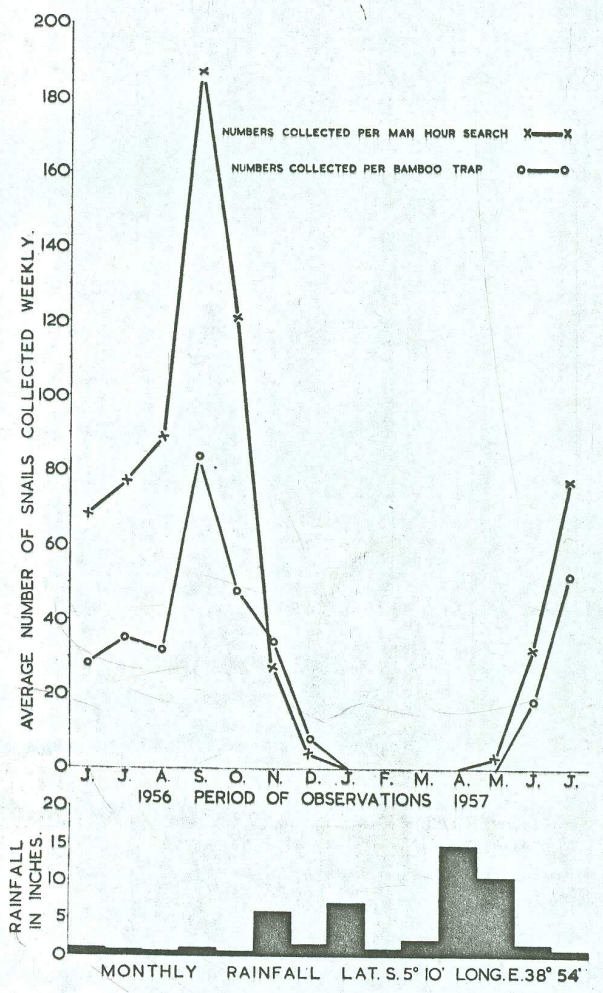


FIG. 2. Showing the monthly fluctuation in the numbers of *B.(P.) globosus* in pond C, and its relationship to rainfall.

II and III. The results from ponds B and C and stream D are also shown graphically in figs. 1, 2 and 3. Table IV shows the approximate age-composition of the snail populations, as measured by shell height, and Table V records the average free-calcium content of each habitat, and the total chlorides measured at different times.

Numbers of Snails Found

Observations on ponds A and B began in August, 1955; they continued in pond B until August, 1957, but in pond A they came to an end in July, 1956, when the pond dried up completely. Numbers in both ponds decreased from August until October, when an increase was observed. This was markedly shown in pond A, the increase continuing until the following March, when another sharp decline in numbers began. The finding of large numbers of snails in pond A during January, February and March, while reflecting a definite increase in the population at that time, was probably also partly due to the concentration of snails consequent upon the reduction in the size of the pond after the short rains (November-December). The second sharp fall in numbers in April is thought to be due

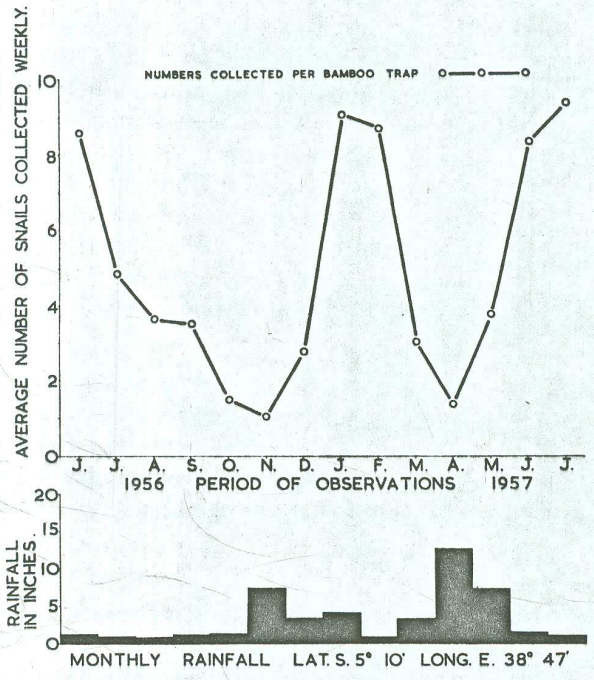


FIG. 3. Showing the monthly fluctuation in the numbers of *B.* (*P.*) *africanus ovoideus* in stream D, and its relationship to rainfall.

to the removal of large numbers during the previous months. In pond B, which is some five times bigger than pond A, the increase in the number of snails was less marked; the increase continued until February, after which the population declined until May. After the long rains in April-May, an increase in numbers began, in pond A in June and in pond B in May.

Pond B became considerably reduced in size in late September, 1956, and the large

numbers of snails collected in September and October may again reflect the denser concentration of the population in the reduced body of water. The sharp fall in numbers in November and December, while showing a naturally declining population (a true reflection of conditions prevailing at that time), was almost certainly partly due by the collecting of the previous months. All higher plant life disappeared from pond B before the end of November. In January no snails were found in this pond by either method of collecting; a few old snails were collected in February, and a further increase in numbers occurred in March (following the short rains of December-January). Thereafter the population declined until May; higher plant life began to reappear in late April, and the snail population began to increase at the end of May. Large numbers of snails were again collected in June, July and August.

In pond C numbers rose during June, July and August, reaching a peak in September, followed by a sharp fall in November and December. No *B.* (*P.*) *globosus* was collected from January until the middle of May. The pond became considerably reduced in size at the end of October, when higher plant life disappeared. There was considerable fluctuation in the total chloride content of the water, as shown by determinations made in October, December, March, April and July (see Table V). Fluctuation in *p*H values was also observed. It is noteworthy that, while the population of *B.* (*P.*) *globosus* apparently disappeared during the period January-May, *C. ferruginea* (an operculate snail) flourished, its numbers reaching a peak at the end of March. The short rains, which began in November and continued until January, did little to restore this habitat, and not until the long rains in April and May did the body of water resume normal proportions. *Physopsis* snails were again collected at the end of May, and numbers rose sharply in June and July.

In stream D snail numbers fell during the months June-November, and rose again sharply in December and January, following the short rains. From February to April a population decline was observed, followed by a sharp increase after the long rains of April-May.

Cercarial Shedding

The average weekly infection rates of the snail populations in ponds A and B are shown in Table I and, for pond B, in fig. 1 also; they refer to 'avian type' cercariae. In both ponds high infection rates were associated with a high proportion of older snails. In pond C and stream D only isolated infections were found among the populations, and no rates were measurable.

Occurrence of Young Forms

The measurement of the height of snail shells to show the approximate age-composition of the population (Table IV) serves also to show the occurrence of breeding. Although it cannot be pretended that such measurements give an accurate analysis of the age-composition of a population, they do show the proportion of ' very young ' snails to ' old ' and ' very old ' snails, and so help to confirm the breeding seasons.

Some observations on the probable breeding seasons were made in pond B, by noting the presence or absence of egg-masses on the underside of water-lily leaves. Egg-masses were found on a large proportion of the leaves (on over 60 per cent. of those examined) in late April and May, 1957. Egg-masses were also noted on the underside of the bamboo traps during the same period. In pond C egg-masses were found on the underside of the bamboo traps in April, before any *Physopsis* had reappeared.

Effect of Desiccation

Live *B.* (*P.*) *nasutus* were recovered from the dried mud of pond A five months after it had dried out. The pond was partially refilled after the short rains at the end of January, and *B.* (*P.*) *nasutus* collected from it 21 days after it had refilled shed ' mammalian type ' cercariae. A near-by pond containing *B.* (*P.*) *globosus* dried up two months before pond A, and live *Physopsis* were recovered from the mud for up to eight months afterwards.

DISCUSSION

In North Africa the seasonal fluctuations in the fertility and growth of the snail vectors of bilharziasis are known. Investigations on *B. truncatus* Audouin have been carried out in Egypt by Barlow and Azim (1946) and in Iraq by Watson (1951); and Gaud (1956) has discussed the seasonal fluctuations of *B. truncatus* and *Planorbis metidjensis* Forbes in Morocco. The evidence presented by these authors shows that the factors responsible for the seasonal fluctuations are multiple, and that the existence of an internal rhythm, whether of species or of race, seems to be excluded. Gordon *et al.* (1934), working in Sierra Leone, found that the optimum temperature for *B.* (*P.*) *globosus* was 27-33° C., but that the species was capable of surviving for prolonged periods at a slightly higher temperature and for short periods at a markedly higher temperature. They found that, under laboratory conditions, spawn was never deposited at temperatures of over 33° C., that transference to aquaria maintained at 20° C. resulted in spawning, but that no spawning was observed at 15° C. Gordon and his collaborators further considered that in nature spawning probably took place at all seasons of the year, but a marked increase in the number of young snails was noticed at the commencement of the cool rainy season. Mozley (1939) found that in a pond at Muyuni, Zanzibar, *B.* (*P.*) *globosus* bred rapidly, with generations both during and after the ' great rains ' (April-May) and another generation at the time of the ' little rains ' (November-December). Between the two rainy seasons there were periods of drought, when most of the snails were inactive. Mozley considered that the temperatures commonly met with in that part of Africa did not appear to have any marked direct effect upon the distribution of molluscs, but that relatively high temperatures during periods of minimum rainfall resulted in the drying-up of many ponds, with the result that the annual period during which it was possible for freshwater molluscs to be active was greatly reduced.

The present observations confirm both that seasonal fluctuations in populations occur and that breeding peaks are found at the times of the long and short rains in April-May and November-December respectively. An approximate age analysis of the populations shows a high proportion of very young snails at those times and confirms them as being the main breeding periods. The main breeding peak during the long rains occurs at the beginning of the cool weather, when temperatures for spawning are probably optimal. The second breeding season, during the short rains, seems to be chiefly limited by the high temperatures that are likely to occur. For example, in pond B during November and December, 1955, the average weekly temperatures at 10.30 a.m. were 32·8° and 32·9° C. respectively (probably near the upper temperature limit for spawning). In pond C in November, 1956, the average weekly temperature at 11.30 a.m. was 33·2° C., and, although rainfall was relatively high, there was no evidence that breeding was taking place. The sharply defined population maxima in stream D followed the two main breeding periods.

The need for observations on the effect of mass treatment in a community's economy has long been felt by many workers. Recently Davey and Gordon (1956) have drawn attention to this matter, and to the necessity for studying the parasite load as well as mere infection.

In Tanganyika, observations of this sort on peasant communities are difficult on account of the various factors that have to be considered, such as changeable rainfall, varying opportunities for outside work, plant and animal diseases, etc. But it might be possible to make an assessment on a large plantation or mine, where the labour force is stable and wages are based on piecework.

Even more important than the study of the effect on the economy is the investigation of the effects on the health of women during the child bearing age, and on the ante-natal and neo-natal well-being of children. Such studies cannot be properly undertaken in the course of a routine survey, but gynaecological studies could be made at certain centres where large enough numbers of young women live under discipline, as in boarding schools and colleges, and teaching hospitals. Child welfare centres, especially if they are connected with a maternity hospital, can be used to study the bearing of infection and parasite load on maternity, ante-natal and neo-natal well being.

Newsome (1956) has pointed out the importance of investigating immunity and of taking it into account before embarking on control schemes. Field observations could be carried out on school children in heavily infected areas. They could be kept under periodic observation for four years at least, and in some schools up to ten years, to see whether any of them remain resistant to infection. If they do, it might be possible to get some volunteers to co-operate on exposure to experimental infection.

The investigation of the haematurias in the older age group should have a high priority, because of their possible association with secondary renal and urinary diseases, including malignant growths. Cystoscopic examinations and collection of material for histological examination might well be undertaken as a routine in the large hospitals in endemic areas.

The protection of those who are anxious to take rational precautions against infection presents a series of problems which may vary from place to place. It is not improbable that, by helping this class of people, and getting their active and intelligent co-operation, more will be achieved in the end than by major schemes in which the people to be protected are themselves passive.

In any case it would be premature to consider extensive control methods until the necessity for them has been proved and the cost estimated. Limited focal control is however desirable in some places now (as in parts of the area surveyed, where there are infected foci near large teaching centres), and data could be collected in preparation for experimental work on molluscicides.

SUMMARY

A bilharzia and molluscan survey carried out ten to 25 miles from the Tanganyika coast is described. The urines of 3,400 persons, (of whom 1,800 were males and 1,600 were females,) were examined, and also stools from 900 of the same group. 38·8 per cent of the urines examined, and 0·4 per cent of the stools, showed ova of *S. haematobium*. Only seven showed *S. mansoni*, and four of these cases gave histories of having lived outside the province.

The highest incidence of *S. haematobium* was in the 11-15 age group, in which 54·2 per cent of a total of 373 boys and girls were found to be passing ova, and 80 per cent of the 200 boys of this group were passing either ova or red blood cells or both. There was no great difference between this group and the 16-20 age group; but from the age of 26 or earlier the incidence, as judged by the evacuation of ova, fell. The incidence in both sexes together in the age group 26-50 was 17·7 per cent. The fall in the incidence of haematuria was less marked, the proportion of men passing ova, red blood cells or both being 56·3 per cent. Our figures for the groups over 50 years of age are too small to show whether there is a significant change in the percentage who pass ova or red blood cells, but both ova and cells persisted in some and the question of whether any of these cases may not be malignant has to be investigated.

With the possible exception of the older age groups, no evidence was obtained of gross disease or interference with function; but there is a good deal of discomfort associated with the infection in a large proportion of children and in some adults as well.

There is evidence that most if not all of the young people in the area are susceptible to infection and that subsequently, in heavily infected areas, a certain amount of immunity develops.

The investigation of certain aspects of the bilharzia problem in Tanganyika, particularly in connection with economic welfare, the welfare of women and children, and control measures are discussed.

During the snail survey *B.* (*Physopsis*) *globosus*, *B.* (*Physopsis*) *africanus ovoideus* and *B.* (*Physopsis*) *nasutus* were found. It is very probable that the first is the chief vector of *S. haematobium* in the area.

No *Biomphalaria* was found.

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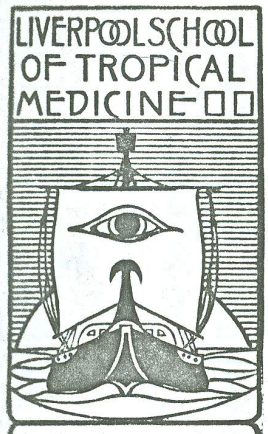
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ANNALS

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OBSERVATIONS ON THREE SPECIES OF *BULINUS* ON THE EAST COAST OF AFRICA

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The collection and interpretation of ecological data concerning vector snails is clearly of importance in the control of bilharziasis. The expert committee on bilharziasis of the World Health Organization (1953) commented on the scarcity of information on the bionomics and ecology of aquatic snails, and stressed the necessity for more research into these problems. Gaud (1956) considered that, as regards snail control in particular, a precise knowledge of the influence of seasonal and climatic factors on the biology of the snail vectors would be valuable. He pointed out that products available for such control have two drawbacks: 'under natural conditions their use does not lead to complete destruction of the snail population but only to a pronounced reduction in density; most molluscicides at present available are much less effective against the eggs of snail vectors than they are against the snails themselves. Repopulation after molluscicidal treatment of dangerous breeding places will be all the swifter if the operation has been carried out at a time when the fertility of the snail vectors is higher and their growth more rapid.' The choice of the moment for the first application of molluscicides, and a forecast of the period when a fresh application would be necessary, should therefore take into account the influence of seasonal and climatic factors on the biology of the vectors. Watson (1957) pointed out the necessity to avoid mistaking seasonal fluctuations, or other natural population changes due to normal environmental factors, for the effects of molluscicides. Conversely, he suggested that fundamental ecological studies might reveal possibilities of control by the use of natural environmental changes which, where practicable, might be superior to the use of molluscicides. Extensive molluscan surveys have been carried out in Tanganyika Territory by Mozley (1939) and, more recently, in a coastal area of the Tanga district by Maclean *et al.* (1958).

HABITATS

The present observations were carried out at three places in the Tanga district of Tanganyika, 10-25 miles inland from the East African coast. *Bulinus* populations were studied in two ponds at Pongwe (latitude 5° 7′ south, longitude 38° 59′ east, altitude 330 feet), designated A and B; in a dam at Mlingano (latitude 5° 9′ south, longitude 38° 54′ east, altitude 600 feet), designated C; and in a stream near Muheza (latitude 5° 10′ south, longitude 38° 47′ east, altitude 600 feet), designated D. The habitats A, B, C and D may briefly be described as follows.

Pond A: two acres at highest level; short emergent vegetation at edges, composed of grasses and sedges; 60 per cent. coverage of floating vegetation composed of water-lilies and water lettuce; snail population of *Bulinus* (*Physopsis*) *nasutus* von Martens,

No high temperatures occurred to limit them, and it is unlikely that the lower temperature limit for spawning is ever reached in this area. In breeding-places with the characteristics described the results show that *Bulinus* populations in this area follow an average growth curve, the maxima and minima of which are related to rainfall and temperature and to the ecological changes brought about by them. No significant divergence from this general pattern of seasonal fluctuation was noted in any of the three *Bulinus* species studied.

Many so-called freshwater bodies in the coastal area studied are in fact brackish, and quite large increases in the total chloride contents are apparently tolerated by their snail populations. For example, a value of 1,130 mgm. per litre total chlorides was recorded in pond B in December, 1956, and, though few snails were apparent at the time, some survived, as was shown by subsequent collections. In pond C total chlorides reached 1,792 mgm. per litre in March, 1957, and 2,220 mgm. per litre in April, and were apparently tolerated. Malek (1956) considered that *p*H was rarely a limiting factor in the distribution of bilharzia vectors, and that the combined effect of other factors correlated with *p*H (alkali reserve, carbon-dioxide content, sunlight, photosynthesis with its active removal of CO_2 and the production of O_2, and the character of the substratum) was more important than *p*H considered alone. Welch (1952) explains how these other factors influence *p*H. In the present investigation the *p*H values measured weekly in the four habitats were remarkably constant for the greater period of the observations, the lowest recorded value being 5·5 in pond C when the water-body was considerably reduced.

The average free-calcium contents of the habitats (Table V) show a big range of values. The low figures obtained in pond B and in stream D are unlikely, however, to limit snail numbers, in view of the presence of abundant vegetation in both habitats.

Many observations have been made on the reaction of African bilharzia vectors to drying. Blacklock and Thompson (1924) showed experimentally that some vectors could live for at least a few days out of water. Other authors, including Humphreys (1932), Archibald (1933), Barlow and Azim (1945) and Gerber (1952), have made further contributions, and Olivier's (1956) observation that pulmonate bilharzia vectors may survive out of water for weeks or even for months has important consequences in relation to the epidemiology of the disease and to control measures. The present observations show that *B.* (*P.*) *nasutus* and *B.* (*P.*) *globosus* survived drying for five and eight months respectively. Barbosa and Coelho (1955) showed that survivors of infected *Australorbis glabratus* which were subjected to desiccation came out free of infection only when the infection was mature. These authors found that, if the infected snails were removed from the water within 25 days of exposure to the miracidia of *Schistosoma mansoni*, the snails kept the infection for 90 days or more. From these experiments they concluded that development of the infection stopped. Barbosa (1956) found an immature infection under field conditions, and suggested that this finding might have epidemiological significance, since it raised the question of whether infection in snails could be carried from one wet season to the next. During the present observations *B.* (*P.*) *nasutus* shed ' mammalian type ' cercariae only 21 days after pond A had refilled after being dry for five months. Unfortunately, experimental infection of a laboratory animal with these cercariae failed, and the identity of the schistosome infection is therefore not known. In view, however, of the short period that elapsed between the refilling of the pool and the shedding of mature cercariae by the snails, it is possible that they contained immature infections.

SUMMARY

1. The importance is discussed of the collection and interpretation of ecological data concerning bilharzia vectors.

2. Observations were made on the seasonal fluctuation in numbers of three species of *Bulinus* on the East African coast. The species studied were *Bulinus* (*Physopsis*) *globosus*, *B.* (*P.*) *nasutus* and *B.* (*P.*) *africanus ovoideus*.

3. Snail numbers were estimated in two ways: by hand-collecting for a fixed period of time, and by the use of snail-traps. The value of these quantitative methods of estimation is discussed.

4. The approximate age-composition of the snail populations was estimated by measuring the height of the shell and by assigning the snails to three size-groups. Some observations were made on the probable breeding seasons, by noting the presence of egg-masses on the underside of water-lily leaves.

5. The average weekly infection rates of two of the snail populations is recorded. High infection rates are associated with the presence of a high proportion of older snails.

6. Taking into account the characteristics of the breeding-places, the results show that *Bulinus* populations in the area studied follow an average growth curve, the maxima and minima of which are related to rainfall and temperature and to the ecological changes brought about by them. No divergence from the general pattern was noted in any of the three *Bulinus* species studied. The breeding peaks occur at the times of the long rains and the short rains, in April-May and November-December respectively. The main breeding peak during the long rains occurs when temperatures are probably optimal for spawning, and the second breeding peak, during the short rains, seems chiefly to be limited by high temperatures.

7. The total chlorides and average free-calcium contents of the habitats are discussed, together with *p*H values.

8. It was observed that, under natural conditions, *B.* (*P.*) *nasutus* and *B.* (*P.*) *globosus* survived drying for five and eight months respectively.

9. *B.* (*P.*) *nasutus*, which shed 'mammalian type' cercariae only 21 days after the refilling of a pond that had been dry for five months, are considered probably to have contained immature schistosome infections, which completed development when the aquatic environment was restored.

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The Value of a Spreading Agent in Larvicidal Formulations Containing DDT

A. S. MSANGI, B.Sc.[1]

The value of a spreading agent in a 5% solution of DDT in oil was assessed under semi-field conditions using third-stage laboratory-bred larvae of Anopheles gambiae. *These larvae were treated with known dosages of the larvicide with and without the addition of spreading agent, and the mortalities produced by the two forms of the larvicide were compared. An attempt was also made to compare the efficacy of the two forms under field conditions. The trials described seem to have shown quite conclusively that, so far as a 5% solution of DDT in oil is concerned, there is no advantage to be gained by adding spreading agents to the larvicide.*

ON STANDING WATER

All natural waters have surface films which, to a greater or lesser degree, impede the immediate spread of droplets of oil that fall on the surface. It has consequently been assumed that larvicidal oils with a high spreading pressure would, other factors being equal, be correspondingly more effective. A careful search of the literature has failed to reveal evidence of this corollary having been subjected to adequate confirmation by experiment. In view of reports which threw some doubt on the validity of this assumption, it was decided to carry out a series of trials.

In these trials the larvicidal efficiency of "Shell Malariol HS", referred to below as "HS", was compared with that of an oil of similar composition but lacking the normal spreading agent. This solution, referred to below as "Standard", was kindly supplied by Shell Chemicals.

Using Adam's method (Adam, 1945), the spreading pressure of HS was observed to be about 35 dynes/cm, and that of Standard to be about 16 dynes/cm. Preliminary trials were carried out in a series of concrete tanks measuring 10 ft × 8 ft (3 m × 2.4 m) and 1.5 ft (0.46 m) deep. The base of each tank was covered with a layer of topsoil moulded to form a central depression, and grass was encouraged to root. When water was introduced, the hollow closely resembled a natural rain-pool. Before applying the larvicide, 100 fourth-stage laboratory-bred larvae of *Anopheles gambiae* were introduced into the pool and, 24 hours later, the number that could be recovered by the method of Christie (1955) was ascertained. The percentage that was missed in each of these preliminary counts was regarded as the control mortality for the ensuing experiment. The natural surface-film pressure of the pool was also measured. Before each application of larvicide, 100 third-stage laboratory-bred larvae of *A. gambiae* were introduced. In all cases the larvicide was applied to the water surface near the centre of the pool by means of a micrometer syringe. Twenty-four hours later the larvae were recovered by Christie's method, and the mortality measured. Each tank was then flushed with water and left undisturbed for four days. Larvae were then introduced and the tank was judged suitable for a further experiment when the larval mortality was insignificant. The results of these tests are summarized in Table I.

The higher mortality produced by Standard was later found by chemical estimations to have been due to a higher DDT content. These estimations showed that the DDT content of each sample of larvicide was:

HS	5.02 %
Standard	6.42 %

It was noted that the Standard larvicide did not spread over the water surface as did HS; but that

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TABLE 1
MORTALITY OF 100 THIRD-STAGE LARVAE OF *A. GAMBIAE* EXPOSED TO THE TWO LARVICIDES

Larvicide	Dosage (ml/sq.yd) *	Natural-film pressure	Control mortality (%)	Mortality (%)
HS	0.1	30 dynes/cm	14	100
Standard	0.1	27 dynes/cm	27	99
HS	0.05	10 dynes/cm	11	100
Standard	0.05	20 dynes/cm	9	100
HS	0.025	30 dynes/cm	14	65
Standard	0.025	30 dynes/cm	10	99
HS	0.01	20 dynes/cm	7	35
Standard	0.01	20 dynes/cm	9	63

* 0.1 ml per square yard is equivalent to 5.5 g of DDT per 1000 m².

a gradual extension of the oil did take place, and in all cases it had apparently spread over the entire water surface within 24 hours of application.

As these results were interesting, it was decided to attempt to obtain similar information from a natural anopheline breeding place, although the results would be more difficult to interpret against the natural fluctuation in mosquito larval density. A pond of about 400 m² surface area was selected. This pond was shallow with grassy margins, and had an extensive surface growth of *Ceratophyllum*. The surface film around the margins varied between 20 and 30 dynes/cm. The mosquito larval density was estimated by taking 100 evenly spaced dips around the margins.

The pond was treated first with HS at a dosage of 0.5 ml to the square yard (equivalent to about a litre of larvicide to 2000 m²) with an Eclipse sprayer. Two days after spraying, the pond was again searched by the same method. Weekly larval counts were carried out thereafter, until, two weeks later, the larval population had been restored to a level comparable with that obtaining before treatment. The same dose of Standard was then applied by the same method, and the subsequent immediate mortality and rate of recovery of the larval population were recorded. The results are summarized in Table 2.

The results of these trials throw doubt on the importance of spreading agents in oils whose toxicity essentially depends on their content of chlorinated hydrocarbon insecticides.

ON FLOWING WATER

Although the above trials failed to show that there was any larvicidal advantage of HS over Standard, it was still possible that in flowing waters, such as streams, the low-spread larvicide (Standard) might be carried away by the current before its full effect had been felt by the larvae. It was therefore proposed to repeat the above experiments under flowing water conditions. The chief difficulty here was to produce conditions in which it would be possible for the larvicide applied to the water surface to flow away naturally, leaving the larvae behind. This difficulty was to a large extent (but not completely) overcome by the arrangements described below.

An artificial stream was created by allowing water from a natural stream to flow through an underground pipe into an artificial channel 15 ft×3 ft (4.6 m × 0.9 m) and 1.5 ft (0.46 m) deep. The bed of the channel was covered with topsoil, and was at a slope of about 1 in 30. The sides were plastered with cement and finished with three coats of white Duco paint. A small sedge (*Kylinga* sp. Cyperaceae) was planted on either side of the upper four-fifths of the bed, leaving an area 1 ft (0.3 m) wide in the middle which, together with the downstream one-

TABLE 2

MOSQUITO LARVAL POPULATION OF A POND BASED ON 100 SPACED DIPS BEFORE AND AFTER TREATMENT WITH HS AND STANDARD

	Date	Anopheline larvae						Culicine larvae
		species	larval stages			pupae	total larvae and pupae	all except first stage
			II	III	IV			
Before treatment	17 June	*A. funestus*	0	1	4	0	5	232
		A. coustani	22	19	12	2	55	
HS treatment (started 17 June)	19 June		0	0	0	0	0	0
	26 June	*A. coustani*	11	3	0	0	14	133
	3 July	*A. coustani*	0	7	4	1	12	268
Standard treatment (started 7 July)	10 July		0	0	0	0	0	0
	17 July	*A. coustani*	0	1	0	0	1	149
	24 July	*A. coustani*	3	1	0	0	4	330

fifth of the bed, was left clear of vegetation. The height of the sedge was maintained at about 8 in. (20 cm). There was an outlet drain from the channel back to the stream. The flow and level of water in the channel were controlled by means of a stopcock and a sluice respectively. When water was allowed to flow through the system, the upper four-fifths of the channel resembled a section of a natural stream with grassy margins.

Determination of larval recapture

Water was allowed to flow into the channel to a level of 4 in. (10 cm) at the lower end, and then to overflow into the outlet drain back to the stream. The outflowing water was passed through an open box 10 in. × 8 in. (25 cm × 20 cm) and 2 in. (5 cm) deep with the base made of 60 mesh wire gauze. This was to act as a trap for larvae that might escape downstream. The speed of the current in the channel was adjusted to about 0.2 ft (0.06 m) per second. Two hundred laboratory-bred third-stage larvae of *Anopheles gambiae* were introduced into the channel. After 24 hours the outlet was closed, and the channel filled with water to the brim. Larvae were then recovered by two searchers (one of whom was the author) using teated pipettes. The search was regarded as exhausted after 15 minutes of no find by either searcher. This was found to be after about one hour of continuous search by the two observers, that is, after about two man-hours of search. The trap at the outflow was examined for escaped larvae. On the whole comparatively few larvae tended to escape downstream when no larvicide had been used. During these preliminary trials, out of the 200 larvae placed in the channel, the largest number found in the trap after 24 hours was 15. It was found that most of the larvae preferred to remain at the upper section of the channel, where they were sheltered by the vegetation, and that the open area at the lower portion of the channel appeared to act as an invisible barrier to the larvae. It was also found that the visibleness of larvae was greatly aided by the white walls of the channel, against which many of them preferred to rest.

The above operation was repeated four times in the absence of larvicide, and the average percentage number of larvae recovered from the channel was found. The results of these trials are shown in Table 3. After each trial the sluice was opened, the tank emptied completely, and left dry till the next trial. This precaution was taken in order to prevent natural breeding in the channel.

Comparison of the two larvicides

Water was allowed to run into the channel as in the preliminary trials. Two hundred laboratory-bred third-stage larvae of *A. gambiae* were intro-

TABLE 3

PROPORTION OF LARVAE RECOVERED FROM CHANNEL WHEN NO LARVICIDE HAD BEEN USED

Number of larvae placed in channel	Number of larvae recovered after 24 hours	Larvae recovered (%)
200	130	65
200	135	67.5
200	149	74
200	156	78
Average	143	72

duced into the channel. After 24 hours, known dosages of HS or Standard were added in drops to the water in the channel by means of a micrometer syringe. The larvicide was applied along the length of the channel near the margins. After another 24 hours the larvae were recovered as described above, and the mortality noted. After each experiment the sides of the channel were washed with a detergent, and flushed several times with water, to remove any adhering larvicide. This cleansing was greatly facilitated by the paint on the sides, which minimized absorption. The channel was regarded as suitable for another experiment when there was no significant mortality among larvae recovered after 24 hours, that is, when about 72 % of them were recovered. The percentage of larvae missed in each of these test trials was regarded as the control mortality for the next experiment.

In each case the trap at the outflow was examined for escaped larvae. It was found that a considerably larger number of larvae escaped downstream when a larvicide had been used than when no larvicide had been used. Both live and dead larvae were recovered from the trap.

In each experiment the spreading pressure of the surface film of the water in the channel was measured by Adam's method before the larvicide was introduced. This was found to be below 15 dynes/cm in every case. The results of these experiments are shown in Table 4.

The Standard used in this case had a DDT content of 5.2% which was not very far from that of HS (5.02%), and hence equal dosages of the two forms of larvicide were closely comparable.

DISCUSSION

Since the present formulations of larvicides (that is, those formed by dissolving synthetic insecticides in mineral oils) came into general use, it was generally assumed that it was necessary to have spreading agents added to these larvicides in order to ensure their complete spread on water surfaces with natural surface films of high crushing strength. This assumption has been based purely on theoretical considerations. Although it is logical to argue that an oil cannot spread on a surface with a crushing strength greater than the spreading pressure of the oil, the fact has to be borne in mind that conditions in the field, where the weather comes into the picture, are far from static. The action of wind and rain, for example, would be to break the natural surface films on bodies of water, and hence to facilitate the spreading of oils applied to such water surfaces regardless of the magnitude of the spreading pressures of the oils. It has also not been proved that it is necessary for larvae to come into direct contact with the oil film in order to be killed by the insecticide contained in the oil. Buxton (1945), working with a 5 % solution of DDT in dieseline, found that at a dosage of 0.2 ml per square yard he got effective kills of larvae even when the larvicide was dropped on mats of algae in a ditch where the oil did not spread. He suggested that the DDT probably dissolved in the water in quantity sufficient to be larvicidal. It seems that direct contact with the oil film is not the only way in which a larvicide oil solution can kill larvae. It is possible for example that, when the oil evaporates, it leaves behind crystals of insecticide suspended in water, and that larvae are killed by ingesting these crystals. This possibility is strongly suggested by the work of Pal, Mc Cauley & Fay (1952). It is also possible that small particles of matter, such as pollen grains and particles of dust, that fall on treated water surfaces, absorb the larvicide before they sink below the surface whence, by means of the currents created by larvae when feeding, they may reach and be ingested by larvae which are not in direct contact with the oil film. The matter is one which deserves careful investigation.

The arrangements used in the above investigation were necessarily artificial, but it is believed that they closely approximated to those met with in the field. It was for example found that the tanks used in trials with standing water supported wild populations of anopheline larvae when left with water in them for a few days.

TABLE 4

MORTALITY OF 200 THIRD-STAGE LARVAE OF *A. GAMBIAE* EXPOSED TO THE TWO LARVICIDES

Larvicide	Dosage (ml/sq.yd)	Control mortality (%)	Mortality (%)	Larvae from trap
Standard	0,5	27	100	66 dead
HS	0.5	29	100	57 dead
Standard	0.25	32	100	49 dead
HS	0.25	25	100	37 dead
Standard	0.1	31	100	34 dead
HS	0.1	37	100	28 dead
Standard	0.05	35	68	8 dead, 15 alive
HS	0.05	28	70	12 dead, 17 alive
Standard	0.025	34	61.5	11 dead, 20 alive
HS	0.025	29	53.5	2 dead, 4 alive

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RÉSUMÉ

Les eaux naturelles ont une tension superficielle — parfois même un film ténu — qui, à des degrés variables, limite l'étalement des gouttelettes d'huile projetées à leur surface par les pulvérisateurs de substances larvicides. On a donc pensé que des huiles insecticides ayant une forte capacité d'étalement seraient plus efficaces que les autres. Les observations occasionnelles à ce sujet étant contradictoires, la question a été reprise sur une base expérimentale.

L'auteur décrit les expériences faites avec une huile ayant un composant favorisant l'étalement (35 dynes/cm) et une autre ne le possédant pas (16 dynes/cm). Les essais ont eu lieu, en bacs, sur des larves de *A. gambiae*, et sur des eaux courantes, dans des conditions qui, bien qu'artificielles, étaient très proches de celles de la nature.

Discutant ses résultats, l'auteur relève que l'idée d'améliorer la capacité d'étalement d'une huile par un composant capable de vaincre la tension superficielle de l'eau, souvent élevée, procède d'un raisonnement purement théorique. Dans la pratique et la réalité, l'état de la couche aqueuse superficielle est loin d'être statique. Les conditions atmosphériques en particulier jouent un rôle important dans les variations observées. Le vent et la pluie, par exemple, brisent les couches superficielles de l'eau et facilitent l'étalement de l'huile. D'autre part, il n'est pas prouvé que l'huile agisse sur les larves uniquement par contact. Certains expérimentateurs ont obtenu des résultats favorables avec du DDT à 5% déposé sur des paquets d'algues dans des fossés où l'huile ne s'étalait pas. Diverses explications sont plausibles: en s'évaporant, l'huile peut abandonner des cristaux d'insecticides qui, restant en suspension dans l'eau, sont absorbés par les larves; des grains de pollen ou des poussières, tombant à la surface de l'eau peuvent s'imprégner de l'insecticide et servir ensuite de nourriture aux larves. L'ensemble de ce problème serait à reprendre, et certains aspects de l'efficacité des larvicides pulvérisés, à examiner de plus près.

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that the development of these studies and of techniques such as vital staining and the tetrazolium method for estimating the metabolic activity of *M. lepræ*, will result in preliminary drug trials being carried out in periods of months rather than of years.

CONCLUSION

The possibility of a rational approach to the choice of potential leprosy drugs with their subsequent rapid screening, encourages the hope that a really efficient drug for the treatment of leprosy will be discovered in the not-too-distant future.

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COMPARISON OF BHC AND DDT LARVICIDES AGAINST *ANOPHELES GAMBIÆ*
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COMPARISON OF BHC AND DDT LARVICIDES AGAINST *ANOPHELES GAMBIÆ*

By A. S. MSANGI

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LARVICIDING has been and is likely to remain the most practicable and economical method of mosquito control in the urban areas of East Africa. Of the new larvicide formulations, i.e. those formed by dissolving synthetic insecticides in mineral oils, the most widely used has been a 5 per cent solution of DDT in oil. This larvicide has been shown in many parts of the world to be very effective against *Anopheles* mosquito larvæ except in those places where the mosquitoes concerned have developed resistance to DDT. However, in an attempt to find a cheaper larvicide and one that could be formulated more conveniently, a formulation substituting BHC for DDT has recently been introduced in East Africa. Thus a 0.5 per cent solution of the gamma isomer of BHC in oil is now being promoted for use in East Africa at a dosage of two quarts of the oil solution (or 0.4 ounce gamma BHC) per acre of water surface. In view of reports by various workers in other parts of the world indicating that at economic dosages BHC is inferior to DDT as a larvicide, it seemed desirable to compare the two larvicides against larvæ of *Anopheles gambiæ* (the most important vector of malaria in East Africa) under conditions similar to those met with in the field.

Material and method

Using the concrete tanks described by Msangi (1956 and 1959), in a series of experiments, fourth stage larvæ of *Anopheles gambiæ* were tested against known dosages of a 5 per cent solution of DDT in oil on the one hand and 0.5 per cent, 0.75 per cent and 1.0 per cent oil solutions of gamma BHC on the other. For each test (three replicates), a tank was filled with water to a depth of about 20 cm. in the centre and 100 larvæ were introduced into the tank and allowed to remain there for 24 hours. A measured quantity of the larvicide to be tested was then applied on to the water surface by means of a micrometer syringe. After another 24 hours the larvæ were recovered from the tank by the method of Christie (1955) and the mortality was noted. Each test was accompanied by a control in which 100 larvæ were left for 48 hours in another similar tank before being recovered by the same method. The number of larvæ missed in the control was regarded as the control

mortality. The results are summarized in the table. The larvæ used for these tests were mostly insectary-bred except in a few tests with BHC where "wild-caught" larvæ (the first bred-out progeny of wild-caught females) were used in order to check for any reduced susceptibility to BHC which the insectary colony might have developed. As the table shows, no such decrease in susceptibility to BHC was detected.

Mortality of 100 Fourth Stage Larvæ of Anopheles gambiæ to Larvicides containing BHC and DDT

Larvicide	Dosage ml./sq. yd.	24-hour Mortality		Source of Larvæ
		Treated	Control	
DDT 5 per cent	0.025	94	7	insectary
	0.05	100	8	insectary
BHC 0.5 per cent gamma	0.05	11	7	insectary
	0.25	52	14	insectary
	0.25	50	8	wild caught
	0.5	91	10	insectary
	0.5	90	6	wild caught
BHC 0.75 per cent gamma	0.05	9	8	insectary
	0.25	66	2	insectary
	0.5	98	7	insectary
	0.75	98	8	insectary
BHC 1.0 per cent gamma	0.05	5	3	insectary
	0.25	78	11	insectary
	0.5	98	7	insectary
	0.5	95	9	wild caught
	0.75	100	7	insectary

0.5 ml./sq. yd. is equivalent to about two quarts per acre.

The results show that even under these near-ideal conditions of testing, the 1.0 per cent solution of gamma BHC failed to kill all the larvæ at a dosage of 0.5 ml. per square yard. This dosage is equivalent to about 0.8 ounce gamma BHC per acre which is twice the current field dosage. At 0.5 ml. per square yard the 0.5 per cent gamma BHC formulation produced a mortality of only about 90 per cent. Under the conditions of the experiment a 5 per cent solution of DDT produced a 24-hour larval mortality of 100 per cent at a dosage as low as 0.05 ml. per square yard. This is one-tenth the recommended field dosage of 0.5 ml. per square yard (about two quarts per acre).

The new formulation would thus seem to be only one-twentieth to one-thirtieth as effective as a 5 per cent solution of DDT.

DISCUSSION

Busvine and Burnes (1947) have shown that against adult mosquitoes the ratio of toxicity between gamma BHC and DDT can be as high as 10:1 in favour of BHC. However, when these insecticides are used as larvicides this

ratio is found to be much less. Raun *et al.* (1946) in an unpublished report quoted by Keller *et al.* (1951) found that at dosages of 1.6 ounces and 0.8 ounce per acre, BHC (12 per cent gamma isomer) was less toxic to anopheline larvæ than DDT. Incho and Doenier (1950) working with larvæ of *Anopheles quadrimaculatus* found that both in the form of acetone-water suspensions and solutions in No. 2 fuel oil, DDT was more toxic than gamma BHC at equal dosages. In a comparison of oil solutions of DDT and BHC against anopheline larvæ Reid *et al.* (1950) came to the following conclusion: "At the recommended dose of 0.25 ounce of the gamma isomer per acre, BHC is not satisfactory, for control is only a little over 70 per cent. With a dose about five times greater (1.25 ounces per acre), control is still not as good as with DDT at about 4 ounces per acre." In another investigation Reid and Wharton (1952) found that against larvæ the ratio of toxicity between gamma BHC and DDT was 2:1 or even less. They suggested that at this rate BHC would be more expensive.

Many investigators working with a 5 per cent solution of DDT in oil have found that there is a wide margin between the minimum dosage necessary to produce 100 per cent kill of anopheline larvæ and the recommended field dosage of two quarts of the oil solution (four ounces DDT) per acre of water surface. Buxton (1945) found that a 5 per cent solution of DDT in dieseline at 0.1 ml. per square yard produced an immediate kill of 100 per cent among larvæ of *Anopheles funestus*. Ribbands (1945) working with the same larvicide found that a dosage of one pint per acre (about 0.12 ml. per square yard) was lethal to both anopheline and culicine larvæ within 24 hours under optimum conditions and that the same solution at 0.2 pint per acre produced a larval mortality of 75 per cent within one day and 100 per cent within three days. Webbe (1955) working with larvæ of *Anopheles gambiæ* found that under semi-natural conditions a 5 per cent solution of DDT in oil at a dosage of 0.25 pint per acre produced 100 per cent mortality within 48 hours. It would seem therefore that the recommended dosage of two quarts (four pints) of the 5 per cent solution per acre is unnecessarily high. It is suggested that a 1 per cent solution of DDT in oil would be an effective larvicide at a dosage of two quarts per acre. This formulation should be more effective than even a 1.0 per cent solution of gamma BHC, yet allowing for a reasonable margin of safety.

SUMMARY

1. The larvicidal efficiency of solutions of DDT and BHC were compared under identical semi-field conditions.

2. A 0.5 per cent solution of gamma BHC appeared to be less than one-twentieth as toxic to *A. gambiæ* larvæ as a 5 per cent solution of DDT.

3. For a formulation of 0.5 per cent gamma BHC to have a safety margin in any way comparable with that provided by field dosages of 5 per cent DDT, a ridiculously high dosage would be called for.

4. It is therefore suggested that the economics of a reversion to a larvicide based on DDT, but with a reduced percentage, should be reviewed.

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EARLY DAYS IN BRITISH EAST AFRICA AND UGANDA
SECOND TOUR—1904–1907
By The Rev. Dr. C. A. Wiggins, *C.M.G.*

EARLY DAYS IN BRITISH EAST AFRICA AND UGANDA SECOND TOUR—1904–1907

By THE REV. DR. C. A. WIGGINS

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On my return from my first leave I was again stationed at Mombasa but my house and hospital wards were in the Uganda Railway area at Kilindini and the old trolley system on the narrow gauge railway lines was a very convenient mode of transport. I was there when the British Association met in South Africa and had the pleasure of entertaining two Fellows of the Royal Society and their families who were travelling home by the east coast route. They were Professor and Mrs. Poulton of Oxford, whom we knew well, and their two daughters, and Dr. and Mrs. Waller. I had not seen Dr. A. D. Waller since he had taught me physiology at Mary's in the nineties. The time at Mombasa passed pleasantly with little of note save that our first child was born in Nairobi in February, 1905 and when later that year my wife went to Malindi to visit the Macleans, who had a son of the same age, she had to drop the baby from the side of the s.s. *Juba* to the Captain, Wilson, who was standing in a boat alongside. Landing at Malindi was always hazardous with no harbour and a heavy swell running.

My only safari from Mombasa was to Taveta and I walked the long miles from Voi straight through the night. The A.D.C., Heywood, had blackwater fever. He fortunately recovered and he survived a second attack years later when he was at Entebbe, having left the Government service. I remember it well as I diagnosed malaria and when Dr. Duke saw it he said he had never seen such a slide as it was difficult to find an R.B.C. which had not one or more ring parasites in it. He warned me to expect blackwater and sure enough when I saw Heywood an hour later he had blackwater. While at Taveta I had the unpleasant experience of superintending an execution; Heywood told me on arrival that the next day I must, in his absence, see that a murderer, a Masai, was executed by shooting. He said that he had given a shooting party of ten policemen practice at a target of 50 yards for several days and that five of the rifles would be loaded with blanks so that none would know who had hit the man. I did not like it a bit but agreed I must do it but I took my own precautions. I borrowed Heywood's revolver and loaded it, in case! and I saw that all the rifles had live ammunition and reduced the range of 50 to ten yards. It was just as well. The arranged signal was "one, two, three, fire", in English, but unfortunately one man fired at "one", the man fell to the ground and the other nine fired one by one at the figure on the ground. I ran forward and was glad to find the revolver was not needed, the

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THE EXPERIMENTAL STUDY OF WATER SNAILS
IN A FISH POND IN TANGANYIKA.
I. PRELIMINARY TRIAL OF THE METHOD
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THE EXPERIMENTAL STUDY OF WATER SNAILS IN A FISH POND IN TANGANYIKA
I. PRELIMINARY TRIAL OF THE METHOD

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BASIC information on the snail vectors of human schistosomiasis in Africa is still far from complete. Similarly there is little precise information on the merits of various methods of snail control under local conditions.

Progress in these investigations is hampered by the practical difficulty of assessing snail populations in the larger habitats and by the disturbance and consequent alteration of the habitat brought about by repeated, thorough collecting. Furthermore the disappearance of snails following the institution of control is often accepted as *prima facie* proof of the effectiveness of the measure applied although generally no evidence is adduced to show that the fall in numbers was not, at least in part, the reflection of a natural fluctuation in population.

With these problems in mind this Institute has for some time sought a suitable location for the experimental study of aquatic snails. In July, 1958, *Bulinus* (*Physopsis*) *globosus* was noticed to be present in certain ponds in Korogwe Fish Farm, which lies in the valley of the Pangani River, about 50 miles from the coast of northern Tanganyika.

The potentialities of the fish ponds for snail studies were accordingly reviewed: these ponds could be drained and refilled at will and the water could be maintained at any desired level; constructional work and apparatus could be installed and used without public objection or interference; the higher plant life of the ponds could be kept in check or cleared and the number and type of fish could be more or less controlled. With these attributes it seemed that studies on *B. globosus* could be carried out in the Korogwe ponds under relatively advantageous conditions.

Fish Pond No. 16 at Korogwe was selected for the preliminary trial, in which various methods of assessing snail populations were to be compared. This pond was quadrilateral with a water surface area of 42,000 ft.^{2} For the most part the pond was shallow, having a maximum depth of 33 in. at the outlet. An area of some 17,200 ft.^{2} was less than 10 in. in depth and was covered by a dense growth of *Typha* and *Cyperus*, interlaced with grass. The remainder of the pond was without higher aquatic vegetation, but the bed was covered with a layer of gelatinous alga. The water was turbid, due to the large number of *Tilapia* present in the pond.

Before instituting routine snail counts, it was decided to drain the pond; to incorporate certain structures to facilitate snail counting; and to carry out the first trial with a stable water level and as few fish as possible present. During the course of the preliminary drainage it was hoped to obtain an assessment of the numbers and species of water snail present in the pond.

The preliminary count

For the mapping of Pond 16, a cord, marked with coloured tags at intervals of 10 ft., was suspended across the breadth of the pond. Working directly under, and along the axis of, this cord, a team of collectors searched the pond bed as the water drained away, picking up all snails found in a track extending for 18 in. on either side of the cord. In this way several collections were made, representative of the two types of habitat at various depths. Only three species of snails were recognized among those collected; but, in the circumstances, small snails may have been overlooked.

The results of this count are summarized in Table 1. The crude numbers collected are multiplied by a factor, representing the fraction of the total habitat searched, in order to arrive at an estimate of the total population of each species in that particular habitat. It will be noted that over 900 adult *globosus* were apparently present in the pond at a time when it was densely stocked with *Tilapia*.

TABLE 1

Estimates of the population of three species of water snail in Pond 16 before drying, on 1st August, 1958

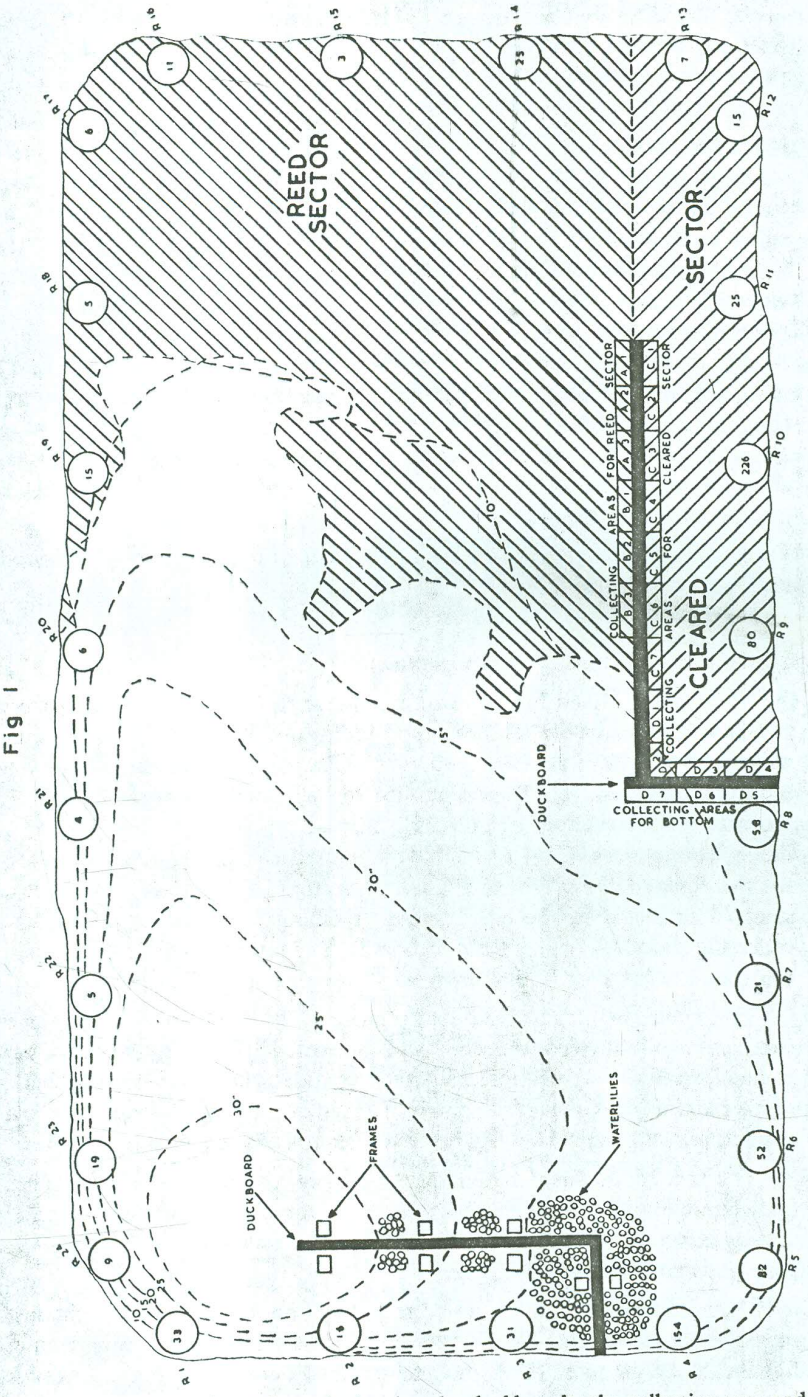
Species of Snail		*Number collected*	*Total in Sector*	*Total in Pond*
Bulinus globosus	(a) Reed Sector	24	607	
	(b) Pond bottom	14	329	936
Cleopatra amæna	(a) Reed Sector	239	6,047	
	(b) Pond bottom	3,971	93,318	99,365
Melanoides tuberculata	(a) Reed Sector	0	0	
	(b) Pond bottom	141	3,313	3,313

The preparation of the Experimental Ponds

Estimates of snail population were based on the numbers that could be recovered by exhaustive collecting from a defined and representative area of the reed-bed and of the open pond bottom.

It was planned to collect visually in the shallow end of the pond and, as the shallows were overgrown with reeds and sedge, a section of the reed-bed was removed as completely as possible to provide a shallow area of open pond bottom. Visual collecting requires limpid water and good access, which had to be provided without damage to the habitat. Accordingly duckboards were laid along the intersection of the "Reed Sector" and the new "Cleared Sector". The duckboards, rigidly supported, provided access at water level to 63 ft.

Fig 1



Sketch map of experimental pond, showing the duckboards, the collecting area and frames. The mooring positions of 25 bamboo rafts are indicated by circles in which the total number of *Bulinus globosus* collected on each raft is shown.

of the "Reed Sector" and ran for 130 ft. around the margins of the "Cleared Sector". The boundaries of the collecting areas were marked by wires suspended parallel to, and 18 in. from, the edge of the duckboards.

Visual collecting from the bed of the pond in the deeper end was manifestly impracticable. Here it was proposed to count snails on samples of the bottom which could, when required, be brought to the surface for examination and then returned to position. Four pairs of deep, wooden frames, each 3 ft. square, were prepared for this purpose. Each frame had a base of coffee-tray wiring, covered by a layer of bamboo for buoyancy. The frames, surfaced with four inches of mud, were bedded into wooden sockets sunk in such a position that the frames rested with their mud surfaces flush with the surrounding pond bed. Attachments to the frames enabled them to be levered to the surface for examination, and guides, fixed to the sockets, eased the task of returning them to position. The frames were sited in pairs at depths of 19 in., 20 in., 29 in. and 32 in. respectively. To provide access to the frames and a means of leverage, a second system of duckboards was constructed in the deeper end of the pond.

A plan of the constructional modifications and other features is contained in the sketch map of the pond, Fig. 1.

The basis of estimation of snail populations

The area of "Reed Sector" that was to be sampled, i.e. collecting areas A1–3 and B1–3 (see Fig. 1) measured 94.5 ft.^{2} out of a total Sector area estimated to be 13,000 ft.^{2}. Thus 1/137 of the Reed Sector was examined and a multiplication factor of 137 was applied to each snail collected to obtain an estimate of the total number present in that Sector. In the "Cleared Sector", the collecting areas (C1–7 and D1–4) measured 190 ft.^{2}, comprising 1/26 of the total area (4,900 ft.^{2}) of the "Cleared Sector". The area of pond bottom sampled consisted of the eight frames, totalling 72 ft.^{2}, and, in addition, collecting areas D5–7 along the duckboards. The total area of bottom sampled was thus 122 ft.^{2}, i.e. 1/198 of the total Sector area of 24,100 ft.^{2}

The pond was drained on 1st August, 1958. Three weeks later, after completion of the reed clearance and constructional work, the pond was re-flooded. As far as possible fish were excluded during re-flooding but a small number of *Tilapia* fry contrived to enter the pond at this time and reached sexual maturity shortly before the completion of the experiment.

The first count was done on 1st September, one week after re-flooding, and counts were repeated at weekly intervals for the first month. Thereafter they were carried out approximately twice per month. The first trial was concluded on 24th January, 1959.

Maximum and minimum water temperatures were taken after the first month only. The range in the "Cleared Sector" was from a minimum of 67° F to a maximum of 94° F (in October). At a depth of 30 in. the range was less: from a minimum of 72° F to a maximum of 87° F.

TABLE 2

Estimates of snail populations at various intervals after re-flooding

Weeks after Re-flooding	*In Reed Sector*	*In Cleared Sector*	*On Bottom*	*Total in Pond*
1. BULINUS GLOBOSUS		(a) *Adult Snails*		
1	890	221	198	1,309
2	548	545	198	1,291
3	1,370	651	1,386	3,407
4	1,918	3,307	2,178	7,403
7	1,918	2,005	3,168	7,091
8	1,370	3,437	4,158	8,965
10	959	1,302	11,286	13,547
11	1,781	3,021	9,702	14,504
14	1,781	1,120	2,772	5,673
15	1,644	1,016	2,574	5,234
22	137	378	990	1,505
		(b) *Young Snails* (Shell diam. < 5 mm.)		
1	0	0	0	0
2	0	0	0	0
3	0	21,463	110,880	132,343
4	0	39,945	71,280	111,225
7	137	3,437	24,750	28,324
8	0	3,437	22,572	26,009
10	2,192	1,276	3,564	7,032
11	1,781	2,370	6,138	10,289
14	0	495	594	1,089
15	0	260	1,584	1,844
22	0	208	1,188	1,396
2. BULINUS FORSKALII				
1	0	0	0	0
2	685	781	0	1,466
3	1,096	1,068	1,386	3,550
4	27,263	7,421	13,068	47,752
7	15,618	3,229	2,574	21,421
8	8,220	3,567	8,118	19,905
10	4,521	1,614	2,376	8,511
11	548	1,719	1,584	3,851
14	137	78	0	215
15	0	0	0	0
22	0	0	0	0
3. ANISUS NATALENSIS				
1	137	104	594	835
2	6,302	1,120	0	7,422
3	22,194	469	990	23,653
4	43,840	2,448	3,544	49,832
7	110,148	13,567	990	124,705
8	41,237	6,276	5,940	53,453
10	18,554	4,479	2,574	25,607
11	7,261	2,488	792	10,541
14	1,370	781	396	2,547
15	548	312	0	860
22	0	0	0	0

(Table continued on page 280)

TABLE 2 (Continued)

Weeks after Re-flooding	*In Reed Sector*	*In Cleared Sector*	*On Bottom*	*Total in Pond*
4. CLEOPATRA AMÆNA				
1	10,588	3,255	23,364	37,207
2	274	4,583	22,770	27,627
3	822	5,286	37,026	43,134
4	1,370	7,239	55,440	64,049
7	1,096	11,119	30,888	43,103
8	2,055	16,041	35,640	53,736
10	548	11,249	36,432	48,229
11	1,781	9,739	54,450	65,970
14	6,439	8,359	42,966	57,764
15	7,809	7,656	40,986	56,451
22	14,522	13,489	43,560	71,571
5. MELANOIDES TUBERCULATA				
1	0	52	693	745
2	0	208	594	802
3	137	26	396	559
4	274	156	396	826
7	0	26	1,782	1,808
8	0	130	3,360	3,490
10	0	130	1,584	1,714
11	0	0	1,584	1,584
14	0	208	2,772	2,980
15	274	78	3,762	4,114
22	0	312	6,450	6,762
6. LYMNEA NATALENSIS				
1	0	0	0	0
2	411	0	0	411
3	0	0	0	0
4	137	26	0	163
7	137	0	0	137
8	274	0	0	274
10	1,370	0	0	1,370
11	137	104	0	241
14	137	0	0	137
15	0	26	0	26
22	137	0	0	137

Population changes in Bulinus globosus

As will be noted from Table 2 and Figs. 2 and 3, adult *Bulinus globosus* were present, in numbers comparable to those found before drying, one week after re-flooding. They increased fairly steadily thereafter to reach a new peak after one month. The snail showed some preference at this stage to the shallow area which had been cleared of reeds. The increase in adult snails over the first month seems to be too great and too regular to be accounted for by sampling errors and appears to represent a slow re-invasion of the habitat. If so, a considerable population of snails may have withdrawn from the pond before being driven to do so by the preliminary drying. An attempt was made to demonstrate "withdrawal" of adult *globosus* from the pond before drying had started: a strip of earth for a stretch of 40 ft. from six inches above and below the old water level was dug out, sieved and washed for snails, just as the water level of the pond was beginning to drop on 24th January, 1959. Although no living *globosus* were recovered from the damp mud, a

Fig 2

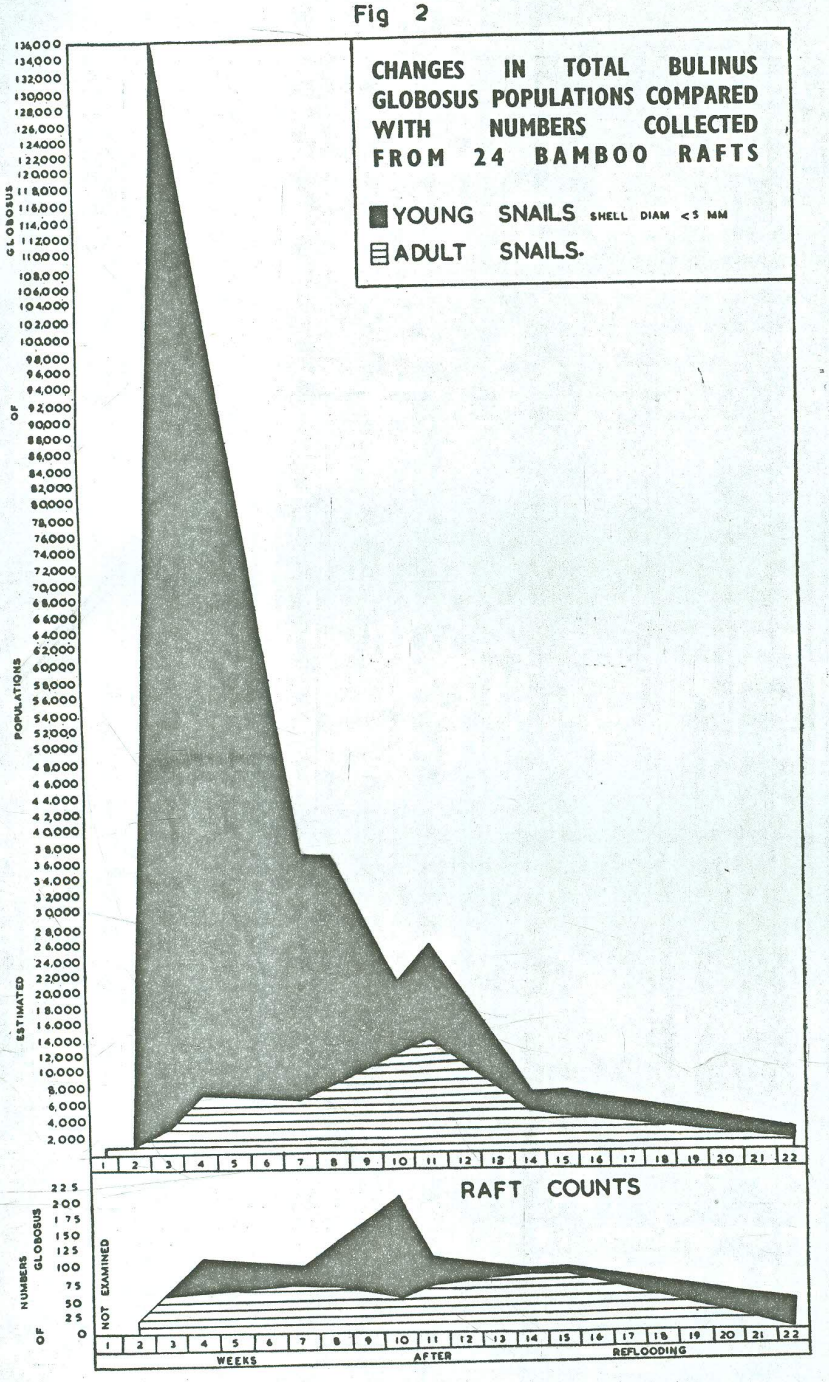
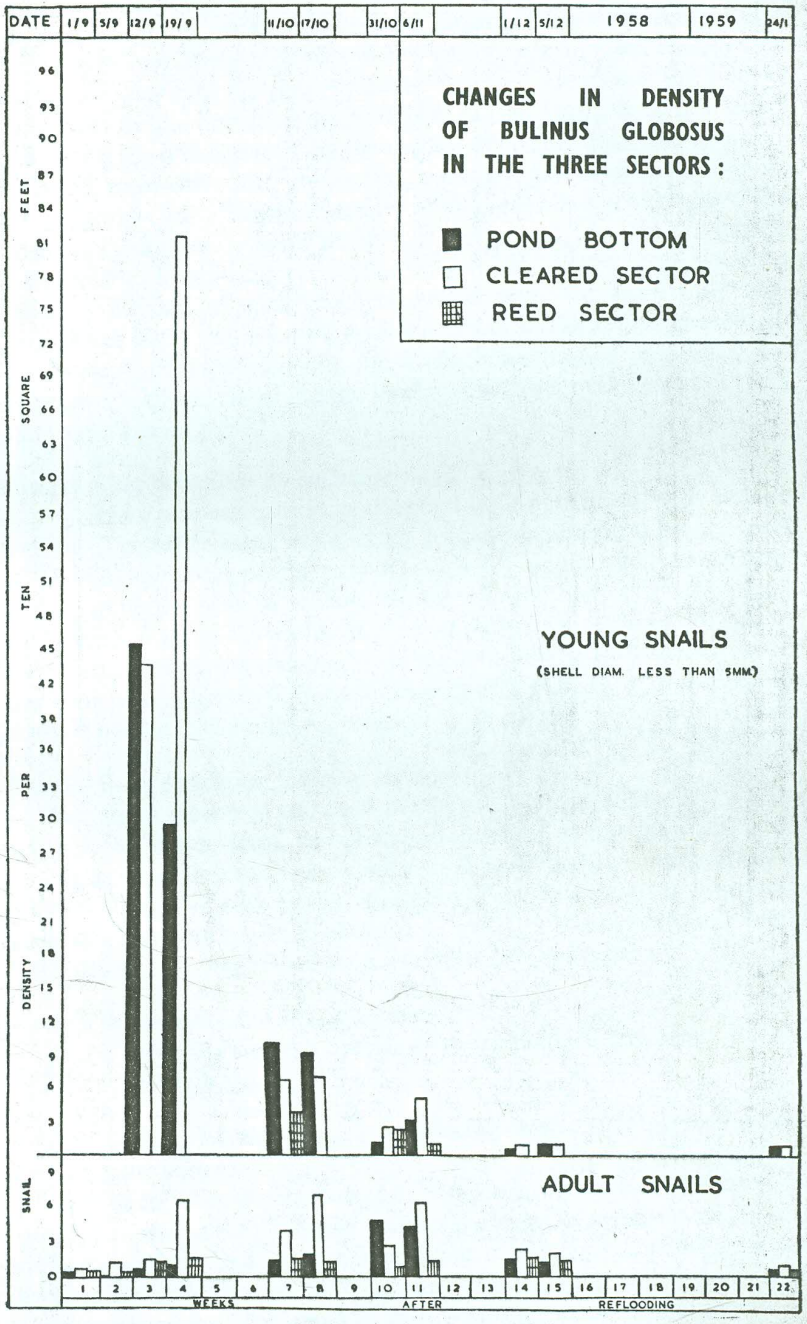
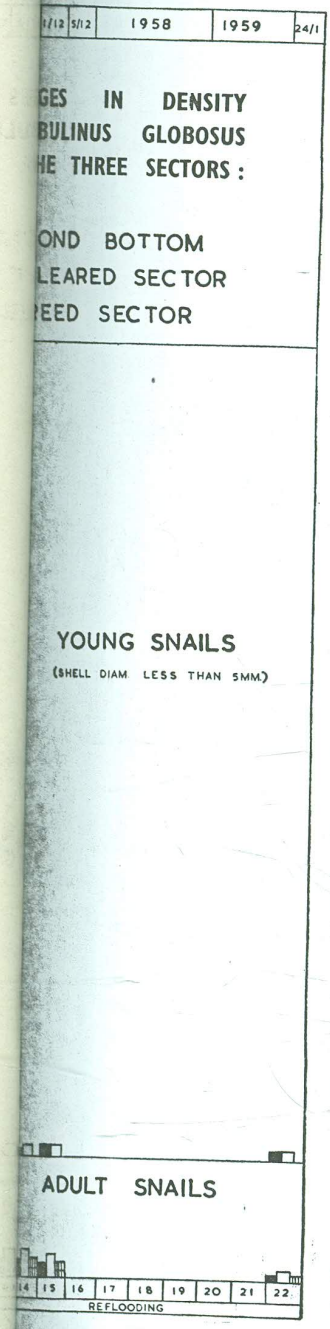

CHANGES IN TOTAL BULINUS GLOBOSUS POPULATIONS COMPARED WITH NUMBERS COLLECTED FROM 24 BAMBOO RAFTS
YOUNG SNAILS SHELL DIAM <5 MM
ADULT SNAILS.
ESTIMATED POPULATIONS OF GLOBOSUS
RAFT COUNTS
NUMBERS OF GLOBOSUS NOT EXAMINED
WEEKS AFTER REFLOODING

Fig 3


DATE
1/9
5/9
12/9
19/9
11/10
17/10
31/10
6/11
1/12
5/12
1958
1959
24/1
CHANGES IN DENSITY OF BULINUS GLOBOSUS IN THE THREE SECTORS:
POND BOTTOM
CLEARED SECTOR
REED SECTOR
YOUNG SNAILS
(SHELL DIAM. LESS THAN 5MM)
ADULT SNAILS
SNAIL DENSITY PER TEN SQUARE FEET
WEEKS AFTER REFLOODING



number of living *Cleopatra* were found buried some inches below the surface.

Intensive breeding of *globosus* commenced as soon as the pond was flooded, and the build-up of young *globosus* was dramatic. They were concentrated for the most part in the shallow water where they were often clustered on lengths of rotting reed remaining from the clearance operations. The initially high figures for the density in the pond bottom (see Fig. 3) is in fact biased by a very high concentration in the shallow collecting area, D5–7 (e.g. in sector D6, three weeks after re-flooding, the concentration of young *globosus* averaged 20 per ft.^{2}). The peak density of young snails was short-lived and there was a sharp decline in the numbers of young snails after the first month. Development of surviving young snails was presumably responsible for a secondary increase in adult snails noticeable about the tenth week after flooding (see Fig. 2). By the 14th week the habitat was becoming increasingly less favourable for *globosus*, and the available adult snail population had returned virtually to its pre-drying level by the 22nd week, when the trial was discontinued.

Changes in the population of Bulinus forskalii (Figs. 4 and 5).

B. forskalii was not noticed in the pond until the second week after re-flooding. Thereafter there was a steady increase in numbers, largely young snails, culminating in a peak density in week 4. It is noteworthy from Diagram 4, that, while the peak of *forskalii* closely followed that of young *globosus*, the former species underwent most of its increase in the reed-bed. *B. forskalii* was present in declining numbers up to the 15th week, after which no further specimen was collected. *B. forskalii* shared with *globosus* a propensity for the rafts nearest to the collecting areas.

Changes in the population of Anisus natalensis (Fig. 6).

This small planorbid appeared in the pond immediately after flooding and became, at one stage, the commonest mollusc in the pond. As in the case of *B. forskalii* it showed a preference for the reed-bed; but reached its peak of abundance rather later than that of *forskalii*. The last specimens were collected from the Cleared Sector in week 15. The population curve of this species in the pond was closely reflected in the raft counts.

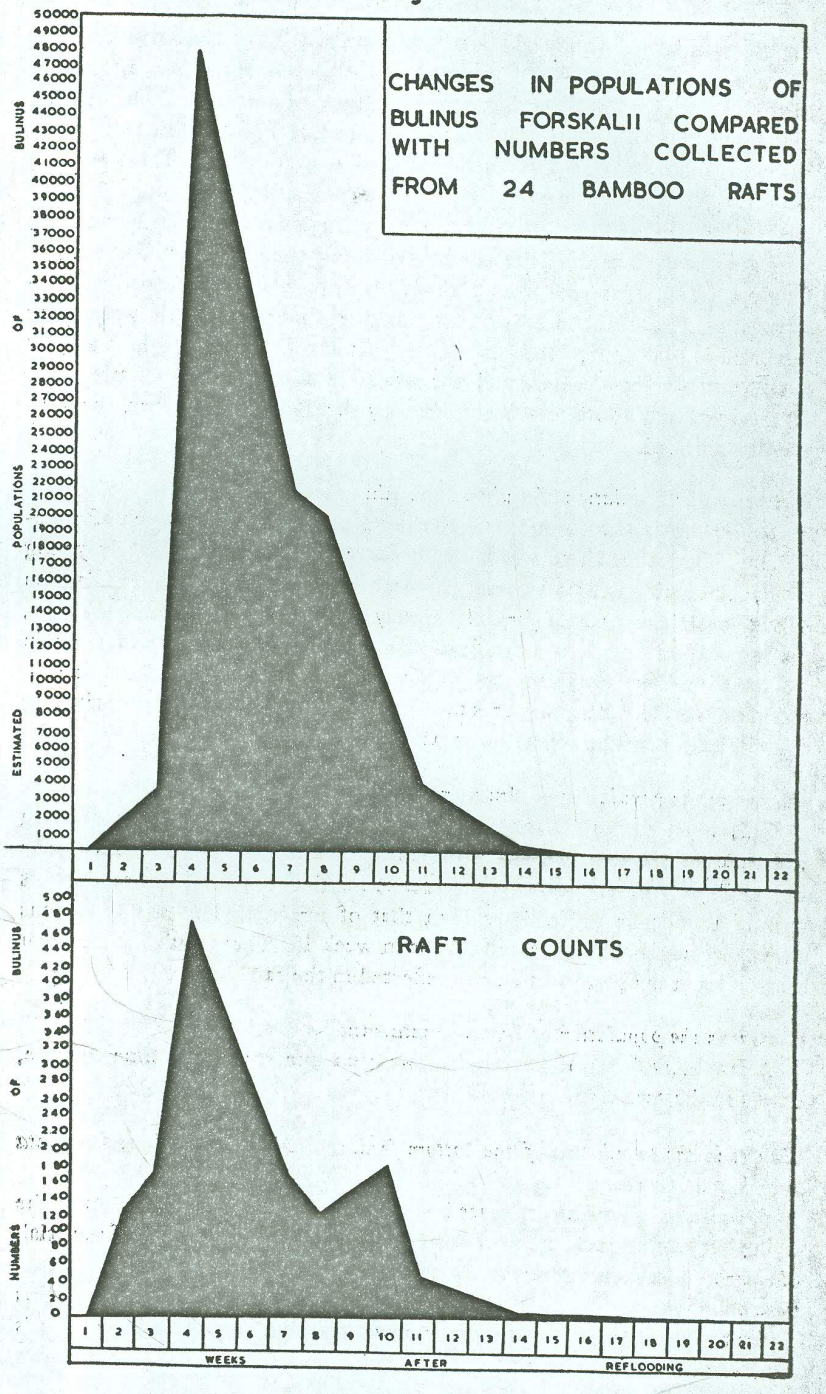
Changes in the population of Lymnea natalensis

A few individuals of this species were encountered from time to time, usually in the reed-bed.

Changes in the population of the bottom-feeding snails, Melanoides tuberculata and Cleopatra amœna.

Melanoides tuberculata appeared to recover slowly from the effects of the drying but was, in fact, the only snail on the increase at the end of the trial. *Cleopatra* underwent a series of fluctuations in density, due probably in part to sampling error, but possibly also due to a tendency on the part of this species to leave the habitat and to burrow into the damp mud at the water's edge, when conditions become sub-optimal.

Fig 4


CHANGES IN POPULATIONS OF BULINUS FORSKALII COMPARED WITH NUMBERS COLLECTED FROM 24 BAMBOO RAFTS
BULINUS OF ESTIMATED POPULATIONS
50000 49000 48000 47000 46000 45000 44000 43000 42000 41000 40000 39000 38000 37000 36000 35000 34000 33000 32000 31000 30000 29000 28000 27000 26000 25000 24000 23000 22000 21000 20000 19000 18000 17000 16000 15000 14000 13000 12000 11000 10000 9000 8000 7000 6000 5000 4000 3000 2000 1000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
RAFT COUNTS
BULINUS OF NUMBERS
500 480 460 440 420 400 380 360 340 320 300 280 260 240 220 200 180 160 140 120 100 80 60 40 20 0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
WEEKS AFTER REFLOODING

IN POPULATIONS OF
FORSKALII COMPARED
UMBERS COLLECTED
4 BAMBOO RAFTS

14 15 16 17 18 19 20 21 22

COUNTS

14 15 16 17 18 19 20 21 22
REFLOODING

Fig 5

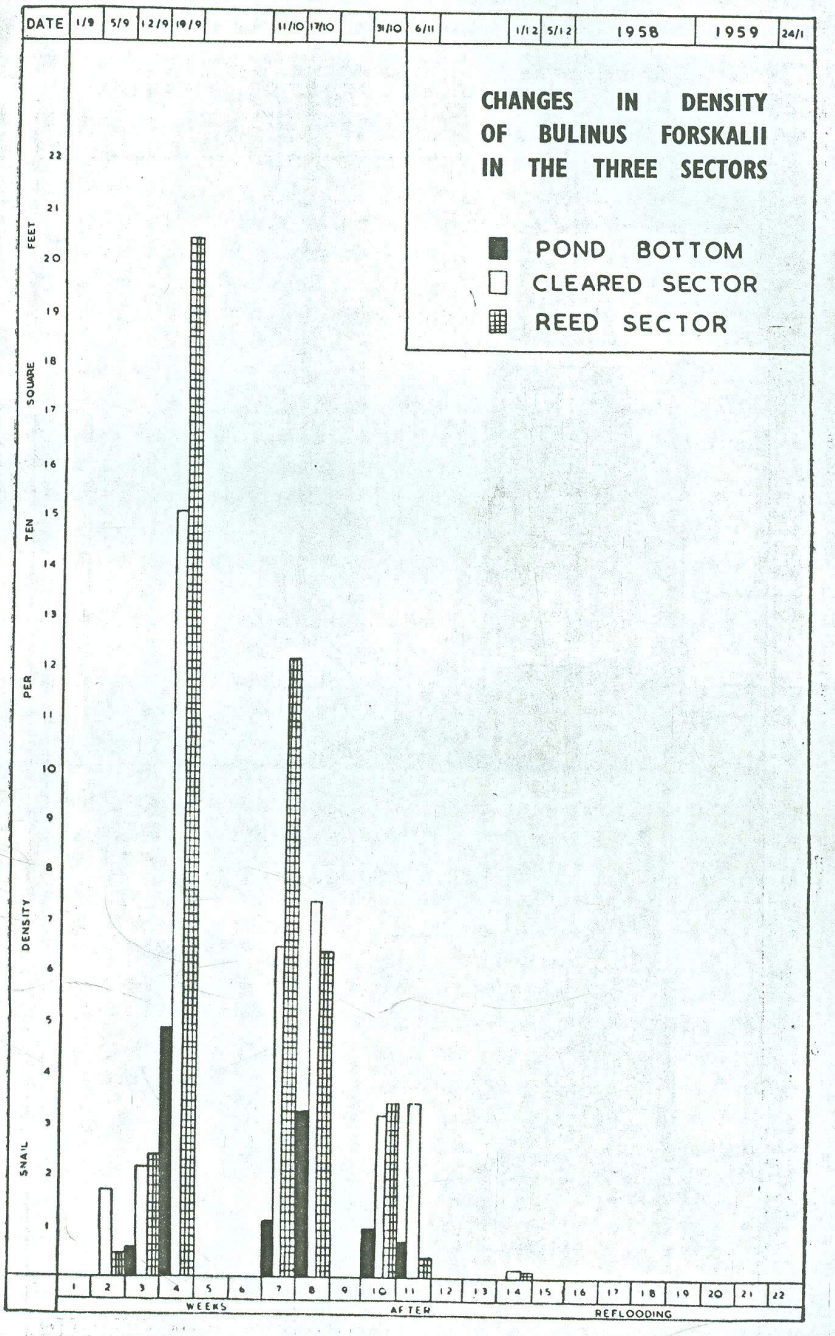
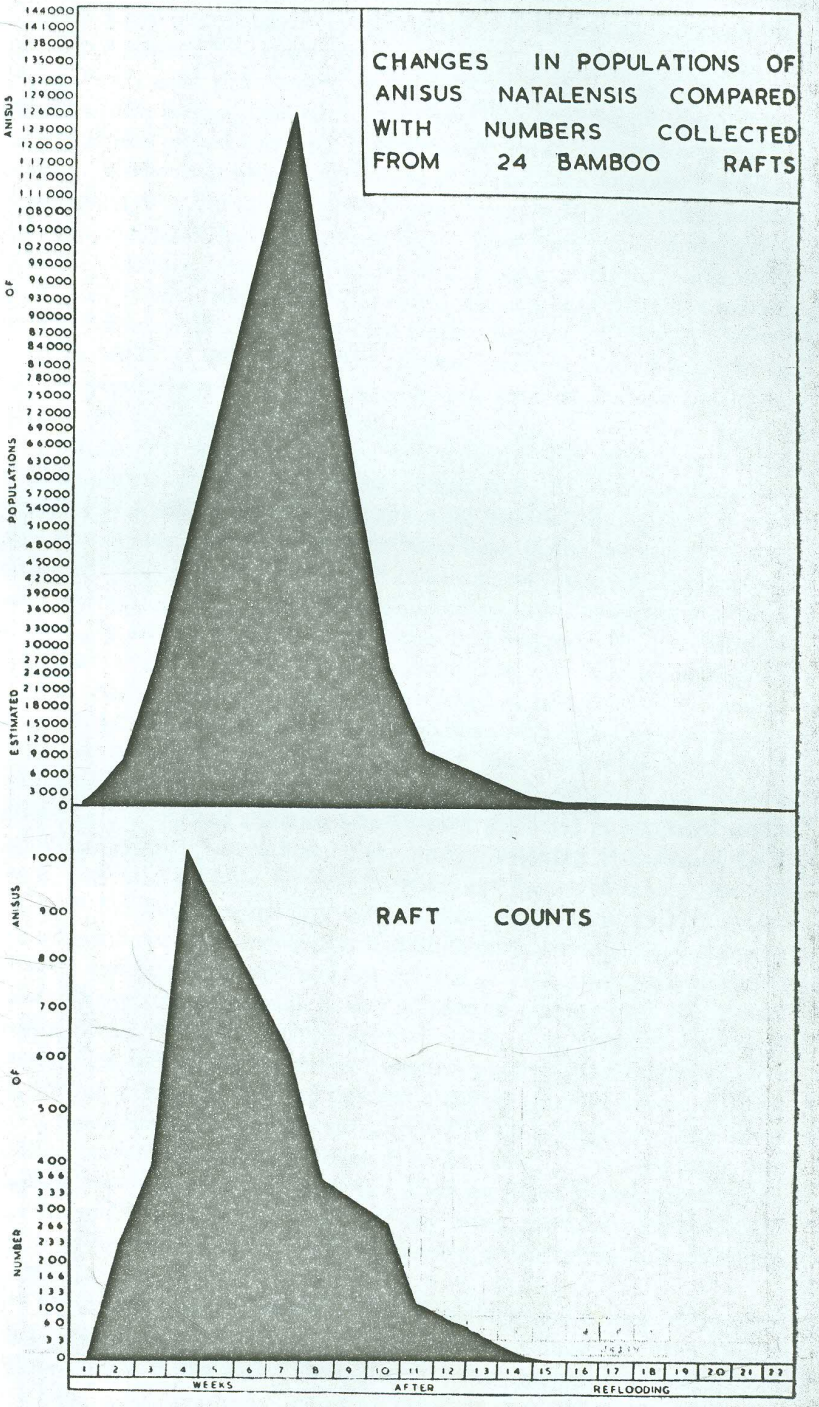


Fig. 6


CHANGES IN POPULATIONS OF ANISUS NATALENSIS COMPARED WITH NUMBERS COLLECTED FROM 24 BAMBOO RAFTS
ESTIMATED POPULATIONS OF ANISUS
144000
141000
138000
135000
132000
129000
126000
123000
120000
117000
114000
111000
108000
105000
102000
99000
96000
93000
90000
87000
84000
81000
78000
75000
72000
69000
66000
63000
60000
57000
54000
51000
48000
45000
42000
39000
36000
33000
30000
27000
24000
21000
18000
15000
12000
9000
6000
3000
0
RAFT COUNTS
NUMBER OF ANISUS
1000
900
800
700
600
500
400
366
333
300
266
233
200
166
133
100
66
33
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
WEEKS AFTER REFLOODING

The marking and releasing of Bulinus globosus

The measurement of animal populations by the release, and later recovery, of marked batches of individuals is a widely accepted technique. Pimental *et al.* (1957) used this method successfully with *Australorbis glabratus* in Brazil, but the method does not seem to have been tried for the measurement of populations of *Bulinus* snails. A preliminary test of a method was made at Amani, on the *Bulinus globosus* colony in Amani lake. On two occasions a collection of over 100 adult snails was made from the lake; the snails remaining, after collection, in a bowl of lake water. They were removed singly from the bowl; dabbed gently with filter paper until a convenient area of the shell was quite dry; they were then marked with a spot of white quick-drying enamel paint and placed on a shaded surface for half an hour to allow the paint to dry. The snails were then scattered over the lake surface. On the following day a number of marked snails were recovered among a collection made in their normal habitat.

On 12th September the method was applied in the experimental pond: 86 adult *globosus* from the pond were marked with "A" in white enamel and scattered as evenly as possible over the pond surface. Among the 224 adult *globosus* collected in the pond a week later, three of the marked batch were recovered. This rate of recovery was consistent with a population of 6,431 adult *globosus*, a figure comparable with the estimated population of 8,033 on that day arrived at by the routine counting methods. On 11th October, the seventh week after re-flooding, 218 adult *globosus* were collected in the pond, none of which was marked. These were marked with an enamel "C" and released, as previously. One week later ten marked with a "C" were recaptured among a total of 247 collected from the pond. Again none of those originally marked with "A" was recovered. The population of *globosus* calculated from the recovery of marked snails on 17th October was 5,385 as compared with a population estimate, arrived at by the routine counting methods, of 9,620 adults. On 31st October no marked snail was recovered among the 188 collected. On this occasion they were marked with an enamel "D" before release in the pond. One week later 250 adult snails were collected, only one of which carried a small speck of enamel. No painted snails were recovered subsequently from the pond. It was considered possible that the enamel became brittle and flaked off the growing shells. An alternative method of marking was therefore tried out at Amani: a small daub of Bostik adhesive was applied to the dry shell; to this was attached a minute square of silver paper. Snails marked in this way survived well in the laboratory and the silver paper squares remained firmly adherent to the shell. On 1st December, 143 adult *globosus* were marked with Bostik silver paper and were released in the experimental pond. None of these (or any other previously marked snail) was recovered from the pond on 5th December or during the final collecting on 24th January.

The variable results obtained by the marking and release of *globosus* presumably underline the rapid turnover of populations occurring during the later course of the trials. Thus, after October, the chances of recovering

a previously marked snail apparently became slight; suggesting that the mortality of adult snails was very high by this period and the adult snails caught must have originated mainly from the recent development of young snails. Alternatively, drying and marking may have caused the death of a proportion of the snails handled. This proportion would be likely to rise as competition for food in the pond increased and so render this counting method progressively less reliable.

The estimation of snail population changes by bamboo rafts

Along with the routine estimates of snail population, 24 bamboo rafts, 3 ft. x 1 ft., were tethered at intervals around the edge of the Experimental Pond in the positions indicated in Fig. 1. Counts were made from these rafts on the same day that estimates were being made by the routine method.

TABLE 3

(a) *Collections made from 24 bamboo rafts moored around the margins of the Experimental Pond. The rafts were placed in position on 29th August and collecting was started on 5th September, two weeks after flooding*

Weeks after Flooding	*Bulinus globosus*		*Bulinus forskalii*	*Anisus natal-ensis*	*Cleo-patra amæna*	*Melanoides tuber-culata*	*Lymnea natalensis*
	Young	*Adult*					
2	0	18	124	231	9	0	0
3	2	48	173	385	4	0	0
4	52	51	471	1,032	17	0	0
7	23	71	175	606	3	0	0
8	55	66	121	362	12	0	0
10	150	49	186	284	34	1	0
11	36	68	50	113	2	0	0
14	3	83	6	8	8	0	0
15	5	83	5	0	17	0	0
22	39	4	0	0	112	0	0

The results are shown in Table 3. In Fig. 1 the total number of *globosus* collected from each raft during the course of the trial is indicated by a number in the corresponding circle. The degree of attraction exercised by individual rafts thus varied widely: rafts with the highest counts were generally those closest to areas of high snail density and to the collecting areas, and the least attractive were those in the reed-bed and in the least disturbed parts of the pond. As seen in Fig. 2, the curve of *globosus* collected from rafts was much flatter and more prolonged than the curve of snail density in the pond generally.

As would be anticipated, the rafts were relatively more attractive in the later stages of the trial when, unlike the exposed surfaces, they continued to provide grazing unchoked by filamentous algæ and *Chara*.

Observations on a bed of water lilies in the Experimental Pond

There were no lilies in Pond 16 before it was dried. Forty plants were introduced near the duckboards in the deep section at the time of re-flooding

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is period and the adult snails
recent development of young
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tion would be likely to rise as
and so render this counting

mboo rafts

population, 24 bamboo rafts,
the edge of the Experimental
ts were made from these rafts
by the routine method.

nd the margins of the Experimental
ast and collecting was started on
r flooding

Cleo-patra amæna	*Melanoides tuber-culata*	*Lymnea natalensis*
9	0	0
4	0	0
17	0	0
3	0	0
12	0	0
34	1	0
2	0	0
8	0	0
17	0	0
112	0	0

the total number of *globosus*
trial is indicated by a number
ction exercised by individual
counts were generally those
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l surfaces, they continued to
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mental Pond

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and snail counts from the lily leaves soon became feasible. Counts of snails made from these lily leaves at intervals during the trial are summarized in Table 4.

TABLE 4

(b) *Collections made from the undersurface of 100 lily pads*

Weeks after Flooding	*Bulinus globosus*		*Bulinus forskalii*	*Anisus natal-ensis*	*Cleo-patra amæna*	*Melanoides tuber-culata*	*Lymnea natalensis*
	Young	*Adult*					
2	0	3	43	167	0	0	0
3	164	1	74	147	0	0	0
4	84	9	162	325	0	0	0
7	25	22	33	0	0	0	1
8	20	19	21	43	0	0	1
10	22	33	33	121	0	0	0
11	14	28	28	112	0	0	0
14	0	44	0	44	0	0	0
15	0	44	0	22	0	0	0
22		not counted					

It will be noted that a small but consistent number of adult *globosus* were found on the lily pads and the early increase of young *globosus* is reflected in the numbers collected. Over the course of the trial there was an average density of one young snail per three lily pads and one adult per 25 lily pads.

Bulinus forskalii and *Anisus natalensis* were also collected in appreciable numbers from the undersurface of these leaves.

In the last period the lily plants were so restricted by reeds that many of the pads were raised above the water level and were arranged in a confused pattern of superimposed leaves. In these circumstances no accurate estimates of the total snail population in the lilies could be done by sampling, and counting was discontinued.

TABLE 5

Comparative attraction of rafts and lily pads

Snail counts over the period 5th September to 1st December from lily pads and rafts are compared. The results are expressed both as the crude average number per raft (or lily pad) collected, and as the average number collected per unit of undersurface area in each case.

Species of Snail	*Average number collected per*		*Density per 50 sq. in. on undersurface of*	
	(a) *Bamboo Raft*	(b) *Water Lily Pad*	(a) *Bamboo Raft*	(b) *Water Lily Pad*
Bulinus globosus				
(a) Young snails	1.1	0.36	0.1	0.36
(b) Adult snails	2.3	0.05	0.21	0.05
Bulinus forskalii	6.7	0.33	0.61	0.33
Anisus natalensis	15.2	0.85	1.38	0.85

The degree of attraction for *globosus* and *forskalii* to the undersurface of the lily leaf and the bamboo raft is thus similar; and is apparently connected with the physical suitability of the surface for movement and grazing and its freedom from higher forms of algæ and other vegetation.

The micro-flora of the Experimental Pond

The microscopic flora, or periphyton, constitutes an important element in the diet of *globosus*. An attempt was made to measure the quality and density of this growth by suspending glass slides for a month in a protected site in the pond, at various intervals after re-flooding. The organisms that appeared on the surface of the slides could not be identified, but were grouped into the crude divisions given in Table 6. The figures refer to periphyton developing on a microscope slide during a period of seven days, at various intervals after re-flooding. The slides were examined, under one-twelfth-inch objective, with an Ehrlich eyepiece.

TABLE 6

Growth of periphyton on a glass slide submerged for one week in the Experimental Pond

Period of Growth	*Calculated density per square centimetre*				
	Unicellular Algæ	*Compound Algæ*	*Filamentous Algæ*	*Desmids & Diatoms*	*Protozoa (various)*
During 5th week	500,000	700	700	31,600	4,500
During 8th week	520,000	150,000	8,000	33,000	1,000
During 12th week	6,000	600	300	90,000	1,700
During 16th week	5,000	800	0	55,000	200
During 22nd week	6,000	700	0	19,000	0

It will be noted that there was a considerable production of unicellular algæ during the first two months of the trial and a significant increase of diatoms and desmids during the subsequent month; thereafter the pond became progressively less productive.

Changes in the pattern of vegetation

Before drying the pond bottom was covered by a skin of gelatinous alga, which dried and cracked on exposure to the sun. After flooding, sheets of dead alga floated to the surface and decayed slowly during the early weeks of the trial. On the pond bottom it was replaced rapidly by felted algæ, extensive plaques of which became detached and drifted with the wind on the pond surface. Within three weeks of flooding *Typha* began to sprout from all but the deepest sections of the pond bed. By November the growing reeds had emerged from the surface and were beginning to impede the manipulation of the frames. By December the character and appearance of the pond had undergone a substantial change: the divisions between the three Sectors were disappearing under a vigorous growth of *Typha*, *Cyperus* spp. and *Polygonum*; strands of *Commelina* were invading the water surface from the banks and all but the superficial water layers were invested by a deep mat of *Chara* and filamentous algæ.

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novement and grazing and its
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e week in the Experimental Pond

r square centimetre		
ntous *gæ*	*Desmids & Diatoms*	*Protozoa (various)*
00	31,600	4,500
00	33,000	1,000
00	90,000	1,700
0	55,000	200
0	19,000	0

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These changes complicated the task of collecting snails: visual collecting in the original sense became impossible and it eventually became necessary to grope for snails through algal and plant forms lifted to the water surface. Inevitably this procedure altered the habitat in the collecting areas, which became progressively less representative of the corresponding Sector. This change must have militated against the accuracy of the snail population estimates during the later stages of the trial.

The reed count

Observations on the fringes of the new *Typha* bed suggested that *globosus* and other snails were grazing on the submerged stems. An attempt was made to assess the snail population in these reeds by counting all the snails on a certain number of uprooted reeds and by estimating the total number of new reeds in the pond. Obviously such an operation could not be carried out without permanent alteration of the habitat and it was deferred until the final stage.

The counting was done by lifting out all reeds in a track one foot broad, extending across the pond along a definite line. The position and species of each snail present on the reed was noted as it was lifted clear of the water and the total number of reeds present at each depth was recorded. One hundred and twenty reeds were counted in December and 172 in January out of an estimate of 30,000 new *Typha* plants. The count was repeated on the last day of the trial and the populations of each species of snail on the pond bottom, as estimated by this and by the routine counting method, are compared in the following table.

TABLE 7

Estimates of snail populations on the pond bottom

	(a) *Young snails*		(b) *Adult snails*	
	By Reed Count	*By Routine Method*	*By Reed Count*	*By Routine Method*
1. Bulinus globosus				
12th December	3,000	1,584	6,250	2,574
24th January	3,570	1,188	357	990
2. Cleopatra amæna			*3. Melanoides tuberculata*	
12th December	2,750	40,986	3,500	3,762
24th January	74,970	43,560	9,639	6,450

These observations suggest that orthodox counting methods were providing an under-estimate of the *globosus* population of the pond in December. The other two snails encountered on the reeds, the bottom-haunting *Melanoides* and *Cleopatra* showed, in December, relatively little interest in the reeds. By January, possibly due to the further choking of the pond bed, the numbers on the reeds showed an increase.

It is noteworthy that 30/37 *globosus* were recovered from the basal third of the submerged reed stem in December while in January the proportion recovered from the basal third of the stem had declined to 2/11. In December all the *Cleopatra* and *Melanoides* were recovered from the reeds immediately above the root, whereas in January the proportions were 172/220 and 20/27 respectively. On the average, therefore, the *globosus* were grazing at a higher level on the reed stems than the other two species of snails and this distinction became more marked as the bottom of the pond became more deeply occluded with algæ.

DISCUSSION

The main object of the trial, namely to establish an experimental site that could be exploited to study methods of *Bulinus* control, appears to have been achieved.

Similarly the routine method of sampling adopted appears to provide a satisfactory indication of snail population trends over a period of several months. Trends observed by this method were compared with snail densities on bamboo rafts and lily pads, and with estimates of *globosus* populations based on the release and recapture of marked snails.

Information was collected on snail population trends in a freshly re-flooded pond. *Bulinus globosus* was noticed to graze over any smooth, submerged surface, inorganic as well as organic. Brightly sunlit surfaces were preferred in the first instance, but at the time that these became infested with filamentous algæ, *globosus* retreated to shaded microhabitats where (presumably) the growth of filamentous algæ was to some extent inhibited. Conditions appeared optimal for this species only during the first month after re-flooding.

The data suggest that adult *globosus* may have "withdrawn" in considerable numbers from the pond before being stimulated to do so by desiccation and that this population of snail reinvaded the pond slowly over the first month after flooding. If this interpretation is valid it is possible that the fall in numbers of adult *globosus* that took place after the 11th week was due only partly to an increasing mortality. The implication of such movements on the infection rate in nature, and on snail control by molluscicides, is obvious.

The observed distribution of *globosus* on the rafts suggested that different parts of the pond were varyingly attractive. Those rafts near the duckboards held notably greater numbers of snails than those afloat in parts of the pond not otherwise visited for collecting. In this instance it is certain that human pollution was not among the factors responsible for this distribution. On the other hand it could be that the periodic disturbance of the habitat caused by the routine collecting may have provided conditions locally favourable for the snail.

Subsequent efforts to repeat the population trends noted in this trial have failed but the investigations are continuing.

SUMMARY

1. A description is given of a fish pond in northern Tanganyika, modified to enable regular assessments of snail populations to be made with minimal disturbance of the habitat.

2. As a preliminary the pond was dried out for three weeks. Snail population trends following re-flooding of the pond are summarized over the subsequent 22 weeks.

3. Adult *Bulinus globosus* apparently underwent a steady increase during the first four weeks after re-flooding, due possibly to a slow reinvasion of the pond. There were indications of an increasing mortality of adult snails after the 11th week.

4. Heavy breeding of *Bulinus globosus* commenced in the open shallow water of the pond immediately after re-flooding. The peak population of young *globosus* was reached by the fourth week, thereafter declining to a low level.

5. Population estimates reached by the routine counting method are compared with regular collections of snails from 24 bamboo rafts, and 100 lily pads, in the same pond. Release and recapture of *globosus*, marked with enamel paint, was carried out several times, but gave inconsistent results.

6. An increase of *Bulinus forskalii* occurred, at the same time as that of *globosus*, but, in contrast to that species, the breeding of *forskalii* took place mainly in reeds.

7. Both *globosus* and *forskalii* showed a preference for bamboo rafts moored in the vicinity of the routine collecting areas.

ACKNOWLEDGMENTS

We wish to acknowledge the substantial contribution made by Mr. E. Hemingway to this work, with other members of the staff of the Parasitology Section of this Institute. We would also record the help of Mr. J. C. Carlin in the design and construction of the frames and the lifting apparatus, and Mr. R. Smith and Mr. T. J. Wilkes for assistance during the course of the observations.

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By D. F. CLYDE AND A. S. MSANGI

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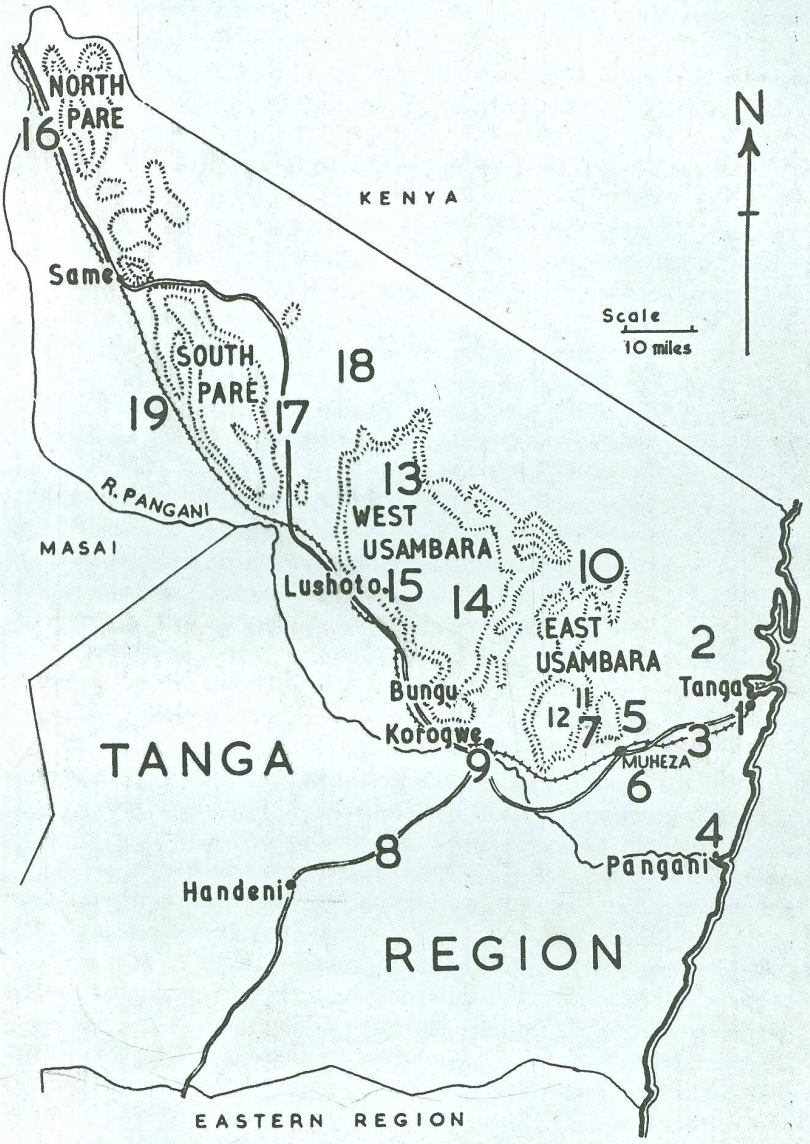
THE INCIDENCE of malaria has been studied to a greater extent in the Tanga Region than in any other part of Tanganyika. This is attributable to the presence there in previous years of general duty medical officers with a particular interest in malaria, such as Panse at the turn of the century, and of specialist units of the Ministry of Health and of the Common Services Organization.

For descriptive purposes the Region is separated here into the following zones: the coastal plain including Tanga town; Bondei country; the inland plain; the Usambara Mountains; and the Pare plains. The site of each survey reported here is indicated on the map by a number related to the text.

THE COASTAL PLAIN

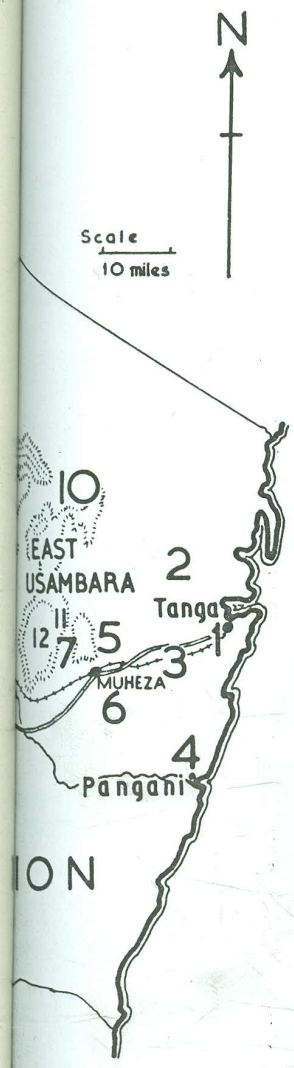
The incidence of malaria on the coastal plain of the Tanga Region has been studied at several places and in fact two of the classic reports concerning the disease in East Africa were produced in this area, one by Panse in Tanga town and the other by Bagster Wilson at Gombero 30 years later. On the sea-coast itself, at Tanga (Map reference 1), Otto Panse carried out blood examinations among people of different races living in the town, before malaria transmission was reduced by the introduction of control measures. In his paper (Panse, 1902) he recorded the rates among Africans who were apparently healthy, commenting on the beneficial effects of acquired immunity as demonstrated by the crude parasite rates: the rate among children aged 0–1 year was 48 per cent, aged 1–2 years was 88, aged 2–5 was 79, aged 5–15 was 45 and aged more than 15 was 15.

Later records from Tanga Government Hospital indicate the prevalence of the principal species of parasite among Europeans sick with malaria. These cases included German troops and it was estimated that a third was contracted within the town and the remainder on safari in the district. From 1904 to 1908 (there was little variation each year) *Plasmodium falciparum* was found in 92·5 per cent of the cases, *P. vivax* in 6·7 and *P. malariae* in 0·7, while very rarely a mixture of subtertian and benign tertian was noted (Annual Reports, 1904/5–1907/8). A few years later Senior Staff Surgeon Lott reported from the same hospital (Annual Report, 1911–12)



an incidence among malarious Europeans of 89·3 per cent *P. falciparum*, and 9·3 and 1·4 *P. vivax* and *malariae* respectively.

Although the German administration introduced a mass suppression campaign using quinine at Tanga, little if any reduction in transmission was achieved until mosquito control measures were introduced later. Since drainage and larviciding were commenced, most of the infections becoming clinically apparent in Tanga have been contracted outside the town. In 1933 Dr. and Mrs. Bagster Wilson repeated Panse's studies among apparently



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healthy Africans residing in the town (Wilson, 1936a); the crude parasite rates and species prevalence were:

Ages 0–1 year: Rate 17 per cent (the species *P. falciparum* appearing in 98 per cent of positive films, *P. malariae* in 13 and *P. vivax/ovale* in 1 per cent);

Ages 1–5 years: Rate 60 (species respectively 93, 33 and 8);

Ages 6–10 years: Rate 68 (species 91, 22 and 2).

The rates among people aged 11–20, and more than 20 years, were 48 and 27 respectively. Bagster Wilson noted that the ratio between *P. vivax* and *ovale* was 3 to 1. The sporozoite rate for *Anopheles gambiae* and *funestus* combined was found to be 12·7 within the town and 6·9 immediately outside, where *A. funestus* was more common.

A recent examination of 94 young children reporting sick at the Tanga Town Welfare Clinic in Ngamiani includes the densities of parasites. Of the various methods used for expressing the numbers of parasites present in blood films one of the most convenient and suitable is that of Bruce-Chwatt (1958) and his Positive Parasite Density Index is used generally by the Tanganyika Malaria Service. This Index is calculated by allotment to different parasite densities of values from 1 to 10, as follows: densities of 1–100 parasites per c.mm. are valued at 1; 101–200 at 2; 201–400 at 3; 401–800 at 4; 801–1,600 at 5; 1,601–3,200 at 6; 3,201–6,400 at 7; 6,401–12,800 at 8; 12,801–25,600 at 9; and 25,601 or more at 10. These values are then added and the total divided by the number of infected cases.

Using Bruce-Chwatt's Positive Parasite Density Index (PPDI) among sick children attending the Tanga clinic in 1959, it was found that of the infants 33 per cent were suffering from malaria, with a PPDI of 8·5; of children aged from 12 to 24 months, 47 per cent with a PPDI of 6·1; and of those aged from 3 to 5 years, 71 per cent with a PPDI of 5·6. In every case the predominant parasite was *P. falciparum*, although *P. malariae* was noted as a mixed infection in a third of the cases. Other species were not encountered on this occasion.

From ten to 20 miles inland, malaria surveys have been carried out among apparently healthy rural populations living under hyperendemic conditions. The classic study by Dr. and Mrs. D. Bagster Wilson (Wilson, 1936a, 1936b) made at Gombero and neighbouring villages (Map reference 2) revealed a combined sporozoite rate of 12·4 (at Ngomeni, some miles to the south, the rate was 10·8). The very large sample of people examined at Gombero, 3,300, probably included the whole population, predominantly Wadigo with a few Arabs. The crude parasite rates and species prevalence proved to be:

Ages 0–1 year: Rate 88 per cent (the species *P. falciparum* appearing in 83 per cent of positive films, *P. malariae* in 38, and *P. vivax/ovale* in 20);

Ages 1–5 years: Rate 99 (species respectively 85, 42 and 20);

Ages 6–10 years: Rate 79 (species 89, 15 and 5).

The rates among people aged 11–20, and more than 20 years, were 55 and 44 respectively. Among the Digo portion of the population the

prevalence of *P. falciparum* was greater, although there was no reduction in the other species. It was found (Wilson and Wilson, 1935) that the ratio between *P. vivax* and *P. ovale* was 3 to 1 among asymptomatic infants and 5 to 1 among children aged from 1 to 10 years.

At Gombero during the wet season a slight rise in rates was observed, this being attributed to a more rapid infection of babies after birth. A similar rise was found in 1959 when comparing wet and dry season surveys at Pongwe, some miles south of Gombero, and at Madanga, not far inland from Pangani (Map references 3 and 4). The rates and species distribution did not differ much from those found by Bagster Wilson at Gombero 25 years before, except for the *vivax* group which was only half as frequent as at Gombero. When the Pongwe population was divided tribally, it appeared that both *P. vivax* and *malariae* were more common among the Digo people than among all other tribes. The PPDI among 250 people examined at Pongwe in the month of August, 1959, were as follows: Africans aged less than 1 year: 7·1; aged 12–24 months: 6·3; aged 3–5 years: 5·6; aged 6–10 years: 4·1; and aged 11–15 years: 3·0.

On the coastal plain a small portion of the population examined in each survey is of Arab descent. The differences that exist between the parasite infestation of Arab and African children were recorded in a survey conducted at Kicheba (Map reference 5), a large village lying at the coastal foot of Mlingoti Hill, the easternmost outcrop of the Usambara Mountains. As Kicheba is situated amidst sisal estates, its inhabitants include representatives of tribes from many parts of the country and particularly the Southern Region. The crude parasite rates and species distribution among Africans at Kicheba were as follows:

Ages 0–11 months: Rate 50·0 per cent (the species *P. falciparum* appearing alone in all positive films);

Ages 12–24 months: Rate 71·8 (*P. falciparum* in 96·4 per cent of the positive films, and *P. malariae* and *vivax* in 21·4 and 7·1 respectively);

Ages 3–5 years: Rate 67·1 (*P. falciparum*, *malariae* and *vivax* 97·9, 20·4 and 4·1 respectively);

Ages 6–10 years: Rate 64·9 (*P. falciparum* 97·2, *P. malariae* 5·6 and *P. ovale* 1·4).

The rates among those aged 11–15, and more than 15 years, were 52·7 and 25·6 respectively. The number of Africans examined in the course of this survey was 326; a small number of Arab children was also examined, those aged 12–24 months having a parasite rate of 28·6 and those aged 3–5 years a rate of 25·1, every infection being subtertian. In view of the better economic status of the Arab children in February, 1958, when this work was done, it is likely that they made greater use of measures of personal protection from malaria.

BONDEI COUNTRY

Twenty miles inland from Tanga the land rises from 500 to 1,000 feet but does not differ remarkably from that of the coast. Centred upon Muheza, the Bondei people inhabit an area which is dry in the south but better watered

in the north, where it lies beneath the eastern range of the Usambara Mountains. In this homogeneous tribal group the climatic contrasts in the incidence of malaria among apparently healthy village folk have been studied during the period 1952–59, preparatory to chemotherapy trials conducted by the senior author.

(*a*) *Southern Ubondei*

To the south of Muheza the area of Ubondei covered in detailed surveys by the Malaria Service reaches from Lusanga and Kilulu villages some seven miles to Mkuzi (Map reference 6). The climate and physical features

Table 1

Dry Season Parasite Rates and Species in Southern Ubondei

Human age groups	*Malaria parasites**					
	All species	*Plasmodium falciparum*	*Plasmodium malariae*	*Plasmodium vivax*	*Plasmodium ovale*	*Positive Parasite Density Index*
0–11 months	60·5	96·9	8·2	10·9	0·0	5·3
12–24 months	95·5	95·1	43·9	7·5	0·0	5·9
3–5 years	92·4	98·7	30·2	4·8	0·9	3·9
6–10 years	84·0	95·7	12·4	1·2	0·0	3·6
11–15 years	66·3	100·0	1·8	0·5	0·0	2·9
16 and older	32·0	97·4	2·6	0·0	0·0	2·4

*The species prevalence is expressed as the number of people with *P. falciparum* (or other) parasitaemia divided by the total number of infections of all species: e.g., in the age group 0–11 months the *P. falciparum* prevalence is 63 divided by 65. The prevalence exceeds 100 per cent in most instances because of the frequency of mixed infections.

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closely resemble those of the coast and during the dry season there is little surface water. Surveys carried out in the months of June and July, during the long rains, and in February and March, during the dry season, revealed little difference in parasite or species incidence and accordingly the data obtained during the dry season are recorded here in Table 1: they may be contrasted with the wet season data of northern Ubondei given later. The sample in Table 1 was composed of 1,361 people.

At the time that the survey recorded in Table 1 was carried out the combined sporozoite rate in the same area was 8·1. At Tengeni, two miles to the west of Muheza, Gillies, over a period of eight months, made a special study of the sporozoite rate, separating pre-gravid from gravid mosquitoes in order to eliminate the wide fluctuations in the rate attributable to new emergence of *A. gambiae*. Among gravid *A. funestus* he found the rate (taken as the fortnightly mean) to vary between 0·7 and 5·8, but among gravid *A. gambiae* the fortnightly mean varied between 2·5 and 15·4 per cent (Gillies, 1954).

(*b*) *Northern Ubondei*

To the north of Muheza surveys have been made along the well-watered valley lying between the main massif of the eastern Usambara Mountains and Mlingoti Hill, this area from Magila to Kiwanda being densely populated (Map reference 7). During the short rains of September–December, 1952, Davidson and Draper (1953) found in the neighbourhood of Kiwanda a sporozoite rate in *A. gambiae* of 4·7 and in *A. funestus* of 3·4. The parasite rates they recorded are of particular interest because of a detailed analysis of the infant age groups, in which the rapid rise of quartan malaria is indicated:

Ages 0–2 months: Rate 21 per cent (the species *P. falciparum* appearing in all the positive films, *P. malariae* in 9 per cent and *P. vivax/ovale* in none);

Ages 3–5 months: Rate 75 (species respectively 99, 7 and 9);

Ages 6–11 months: Rate 88 (species 99, 42 and 9);

Ages 12–23 months: Rate 87 (species 100, 46 and 7);

Ages 2–4 years: Rate 96 (species 99, 19 and 2);

Ages 5–10 years: Rate 85 (species 99, 6 and 4).

The rates among people aged 11–14, and more than 14 years, were 74 and 42 respectively. Similar rates and species distribution may be compared with those of southern Ubondei obtained during the dry season: Tables 1 and 2 should reveal the maximum seasonal differences, if any occur, in the incidence of malaria among the Bondei people at each end of their territory, the former representing the position in a normally dry area at its driest and the latter in a normally wet area at its wettest. The sample composing Table 2 was 1,693 people, examined by the Malaria Service.

The comparison shows that there is little difference between the dry and the wet season rates in Ubondei.

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Table 2

Wet Season Parasite Rates and Species in Northern Ubondei

Human age groups	*Malaria parasites*					*Positive Parasite Density Index*
	All species	*Plasmodium falciparum*	*Plasmodium malariae*	*Plasmodium vivax*	*Plasmodium ovale*	
0–11 months	63·7	98·7	16·0	2·9	3·0	5·5
12–24 months	88·7	100·0	32·1	12·0	0·0	5·8
3–5 years	83·5	98·8	26·9	3·5	0·0	4·4
6–10 years	75·6	98·2	10·1	0·8	0·0	3·6
11–15 years	63·5	99·4	5·3	0·0	0·6	3·2
16 and older	35·0	99·0	3·0	0·0	0·0	2·8

THE INLAND PLAIN

Proceeding inland from Ubondei the country lying beneath the Usambara Mountains is at an altitude of 1,000–2,000 feet; to the south-west it stretches as Uzigua to Handeni, while to the north-west it encircles the Usambaras as far as Pare District. Except in the immediate vicinity of the mountains the population is sparse because of the dryness of the climate and scarcity of surface water.

(*a*) *Uzigua*

A survey was undertaken by the Malaria Service at Sindeni (Map reference 8) in July, 1958, during the rainy season. The high parasite rates shown in Table 3 were found but, strange as it may seem, the children were apparently healthy; although the sample consisted of only 116 individuals the findings can be vouched for as accurate.

Table 3

Parasite Rates and Species in Uzigua

Human age groups	*Malaria parasites*				
	All species	*Plasmodium falciparum*	*Plasmodium malariae*	*Plasmodium vivax/ovale*	*Positive Parasite Density Index*
0–11 months	90·9	91·2	29·4	26·4	6·7
12–24 months	100·0	100·0	59·1	11·4	6·1
3–5 years	100·0	96·8	29·0	6·5	4·3
6–10 years	100·0	100·0	38·5	0·0	3·4

(*b*) *At the foot of the Usambara Mountains*

Surveys were made in 1959 in the vicinity of Korogwe, the town itself being protected by a mosquito control programme, and at Daluni. Around Korogwe (Map reference 9) the sample of 107 children aged less than 6 years, and 278 older people, included Wazigua, but no tribal differences in malaria incidence were noted despite the remarkable findings at Sindeni 20 miles south-west. At Korogwe the crude parasite rates, the prevalence of *P. malariae* (*P. falciparum* was present in every positive film among children aged less than 6, while *P. vivax/ovale* were not encountered at all) and the PPDI were as follows:

Ages 0–11 months: Rate 59·4 per cent (*P. malariae* appearing in 13·2 per cent of positive films) and the PPDI was 5·9;

Ages 12–24 months: Rate 71·4 (*P. malariae* 25·0), PPDI 6·0;

Ages 3–5 years: Rate 73·3 (*P. malariae* 27·3), PPDI 4·8.

The rates among people aged 6–10 years, 11–15, and more than 15, were 74·2, 52·6 and 33·1 respectively.

At Korogwe medical care is more readily available than in rural areas and small children are more frequently and adequately treated. At Daluni (Map reference 10), beneath the northern heights of the eastern Usambaras, many of the Sambara inhabitants divide their time between the mountain and the plain. The results of a survey among children carried out in January, 1959 were as follows:

Ages 0–11 months: Rate 52·1 (*P. falciparum* appearing in all the positive films, *P. malariae* in 32·0 per cent and *P. vivax/ovale* in 4·0);

Ages 12–24 months: Rate 90·0 (species respectively 100·0, 44·4 and 21·7);

Ages 3–5 years: Rate 81·9 (species 97·1, 25·0 and 4·4);

Ages 6–10 years: Rate 74·4 (species 100·0, 10·8 and 1·4).

USAMBARA MOUNTAINS

The Usambara Mountains are divided by the Luengera Valley into eastern and western ranges, the former rising to 4,000 and the latter to 7,000 feet. The eastern Usambaras (the Amani Hills) are covered in rain forest except where cleared for tea cultivation; malaria transmission may occur seasonally from January to March in the vicinity of the lower-lying dams, notably that at Nderema, but most of the infections reported at Amani and other centres have been contracted on visits to the plains. The western Usambaras are considered to be free of malaria transmission above the altitude of 5,000 feet, although the rare indigenous case may arise from the bite of *A. gambiae* carried up on motor vehicles.

(*a*) *Eastern Usambaras*

In the Annual Report for 1909–10 there is a reference to the type of parasite causing clinical malaria among Europeans in the Amani Hills, although some of the cases reported were undoubtedly contracted at lower altitudes. Among people living at "Amani, Derewa, Bulwa, Gambo, Monga and Kwamkoro" there were 14 cases of subtertian and six of benign tertian malaria.

At Nderema (Map reference 11) in February, 1954 an epidemic of malaria broke out, borne largely by *A. funestus* whose sporozoite rate was the unusually high one for this anopheline of 9·6 (Clyde, Webbe and Shute, 1958). All four species of malaria parasite were involved, in the proportion 100 *P. falciparum*, 10, 6·3 and 3·8 *P. malariae*, *vivax* and *ovale* respectively, the minor species being as common among adults as among children. The labourers on the tea estate at Nderema were nearly all recruited from another mountainous area of Tanganyika, Njombe, where because malaria is rare or unknown they had had little opportunity to acquire immunity; 90 per cent of the children and 80 per cent of the adults were infected.

Differences at Nderema in degree of infection between the Wabena labourers from Njombe and the somewhat more immune Wasambara, indigenous to the Nderema area, were demonstrated not only by the parasite densities but also by the gametocyte prevalence. The data are of interest in view of the importance of this epidemic as one of the few (if not the only one) carefully studied in Tanganyika where epidemic malaria is a rare occurrence. The differences in the PPDI were as follows:

	Wabena	*Wasambara*
Ages 0–5 years	5·6	5·3
Ages 6–10 years	5·3	4·6
Ages 11–20 years	5·6	4·2
Ages 21 and older	4·5	3·3

Of course these indices among Wasambara at Nderema, let alone Wabena, are appreciably higher than those recorded (for example in Tables 1 and 2) among their neighbours the Wabondei inhabiting the plains below.

The gametocyte prevalence also is significant: whereas Wabondei aged 0–10, 11–20 and 21 and older had gametocyte rates of 19, 5 and 2 respectively, the rates among Wabena during the epidemic were 24, 17 and 15.

In a study from December, 1958 to March, 1959 of 375 Wasambara children living in mountain villages near Amani (Map reference 12), the Malaria Service obtained the data recorded in Table 4. The infected cases tended to be among those children living at the edge of the mountain and maintaining close contact with the plains nearby.

Table 4

Parasite Rates and Species near Amani

Human age groups	*Malaria parasites*					
	All species	*Plasmodium falciparum*	*Plasmodium malariae*	*Plasmodium vivax*	*Plasmodium ovale*	*Positive Parasite Density Index*
0–11 months	8·7	100·0	0·0	0·0	0·0	4·5
12–24 months	22·4	100·0	9·1	0·0	0·0	4·9
3–5 years	21·9	96·5	6·9	6·9	0·0	3·9
6–10 years	20·5	97·1	2·9	0·0	2·9	3·1

(*b*) *Western Usambaras*

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(*b*) *Western Usambaras*

During the First World War a severe malaria epidemic was reported from Bungu in the western Usambara Mountains. Remembering that Robert Koch in a classic investigation in 1897–98 (soon after the discovery of mosquito transmission by Ross) established that subtertian malaria occurring in the western Usambaras had actually been contracted on safari to the plains (Koch, 1898b), Max Taute showed that most if not all of the cases in the epidemic of 1915 had also been contracted at the foot of the mountain when the victims were mounting military guard on the railway line. He found (Taute, 1919) that benign tertian predominated over subtertian.

From December to February, 1941–42, another malaria epidemic occurred along the south-west face of the western Usambaras, from Ngulwi and Ubiri near Lushoto, through Vuga to Bungu and as far as the outskirts of Bumbuli. In the districts concerned 11 per cent of the population were infected, at least 1,500 cases with 240 deaths being reported by R. Mackay who considered the cause to be unusual facilities for vector breeding, the rains being prolonged into the warm season. Malaria parasites were introduced by labourers visiting the mountain villages from the sisal estates on the plains below, but anophelines undoubtedly maintained transmission for a few months thereafter at an altitude of 4,500 feet. A survey carried out in August, 1948 confirmed the presence at that altitude of larval stages of *A. gambiae* in very small numbers, while adults of both vectors were taken in substantial numbers, and it was concluded that a small amount of transmission persisted throughout the second half of the year.

In the Mlalo Basin, in villages situated between Malindi and Mlalo close to the Lushoto/Kitivo road (Map reference 13), a survey was carried out in August, 1948. Among the residents of Zaizo, Dule, Handei, Bagai, Fuizai, Malindi, Mlalo, Shita, Kifuilo and Mndaro the following parasite rates were found:

Wasambara	aged 0–1 year	27·5
	aged 1–5 years	26·1
	aged 5–10 years	28·7
	aged 10–15 years	26·7
	aged 16 and older	17·8

The Mlalo Basin in which these villages lie is situated at an altitude of 4,000–5,000 feet and mosquito searching at that time was unproductive of vectors, larval or adult. At the foot of the nearby escarpment, at Kitivo (Lunguza) in the plain, there was the usual abundance of vectors and it was considered that much of the infection found at Mlalo had been contracted on visits down the scarp. As a matter of fact, Professor Koch had made this identical journey to Kitivo 50 years previously and had reached the same conclusion. But that a small amount of transmission does occur in the Mlalo Basin has been shown by the collection of vectors there in January, 1959.

A survey at Funta and Bumbuli (Map reference 14) in January, 1959 revealed one infection with *P. falciparum* among 20 infants, none among 27 children aged 1–2 years, none among 39 aged 3–5, and another single

infection with *P. falciparum* among 150 children aged 6–10. In Lushoto town (Map reference 15) a year later no infections were found among 23 children aged 6–10 and one *P. falciparum* among 48 aged 11–15. All these children were Wasambara.

PARE PLAINS

Immediately prior to the residual spraying campaign carried out by the East African Malaria Institute in Pare District and across the Kenya border to Taveta during the years 1954 to 1959, detailed malaria surveys were performed in villages in the plains. Differences in incidence were found between North and South Pare and, in the latter, transmission varied from area to area. Among inhabitants of the North Pare villages Kileo, Kituri, Kitogoto and Nyasa (Map reference 16) the following parasite rates occurred during the peak of the wet season in the month of June: infants aged 0–11 months, 54 per cent; children aged 12–23 months, 63; 2–4 years, 68; 5–9, 71; 10–14, 66; 15–19, 42; and adults aged 20 and more, 33. During the dry season, in February, the rates among children aged 2–14 years were about three-quarters of those of the wet season, and among other ages about half.

Among inhabitants of the South Pare plains a much greater variation in incidence was found from place to place. Malaria proved to be of a hyper-endemicity akin to that of North Pare in the villages of Kisiwani, Gonja, Ndungu and Kihurio (along the main Tanga/Moshi road; Map reference 17). Dissections of vector anophelines in these South Pare roadside villages revealed a sporozoite rate in *A. gambiae* of 0·5 and *A. funestus* of 0·3, while similar dissections in the more swampy areas of Lower Ndungu, Lower Gonja and Bendera revealed the rate to be 0·3 and 0·5 respectively. The parasite rates and species prevalence among people living in these swamp areas (Map reference 18), as found from March to June, 1955 by Draper and Smith (1957), are shown below:

Ages 0–11 months: Rate 40 (*P. falciparum* appearing in 95 per cent of the positive films, *P. malariae* in none and *P. vivax/ovale* in 10 per cent);
Ages 12–23 months: Rate 78 (species respectively 100, 31 and 0);
Ages 2–4 years: Rate 84 (species 98, 25 and 2);
Ages 5–9 years: Rate 72 (species 99, 15 and 3).

The rates among people aged 10–14 years, 15–19, and older than 19, were 64, 47 and 29 respectively. These parasite rates remained nearly constant at all seasons of the year despite the low sporozoite rates found in the vector anophelines.

Only along the railway line to the south-west of the South Pare mountain mass, on the border of the arid Masai steppe, were parasite rates indicative of mesoendemicity recorded. In the villages of Hedaru, Makanya and Mwembe (Map reference 19) during the month of June the following prevailed: infants aged 0–11 months, 26 per cent; children aged 12–23 months, 33; 2–4 years, 36; 5–9 years, 40; 10–14, 37; 15–19, 28; and 20 years and more, 20.

References

References will appear at the end of the concluding Part of this series.

Transmission of *Plasmodium gallinaceum* Brumpt to Chicks by *Aedes aegypti* (L.) Sterilised by an Alkylating Agent, Thiotepa

D. S. BERTRAM, *Professor*
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Transmission of *Plasmodium gallinaceum* Brumpt to Chicks by *Aedes aegypti* (L.) Sterilised by an Alkylating Agent, Thiotepa

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Introduction

Weidhaas (1962) showed that adult female mosquitoes, *Aedes aegypti* and *Anopheles quadrimaculatus*, allowed to rest for 4 hours on a deposit of the alkylating agent, tepa [tris(l-aziridinyl)phosphine oxide], laid eggs which, however, failed to hatch. Bertram (1963) reported similar findings for *An. gambiae* var. *melas* and *Ae. aegypti* with thiotepa [N,N′N″-triethylene thiophosphoramide] a sulphur analogue of tepa. Moreover, with the latter species, a single exposure to thiotepa for 3 hours on the day before their first blood meal maintained chemosterilization of inseminated females through 4 gonotrophic cycles over nearly 6 weeks. Chemosterilization was also effective, except for one female, exposed at other times in relation to the first, and subsequent blood meals. These results and those also obtained from matings of normal females and treated males of *Ae. aegypti* were discussed by analogy with cytogenetic studies on the mode of action of mutagenic agents injected into *Drosophila* males (Fahmy and Fahmy, 1954). Genetic and chromosomal changes induced in the gametes following exposure of the mosquitoes to thiotepa appeared to be the cause of the infertility of the eggs; and, with time, somatic effects were also evident, at least in some females, in their greatly reduced ovarian structure and reproductive potentialities. It appeared possible that the mutagenic properties of thiotepa might also induce, as in the mosquito, chromosomal and genetic changes in a malaria parasite undergoing sporogony in thiotepa-treated insects, causing failure in the development of the parasite and in its transmission by the vector. Using *Ae. aegypti* as a vector of the malaria parasite of fowls, *Plasmodium gallinaceum*, experiments were made to investigate this possibility.

Altman (1963) reported substantial but incomplete suppression of the development of *P. gallinaceum* in *Ae. aegypti* and of its transmission to fowls following contact exposure of the mosquito to the related alkylating compound, tepa, and pointed to the need to determine the susceptibility of the different stages in the extrinsic cycle. The present paper contributes to this aspect and goes on to show that: dosages of thiotepa sufficient to sterilize the mosquitoes themselves are inadequate to prevent transmission of the malaria parasite; exposures to thiotepa capable of suppressing oocyst development, or the infectivity of sporozoites, approach dosages lethal to the vector; parasites circulating in the blood of chicks infected by the bites of thiotepa-treated *Aedes* can complete the extrinsic cycle in clean *Aedes* and, moreover, are transmissible, with subsequent parasitaemias, to further chick hosts.

Materials and Methods

Freshly emerged *Ae. aegypti* ♀ ♀ were allowed to mate with ♂ ♂ for 5 days after emergence. The ♀ ♀ were then isolated from the ♂ ♂ and infected by feeding on a 6- to 8-week-old *P. gallinaceum*-infected fowl, the period of feeding being in three experiments ½, ¾ and 2 hours. The infected fowl was restrained on its back in a suitable holder for the *Aedes* feeds, the cylinders containing the mosquitoes being changed at least once from one side to another of the fowl. Control malariometric data were obtained from an unexposed group of these *Aedes*, and others were allowed contact with thiotepa for 1, 2 or 3 hours.

Thiotepa deposits on which the mosquitoes rested during these exposures were prepared from an aqueous solution of thiotepa supplied as powder in vials for parenteral use by Lederle Laboratories in 15 mgm. quantities. The solution was pipetted on to Whatman No. 1 paper which, after drying, was inserted as the lining of a tube into which mosquitoes were passed for their period of exposure, as described by Bertram (1963). The eggs of treated and untreated *Aedes* were observed for hatch as a check on absorption of the alkylating agent.

Appropriate dissections were made for oocyst counts and gland infections of sporozoites. About the 15th day, mosquitoes of each group fed on 3-day-old chicks to test transmission. Later, clean *Ae. aegypti*, not exposed to thiotepa, fed on some of the recipient chicks infected by the bite of the treated *Aedes* or control *Aedes*. Dissections were made of these insects for oocysts and sporozoites of this second sporogony cycle, and transmission tested by feeds on chicks. Examination of chicks for parasitaemia were made 6–7 days after exposure and at daily intervals then for a week, and thereafter every 2–3 days for a further 1–2 weeks. Parasitaemia was usually severe, followed by death about the 8th-10th day after exposure.

The mosquitoes were kept between blood meals on sugar solution at a temperature of 25°–27°C. and a relative humidity of 80 per cent.

The range of oocysts per gut in control *Aedes* is so great (*e.g.* 22–1188 in 15 ♀ ♀ dissected) that dissection of sufficient to give a satisfactory arithmetic mean estimate was impossible. Instead, the geometrical mean (Geo. Mn.) is given, which tends to correct the effect of high values, and since one series included a negative *Aedes* the special form of Geo. Mn.(Wm.) is used throughout (see Williams, 1937).

Results

Three experiments are reported here, in each of which previously fertilised *Ae. aegypti* ♀ ♀ were first infected by feeding on a *P. gallinaceum*-infected fowl and then divided into (a) a control group which was not treated and (b) one or more groups which were exposed either immediately after the meal or 24 hours after it, for 1–3 hours to contact with a thiotepa deposit of 20 mgm., or 40 mgm., per square foot.

Insemination was 100 per cent for all three experiments, 60/60 ♀ ♀, 53/53 ♀ ♀ and 30/30 ♀ ♀ being sperm-positive in their spermathecae in the respective experiments. The sperms were, in most ♀ ♀, active. Failure of eggs to hatch following thiotepa exposure could be taken as proof that thiotepa had been absorbed by the *Aedes*, and effects on malariometric indices interpreted accordingly.

I. *Controls: P. gallinaceum infection in normal Ae. aegypti*

Table I tabulates the data for the 3 control groups infected with *P. gallinaceum* but not exposed to thiotepa. Hatch rates for the eggs laid by these untreated ♀ ♀ were good (56 per cent, 75·8 per cent and 86·2 per cent) and, in all 3 groups the malariometric data show high levels of infection for oocysts (93·3 per cent–100 per cent), for sporozoites in the glands (85·7 per cent–100 per cent), and 100 per cent transmission in each of 20 chicks on which mosquitoes with sporozoite-positive glands had engorged. Actually, 14 of these chicks were each bitten by a single gland-positive *Aedes* only. This evidence of completely successful transmission, if the glands of an *Aedes* not exposed to thiotepa contact are certainly sporozoite-positive, can be further supplemented: in 16 other tests in recent months, in which

TABLE I. SHOWING THE HIGH INFECTION RATES AND TRANSMISSION RATES FOR *P. GALLINACEUM* IN CONTROL *AEDES AEGYPTI*, NOT EXPOSED TO THIOTEPA, AND THE HIGH FERTILITY RATES OF THEIR EGGS.

Control Group	*No.* Aedes	*No. Eggs*	*% Hatch*	*Death rate in 2–4 days after meal*	*Oocysts per gut* — *No. of* Aedes *dissected*	*Geo. Mn. (Wm)*	*Range*	*Oocyst rate*	*Sporozoite rate*	*Transmission to chicks by gland-positive* Aedes
A	44 ♀ ♀	2,641	86·2%	Nil	15 ♀ ♀	176·5	22 to 1189	100%	100% (9/9)†	100%* (6/6)
B	54 ♀ ♀	1,910	56·0%	3·7%	10 ♀ ♀	14·8	1 to 91	100%	85·7% (6/7)†	100%‡ (5/5)
C	80 ♀ ♀	4,852	75·8%	2·5%	14 ♀ ♀	41·6	0 to 198	93·3%	97·1% (33/34)†	100%‡ (9/9)

† Numerator = No. of *Aedes* with sporozoite-positive glands.
Denominator = No. of *Aedes* examined.

* 4 *Aedes* gorged on 1 chick; 1 or 2 *Aedes* on the 5 other chicks.

‡ Each chick exposed to only 1 *Aedes*, which gorged.

only a single gland-positive (confirmed by dissection) *Aedes* gorged on, or probed, a chick, the chick developed a parasitaemia in every case. Thus, 100 per cent transmission (30/30) was obtained if a single *Aedes*, proven gland-positive, engorged on, or probed, a chick.

Comparison of malariometric data for thiotepa-treated *Aedes* follows.

II. *P. gallinaceum infection in Ae. aegypti exposed to thiotepa by resting on a treated surface*

(a) *3-hours exposure immediately after the P. gallinaceum meal*

(i) *Thiotepa deposit of 20 mgm. per square foot*

None of 650 eggs laid by 19 treated ♀♀ hatched, as compared with a hatch rate of 86·2 per cent of 2,641 eggs from the 44 control ♀♀ (Control A, Table I), indicating successful absorption of the alkylating agent sufficient to sterilize the mosquitoes themselves.

Parasitological findings in the thiotepa-treated *Aedes* were as follows:

Oocyst counts per mosquito (5th to 9th day):

15, 21, 108, 119, 222 and 542. (Geo. Mn. $^{(Wm.)}$=89·7 oocysts/gut.)

Sporozoites in glands:

8/8 *Aedes* were gland-positive from the 11th day onwards.

Transmission to chicks:

4 chicks were each gorged upon by a single *Aedes* on the 15th day of the extrinsic cycle. All 4 *Aedes* were gland-positive (graded + + +) for motile sporozoites but only 3 chicks developed a parasitaemia; the persistently negative chick was examined over a month.

Although the oocyst and sporozoite rates were not different from those of the controls, the mean oocyst count (in so far as it is a good comparison) suggests some depression of the parasite, and the single failure of a gland-positive *Aedes* to infect the chick on which it gorged suggested for this mosquito an effect on the sporozoites due to thiotepa.

Two further experiments were carried out at 3-hour exposures immediately after the *P. gallinaceum* meal, but increasing the deposit of thiotepa to 40 mgm. per square foot:

(ii) *Thiotepa deposit of 40 mgm. per square foot*

In one of these experiments, for which the control malariometric data are shown in Table I (Control Group B), successful sterilization of 110 *Aedes* ♀♀ by thiotepa is evident from failure of any of 2,063 eggs to hatch.

Parasitological findings were as follows:

Oocyst counts per mosquito (4th to 8th day):

1, 1, 2, 2, 3, 4, 6, 8, 9, 10, 11, 12, 14, 15, 15, 19, 25, 46 and 49. (Geo. Mn.$^{(Wm.)}$ =8·5 oocysts/gut.)

Sporozoites in glands:

Only 3/11 *Aedes* were gland-positive, 1 on the 11th and 2 on the 15th day.

Transmission to chicks:

Since 8 of 9 chicks were each engorged on by a gland-negative *Aedes*, they were not infected; a few sporozoites were seen in the 9th *Aedes* but the chick on which it gorged remained negative for *P. gallinaceum*.

Although the oocyst rates were not different from those for the controls (B, Table I), the mean oocyst count is again lower. And, although not statistically significant for these small samples, the sporozoite rate is interestingly lower at 27·3 per cent positive (3/11)—20·0 per cent (2/10) on the 15th day—as opposed to 85·7 per cent (6/7) in the controls. Inevitably, transmission to chicks was very unsuccessful with this low sporozoite rate. It is of interest that the only *Aedes* with positive glands which gorged on a chick failed to infect it; the glands, however, were very lightly infected.

Deaths in the controls (in 4 days) were only 3·7 per cent while, in this same period, 41·8 per cent of this treated group died.

In the next test of the same conditions of 3 hours' exposure just after the infecting meal and with a thiotepa paper at, again, 40 mgm. per square foot, the lethal effect on the *Aedes* was more pronounced.

Of 82 *Aedes* exposed, all but 4 died within 72 hours of exposure, a death rate of 95·1 per cent. Of 501 eggs obtained before deaths were so numerous, none hatched. In this period only 2 of 80 control ♀♀ died (2·5 per cent) (Control Group C, Table I). The malariometric data for the control (Group C) do not suggest that an unusually heavy malaria infection was the cause of the heavy mortality of the thiotepa-

treated *Aedes* in this experiment. Thus, these controls had an oocyst rate of 93·3 per cent, a mean oocyst count of 41·6, a range in positive ♀♀ of 4–198 oocysts per ♀, and a sporozoite rate of 97·1 per cent (33/34 *Aedes* positive). These data are, as Table I shows, less than in Control Group A in which deaths were nil. The considerable kill of mosquitoes appears to be due to their treatment with thiotepa.

Of the 4 thiotepa-treated *Aedes* which survived, 2 engorged—each on a separate chick—on the 13th day of the extrinsic cycle and one, gland-positive, successfully transmitted malaria to its chick host; the other was gland-negative. The remaining 2 *Aedes* were only dissected on the 13th day and 1 was gland-positive, the other gland-negative for sporozoites.

Thus, despite the lethal effect of thiotepa on the mosquitoes themselves, the few *Aedes* survivors included not only gland-positive ♀♀, but 1 ♀ which transmitted viable sporozoites causing parasitaemia in the chick on which it engorged.

(b) *2-hour exposure immediately after the infecting meal*

In view of this heavy death rate after 3 hours' exposure to the thiotepa surface at 40 mgm. per square foot, the period of exposure immediately after the infecting meal was reduced to 2 hours. In fact, this shorter exposure was made simultaneously, on a paired thiotepa paper, using 82 *Aedes* ♀♀ of the same lot; control infection data are, therefore, as in Control Group C.

The 2-hour exposure was effective in sterilizing the mosquitoes, no eggs hatching of 5,041 laid. But, parasitological data give little evidence that this lesser exposure affected the malaria parasite, nor was it notably lethal to the *Aedes*.

Parasitological findings were as follows:

Oocyst counts per mosquito (4th to 6th day):

1, 3, 5, 6, 18, 37, 42, 49, 49, 54, 78, 167, 205 and 358. (Geo. Mn. (Wm.)=31·4 oocysts/gut.)

Sporozoites in glands:

35/37 (94·6 per cent) *Aedes* were gland-positive, as observed by dissection, for motile sporozoites from the 12th to 18th day of the extrinsic cycle.

Transmission to chicks:

All of 24 chicks were each engorged upon, or probed by, a separate *Aedes*, every one proven gland-positive by immediate dissection after feeding, and every chick developed a parasitaemia. (The transmission feeds were on the 13th and 16th day of the extrinsic cycle.)

Only 4 *Aedes* deaths (5 per cent) occurred in the 72 hours after the infecting meal. Thus, the mosquitoes were not killed by this 2-hour exposure, and neither was there marked suppression of the development of the malaria parasite, nor inhibition of its transmission to chicks by the bites of infected *Aedes*.

(c) *1-hour and 2-hour exposures to 40 mgm. thiotepa per square foot, 24 hours after the P. gallinaceum meal*

Exposures were made of *Aedes* to thiotepa at various later times than immediately after the infecting meal on the malarious fowl. In view of the deaths of mosquitoes in experiments at 3-hour exposures, only 1-hour and 2-hour periods were tried in experiments with exposure at 24 hours after the malarious meal. The results were as follows:

(i) *1-hour exposure, 24 hours after malaria infection*

Control data for untreated, infected *Aedes* are as for Control Group B (Table I). About 50 treated ♀♀ laid 2,699 eggs, of which none hatched. This dosage was insufficient, however, to prevent transmission of the malaria parasite, 6/6 *Aedes* having sporozoite-positive glands (+ to + +) and they transmitted infection successfully by engorgement on 6 separate chicks on the 15th day.

(ii) *2-hour exposure, 24 hours after malaria infection*

Control data (Control B, Table I) for untreated, infected *Aedes* are as for the above ineffective 1-hour exposure, and also the 3-hour group (exposed immediately after the meal) in which, although the *Aedes* survived well, the malaria parasite was severely inhibited and transmission to chicks completely unsuccessful owing to most *Aedes* failing to develop sporozoite infections of the glands.

None of 2,455 eggs laid by approximately 50 ♀♀ exposed for 2 hours 24 hours after the malarious meal hatched, confirming absorption of the thiotepa. No oocyst counts were made for this group, but sporozoite and transmission data again indicate an effect on the malaria parasite.

Sporozoites in glands:

Only 6/11 (54·5 per cent) of the *Aedes* were gland-positive for motile sporozoites on the 15th day.

Transmission to chicks:

Only 2/5 chicks (40 per cent), each engorged upon on the 15th day by a separate *Aedes*, all proven by dissection to have motile sporozoites in their glands (graded + +), developed a parasitaemia.

Thus, although a 1-hour exposure 24 hours after a malarious meal sterilized the mosquitoes themselves but not their malaria infection, a 2-hour exposure at this same time reduced the sporozoite rate to 54·5 per cent and the transmission rate (by, let it be emphasized, proven gland-positive *Aedes*) to 40 per cent. These data are interestingly lower than the corresponding data for controls of, respectively, 85·7 per cent and 100 per cent. With the small size of samples the difference is not statistically significant. Nevertheless the biological implications of the differences, in conjunction with the findings of the other experiments, cannot be disregarded.

Deaths within 72 hours of thiotepa exposure were of the order of 28 per cent in these two experiments, higher than in controls (0 to 3·7 per cent) but lower than in the lethal exposures at 3 hours just after the blood meal, *viz.* 41·8 per cent and 95·1 per cent. Thus, at least with this 2-hour exposure, a detectable adverse effect of the alkylating agent on the development and the transmission of the parasite is again associated with some lethal action on the mosquitoes.

III. *Transmission by normal Ae. aegypti of P. gallinaceum circulating in chicks infected by the bites of thiotepa-treated Ae. aegypti*

The above findings show that *P. gallinaceum* could complete sporogony in, and be successfully transmitted to chicks by, *Ae. aegypti* sterilized by contact with thiotepa although certain heavy dosages could either inhibit oocyst development partially or altogether, render motile sporozoites non-infective, or be lethal to the mosquitoes. It could be concluded that in those cases where infections were transmitted to chicks, apparently quite successfully, by thiotepa-treated *Aedes*, the parasites observed in the chick parasitaemia carried, or might carry, genetic modifications in their chromosomes. These might not become manifest until their incompatibilities were tested further in syngamy, meiosis and mitosis during the extrinsic cycle in normal *Aedes*. The following observations were made to determine if the parasites circulating in such chicks could complete their development to sporozoites in the vector.

Untreated *Ae. aegypti* ♀ ♀ were allowed to engorge on 6 of the plasmodium-positive chicks which had developed a parasitaemia after infection by bites of thiotepa-treated *Ae. aegypti* and, as a check, on 4 of the control series of chicks infected by control, unexposed *Aedes*.

All 10 chicks proved infective to the mosquitoes, as follows:

Oöcyst counts per mosquito (4th to 7th day)

1. *Controls*

1st chick: 23, 23, 35 and 151 oocysts.
2nd chick: 9, 6, 83 and 91 oocysts.
3rd chick: 1, 4, 35, 39 and 65 oocysts.
4th chick: 3, 3, 10, 45 and 105 oocysts.

2. *Original transmission by Aedes exposed to thiotepa*

(a) *Immediately after infection for 3 hours at 20 mgm./sq. ft.*
1st chick: 15, 21, 28 and 31 oocysts.
2nd chick: 6, 9, 129 and 131 oocysts.

(b) *24 hours after infection*
(i) For 1 hour at 40 mgm./sq. ft.
1st chick: 45, 129, 256 and 306 oocysts.
2nd chick: 45, 68, 173, 234 and 348 oocysts.
3rd chick: 34, 61, 117, 143 and 139 oocysts.
(ii) For 2 hours at 40 mgm./sq. ft.
1st chick: 12, 27 and 37 oocysts.

Sporozoite infections

Motile sporozoites had reached the glands of mosquitoes infected from each of these chicks by the 9th to 10th day.

Transmission to chicks

Finally, a single *Aedes* from one of the control series, 2 *Aedes* in the 1-hour exposure group and 2 *Aedes* in the 2-hour exposure group were each allowed to engorge on a separate chick. All 5 chicks subsequently developed parasitaemia and died, proving that motile sporozoites of the second extrinsic cycle after thiotepa-exposure were transmissible and capable of causing an apparently normal infection in the recipient chick.

Discussion

Altman (1963), with the related alkylating agent tepa as a deposit on glass at 10 mgm./sq. ft., obtained good reduction of malaria infection in tepa-treated *Ae. aegypti* infected with *P. gallinaceum*. Oocyst data and transmission rates to fowls were considerably lower than in controls; in some trials, the parasite was eliminated from the treated vectors. Exposures were up to 9 hours just before, or after, the infecting meal or, at the sporozoite stage, for 1½ to 3 hours before feeding on fowls to test for transmission. However, no dissections were made for sporozoites in the glands of any of the *Aedes* so that it is not known if motile sporozoites were present in the glands of tepa-treated *Aedes* which failed to infect the fowls, although this inference might be made. Deaths of *Aedes* during exposure, or afterwards, sometimes occurred.

The present study shows, for the related compound thiotepa, that 3 hours' contact with a deposit of 40 mgm. thiotepa per square foot just after an infecting meal is effective in suppressing oocyst development to the extent that few or, often, no sporozoites develop to infect the glands. This exposure, however, approaches the lethal dose for the mosquitoes themselves, and most may die early in the extrinsic cycle of the parasite. Transmission to chicks fails necessarily in the absence of sporozoites but it is of particular interest that transmission also failed with 2 *Aedes* which had each gorged fully on its chick host, one with few and the other with numerous sporozoites (+ + +) in their glands. The latter had been exposed to only a 20 mgm. deposit for 3 hours. At this lighter exposure as well as after the heavier exposure a total of 4 *Aedes*, however, infected their chick hosts, with resultant parasitaemia and death. Altman (*loc. cit.*) observed oocyst growth to be retarded; our observations were essentially in agreement. Final failure in the development of many oocysts may not be obvious until shortly before sporozoite formation, *i.e.* about a week after the infected vector has rested on the thiotepa deposit. At the rather lighter dosage of 2 hours on a 40 mgm. deposit, this time at 24 hours after the infecting meal, the sporozoite rate dropped by 30 per cent and 3 *Aedes* with glands graded + + for sporozoites failed to infect the chick host although gorging well. This effect against the malaria parasite was again associated with some toxicity to the mosquitoes themselves. Finally, a 1-hour exposure on the day after the malarious meal and a 2-hour exposure just after the meal, both on a 40 mgm. deposit of thiotepa, had no conspicuous effect on the extrinsic cycle of the malaria parasite. All of 30 gland-positive *Aedes* each infected its chick host successfully. Notwithstanding this failure against the plasmodium, the eggs of the *Aedes* were sterilized.

The motile sporozoites in the glands of 5 thiotepa-treated *Aedes* which failed to produce a parasitaemia in chicks were, it may be concluded, abnormal, either physiologically or genetically, to a degree preventing in some as yet indeterminate way, normal parasitisation of the chick host. As regards thiotepa-treated *Aedes* which did induce parasitaemia in the chick, these may also have transmitted sporozoites which were abnormal, although insufficiently so to prevent apparently normal parasitisation with parasitaemia. If, indeed, the parasites were abnormal they were not sufficiently modified, physiologically or genetically, to prevent them from undergoing in the vector syngamy and meiosis in the first 2 days or so after ingestion (Bano 1959), or subsequent mitoses in the production of sporozoites. Moreover, the resultant sporozoites could invade the salivary glands of the vector and be transmitted to cause parasitaemias in further chick hosts. Presumably, serial transmissions could go on indefinitely, unless with time some recessive genetic changes induced at initial exposure of the vector were able to manifest themselves by, for example, cessation of parasite development in the chick, or mosquito, host. Alternatively, successful serial transmissions by thiotepa-treated *Aedes* may be explained as due to the presence of some normal sporozoites in the glands derived from a proportion of the parasites which, by chance, escaped the action of the alkylating agent.

It is of particular interest that light exposures which were adequate to sterilize the mosquito eggs had no apparent effect on the malaria parasite, and that, at the other extreme, complete suppression of the malaria extrinsic cycle was obtained only at an exposure which was highly lethal to the mosquitoes themselves. Intermediate exposures which were rather less harmful to the vector (although still sterilizing the eggs) only partially suppressed the malaria parasite in the vector. Oocyst infections and sporozoite rates were lowered; some gland-positive vectors failed to infect the chicks on which they fed.

This relative insusceptibility of the malaria parasite is not favourable to the theory (Lindquist 1961) that chemosterilants might increase

the efficacy of control of an insect-borne disease by their adverse effect on the parasites as well as on vector sterility. In view of the mutagenic mode of action of alkylating agents it would be more acceptable in principle to aspire only, with lesser dosages, to sterilise the eggs of the vector or to kill the mosquito by methods less intrinsically hazardous to other forms of life.

This point of view does not, however, take into account the effects of other periods of exposure and different deposits of the chemosterilant, nor the effect of the chemosterilant on the malaria parasite at phases of the extrinsic cycle other than early stages.

Summary

1. *Aedes aegypti* ♀ ♀ infected with *Plasmodium gallinaceum* were allowed to rest on paper surfaces treated with thiotepa at 20 mgm. or 40 mgm. per square foot for 1, 2 or 3 hours just after, or 24 hours after, the infecting meal on a malarious fowl.

2. None of nearly 13,000 eggs of the thiotepa-treated *Aedes* hatched, as opposed to 75 per cent of 9,403 control eggs, indicating absorption of thiotepa sufficient to sterilize the mosquito eggs.

3. Almost complete suppression of the growth of the oocysts, and failure of glands to become infected with sporozoites, was obtained at exposures of the *Aedes* for 3 hours just after the infecting blood meal to deposits of 40 mgm. thiotepa per square foot. This approached the lethal dose for the mosquitoes themselves; deaths were numerous.

4. 2 hours' exposure 24 hours after the meal, at 40 mgm. per square foot, caused partial suppression of oocyst development; about 50 per cent of *Aedes* did become gland-positive for sporozoites. A few of the gland-positive *Aedes* failed to infect chicks although they had gorged well on the chick host. This dosage was also rather toxic to the insects.

5. Exposure for 3 hours on a 20 mgm. deposit just after the meal was mostly ineffective, but, again, one gland-positive *Aedes* failed to infect the chick on which it engorged.

6. With 40 mgm. per square foot deposits, 2 hours' exposure just after the infecting meal and 1-hour exposure 24 hours after had little or no effect on the malaria parasite and its transmission to chicks.

7. Chicks developing a parasitaemia after the bites of thiotepa-treated *Aedes*, were infective to the vector and the infection was transmissible, with parasitaemia and deaths, to further chicks.

8. Thus, thiotepa approaches complete effectiveness against the early stages of the malaria parasite in the mosquito only at dosages which tend also to be lethal to the vector, and which are considerably in excess of the effective sterilization dose for the eggs of the vector.

9. These experiments on the early stages of the malaria extrinsic cycle offer little support to the concept that the efficiency of malaria control would be enhanced by the dual effect of an alkylating agent sterilizing both the parasite and the vector. It would seem more acceptable to kill the vector by methods less intrinsically hazardous to other forms of life, or to aspire only to chemosterilization of the mosquitoes themselves.

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INVESTIGATIONS ON THE MOLLUSCICIDAL EFFECTS OF THE FRUITS OF *SAPINDUS SAPONARIA* ON THE BILHARZIA VECTOR SNAIL, *BULINUS (PHYSOPSIS) AFRICANUS*

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INTRODUCTION

Many substances of vegetable origin are known to be lethal to snails. Mozley (1939, 1952) who tested a number of different vegetable substances against bilharzia snails listed the fruits of *Balanites aegyptiaca*, *Sapindus saponaria* and *Swartzia madagascarensis* as being among the most promising vegetable molluscicides. The active principles in the fruits of these plants are known to be saponins which are glucosides. Apart from their molluscicidal properties, saponins are also known to be highly poisonous to fish and other cold-blooded animals. Mozley, in laboratory experiments, obtained a 24-hour mortality of 100 per cent using a 0.015 per cent solution of a saponin (from chemical manufacturers) against the snail *Physopsis globosa*.

Apart from Mozley's observations no critical scientific work seems to have been carried out regarding the possible use of naturally occurring vegetable molluscicides for the control of bilharzia snails. Mozley was led by his work to draw the conclusion that although vegetable molluscicides were unlikely to replace the conventional chemical molluscicides, they might find use as accessory or additional molluscicides.

In most places where bilharzia is a public health problem, the disease and the vector snails are often scattered over a wide area. This makes it difficult for developing countries, where the disease is endemic, to afford a country-wide bilharzia control programme based on snail control by commercial molluscicides. With this realisation a closer look into the possibilities of vegetable molluscicides is indicated.

This article describes various aspects of the molluscicidal effects of the fruit of the soap berry-tree *Sapindus saponaria* which grows widely along the coastal areas of East Africa and on the islands of Zanzibar and Pemba. Most of the experiments were carried out under laboratory conditions and were followed by a single field experiment.

MATERIALS AND METHODS

Adult healthy looking specimens of *Bulinus* (*Physopsis*) *africanus* were collected from a permanent pond at Kurasini within the city of Dar es Salaam where they thrive throughout the year. The snails were taken to the laboratory and kept in water from the breeding site for 24 hours before being used.

Ripe fruits of *Sapindus saponaria* were collected during November-February and stored in the laboratory to be used as required. The fruit is roundish, has a diameter of about 20 mm. and a central round stone seed of about 10 mm. in diameter. The fruit pulp is somewhat sticky and has a consistency of a stiff jelly. The skin of the fruit is tough and leathery.

In preliminary trials it was found that only the pulp of the fruit contained the active principle. Tests with the seed (whole or crushed) indicated that it had no molluscicidal effect whatsoever. In fact the snails were found to be feeding on the crushed seed.

For each test in the experiments carried out ten or twenty snails were placed in 500 ml. of pond water from the breeding site in white enamel bowls and treated as required. Although observations were made at shorter or longer intervals mortality was always recorded 24 hours after treatment. A snail was regarded as dead when it retreated into its shell completely and/or failed to respond to a prick with a sharp object on its soft parts. Death was found to be often accompanied by haemorrhage. A few dead snails were found to have completely come out of their shells.

EFFECT OF DIFFERENT CONCENTRATIONS OF THE ACTIVE PRINCIPLE

Twenty snails were treated with different quantities of the fruit pulp, and mortality was observed after 24 hours. The results are shown in Table 1.

Table 1

THE MOLLUSCICIDAL EFFECT OF DIFFERENT QUANTITIES OF THE FRUIT PULP ON TWENTY SNAILS

Weight of Pulp in gm. per Litre of Water	*No. of Snails Dead after 24 Hours*	*Mortality Per cent*
0.0 Control	0	0
0.1	3	15
0.25	16	80
0.5	20	100
1.0	20	100
2.0	20	100
4.0	20	100

Table 1 shows that under the conditions of the experiment 0.5 gm. or more of the fruit pulp per litre of water produced enough concentration of the active principle to cause 100 per cent mortality of the snails in 24 hours.

It was noted during this experiment that the active principle affected the snails very quickly. In the tests with 1 gm. or more of the pulp per litre, for example, it was noted that all the snails were knocked down within 30 minutes of exposure and never recovered from the shock.

THE DIFFUSION OF THE ACTIVE PRINCIPLE INTO THE WATER

This experiment was designed to try to find out how quickly the active principle was extracted from the fruit pulp. The fruit pulp was weighed out in 1 gm. lots and placed in 500 ml. of water for different periods after which the water extracts and the pulp residues were used against 10 snails. The results are shown in Table 2.

Table 2

THE MOLLUSCICIDAL EFFECT OF WATER EXTRACTS AND RESIDUES OF IMG. OF THE FRUIT PULP AGAINST TEN SNAILS

Time of Extraction	*24-hour Mortality Per cent*	
	Water Extract	*Residue in 500 ml. of Water*
Control	0	0
1 Min.	0	100
2 Min.	0	100
5 Min.	30	100
10 Min.	40	100
30 Min.	100	100
24 Hours	100	100
48 Hours	100	60

Table 2 shows that the active principle diffuses fairly rapidly into the water but that in the uncrushed pulp considerable amounts of it remain within the pulp for up two days. When the extraction time was 24 hrs., it was found that there was still enough of the active principle left for the residue to produce a snail mortality of 100 per cent. However, after 48 hours of extraction, this mortality was reduced to 60 per cent.

THE EFFECT OF SHORT TIME EXPOSURES OF THE SNAILS TO DIFFERENT CONCENTRATIONS OF THE ACTIVE PRINCIPLE

It was considered important to know how long it was necessary for the snails to remain exposed to lethal concentrations of the active principle in order to receive lethal doses.

Ten snails were exposed to different concentrations of the active principle for different lengths of time and were then placed in clean pond water. The 24-hour mortalities are shown in Table 3.

Table 3

THE MORTALITY OF TEN SNAILS EXPOSED TO DIFFERENT CONCENTRATIONS OF THE FRUIT PULP FOR DIFFERENT PERIODS

Time of Exposure	*24-Hour Mortality*				
	Control	*0.25 gm/litre*	*0.5 gm/litre*	*1 gm/litre*	*2 gm/litre*
15 Min.	0	0	0	0	10
30 Min.	0	0	0	10	20
1 Hour	0	0	0	30	90
2 Hours	0	0	20	40	100
4 Hours	0	10	80	100	100

Table 3 shows that whereas at high concentrations of the active principle relatively short exposures are sufficient to kill the snails, at low concentrations exposures of several hours are necessary.

It was noticed during this experiment that although many snails were knocked down soon after being placed in the treated water, many of these, especially in the lower concentrations, recovered after being transferred to clean water.

THE EFFECT OF SOIL ON THE MOLLUSCICIDAL ACTIVITY OF THE FRUIT PULP

Although the results of the above experiments seemed encouraging, it was possible that in the field there might be factors which would interfere with the molluscicidal effect of the fruit. One such factor could be the underlying soil in a snail habitat. Thus the effects of different soils on the molluscicidal activity of the fruit pulp were investigated.

All the soils used in this experiment were obtained from natural habitats of *Bulinus* (*Physopsis*) *africanus*. The snails were placed in a bowl containing 250 ml. of the soil and 500 ml. of pond water and were treated with different quantities of the fruit pulp. No soil was used in the control. The results are shown in Table 4.

Table 4

THE MOLLUSCICIDAL EFFECT OF THE FRUIT PULP IN WATER CONTAINING SOIL

Quantity of Fruit Pulp gm/litre.	*24-Hour Mortality Per cent on Ten Snails*				
	Control (No Soil)	*Mud Magomeni*	*Mud Kurasini*	*Sand Kurasini*	*Clay Kinondoni*
0.5	100	80	80	70	70
2.0	100	—	—	100	100
4.0	100	100	100	100	100

Table 4 shows that the presence of different types of soil in the water slightly reduces the molluscicidal effect of the fruit. Thus whereas a concentration of 0.5 gm/litre of the fruit pulp in water produced a snail mortality of 100 per cent in the absence of soil, the addition of soil reduced this mortality by 20-30 per cent.

EFFECT OF THE FRUIT PULP ON OTHER FORMS OF AQUATIC LIFE

1. *A Small Type of Fresh Water Fish*

A concentration of the fruit pulp of 1 gm/litre of water was found to kill all the four individuals of a small species of fresh water fish (unidentified) within three hours; there was no mortality in the control.

2. *Larvae of Mosquitoes*

The fruit pulp at concentrations of 1 gm/litre and 2 gm/litre of water was found to have no effect at all on 100 4th instar laboratory-bred larvae of the mosquito, *Culex fatigans*.

EFFECT OF DRYING THE FRUIT

It was found that when the fruit pulp was dried to constant weight in the oven at 80°C. and then ground into powder, the molluscicidal activity was not lost.

EXTRACTION OF THE ACTIVE PRINCIPLE WITH BOILING WATER

When the fruit pulp was boiled in water for ten minutes, it was found that the molluscicidal effect of the cooled extract was unimpaired.

THE PERMEABILITY OF THE FRUIT SKIN TO THE ACTIVE PRINCIPLE

A whole intact fruit was placed in water containing snails. No molluscicidal activity was detected for up to three days. Thus in order that the active principle of the fruit may diffuse into the water and kill snails, it is necessary for the tough leathery skin to be broken.

FIELD TRIAL

For this experiment the pond at Kurasini mentioned above was chosen. This pond contained many *Bulinus* (*Physopsis*) *africanus* whose fluctuation in population density had been studied for about a year.

The experiment was carried out at the height of the dry season when the water level was at its lowest. The pond was circular in shape and a day before the experiment was found to contain water to a diameter of about twenty metres and to an average depth of about 0.25 metres. This gave a water volume of about 78 cubic metres. This water was treated with 120 kg. of crushed berries of *Sapindus saponaria*. The berries had previously been found to have a pulp content of about 65 per cent and hence the dosage applied was about 1 gm of the fruit pulp per litre of water or 1 Kg. of the fruit pulp per cubic metre of water. The berries were placed in gunny bags and then crushed by being run over several times by a steam roller on a hard surface. The resultant product had the appearance of commercial dates but was much more sticky.

The crushed berries were scattered by hand over the whole pond as evenly as possible. The snail population density was estimated just before the experiment by counting the number of snails caught per one man-hour of search. The number of dead snails found during this counting was also recorded. This operation was repeated 24 hours after the experiment and thereafter the pond was kept under observation for 2 months.

The results (Table 5) show that within 24 hours of treatment there was no live snail to be found in the pond. Apart from masses of dead snails, large numbers of dead tadpoles (*Xenopus sp.*) were found floating all over the water surface. Two days after the treatment of the pond the long rains started and within a week the water level had risen about 2 inches.

Live snails were first noticed in the pond eleven days after the treatment, and thereafter there was a rapid build-up of the snail population as is evident from Table 5. It is considered that the rapid increase of the snail population was largely due to snails that had come out of aestivation after the rains since most of the snails were of medium and large size. This view is supported by parallel observations in another pond (Buguruni) which, being of a temporary nature, had dried up completely during the dry season and had been repopulated by snails (*Bulinus africanus*) after the onset of the rains. It is evident from Table 5 that the population increases in the two ponds were remarkably similar.

Table 5

SNAIL POPULATION DENSITIES IN A PERMANENT TREATED AND A TEMPORARY NEWLY-FILLED POND

Date	*Permanent Pond (Kurasini)*		*Temporary Pond (Buguruni)*
22 March '65 (Pre-treatment count)	486	(7 Dead)	Pond Dry
		Pond Treated	—
23 March 65	Zero	(443 Dead)	Pond Dry.
25 March 65		Rain Started	
5 April 65	74		Not Collected
23 April 65	24		75
7 May 65	150		267
14 May 65	213		229
21 May 65	120		150
28 May 65	109		117

DISCUSSION

In his laboratory experiments, Mozley used cold and warm infusions prepared from 30 gm of the fruit pulp of *Sapindus saponaria* in 250 ml. (120 gm/litre) and obtained 100

per cent kill of *Physopsis globosa* after 21-hour exposure. A similar cold infusion prepared from the broken up seeds of the fruit was found to have no effect after 16 hours.

These results agree with those obtained in the laboratory in the present work. It should be noted however that Mozley's laboratory dosage of 120 gm/litre was 240 times higher than the minimum dosage of 0.5 gm/litre found in the present work to be sufficient to produce 100 per cent mortality of *Bulinus africanus* in 24 hours.

In his field experiments Mozley used a pond about 200 metres in diameter and a maximum depth of about 2 metres. If it is assumed that the average depth of the pond was only about 0.5 metre, this would give a water volume of about 15,000 cubic metres. Since the pond was treated with 200 lbs. of whole berries (corresponding to less than 60 Kg. of fruit pulp), the dosage applied was less than 0.004 gm/litre which was about 125 times less than the dosage found in the present work to be minimal for 100 per cent mortality in 24 hours under laboratory conditions and about 250 times less than the field dosage applied in the present work.

Considering the low dosage and the fact that the berries were applied unbroken it is surprising that Mozley got any kill at all. It is possible however that the mortality in his field experiment was due to localised pockets of high concentration as a result of an uneven distribution of the berries in the body of the pond. Since laboratory observations in the present work indicated that a complete intact berry with the skin unbroken had no molluscicidal effect, it is reasonable to assume that at least some of the berries used by Mozley in his field experiment had broken skins.

It is evident from the present work that the fruit of *Sapindus saponaria* are effective against *Bulinus* snails when applied at sufficient dosages by an appropriate method.

It would appear that the main disadvantages of this vegetable molluscicide are its lack of any residual effect, the fact that for effective application somewhat clumsy methods of preparation are called for and that like some of the commonly used molluscicides it is toxic to fish.

To get the best results it is considered that the fruit should be applied at a time when there are no snails aestivating and that it should be previously crushed before application. This means that the best time of application would be at the end of the rainy season.

The most suitable snail habitats for treatment by this method would be small bodies of water such as small pools, ponds, wells, and roadside excavations since in most cases it would be almost impossible to get the large quantities of fruit necessary to treat large bodies of water. In many places such small bodies of water form important habitats for bilharzia vector snails. Webbe (1962) and Kinoti (1964) have shown that in the Lake Region of Tanzania around Mwanza small bodies of water such as those mentioned above were the main sources of bilharzia transmission and that large dams were relatively unimportant in this respect.

SUMMARY

1. The molluscicidal effects of the fruits of *Sapindus saponaria* against *Bulinus* (*Physopsis*) *africanus* were investigated both under laboratory and field conditions.

2. A dosage of 0.5 gm of the fruit pulp per litre of water was found to be sufficient to produce 100 per cent mortality of the snail within 24 hours.

3. It was found that the active principle was confined to the fruit pulp, that it diffused rapidly into the water, and that it was stable to drying.

4. At the dosages that were lethal to bilharzia snails the fruit pulp was found to be toxic to fish and to tadpoles but not to mosquito larvae.

5. A dosage of 1.0 gm of the fruit pulp per litre of water was found to kill all *Bulinus* (*Physopsis*) *africanus* snails that were in the water of a natural pond.

6. It was found that the active principle had no residual effect.

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