VECTOR SPECIES OF GUINEA WORM IN WEST AKIM DISTRICT OF GHANA, AND THE EVALUATION OF ABATE AS A CYCLOPSCIDE.

BY

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DECLARATION

This research work was conducted by me as presented, under the supervision of Prof. J. K. M. Hodasi of the Zoology Department, University of Ghana, Legon.

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DEDICATION.

In ever loving memory of my late sister Miss Joyce Feikandin Bimi.

May your soul rest in perfect peace.

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ABSTRACT

Field studies were performed to identify the vector species of *Dracunculus medinensis*. From these studies, *Mesocyclops kieferi* was implicated as a major vector. Other vector species identified were *Mesocyclops aspericornis* and *Thermocyclops inopinus*. Studies were also carried out in the endemic villages using a questionnaire to ascertain the pattern of disease incidence during the years 1994-1996. The results revealed that the socio-cultural practices of the people assist in promoting the disease transmission. Of particular interest was noncompliance with control measures as well as traditional beliefs in the incidence and mode of transmission of the disease.

Toxicity studies were also undertaken in the laboratory to evaluate the effect of Temephos (ABATE) on different species of *Cyclops* (the vector of Dracunculiasis). Results obtained from these tests indicated 24-hr. LC50 values of 0.58, 1.59, 1.28 and 0.94ppm for *Mesocyclops kieferi, Mesocyclops aspericornis, Thermocyclops inopinus* and a mixture of species respectively. The corresponding LC95 values were 9.15, 6.98, 3.33 and 2.42ppm. Following a 48-hr. exposure, the concentrations of the insecticide required to effectively kill 50 and 95% of the *Cyclops* (mixture) were 0.34 and 0.84ppm respectively. An expired stock however produced 1.65ppm (LC50) and 5.36ppm (LC95) after a 48-hr. exposure.

LIST OF SYMBOLS AND ABBREVATIONS.

(1) BHC	Benzene hexachloride
(2) CDRs	Committees for the Defence of the Revolution
(3) DBL	Danish Bilharziasis Laboratory
(4) DDT	Dichloro-diphenyl-tetrachloro-ethene
(5) GW	Guinea Worm
(6) GWD	Guinea Worm Disease
(7) GWEP	Guinea Worm Eradication Programme
(8) GWEPS	Guinea Worm Eradication Programmes
(9) HE	Health Education
(10) IDWSSD	International Drinking Water Supply and Sanitation Decade
(11) L_1,L_2,L_3	Larval stages 1,2 and 3 respectively
(12) LC	Lethal Concentration
(13) MOH	Ministry of Health
(14) NGO	Non-Governmental Organization
(15) Res.	Resolution

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Chapter 1

1.0 INTRODUCTION

Guinea worm infection belongs to a group of maladies generally known as tropical diseases. These diseases which are caused by various parasites, are commonly associated with ignorance, poverty, malnutrition and squalor. As it is, parasitic diseases have been virtually eradicated from those countries in which the high socio-economic and educational standards of the people have engendered a proper appreciation of the important role played by personal and environmental hygiene in the epidemiology of communicable diseases. Further more, the provision of potable water, an increase in the level of awareness of the people on the aetiology of the disease as well as the creation of conditions which inhibit breeding and development of insects and other vectors of these diseases, lead to an improvement in the welfare of the people (Ukoli, 1992).

In contrast to the situation in the developed countries, life in tropical Africa, like in other parts of the Third World, is characterised by the terrible trinity of poverty, ignorance and disease. Forgetting for the moment the debate on which came first in this vicious cycle, the net results is that they are interdependent. This cycle must be broken if any progress is to be made in the socio-economic development of the afflicted countries. Secondly, the health profile of these nations is dominated by the most debilitating and disabling of parasitic diseases such as malaria, schistosomiasis, trypanosomiasis, leishmaniasis and filariasis (including onchocerciasis and Dracunculiasis). Although these parasitic diseases form one of the obstacles to the development of the Third World, national budgets are unfortunately often too meagre for preventing or controlling them effectively. The major preoccupation of the people, and this is a more realistic

view, is to secure enough food, reasonable environmental quality and develop societies in which humane values prevail (Kale, 1990; Ukoli, 1992).

Apart from the internationally quarantinable diseases (cholera, plague, and yellow fever) which from time to time occur as pandemics, there are those which are confined to special risk groups within defined national boundaries. Diseases in this group include measles, meningitis and paralytic poliomyelitis. The third group is made up of the "invisible" and neglected epidemic diseases. Invisible and neglected because, although they are often fatal, they tend to occur in and be confined to remote agrarian communities. These residents, although constituting approximately 75-80% of the population in Africa, have little or no access to even the most basic modern health facilities (Kale, 1990; Rab *et al.*, 1991). Moreover, these communities do not possess the sort of political, economic or social clout that could compel urban-based decision makers and providers of medical care to undertake meaningful and effective interventions aimed at eliminating or controlling these diseases. A classical example of a disease that belongs to this group is Dracunculiasis or Guinea worm infection (Kale, 1990).

This filarial infection has until recently been neglected in national control programmes because there is no effective treatment currently available and affected villagers rarely seek medical care. However, the fact that Dracunculiasis causes severe disability, with major consequences for public health, education and agriculture have been highlighted (Smith *et al.*, 1989; Brieger and Guyer, 1990; Kambire *et al.*, 1993).

Despite its low case-fatality, Guinea worm Disease does cause severe disability, often for protracted periods of time and at critical times of the agricultural season (Belcher *et al.*, 1975; Kale, 1977; Nwosu *et al.*, 1982). While the annual prevalence rates vary widely from one area

another, some villages report an annual prevalence rate of up to 70%, with the disease primarily affecting the most productive members of the village (Belcher *et al.*, 1975; Kale, 1975; Nwosu *et al.*, 1982; Hopkins, 1983; Edungbola and Watts, 1985).

A true case of Guinea worm is recognised as a long, white thread-like worm coming out from an ulcer or sore on the skin of the affected person (Brieger and Rosenwieg, 1988; Rab, *et al.*, 1991). The mature worm makes a partial exit to discharge its larvae into water in the process of procreation. Ebenhard *et al.*, (1989), however reported two unusual cases of *Dracunculus medinensis*. Both involved the emergence of a bright red worm, typical in size and location to *D. medinensis*. "To our knowledge, these cases are the first reported in modern literature of the emergence of red worms through the skin of humans", they concluded. Clinical features of Guinea worm at the time of blister formation (the first sign of infection), include local itching, urticaria and a burning sensation at the site of a small blister (Muller, 1971).

Dracunculiasis, although posing a serious health problem in Africa, Asia and the Middle East where people rely on ponds or wells for their drinking water, remained as an ignored problem for many years. There is now, however, a greater realization of the public health importance of the disease, especially the burden it posses on human health and welfare, and in particular on agricultural productivity. There is therefore heightened interest in the eradication of the disease in Ghana as a means of removing a serious obstacle to socio-economic development, especially in the rural areas.

It is however important to note that the Guinea Worm Eradication Programme (GWEP) in the country has a checkered history, with documented dates of commencement ranging from 1987 to 1989. The Plan of Action of the GWEP in Ghana states the methodology, strategy,

targets and the estimated cost of achieving the objective of total eradication of the disease by the year 1995 (this date has since been extended twice; the current target date being 6th March 1997). The programme in Ghana began identifying and training resident village volunteers (VVs) to report cases of dracunculiasis in endemic communities in the early part of 1989 (Hopkins *et al.*, 1991). Control measures were directed towards freeing domestic water sources of *Cyclops* and preventing infected people from contaminating water supplies. These measures included boiling, filtering and chemical treatment of unsafe drinking water (Quashie, 1982).

The GWEP in Ghana is supported by the government as well as donor agencies such as the Carter Centre in Atlanta Georgia, the then Bank for Credit and Commerce International (BCCI) and the Sasakawa Global 2,000 Project. Since the government recognized the need to eradicate Dracunculiasis as a means of poverty reduction, the National Guinea Worm Eradication Programme was incorporated into the Ministry of Health (MOH) with an autonomous administration headed by a National GWEP Coordinator. The mandate of the programme was to evolve a focal control strategy for eradicating the disease by 31st. December, 1995. The intervention strategies adopted were based on seven points:

(i) Surveillance.

(ii) Health Education (HE).

(iii) Provision of safe drinking water.

(iv) Training.

(v) Monitoring and evaluation.

(vi) Research.

(vii) Vector control.

The main emphasis of the GWEP as of July 1995 was all but research. An extraordinary level of public mobilization was achieved in June 1988 when the Head of State, Flt. Lt. Jerry John Rawlings spent eight days visiting 21 villages in which the disease is endemic in the Northern Region, promoting the goals of the national eradication campaign: "an exceptional degree of involvement by any head of state in combatting any disease" (Report on IDWSSD Impact on Dracunculiasis, October 20, 1989). Ghana also began distributing several copies of a manual to Secondary Schools in 1989 for teaching on the Guinea worm disease. Both Ghana and Nigeria are placing great emphasis on Health Education, Community Mobilization and Rural Water Supply in their control programmes. An extensive use of Temephos (ABATE) in selected villages began in these countries in 1991 (Report on IDWSSD Impact on Dracunculiasis, October 20, 1989).

Chapter 2

2.0 LITERATURE REVIEW.

2.1.0 HISTORY OF *DRACUNCULUS MEDINENSIS.*

Guinea worm disease (Dracunculiasis, Dracontiasis, or Dracunculosis), is one of the ancient scourges of mankind. It is believed to be the "Fiery Serpents" referred to by Moses in the Old Testament (Numbers, 21:6) when it plagued the inhabitants settled along the shores of the Red Sea at that time (Rab, 1989; Muller, 1971). This fact is further buttressed by the many vernacular names used to describe the parasite (Guinea worm, Medina worm, filaire de Medine, le dragonneau, pharaonswurm (Muller, 1971; Ukoli, 1992).

The first documented information on *Dracunculus medinensis* (Linnaeus, 1758) was found in the writings of Egyptian, Roman and Greek physicians (Litvinov and Lysenko, 1982). Al Rhazes (865-920) showed for the time that swelling caused in the disease is due to a parasite, the Guinea worm. Avicenna (980-1037) was the first to give a detailed clinical description of an illness that was called Madina sickness which was common in that region.

Historically, there has however been a lot of debate concerning the origin of the disease. Yelifari (1993) reported that Manson-Bahr (1966), believed it was imported from America, while Abren described it as an African disease (Guerra, 1968). Likewise, there seems to be considerable confusion concerning the nature of the disease. Thus, while Aetius Paulus and Rhazes felt it was a worm, others such as Seramus and Pollux called it a corrupt nervous substance. Still other schools of thought had different interpretations. Garraeus, Aldrovni and, Montramus felt it was a tumour, an abscess, an elongated vein, a black bile, a fibrous concentration or an atrophied cellular tissue.

tissue. Undoubtedly, Amatus Lusitanius (1551- 1568), was aware of the animal origin of Guinea worm as he wrote; "authors are in doubt whether this is a nerve, a vein or a worm. But I have seen the condition with my own eyes and bear witness that a thin white worm in many coils was found" (Grove, 1990; as cited in Yelifari, 1993).

In 1674, Velschius wrote about how *Dracunculus medinensis* was put on ancient Roman emblems, in Arabic lettering, in many Greek sculptures and in the emblem of the medical profession and still described it as verminous. According to Yelifari (1993), Avicinus, following Galen, thought that the disease was of nervous origin until he noted the animal origin of the pathogen. Also, Monographs by Velschius (1674) and Barlet (1909) give lists of historical references (Muller, 1972). Interest in the structure of the parasite dates from the seventeenth and eighteenth Centuries. In 1674, Velschius described the parasite and discussed various theories concerning its existence. In 1758, Linnaeus published his *Systema Naturae*, in which names were given to all the then known helminths, including the dracunculus parasite, which therefore bore the name *Dracunculus medinensis*.

In 1868, a young Russian researcher called Alexksi Pavloviv Fedchenko (1844-1873) noted the great harm caused by *Dracunculus medinensis* to the health of the populations of Samarkhand, Bukhara, Dzizak and Karshi. Consequently he begun to study the disease in 1869. Until the middle of the nineteeth Century, there were four points of view as to how humans contracted the disease. Thus, the parasite larvae either: (i) were carried by insects, (ii) were dispersed in the air and entered the human body when infected air was breathed, (iii)entered the human body with food and water or (iv) were present in ponds and soil and entered the human body through uncovered parts.

In 1869, Fedchenko discovered *Dracunculus medinensis* larvae in the body cavity of a copepod (*Cyclops*). He also successfully infected *Cyclops* with larval parasites in a number of experiments and traced their development in the *Cyclops*. Fedchenko's discovery of the intermediate host of dracunculiasis provided information on the life-cycle of the helminth and explained how the disease is contracted. This was one of the mile-stones in the history of tropical medicine, as it was the first record of an arthropod acting as an intermediate host in the transmission of a human disease, some years before Manson's more famous implication of *Culex* mosquitoes in the transmission of bancroftian filariasis. Based on this discovery, Fedchenko put forward the epidemiological formula of Dracunculiasis: *Cyclops* are the intermediate hosts; *Cyclops* are infected with larval parasites that enter water from a person with the disease; and man becomes infected when he drinks unwholesome water containing *Cyclops* with mature larvae in their bodies (Litvinov, 1982).

2.2.0 TAXONOMY AND LIFE-CYCLE OF *DRACUNCULUS MEDINENSIS.* 2.2.1 Taxonomy

The phylogenetic systematics of *Dracunculus medinensis* has seen some form of metamorphosis as has been the case for most organisms. In literature therefore, the Nematoda is sometimes listed as a class within another phylum, the Aschelminthes. The Aschelminthes are often referred to as the "Cavity worms" because they posses a pseudocoel. The majority of groups contained within the Aschelminthes (Nematoda, Rotifera, Gastrotricha, Kinorhyncha, Nematomorpha, Acanthocephala and Gnathostomulida) are now generally considered more distantly related, so that each class has been elevated to the phylum status (Pechenik, 1991). Thus, *Dracunculus medinensis* has been assigned the following taxonomic groups.

PHYLUM: Nematoda

CLASS: Secernentea.

SUBCLASS: Spiruria.

ORDER: Camallanida.

FAMILY: Dracunculidae.

GENUS: Dracunculus.

SPECIES: medinensis.

SCIENTIFIC NAME: *Dracunculus medinensis.*

COMMON NAME: Guinea worm.

2.2.2.0 LIFE-CYCLE OF *DRACUNCULUS MEDINENSIS* .

2.2.2.1 Discovery.

Although the discovery of the Life-Cycle of *Dracunculus medinensis* has usually been credited to Fedchenko (1869), Manson-Bahr (1966) made the following statement: "Fedchenko (1869) is credited with the discovery of the transmission of the guinea worm, but probably, Manson was the original observer (1895). He believes that the stages figured by the former are those of *Cucullanus spp* (a parasite of fish), and not *D. medinensis*" (Hughes, 1967). Hughes however agrees that Fedchenko correctly postulated that human infection is caused by the ingestion of infected *Cyclops* in drinking water. This was obviously because he was already aware that the life-cycle of some parasitic helminths involved alternative hosts, and he was looking out for such a host for the Guinea worm.

Conversely, an investigator 75 years earlier did not know about alternative hosts, and so he (Manson) missed the complete story as unfolded by Fedchenko. Colin Chisholm (1795) also noted the occurrence of the "dracunculus or Guinea worm" and wrote: "The cause of this singular disease seems to be confined to the water of some wells". He described how filling up these wells prevented the spread of the disease, and continued; "In the water which contains the embryos of the dracunculi, the naked eye distinguishes innumerable animalculi, darting in every direction with astonishing force and rapidity; these on being subjected to examination with a small microscope, exhibit a very extraordinary figure, differing from any animalcule hitherto described" These were surely *Cyclops*. Thus, it was Fedchenko's better knowledge of parasitology and familiarity with the appearance of unparasitised *Cyclops* which enabled him to make the observations that had eluded Chisholm; that the Guinea worm embryos were inside *Cyclops* (Hughes, 1967).

Another account of the mode of transmission of Guinea worm is given by Sir James Emerson Tennent. As the Colonial Secretary of the British Government in Ceylon from 1845 to 1850, Tennent noted in the course of a description of "parasitic worms" found there, that "of these entozoa, the *Filaria Medinensis* or Guinea worm which burrows in the cellular tissue under the skin, is well known in the north of the Island, but rarely found in the damper districts of the south and west. The natives of these areas attribute the occurrence to drinking the waters of particular wells" Tennent thus records the fact that the mode of infection/transmission seems to have been known on the African coast in at least the sixteenth century, and in Ceylon for some time before the establishment of British rule in the eighteeth century, thereby giving additional support to Dr. Muller's contention that "the belief that transmission is associated with wells and water holes has been held since ancient times".

Tennent also goes further to suggest that "these pests in all probability received their popular name of Guinea worm from the narrative of Bruno or Braun, a citizen or surgeon of Balse, who

about the year 1611 made several voyages to that part of the African Coast, and on his return, published, among other things, an account of the local diseases" (Goonertne, 1969).

2.2.2.2 Life-Cycle .

The rather bizarre Life-Cycle of the Guinea worm, *Dracunculus medinensis*, is actually very well adapted for the transmission of a parasite that utilises an aquatic intermediate host which occurs principally in arid or semi-arid environments. The mature female worm is about 70-100cm long and 0.20cm wide (Plate 1) and lives in the subcutaneous connective tissue of the human host. Human infection occurs when *Cyclops* containing the infective stage larvae (L_3) in water are ingested. The *Cyclops* are killed by gastric juices in the stomach and the larvae are activated and liberated and quickly pass through into the duodenum of the human host within 4 hours after ingestion (Muller, 1982).

In experimentally infected animals, the larvae are seen to penetrate through the duodenal wall in 10 to 13 hours post ingestion, and migrate via the mesenteries to the abdominal and thoracic muscles by about the fifteenth day (Rab, 1989). The larvae do not grow during this period , but there is probably a moult between the fifteenth and the twenty-first days. As they develop further, they begin to migrate towards the connective tissues of the axillary and the inguinal regions where they mature into adult worms. The size of the worms at this stage remains small and mating occurs between 80 and 100 days after infection (Muller, 1982). The males, (size: 1 to 4cm long) move into the deeper tissues and perish after six months. Within eight months after infection, the gravid female is filled up with developing eggs and with first-stage larvae by the tenth month. At this time, the worm begins its migration usually towards the extremities and is ready to emerge from the body

between 10 to 14 months after infection. Before, the 14th month, the gut becomes flattened and non-functional, and the whole worm is filled by the larvae-containing uterus (Muller, 1982).

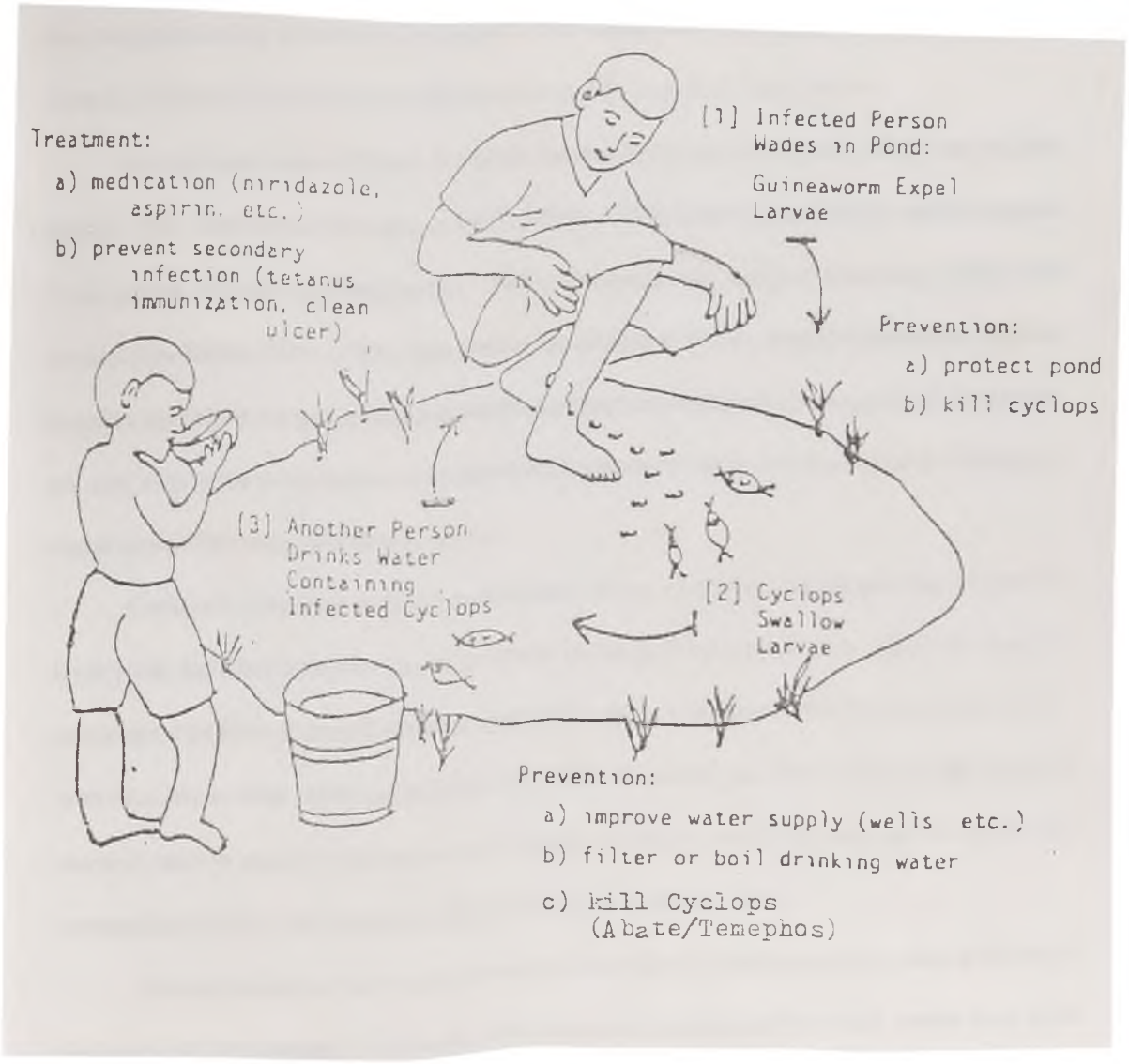
When the worm (female) is ready to emerge, the anterior end of the worm provokes the formation of a painful burning blister in the human skin. The worm emerges when this blister ruptures (especially upon coming into contact with water). Numerous first stage larvae (L_1) are expelled into the water in a milky white stream. Estimates of the number of larvae contained in the uterus of a single worm range from 1.4 to 3.0 million. Not all the larvae are released at once, and it has been shown that about half a million larvae are released on first immersion in water. The anterior end of the worm then becomes flaccid and dries up. When the affected part comes into contact with water again more larvae are expelled through the broken end of the worm. The number of larvae expelled at each immersion decreases, and the worm is completely expelled within one to two weeks. This intermittent discharge and drying up of the blister aperture is an adaptation to increase the chances of some of the larvae finding *Cyclops* in the water. This process is "one of the neatest adaptation in behaviour in all of the realm of biology, enabling a blind unmediative burrowing worm to give her aquatic *Cyclops*-inhabiting offspring a fair chance in life, even in deserts" (Rab, 1989; Muller, 1971).

The first stage larvae, (640 by 13μ) remain active in the pond for about one week. Following ingestion by a *Cyclops*, the larvae penetrate the gut wall of the *Cyclops* and reach its haemocoel within one to six hours. They moult twice inside the *Cyclops* and reach the infective third larval stage (L_3) in 14 days. It is when man drinks this *Cyclops*-contaminated water that the cycle is repeated (Rab, 1989; Muller, 1971; Brieger and Rosenweig, 1988).

The rate of development of the larvae in the *Cyclops* has been found to be temperature dependent. Temperatures above 24 °C and below 19 °C inhibit the growth of the larvae, which are then incapable of reaching the infective stage. It has also been observed that those larvae-containing *Cyclops* are sluggish in their movements and tend to sink to the bottom of the ponds, as compared to the non-infected ones. There is also some evidence to suggest that the life span of the infected *Cyclops* is shortened (Rab, 1989). The following is an annotated diagram of the Life-Cycle of *Dracunculus medinensis.*

LIFE-CYCLE OF DRACUNCULUS MEDINENSIS.

(GUINEA WORM: CAUSES. PREVENTION AND "TREATMENT").



Source: Brieger and Rosenweig, 1988.

2.3.0 TAXONOMY, BIOLOGY AND ECOLOGY OF *CYCLOPS*:

The vectors of guineaworm are cyclopoid copepods that inhabit stagnant ponds (Figure 1). *Dracunculus medinensis* however exhibits a high level of host specificity and only a few species act as vectors in nature. Cyclopoid copepods (Cyclopoida) are known as the intermediate hosts of more than ten genera of the Cestoda and Nematoda. Two among these are important parasites of man; *Diphyllobothrium latum* (the broad fish tapeworm) and *Dracunculus medinensis*.

Mesocyclops leukarti (Claus) is widely reported as the common intermediate host in India (Sarkar, 1982) and Africa (Onabamiro, 1950; Muller, 1970). Other reported hosts include species of the genera *Mesocyclops* Sars (Sarkar, 1982), *Thermocyclops* Kiefer (Onabamiro, 1952a) and *Metacyclops* Kiefer (Steib, 1985). The correct identification of the copepod intermediate hosts is therefore not only important in mapping out the geographical distribution and spread of the disease, but also vital in the development of eradication programmes which aim to combat the disease by vector control (Boxshall and Braide, 1991).

Copepods (classified as Macrozooplankton, *Sensu stricto)* are subdivided into Calanoids, Cyclopoids and Harpacticoids. Recent progress in copepod systematics has refined the level of taxonomic resolution of these freshwater copepods and it is now known that *Mesocyclops leukarti* does not occur in either Africa or India (Keifer, 1981; Van de Velde, 1984). There is, therefore, an obvious need to record these taxonomic changes, to review earlier records, and to update the nomenclature of the hosts where possible (Boxshall and Braide, 1991).

The various groups have been observed to have diverse feeding regimes, often modified in the course of development. Cyclopoids have an erratic jumping motion which makes them more conspicuous than the gliding motion of calanoids (Delince, 1992).

The broad taxonomic grouping of *Cyclops* is as follows;

Phylum: Arthropoda

Subphylum: Crustacea

Class: Copepoda

Order: Cyclopoida

Family: Cyclopidae

Thus, *Cyclops* belong to the Cyclopoid copepods, one of the orders in the class Copepoda. The Copepoda is included in the subphylum Crustacea which also include such familiar invertebrates as crabs, shrimps and lobsters (Barnes, 1968). Freshwater Cyclopoid copepods are minute, pinhead-sized crustaceans which are biologically very successful, comprising many genera with diverse feeding habits. They are found world wide and almost exclusively in standing or slow-flowing, marine, brackish and freshwater bodies. The free living cyclopoid copepods (often referred to as *Cyclops*), have pear-shaped bodies, comprising a cephalothorax, an abdomen and a telson with a tail which has two caudal rami. The sexes are separate and the eggs hatch into typical nauplius larvae, which are then succeeded by several metanauplius stages before moulting into the first of five successive copepodite stages (McCullough, 1982).

Muller (1971), listed 17 species of *Cyclops* that potentially act as intermediate hosts in different dracunculiasis endemic areas. More recently Steib, (as cited in Olsen, 1993), working in Burkina Faso, added two more species (*Thermocyclops incisus* and *Metacyclops exsulis*) to the list of potential vectors. In Africa however, approximately 150 different species of freshwater cyclopoids have been described. Of these only 60 are prevalent in areas endemic for Guinea worm disease. Probably, only 34 of these species are frequent vectors. Generally, only members of the genera

Thermocyclops and *Mesocyclops* are regarded as truly planktonic forms and can therefore act as the most important vectors of the disease (Kiefer, 1978; as cited in Oslen, 1993).

McCullough (1982), states that only large predatory species can readily ingest *Dracunculus medinensis* larvae and can therefore act as potential intermediate hosts. Of these carnivorous species, the older and larger copepodid stages are more predatory than the younger smaller ones. Also, that in each endemic zone usually one of the local predator species is the dominant intermediate host by virtue of its preferred habitat and seasonal population dynamics or both.

Furthermore, Boxshall *et al.*, (1991), working on the freshwater Cyclopoid copepods of Nigeria, identified forty valid and four non-valid vector species of dracunculiasis. Species in the genera *Thermocyclops, Mesocyclops* and *Metacyclops* are often implicated as intermediate hosts of *D. medinensis.* Boxshall and his coworkers were however quick to warn that the often implicated (and misidentified) host, *Mesocyclops leukarti* does not occur in either Africa or India. This view is also held by Olsen (1993), who states in his key "Vectors of Guinea worm disease in tropical Africa - A key to the species of *Thermocyclops* and *Mesocyclops*", that of the 13 taxa of this genus described for Africa, most forms were recorded as *Mesocyclops leukarti,* which does not in fact occur in tropical Africa. Chippaux (1991), also identified 14 species of cyclopoids out of which 4 were suitable intermediate hosts for *D. medinensis.* Of these, *Thermocyclops oblongatus* appeared to be the most common, especially in ponds, followed by *T. neglectus* whilst *T.crassus consimilis* was considered a minor intermediate host. *T. emini* also played an important role as an intermediate host, especially in rivers at the beginning of the dry season when the rivers had stopped flowing (Chippaux, 1991). Other species of *Cyclops* known to transmit *Dracunculus medinensis* are *Thermocyclops nigerianus and T. hyalinus* (Onabamiro, 1950).

With respect to the food and feeding habits of *Cyclops*, the work of Klugh (1927), gives a comprehensive review of the food of freshwater Entomostraca (Birge, 1897; as cited in Fryer, 1955). Klugh also recorded the alga *Chaetophora elegans, Chlamydomonas* as well as *Diaptomus birgei* from various genera of *Cyclops*. He also claimed that *Cyclops* are carnivorous, eating rotifers, nauplii and "other animals"

Horse dung infusions (essentially protozoan cultures) appear to have been the chief source of food used in cultures. Coker (1933; as cited in Fryer, 1955), remarks that this medium is satisfactory for the rearing of *Acanthocyclops vernalis* and *Eucyclops (= serrulatus)*, but states, "we had reason to doubt its effectiveness with respect to the fertility of adults reared as to its general sustainability for *A. viridis*". Later Coker noted that he had satisfactory results by the addition of unicellular green algae and chopped fragments of the filamentous green alga *Mougeutia spp.* to the culture medium (Fryer, 1955). Fryer also revealed that individual species of *Cyclops* had preferred food material. The carnivorous species included *Macrocyclops albdus, M. fuscus, Acanthocyclops viridis, A. vervalis, Cyclops strenuus and Mesocyclops leukarti.* The herbivorous species were mostly from the genus *Eucyclops* and some *Microcyclops*.

The physico-chemical properties of *Cyclops* habitats depend on the general pattern of seasonal events. As Burgis (1971), points out, in the temperate lakes, the seasonal changes are due mainly to the incident solar radiation, and the consequent changes in water temperature leads to an alternate building-up and breakdown of thermal stratification. In the tropical regions however, incident solar energy is high throughout the year, thus, diurnal stratification is of greater significance than seasonal changes. This phenomenon is pronounced in large bodies of water. In the small ponds that are often used as sources of drinking water, the almost constant mixing of the water produces an environment remarkably homogenous, with stable physico-chemical conditions. The only apparent seasonal changes are those associated with increased inflow during the rainy season and the consequent increase in volume/level, probably coupled with increased turbidity (Fryer, 1955).

2.4.0 EPIDEMIOLOGY AND IMPORTANCE OF GUINEA WORM DISEASE.

2.4.1 EPIDEMIOLOGY.

Once rampant in most of the Middle East, Africa as well as Central and South Asia, Dracunculiasis is now restricted to only 19 countries of the world; 17 countries in Africa, as well as India and Pakistan. It was introduced into several Latin American countries and the Caribbean Islands along with the "Slave Trade", but apparently all the new World foci are now extinct (Rab, 1989). In a personal communication, Rab (1995), claims the disease has now been eradicated in Pakistan. The disease is most severe in the West African countries of Benin, Burkina Faso, Ghana, Mali, Mauritania, Niger, Nigeria, Senegal and Togo. Serious disease problems also exist in areas of East Africa such as Ethiopia, Sudan and Uganda. In India, the disease has been eradicated from the Southern region of Tamil Nadu, however, it still affects many districts in the two Northwestern states of Andhra Pradesh and Rajasthan which shares borders with Pakistan. There are controversies as to the estimated number of people who suffer from this debilitating disease per year in the endemic regions. Whilst Edungbola *et al.*, (1988) puts it at 5-15 million, Rab *et al.*, (1991) gives a range of 10-48 million. The WHO (1993) also estimates the annual incidence to be of the order of 50 million people.

Of the 17 countries in Africa that are hard hit by the disease, 9 are in West Africa. Nigeria, the most populous country in Africa (101 Million), undoubtedly tops the list whilst Uganda comes second. In Niger the population estimated to be at risk is pegged at 2.5M (Edungbola *et al.*, 1988). If the absolute number of cases in the West African countries in 1990 are to be compared, Burkina

Faso comes third after Nigeria (194,082 cases) and Ghana (123, 793 cases). However, if prevalence per 10,000 population is compared, Ghana ranks highest (82.5 per 10,000), followed by Benin (81.3) and Burkina Faso (46.4) (Kimbire *et al.*, 1993). Dracunculiasis is equally devastating in the Sudan where the government has embarked on a nationwide campaign involving the use of radio, television and the Newspapers to eradicate the scourge. The disease has spread to 21 of the 26 states of this North-Eastern African country where it is estimated that some 50,000 people have died of Guinea worm-related diseases. The situation is further compounded by the civil war in that part of the country, leading to a total collapse in medical services (The African Obsrver, April 3-15, 1995).

2.4.2 The Socio-economic Importance.

Dracunculiasis is endemic in much of the Guinea Coast of West Africa (Muller, 1971., Nwosu *et al*, 1982 and Belcher *et al.*, 1975). The disease does not confer protective immunity and hence, reinfection of the same individual year after year is not uncommon. Secondary bacterial infection of Guinea worm (GW) ulcers occurs in about 50% of cases, and many farmers are too incapacitated to work for up to three months, some for longer periods, and still others are permanently disabled (Kale, 1991). The disease therefore causes considerable suffering and poses a major problem to the health and economy of the rural population in the endemic areas. A few examples will suffice to illustrate the impact of GWD. on the socio-economic status of affected communities.

In Togo, with a national population of 2,747,000, the estimated number of lost workdays per annum is put at 40 million. In Nigeria, with a population of about 100 million, about 120 million workdays are lost, 50% of them to agriculture alone. The World Bank estimates the value of the

global loss of marketable goods attributable to Guinea worm at $1 billion. In Burkina Faso, as much as 10% of per capita income may be lost because of guineaworm disease. Between $56 million and $277 million in wages are lost globally every year as a result of Guinea worm infection . A UNICEF-sponsored study in a part of Nigeria with a population of 1.6 Million suggests that the annual losses in rice production profits alone is of the order of $20 million. If these losses are extrapolated to the rest of the areas of the country susceptible to Guinea worm infestation, taking into account other crops, the total annual agricultural loss caused by Guinea worm in Nigeria, where about 2 million cases occur in all the States of the Federation, is of the order of three-quaters of a billion dollars (Kale, 1990).

2.4.3 Endemicity of Guinea Worm Disease in Ghana.

Although Belcher (1975) and his co-workers reported that little was known about the extent of Guinea worm disease in Ghana, they also indicated that the disease has previously been reported in the northern and middle sections of the country. Scott (1959), also reported that investigations were carried out into Guinea worm infection in the Mo district of north-west Ashanti between 1952 and 1958. Scott further stated that the disease is particularly common in this area which lies to the north-west of Kintampo. The area has a typical woodland savannah vegetation, and covers about 250 square miles. There are 27 villages and hamlets, and the incidence of dracontiasis was as high as 40% in some of the villages (Scott, 1959).

In Ghana, as pertains in the other West African countries, Guinea worm infection is restricted to the rural poor who lack potable/treated water. Out of the ten regions, eight are declared as Dracunculiasis endemic. These are; The Upper East and West Regions, Brong-Ahafo, Ashanti,

Greater Accra, Eastern, Central and The Northern Region which has the highest annual prevalence. According to the Ministry of Health Annual Report (Greater Accra Region), the number of reported cases of Guinea Worm disease in the country for 1993 was 17, 918; a reduction by 46.5% of the 1992 figure. Also the number of villages in which the disease was endemic reduced by 28.4% during the same period. The main strategies that accounted for the reduction in prevalence included:

(i) Intensification of Health Education,

(ii) Vector control through the application of ABATE 500EC to the sources of drinking water,

(iii) Worm Extraction by surgical means, and

(iv) Community based surveillance.

As at the launching of the Guinea Worm Eradication Programme in 1989, there were no reliable estimates of the prevalence of the disease in the whole country, with the hospital records showing gross under-reporting. The number of cases reported annually throughout the country from 1982 to 1986 ranged from 3,413 to 4,717. However, a survey conducted in 1987 in Northern Region revealed an 8% infection rate, with 80% of the villages being endemic. It was also estimated that at least 90,000 GW cases occurred in that region. In contrast, a sample survey in the Eastern Region in February 1988 yielded a regional prevalence rate of 11%.

2.5.0 CONTROL AND PREVENTION OF GUINEA WORM DISEASE.

Although Dracunculiasis appears to be a very simple disease to eradicate, mankind is still plagued by this ancient malady in the dying embers of the twentieth century. The disease has therefore eluded man for ages. The failure to eradicate guinea worm could be due to a number of factors.

Apart from being a disease of the rural poor, it is also impossible to diagnose until the formation of a blister approximately a year after infection. This is the one and basic factor underlying the failure of chemotherapy for the control of Dracunculiasis. In fact, no known drug exist for treatment, and there is no vaccine available. Thus, the only options left for control that appear feasible are; Vector control, Health Education and more importantly the Provision of potable drinking water to all endemic communities.

McCullough (1982), enumerated a number of factors that are implicated for the long neglect of studies on Dracunculiasis. These are that;

(a) Globally, the distribution and public health importance of the disease does not compare with such other parasitic infectious diseases as malaria, schistosomiasis and soil transmitted helminths, thus its priority is relatively low.

(b) Nationally, the disease is seasonally restricted to small, often isolated communities located in impoverished areas without, to say the least, political influence and with little chance of benefit from concerted public health activities.

(c) There are no effective drugs nor vaccines for the treatment or prevention of the disease. Infected villagers therefore have little incentive to seek treatment at hospitals or dispensaries, and tend to rely much more on traditional methods. Consequently, the true gravity of the malady is often hidden.

(d) Prevention and control of Dracunculiasis demand a multi-disciplinary approach.

(e) Biologists have for obvious reasons, concentrated chiefly on medical entomology, occasionally on malacology, and hardly ever on the subclass Copepoda, probably because so few important human parasites are transmitted by this latter group.

Of late however, non-governmental organizations such as UNICEF, WASH, World Vision International and the Global 2000 Project of the Carter Foundation, Georgia-USA, have

succeeded in bringing the misery and havoc caused by this incapacitating disease into the limelight. Thus, GWEPS were initiated by most endemic countries in the late 1980s. These programmes are multi-disciplinary, multifaceted and integrated in approach. They are not only included in the existing health delivery systems, but also inter-sectorial collaboration within and between the various arms of health services is emphasised. Among other things, health education, chemical treatment of contaminated water sources and to a lesser extent, chemotherapy and surgical removal of worms as well as the provision of safe drinking water are carried out.

2.5.1 Health Education.

Even though health education has proven to be an effective tool in combatting Dracunculiasis, some degree of community mobilization, commitment and cooperation, involving both infected and non-infected members are required. These measures essentially include boiling or filtering of drinking water and the prevention of infected individuals from entering sources of drinking water. Of these measures, filtration is the more attractive option since it is the easier of the two methods. Conversely, boiling will mean the use of firewood, and this is not only expensive, but also promotes deforestation and consequently global warming.

A 100μm monofilament filter has been shown to effectively remove *Cyclops* from drinking water and resist clogging as well. This is being used extensively in villages where the disease is endemic in Pakistan, where it is readily accepted and lasts at least one transmission season if handled with care. Meticulous and thoroughly planned health education programmes in certain communities have brought about significant changes in health behaviour, and has resulted in drastic reductions in the prevalence of Dracunculiasis within two years in such communities (Akpovi *et al.*, 1981).

In Ghana, Health Education (HE) is done by the GWEP mainly by the programme coordinators and the village volunteers (VVs). These VVs are usually selected by the indigenes themselves and are therefore more acceptable and effective. Also, opinion leaders such as Assemblymen, chiefs, CDRs as well as identifiable groups are involved in this exercise. This has led to drastic reductions in the prevalence of the disease in most villages where the disease has been hitherto highly endemic.

2.5.2 Provision of Safe Drinking Water:

Since ingestion of contaminated drinking water is the only mode of transmitting Dracunculiasis, the provision and use of drinking water that is not contaminated with the *Cyclops* interrupts transmission and results in the disappearance of the disease in one to two years. In the Ivory Coast, a well drilling programme in the 1970s reduced the prevalence of Dracunculiasis from 30 to 1%, whilst a town in Nigeria recorded a decrease from 60 to 0% in 2 years. Likewise in Pakistan, provision of pipe water by the Public Health Engineering Department has eliminated the disease from some previously known infected foci of high endemicity (Rab, 1989). It must however be emphasized here that, the provision of safe drinking water to infected communities alone does not always result in disease eradication. The proper use of such water must be simultaneously ensured. Several instances are recorded in which villagers continue to use traditionally contaminated sources despite having safe water supplies.

2.5.3 Treatment:

Ancient as Dracunculiasis is, there is up to date no known cure for the disease. Thus, in the endemic communities, there are numerous traditional remedies employed for treatment. The most common and popular among these is the time old method of winding the worm on a forked stick as it emerges. This method has been in use in Africa and Ceylon as far back as the sixteenth

century or even earlier. The Dutch navigator, Linschoten, saw evidence of Guinea worm at Ormusz in 1584, and consequently described the worms as well as the local method of removal as follows: "There is in Ormus a sickness or common plague of wormes, which growe in their legges, it is thought that they precede of the water they drink. These wormes are like unto lute strings, and about two or three fathomes longe, which they must plucke out and winde them aboute a straw or feather, everie day some part thereof, so longe as they feele them creepe; and when they hold still, letting it rest in that sort till the next daye, they bind it fast and amongst the hole, and the swelling from whence it commeth forth, with fresh butter, and so in ten to twelth dayes, they winde them without any let, in the meanetime they must sit still with their legges, for if it braek, they should not without great paine get it out of their legges, as I have seen some men doe" (Gooneratne, 1926).

(i) Chemotherapy;

The fact that so many traditional methods of "treating" Guinea worm are still in use today reflects the lack of a modern chemotherapeutic agent. "Treatment" efforts are therefore aimed at removal of the emerging worms, alleviating pain and reducing secondary infection. In West Africa, palm oil, kerosine or a concoction of leaves are often placed over the ulcer. In Pakistan, treatments frequently observed include the application of the leaves of the desert plant *Calotropis sp,* onion and soap pastes, pulverized grass, cattle excreta mixed with various oils, mud, dough and scorpion biles. It is worth mentioning that these procedures are fraught with many dangers and complications (Rab, 1991).

Since the 1960s however, three compounds have been reported to have some effects on the emerging adult worm. These are Niridazole (at 25 mg/kg body wt, daily for 10 days), Thiabendazole (at 50 mg/kg body wt, daily for 7 days) and Metronidazole (400 mg/kg body wt, for 10 to 20 days). These drugs produce symptomatic relief of pain and pruritus, thereby

hastening the expulsion of worms to a certain degree. They have however no effect on the pre-emerging worms, and it appears that these compounds act primarily against host reaction, as their anti-inflammatory properties reduce the intensity of tissue reaction around the worm's cuticle. Hence, none of them is of any value in the prevention of the disease.

Also, Rab (1991) described a new method of worm expulsion. Here, the patient is put on a 5-day course of an antibiotic, Ampiclox, and an anti-inflammatory drug, Chymoral in their recommended therapeutic doses. Gauze bandages are then applied to ulcers with emerging worms and kept moist continuously by means of a small tube attached to a container filled with water. Alternatively, patients are advised to keep the bandages soaked and wet all the time. These antibiotics and the anti-inflammatory drugs reduce the severity of infection and inflammation around the worm cuticle, thereby enabling the almost empty bag of worms to be pulled out with relative ease. This simple method of worm extraction can not however be regarded as treatment of the disease. Nevertheless, it relieves the patients of their pain and misery, and thus reduces the period of immobilization as well as the number of worm carriers who serve as sources of transmission. The method is therefore a simple aid that can be envisaged as part of a multifaceted approach to control Guinea worm and can therefore play an important role in eradication programmes.

In an attempt to find out the efficacy of some herbal preparations in the treatment of Dracunculiasis, a study sponsored by UNICEF, the Danish Bilharziasis Laboratory (DBL) and Global 2000 was conducted by a three-man medical team in Ghana in 1995. This team recommended the use of the following herbs in Guinea worm treatment. *Azadirachta indica* (Neem tree), *Carica papaya* (male Pawpaw), *Xanthosoma spp.* (Cocoyam leaves), and *Jatropha curcas* ("nkrangyedua" leaves). The rest are; *Desmodium celutigum* ("ananse nkatee"), *Nicotina tobaccum* (tobacco leaves), *Beqiaertrodendron magalismonanum* ("nofonofo"), and *Piper umbrellatum* ("mumuaha"). These herbal preparations help expel the worms within three days.

Thus, the early expulsion is very important because it reduces the possibility of contaminating the sources of drinking water, thereby breaking transmission.

(ii) Surgery;

Guinea worms have been wound on a stick since antiquity. Kuchenmeister and Zurn (1878-81) believed the fiery serpents of brass placed on a staff by Moses was an indication to the Israelites of how to deal with this affliction. This procedure is usually an essential part of treatment even today. Provided bacterial infection or other complications have not occurred, then regular winding out of the worm on a small stick (usually forked), combined with sterile dressing and acriflavine cream results in its complete expulsion in about three weeks with little pain or inconvenience (Muller, 1970).

Surgical removal of the worm after local anaesthesia is also widely done in most endemic countries these days. In Ghana, the GWEP has trained nurses and medical assistants in the endemic villages to surgically remove worms if the outline can be seen or palpated. This is the best method of case containment.

2.5.4 Vector Control:

The provision of permanent safe drinking water in many areas has multiple constraints such as expense involved, length of time needed for construction and so forth. Nevertheless, transmission of Dracunculiasis can be interrupted in endemic villages by periodic chemical treatment of drinking water sources to kill the *Cyclops*.

This method has often been advocated but rarely attempted, partly because of the cost, but also because of the lack of basic epidemiological knowledge necessary to make such treatment effective. In this light, steam treament of step-wells was suggested by Leiper in 1912,

Potassium permanganate and Quicklime by Turhud (1919) and Davis (1913) respectively. Later, Ramarkrishnan and Rathnaswamy (1953), found in the laboratory that 10ppm of DDT caused 100% mortality of *Cyclops* in 48 hours. Following this, and using a single application of DDT at this dilution, Nugent and co-workers (1955) reduced the incidence of Guinea worm markedly (from 26.5 to 6%) in five out of seven villages in an area in Southern Ghana (Scott, 1959).

In recent years, many compounds have been discovered that are effective as molluscicides or insect larvicides, and it was thought that some of these could as well be effective against *Cyclops*. Most of these substances are not only likely to be inexpensive in the quantities required, but also available in suitable formulations (Muller, 1971). To elucidate this, Manonmani *et al.* (1989), studied the susceptibilities of *Mesocyclops* to different insecticides. These insecticides included the organochlorine compounds: DDT, and BHC; the organophosphorus compounds: Dichlorvos, Temephos/ABATE, Fenitrothion, Zolone, Fenthion, Methylparathion, Phorate, Phosphamidon, Monocroptophos and Oxydemeton-methyl; the carbamate compounds: Carbendazin Carbanyl and Carbofuran. Also tested were the synthetic pyrethroid Permethrin; the insect growth regulator Methoprene; and the cyclodiene compound Aldrin.

These insecticides produced remarkable susceptibility levels on the *Cyclops*. The difference in toxicities could have been due to several factors such as species, relative humidity and other ecological and geographic conditions. Considering the highly effective compounds, the study group was to realise that Permethrin ranked first followed by Dichlovos, Temephos, DDT, Carbendazin, Fentrothion, Zolone, and Aldrin in order of potency. Although most of these insecticides proved effective against *Mesocyclops spp*, limitations do exist in their use in the field as most of them are deleterious to non-target organisms and mammals.

Considering biosafety, Temephos/ABATE in the form of granular formulations is recommended for use as the most promising compound for the control of *Cyclops* in Guinea

worm infested areas. ABATE has the added advantage of easy applicability and safety to non-target organisms and persons handling it (Manonmani *et al.*, 1989).

It is worth mentioning that the quest for a chemical agent for the control of *Cyclops* has been going on for a long time. As early as 1931, Davis carried out experiments in the Mongalla Province of the Sudan to find out the action of various agents on *Cyclops*. These chemicals included NaOH, KOH, HCl, Bleaching Powder, Potassium permanganate, Quicklime, Builders slaked lime and $NaHCO_3$ (Davis, 1931).

2.6.0 STUDY OBJECTIVES.

Dracunculiasis is caused by the Guinea worm, *Dracunculus medinensis*. L., and is endemic in parts of Africa and Asia. The vectors are commonly referred to as "*Cyclops*", but *D. medinensis* exhibits a high level of host specificity and only a few species act as vectors in nature. Recent progress in copepod systematics has refined the level of taxonomic resolution of these freshwater copepods, and it is now known that, the all famous and well acclaimed universal vector species, *Mesocyclops leukarti* does not in fact occur in either Africa or India (Kiefer, 1981; Van de Velde, 1984). There is therefore the need to record these taxonomic changes, review earlier records and to update the nomenclature of the hosts wherever possible (Boxshall and Braide, 1991). The purpose of this study is therefore;

(1) To identify and record the freshwater cyclopoid copepods in some village in the West Akim District of Ghana, where GW is endemic, including those that act as vectors of Dracunculiasis, and to document their current names,

(2) To evaluate the value of ABATE as a Cyclopscide, and

(3) To identify and investigate the socio-cultural practises of the indigenes that are of relevance to the transmission of the disease.

Chapter 3

3.0 MATERIALS AND METHODS.

3.1.0 FIELD STUDIES.

3.1.1 Study area and features of sampling sites.

The study was carried out in three villages (Tiokrom, Dzakpatra and Mepom) in the East Akim District of the Eastern Region of Ghana (Figure 1). Whilst Tiokrom and Dzakpatra are small settlements, Mepom is a sub-urban settlement. Both Tiokrom and Mepom are accessible by main roads while Dzakpatra is quite remote.

The terrain is coastal savannah with extensive brush but few trees. Agriculture is the primary occupation for subsistence, with the major crops being cassava, maize (corn) and beans. Some farmers also produce tomatoes, okra, peppers and fruits on a small scale as a cash crop. The average annual rain fall is 48 inches with heavy rains in May to June, and a smaller peak in October. The predominant occupation is farming; 68% of the adult males are farmers and 12.7% are labourers (Belcher *et al.*, 1975).

All the three villages were observed to use water sources which vary seasonally. During the rains water is collected and stored in pots and basins. In the long dry season, November to May, drinking water is obtained from ponds.

Unlike Dzakpatra and Tiokrom which have been declared as Guinea worm endemic villages by the Guinea Worm Eradication Programme, Mepom is not. It is rather a village at the outskirts of the town (about 1km from Kwesi Acheampong known as Gahia Korpe) that experienced an almost

100% infection in 1994. The residents of Mepom though a sub-urban settlement, depend on four different ponds for water, with all hitherto stand-pipes (with water pumped from Accra) broken down for over ten years now.

3.1.2 Pond Morphometry.

The volume of water in the study ponds was estimated every month on each visit. This was done by a relatively simple method using a piece of graduated nylon rope and a meter-rule. The averages of length (L), width (W) and depth (D) of the pond were taken by placing transects 50cm apart. Thus, the estimated capacity of the pond at any particular time was calculated by multiplying the measured averages. That is; **VOLUME = (L x W x D) m^3**.

3.1.3 Estimation of *Cyclops* density:

In estimating the number of *Cyclops* in a known volume of water taken at the surface of a pond, the following method proved simple and satisfactory. It is basically a replicate of that used by Onabamiro (1954), in estimating the relative cyclopoid copepod densities per 10 litres of water. A wide mouthed plastic container of volume 4 litres was lowered into the water at the contact site and scooped. The water fetched was then filtered using a monofilament filter of mesh size 70 μm. The *Cyclops* trapped were then washed into a beaker with the aid of a wash-bottle. This was repeated four times and the collected samples fixed immediately in 10% formalin separately and brought to the laboratory for analysis. The average number of *Cyclops* per unit volume of water was then determined. Since our main concern was the relative densities, the apparatus proved quite satisfactory. Secondly, the method of filtration is similar to that used by the women to fill their pots and basins. The sampling was done once every month for each pond to monitor the population changes of the *Cyclops* with time and/or season.

3.1.4 Retrospective Studies on Dracunculiasis in the area.

The prevalence of Dracunculiasis in the study area was ascertained by the use of a questionnaire (Appendix A). In this respect, three basic parameters implicated in the disease transmission were investigated, viz:

(1) Human Behaviour.

(2) The living conditions of the people.

(3) The people's knowledge of the disease.

The questionnaire was administered by random sampling to investigate the incidence of the disease by sex, age, occupation, month as well as the socio-cultural practices of the people that aid in the disease transmission.

3.2.0 LABORATORY WORK.

3.2.1 Identification of *Cyclops* species.

Having recorded the *Cyclops* count per litre of water as in 3.1.3 above, the specimens were preserved in 70% ethyl alcohol. The identification of the *Cyclops* was done using a phase-contrast microscope (Model: Optiphot-2; Nikon, Japan). Here, only mature and gravid females were examined and identified accordingly. This was to make sure that specimens used in the identification process were matured, since the key uses morphological features on the body. The key used in the identification exercise was that prepared by Annette Olsen (1993), of the Danish Bilharziasis Laboratory- "**VECTORS OF GUINEA WORM DISEASE IN TROPICAL AFRICA; A KEY TO THE SPECIES OF THERMOCYCLOPS AND MESOCYCLOPS**" (Appendix D). I find this key quite adequate because a review of West African records reveal that *D. medinensis* is transmitted

in tropical Africa by seven species of *Cyclops*. There are four *Thermocyclops spp,* two *Mesocyclops spp* and a *Metacyclops sp* (Johnson *et al*, 1990). The use of this key was supplemented by another key prepared by Boxshall and Braide (1991)- **"THE FRESHWATER CYCLOPOID COPEPODS OF NIGERIA, WITH AN ILLUSTRATED KEY TO ALL SPECIES".** The two keys use distinct morphological features on such body parts as the fifth pair of legs, the caudal rami, the antennae, the seminal receptacle, the maxillary palpi, the total body length and the relative lengths of the body segments.

The identification process involved observing the specimens in water-free glycerine on a clean slide under a microscope. The *Cyclops* were then teased with a dissecting pin until the structure under investigation was appropriately orientated or positioned for observation.

3.2.2 Breeding and investigation of species specific toxicities:

To obtain enough *Cyclops* for species specific tests, the species were reared in aquarium tanks measuring 49 by 35 by 19cm. Here, a single gravid female *Cyclops* was selected using a Pasteur pipette and washed several times with tap water in a petri-dish. This was to ensure that no nuplaii or eggs of other *Cyclops* species were carried along with the adult *Cyclops* into the breeding tank. The petri-dishes were placed over a dark background to facilitate easy access, handling and observation of the *Cyclops.* The gravid female was then transferred into a beaker containing 500ml tap water. The nauplii hatching from the eggs were then reared in aquarium tanks containing tap water and fed on cow dung infusion and the green algae *Cladophora* spp as in 3.2.2 above. The water in the tanks was aerated for 15 minutes daily and changed every fortnight until the colony could provide enough adult *Cyclops* for the tests.

3.2.3 Pond Culture of *Cyclops*.

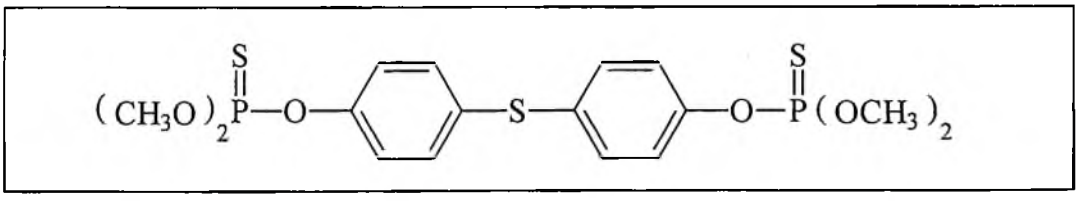
In order to obtain consistent experimental results, it was desirable to maintain colonies of *Cyclops* in the laboratory. Thus, a colony of mixed species was maintained in a fenced pond in the Zoology Department, University of Ghana. This pond measured 113cm by 88cm by 23cm and could contain a maximum of 0.23 cubic metres of water. The main advantage of maintaining the pond outside the laboratory was that natural field conditions were simulated. This pond was located directly under a big tree and fringed by grasses. Also, the pond contained the filamentous green algae *Cladophora spp.* and other floating and submerged vegetation such as *Lemna* and *Ceratophyllum*.

The original stock of the cultured *Cyclops* was obtained from the villages where \guinea worm disease is endemic. After two weeks, the pond became self-sustaining, and had a good growth of algae and flagellates. Thus, no food was introduced artificially. It was also possible to rear large numbers of *Cyclops* in aquarium tanks containing water at room temperature (25-29 °c). These tanks were aerated for 15 minutes everyday and the *Cyclops* fed on a mixture of cow dung infusion and the filamentous green algae *Cladophora spp*. The dung infusion was prepared by dissolving 50mg of fresh/wet dung in 1000ml of pipe water and maintained at room temperature in the laboratory. The preparation was then monitored until the ciliate count per drop of the infusion (using a Pasteur pipette) was 120-150. This was the maximum count obtained from a preliminary study within 9-11 days, after which the count was observed to decline. Also the pH of the tanks containing the *Cyclops* colonies was observed to be between 6.5 and 6.9, thus care was taken when adding the infusion so as to maintain this pH range. The infusion was added to the aquarium tanks at 25ml per week and the water changed every fortnight.

3.2.4. Toxicity testing:

The chemical of choice, Temephos (ABATE, ABATHION, ABAT, SWEBAT, NIMITEX or BIOTHION) O-O-O^{1}-O^{1}-tetramethyl-O-O^{1}-thiodi-P-phenylene phosphorothiote, is an organophosphorus compound of minimal toxicity. It has a molecular weight of 466.5, is available in emulsifiable concentrate, as a brown viscous liquid, or a white crystalline dispersable powder with a granular formulations (1 S.G.). It has a specific gravity of 1.32, melts at 30 to 30.5 °C, is insoluble in water and is stable indefinitely at room temperature (Worthing, 1979; Sastry *et al.,* 1978).

The structural formula of ABATE is:



Thus: $C_6H_{20}O_6P_2S_3$, with a molecular weight of (466.5)

ABATE is eliminated from the body in unchanged and conjugated form both in the faeces and the urine after oral administration. Conjugated forms are in the bulk of the urine elimination products. ABATE probably acts just like any other organophosphorus compound, inhibiting irreversibly the cholinesterase enzyme by alkyl phosphorylation, thus causing paralysis of the *Cyclops* and ultimate death (Sastry *et al.*, 1978).

A preliminary susceptibility test was conducted at doses ranging from 0.1 to 2.05ppm for rough dose estimation with two replicates for each dosage, along with appropriate controls. Observations were recorded for mortalities of *Cyclops* after 24 and 48 hrs. Six doses were selected (0.25, 0.50,0.75,1.00,1.50 and 2.00) for further experimentation. The tests were carried out in 50ml petri-dishes containing batches of 20 adult *Cyclops* and kept at room temperature. Mortalities were determined after 24 and 48 hours using a light microscope. "Death" of a *Cyclops* was defined here as inability to move after being touched with a Pasteur pipette. The LC values were then worked out using a computer programme (Program Malaria in vitro Logdose Response). Further, different tests of statistical analysis were carried out to ascertain the validity or otherwise of various null hypotheses which included the following:

(1) The mortality rate of *Cyclops* dosed with ABATE is independent of the species of *Cyclops*).

(2) The mortality rate of *Cyclops* is independent of the age/state of ABATE.

(3) The mortality rate of *Cyclops* is independent of the concentration of ABATE used.

These tests of significance are:

(1) Two-factor Analysis of Variance (ANOVA).

(2) The Multi-range analysis of Variance (LSD).

(3) The Chi-square (χ^2) test of significance.

In addition to the tests on the laboratory reared *Cyclops*, specimens obtained from the field were also tested. In all these tests, the water used in preparing the solutions was obtained from the culture pond and filtered using a monofilament filter of mesh size 70 μm. This filtered water was further passed through a column of pure cotton wool parked to a height of 30cm in a perspex tube of height 92cm and diameter 4.5cm. The results of these tests are as shown Appendix B.

Chapter 4

4.0 RESULTS.

4.1.0 FIELD STUDIES.

4.1.1 Pond Morphometry.

The estimated volume of water in the various ponds throughout the period of study is shown in Table 5. Plates 2-5 show the physical features/characteristics of the ponds in the rainy and dry seasons.

4.1.2 Seasonal Variation in *Cyclops* Density.

Table 4 illustrates the population densities of *Cyclops* in the sources of drinking water (ponds) in the study areas with time and/or season .

The trend is generally that of a periodic rise and fall in numbers with time and/or season. In all the ponds investigated, there was also a decline in the number of *Cyclops* per litre of water from June to August and then a considerable increase in September and October after which a drastic fall in *Cyclops* densities was observed, the minimum occurring in February. With the exception of the Dzakpatra pond which dried up in March, all the others recorded their lowest volumes in February (Plates 2-5). These results are illustrated in Figure 4.

4.1.3 Prevalence of Guinea worm disease in the areas.

4.1.3.1 Tiokrom.

4.1.3.1a Prevalence by Age and Sex.

The age and sex distribution of those who have ever suffered from Dracunculiasis in the study area within the last three years (1994-1996) was ascertained by the use of a questionnaire. The results obtained from the above village (Tiokrom) are shown in Table 7a and illustrated in Figure 5a. The salient features are as follows:

(1) An overall prevalence of 26.9% (14.6% in males and 12.3% in females).

(2) The highest prevalence in both sexes occurred in the 16-20 age group (33.3% for males and 66.7% for females). The next highest was in the 11-15 year age group, with 30.8% for males and 45.5% for females.

(3) The lowest prevalence in both sexes was in the 6-10 year age groups, with no cases in the 0-6 and above 50 year age groups. Whilst the youngest person to have suffered from Guinea worm was six years of age, the oldest was forty-eight years old at the time of infection.

4.1.3.1b Prevalence by Occupation.

The highest prevalence by occupation occurred among farmers (48.7%) followed by Housewives(25.6%), and the lowest was among pupils/school children (5.1%). This is shown in Table 7b and illustrated in Figure 5b.

4.1.3.1c Monthly Variation in Prevalence.

Of all the cases, 82% became manifest between February and April, the peak occurring in April (34.3%). These are as shown in Table 7c and Figure 5c.

4.1.3.1d Site of Worm Emergence.

The preferred sites of lesions produced on the body by emerging adult guinea worms are summarised in Table 7d and illustrated in Figure 5d. Of all lesions, 31% occurred on the lower limbs, with over 50% appearing on the ankle and feet.

4.1.3.2 Dzakpatra

4.1.3.2a Prevalence by Age and Sex.

The age and sex distribution of Dracunculiasis in Dzakpatra between 1994 and 1996 is presented in Table 8a and illustratd in Figure 6a. The total percentage infection was 49.4%. 45.3% of these occurred in males whilst the percentage infection in the females was as high as 53.8%. The age groups with the highest prevalence rates in both sexes were the 6-20 year age group in the males and the 11-30 year age group in the females. There were no cases among the 0-5 and >50 years age groups in both sexes.

4.1.3.2b Prevalence by Occupation.

The occupational distribution of guinea worm in the village is summarised in Table 8b and illustrated in Figure 6b. Here, the highest infection rate was among the pupils or school children (33%). This is the exact opposite of the situation in Tiokrom. The second highest rate of infection was among farmers (11%).

4.1.3.2c Monthly Variation in Prevalence.

Almost all the cases of Guinea worm attack appear to have occurred between January and May (95.2%), with a few cases in October. The highest prevalence rate was in March (36.9%), with no cases in the other months. These are shown in Table 8c and illustrated in Figure 6c.

4.1.3.2d Site of Worm Emergence.

As found in Tiokrom, the observed preferred site of emerging female guinea worms was the lower limbs, especially the ankle and feet. 51.1% of all lesions were observed to occur on the feet and ankle. This is shown in Table 8d and illustrated in Figure 6d.

4.1.3.3a Mepom (Mataligu section).

There were no cases recorded in this part/section of the village. The results obtained are presented in Table 9a.

4.1.3.3b Mepom (Kwesi Acheampong section).

The only cases recorded in this section of the village, (a typical settlement for Palm oil extraction) was observed to have been imported from Gahia Korpe, another settlement at the outskirts of Mepom which recorded an almost 100% prevalence in 1994. The results are shown in Table 9b. This village can however be considered as a receptive area/zone since the implicated vector species of Dracunculiasis was recovered from ponds in this village.

4.2.0 SOCIO-CULTURAL ASPECTS OF GUINEA WORM DISEASE.

4.2.1 Beliefs, attitudes and values.

In this study, the most astonishing revelation was the peoples unwillingness to change their insanitary habits. Thus, even though the Guinea Worm Eradication Programme (GWEP) is quite active in these areas to improve their lot, this resistance to change could be responsible for the continued prevalence and spread of the disease. There is also a considerable degree of ignorance concerning the origin and transmission of the disease. This ignorance of the aetiology of Dracunculiasis is further compounded by the long prepatent period of the malady. These peasants therefore cannot readily see the relationship between drinking contaminated pond water and suffering from Guinea Worm disease 9-12 months later.

In general however, most people linked the disease with unclean water, though with different interpretations of what they meant by "unclean". For example, in Tiokrom it is generally believed that the causative agent of Dracunculiasis is put into the water by witches. This, they believe, is to incapacitate them at the beginning of the rainy season so as to prevent them from undertaking any meaningful agricultural activity.

This led the people into seeking the help of a fetish priest to fortify the pond that serves as their only source of drinking water. Their belief was further heightened when felling a tree by the pond which the priest claimed was acting as a "storage house" of the Guinea worm disease, a hollow trunk was detected. Thus the indigenes interpreted it to mean that the witches bring the disease and store it in this hole from which they then introduce it into the water.

Likewise, in Dzakpatra where two active cases were recorded (one each in April and May),

the people were of the opinion that the disease is caused by supernatural forces. A woman who suffered from the disease in May believes strongly that her predicament was as a results of her failure to pay the "jujuman" who "treated" her daughter of the same ailment the previous year. Thus, infuriated by her act, the "jujuman" turned the disease onto her, she concluded. On his part, the chief of the village was convinced a settler who came to the village in 1986 was the one who introduced the disease into his "Kingdom" from the village that he came from.

4.3.0 LABORATORY STUDIES.

4.3.1 Toxicity tests.

There are various methods for the control of *Cyclops* (the vectors of Dracunculiasis) populations in ponds, Cisterns and other focal points of Dracunculiasis transmission in villages declared as endemic for the disease. Abate has been tried as a cyclopscide in a number of villages where Guinea worm disease is endemic. In a village in North West Ghana, Lyons, (1973) found out that the insecticide could be useful as a chemical agent for the control of the *Cyclops* populations in the ponds. Abate has also been tried in India in the control of *Culex pipens fatigans* larvae (Sastry *et al.*, 1978).

In the present study, the percentage of adult *Cyclops* dying when dosed with various concentrations of fresh Abate with time (24 and 48 hours) was evaluated and tabulated in the Tables 1a-1c. Generally, there is a marked difference in the mortality rates of the different *Cyclops* species both with respect to time as well as concentration of the chemical. Considering the duration of

exposure of the *Cyclops* to Abate however, lower concentrations of the insecticide was required to effect the same mortality rates within 48-hours as does in 24-hours. These are presented in Tables 1a-1c and illustrated in Figure 3.

4.3.1.1 Lethal Concentrations.

Tables 2 and 3 present the concentration-effect parameters of the studies designed to evaluate the toxicity of Abate to adult *Cyclops*. As indicated, the 24-HR. LC50 values were 0.53, 1.54, 1.36 and 0.94ppm for *M. kieferi, T.inopinus*, and the mixture of species respectively. The corresponding LC90s obtained were 4.54, 7.09, 3.82 and 2.40ppm, whilst the LC95 values were 8.33, 10.82, 5.11 and 3.13ppm.

The computed LC50 values following a 48-hr. exposure were 0.30, 0.43, 0.98 and 0.23ppm for *M. kieferi, M. aspericornis, T. inopinus* and the mixture of species respectively. Likewise, the computed 48-hr. LC90 values were 2.63, 2.68, 3.06 and 1.08 ppm, with the corresponding LC95 being 4.86, 4.50, 4.23 and 1.68ppm. A comparison of the level of toxicity of FRESH and EXPIRED ABATE to adult *Cyclops* was also carried out. These concentration-mortality data of ABATE against adult *Cyclops* were analysed by Log-probit analysis using a statistical package: "**Program Malaria in vitro Test Evaluation, Logdose Response; (WHO, 1983) version: 01**"- to calculate the effective concentration (EC), effective dosage (ED) or lethal concentration (LC) values. Therefore, lethal concentration (LC) determinations were employed in determining the concentration of the chemical that effectively kills the *Cyclops* within a given time interval (Tables 2 and 3).

Generally, the susceptibility of *Mesocyclops kieferi* to ABATE was found to be similar to that of *Thermocyclops inopinus,* although *Thermocyclops inopinus* is smaller in size. It should be noted,

however, that by exposing the test organisms for longer periods (48-hr.), the two *Mesocyclops spp.* were effectively killed at lower concentrations than for 24-hr.

4.3.1.2 Statistical Analysis.

4.3.1.2a Analysis of Variance (ANOVA).

To find out whether there were statistically significant differences in the rate of mortality of the various *Cyclops* species investigated, a computer program (**Microsoft Excel, version 5.0**) was used to analyse the data. This bioassay analysis shows that toxicity of ABATE to *Cyclops* is species specific. Considering the 24-hr. ANOVA for example, the computed F-ratio was 11.88 as against an F-critical of 3.28, with a P-value of 0.000303. This means that there is a Statistically significant difference in the toxicity of the chemical to the various *Cyclops* species. Likewise, the 48-hr. F-ratio was 26.09, with an F-critical of 3.28 and the P-value of 3.35, meaning that there is a significant difference in the toxicity of fresh and expired chemical at 0.05 level of significance or 95% Confidence limits (Appendix B). When the data for comparism of the potency/efficacy of fresh and expired Abate were analysed, both the 24 and 48-hr. exposure times showed marked differences in the mortality rates of the test organisms (Appendix B).

4.3.1.2b Probit Analysis.

The two-factor ANOVA showed that there were differences in the mortality rates of the *Cyclops*. There was, however, no indication as to which *Cyclops* species was more susceptible to the chemical than the other. To elucidate this, another computer program, **Statgraphics version 4.2**, was used to find out the relative susceptibility of the different species to ABATE. The result is shown in Appendix C.

4.3.2 Identified *Cyclops* Species.

4.3.2.1 Tiokrom pond.

The identified *Cyclops* species from this pond included *Thermocyclops inopinus, T. incisus* and *Mesocyclops kieferi.* Whilst *T. inopinus* was the common species observed in June 1995, from July 1995 to February 1996, *M. kieferi* was the most common species (Table 6c).

4.3.2.2 Dzakpatra pond.

As shown in Table 6d, *Mesocyclops kieferi* was the dominant *Cyclops* in this pond throughout the period of study except in June 1995 when *Thermocyclops inopinus* became the dominant species. There was also variability in the species richness in the pond, with some months recording as high as five different species (Table 6d) whilst others recorded only one.

4.3.2.3 Mepom (Mataligu pond).

The results from this pond did not vary very much from that of the Kwesi Acheampong Pond, except that the only observed predominant *Cyclops* species here was *M. kieferi,* whereas the former had *M. aspericornis* as well in June and July. The results of the *Cyclops* species identified are shown in Table 6b.

4.3.2.4 Mepom (Kwesi Acheampong Pond).

The *Cyclops* species identified from this pond are presented in Table 6a. As depicted in the Table, species diversity was higher in June and July (with four different species from the genus *Mesocyclops,* and one each from the genera *Thermocyclops* and *Diacyclops*). This species richness declined until in November when only *Mesocyclops kieferi* was observed. Also, *M. kieferi* was the most common species throughout the year (except in June and July when *M. aspericornis* was equally common).

TABLES.

Table 1.THE EFFECT OF ABATE ON DIFFERENT SPECIES OF *CYCLOPS*.

Table 1a., showing percentage mortality of each species. (24-hr. Exposure).

CONCENTRATION (ppm)	C Y C L O P S		S P E C I E S	
	M. kieferi	*M. aspericornis*	*T. inopinus*	Mixed Species
0.00	0	0	0	0
0.25	27	7	0	10
0.50	56	16	10	14
0.75	59	22	25	25
1.00	66	35	40	54
1.50	72	49	57	75
2.00	76	59	62	91

Table 1b., showing percentage mortality of each species.

(48-hr. Exposure).

CONCENTRATION (ppm)	*CYCLOPS* SPECIES			
	M. kieferi	*M. aspericornis*	*T. inopinus*	Mixed Species
0.00	0	0	0	0
0.25	49	45	5	53
0.50	58	46	20	72
0.75	67	60	42	86
1.00	78	63	55	89
1.50	82	88	70	91
2.00	89	90	74	98

Table 1c., showing percentage mortality with age/state of Abate.

(Mixed species).

CONCENTRATION (ppm)	PERCENTAGE MORTALITY			
	24-hr. EXPOSURE		*48-hr. EXPOSURE*	
	FRESH	EXPIRED	FRESH	EXPIRED
0.00	0	0	0	0
0.25	5	0	35	0
0.50	10	0	80	0
0.75	32	15	91	15
1.00	55	25	94	25
1.50	80	25	100	30
2.00	92	35	100	53

Table 2. TOXICITY OF ABATE TO DIFFERENT SPECIES OF CYCLOPS.

Table 2a. Showing lethal concentrations,

(24-hr. Exposure)

CYCLOPS SPECIES	TOXICITY PARAMETER	CONCENTRATION (ppm)	95% CONFIDENCE LIMITS	
			LOWER	UPPER
M. kieferi	LC50	0.53	0.43	0.65
	LC90	4.54	2.76	7.49
	LC95	8.33	4.36	15.92
M. aspericornis	LC50	1.54	1.34	1.88
	LC90	7.08	4.48	11.20
	LC95	10.82	6.26	18.72
T. inopinus	LC50	1.36	1.23	1.25
	LC90	3.82	2.97	4.91
	LC95	5.11	3.78	6.91
Mixed Species	LC50	0.94	8.87	1.03
	LC90	2.40	2.02	2.85
	LC95	3.13	2.54	3.85

Table 2b. Showing lethal concentrations,

(48-hr. Exposure)

CYCLOPS SPECIES	TOXICITY PARAMETER	CONCENTRATION (ppm)	95% CONFIDENCE LIMITS	
			LOWER	UPPER
M. kieferi	LC50	0.30	0.22	0.41
	LC90	2.63	1.77	3.92
	LC95	4.86	2.79	8.44
M. aspericornis	LC50	0.43	0.35	0.52
	LC90	2.68	1.91	3.75
	LC95	4.50	2.88	7.04
T. inopinus	LC50	0.98	0.88	1.08
	LC90	3.06	2.43	3.86
	LC95	4.23	3.20	5.60
Mixed Species	LC50	0.23	0.18	0.30
	LC90	1.08	0.89	1.32
	LC95	1.68	1.27	2.21

Table 3. COMPARATIVE TOXICITY OF FRESH AND EXPIRED ABATE TO *CYCLOPS*.

Table 3a Showing lethal concentrations,

(24-hr. Exposure).

STATE OF ABATE	TOXICITY PARAMETER	CONCENTRATION (ppm)	95% CONFIDENCE LIMITS	
			LOWER	UPPER
FRESH	LC50	0.93	0.86	1.00
	LC90	2.00	1.76	2.31
	LC95	2.51	2.14	2.95
EXPIRED	LC50	2.60	2.04	3.32
	LC90	9.08	5.30	15.50
	LC95	12.95	6.92	24.20

Table 3. COMPARATIVE TOXICITY OF FRESH AND EXPIRED ABATE TO *CYCLOPS*.

Table 3a Showing lethal concentrations,

(24-hr. Exposure).

STATE OF ABATE	TOXICITY PARAMETER	CONCENTRATION (ppm)	95% CONFIDENCE LIMITS	
			LOWER	UPPER
FRESH	LC50	0.93	0.86	1.00
	LC90	2.00	1.76	2.31
	LC95	2.51	2.14	2.95
EXPIRED	LC50	2.60	2.04	3.32
	LC90	9.08	5.30	15.50
	LC95	12.95	6.92	24.20

Table 3b., Showing lethal concentrations,

(48-hr. Exposure).

STATE OF ABATE	TOXICITY PARAMETER	CONCENTRATION (ppm)	95% CONFIDENCE LIMITS	
			LOWER	UPPER
FRESH	LC50	0.31	0.28	0.35
	LC90	0.71	0.63	0.88
	LC95	0.90	0.77	1.04
EXPIRED	LC50	2.53	2.00	3.20
	LC90	8.78	5.20	14.80
	LC95	12.48	6.79	22.93

Table 4. SEASONAL VARIATION IN *CYCLOPS* DENSITY.

POND: Tiokrom. Table 4a

MONTH	J	J	A	S	O	N	D	J	F	M	A	M
CYCLOPS DENSITY (l^{-1})	16	12	8	18	13	9	5	2	4	1	0	0

POND: Dzakpatra. Table 4b

MONTH	J	J	A	S	O	N	D	J	F	M	A	M
CYCLOPS DENSITY (l^{-1})	12	9	7	13	10	6	6	4	1	--	0	0

POND: Mataligu. Table 4c

MONTH	J	J	A	S	O	N	D	J	F	M	A	M
CYCLOPS DENSITY (l^{-1})	15	21	10	13	12	6	8	2	3	0	7	7

POND: Kwesi Acheampong. Table 4d

MONTH	J	J	A	S	O	N	D	J	F	M	A	M
CYCLOPS DENSITY (l^{-1})	15	19	10	13	12	6	8	2	2	5	11	8

Table 5. POND MORPHORMETRY.

Table 5a. Tiokrom pond.

MONTH	LENGTH(m)	WIDTH(m)	DEPTH(m)	VOLUME (m^3)
June, 1995			-	-
July, 1995			-	
August, 1995	-		-	
Sept., 1995	7.20	7.00	2.20	110.88
October, 1995	7.32	7.13	2.22	115.87
November, 1995	7.25	7.11	2.21	108.23
December, 1995	6.67	6.59	1.98	87.03
January, 1996	4.32	3.44	0.51	7.58
February, 1996	4.00	3.50	0.19	2.66
March, 1996	5.00	4.42	0.28	6.19
April, 1996	6.12	5.73	1.32	46.29
May, 1996	6.50	6.07	1.46	57.60

It was impossible to take measurements/data for June to August 1995 because the pond was highly fringed by vegetation.

Table 5b. Dzakpatra pond.

MONTH	LENGTH (m)	WIDTH(m)	DEPTH(m)	VOLUME (m^3)
JUNE, 1995				
JULY, 1995				
AUG., 1995				
SEPT., 1995	6.21	4.50	0.49	13.69
OCT., 1995	6.26	4.57	0.51	14.59
NOV., 1995	5.95	4.33	0.42	10.82
DEC., 1995	5.87	4.25	0.40	10.17
JAN., 1996	2.20	1.52	0.32	1.10
FEB., 1996	1.16	0.48	0.09	0.05
MAR., 1996				
APRIL, 1996				
MAY, 1996	8.12	5.45	0.64	28.32

t was impossible to take measurements/data for June to August 1995 because the pond was highly ringed by vegetation. The pond was however dry from mid February till early May, 1996.

Table 5c: Mataligu pond.

MONTH	LENGTH(m)	WIDTH(m)	DEPTH(m)	VOLUME (m^3)
JUNE, 1995	-	-	-	-
JULY, 1995	-	-	-	-
AUG., 1995	-	-	-	-
SEPT., 1995	9.23	6.66	1.80	110.60
OCT., 1995	9.34	6.72	1.88	118.00
NOV., 1995	9.22	6.49	1.71	104.00
DEC., 1995	8.31	8.00	1.22	81.12
JAN., 1996	6.20	4.25	1.13	29.78
FEB., 1996	4.12	2.18	0.97	8.71
MARCH, 1996	8.38	5.25	0.35	15.40
APRIL, 1996	8.81	5.66	0.57	28.42
MAY, 1996	9.78	6.23	0.89	54.22

It was impossible to take measurements/data for June to August 1995 because the pond was highly fringed by vegetation.

Table 5d: Kwesi Acheampong pond.

MONTH	LENGTH(m)	WIDTH(m)	DEPTH(m)	VOLUME (m^3)
JUNE, 1995				
JULY, 1995				
AUG., 1995				
SEPT., 1995	8.60	5.25	0.46	20.77
OCT., 1995	7.05	5.46	0.55	21.17
NOV., 1995	8.20	5.00	0.38	15.58
DEC., 1995	8.24	5.23	0.42	18.10
JAN., 1996	7.10	3.25	0.30	6.92
FEB., 1996	4.22	2.81	0.28	3.32
MARCH, 1996	6.00	3.62	0.47	10.12
APRIL, 1996	8.43	5.11	0.49	21.11
MAY, 1996	8.48	5.19	0.52	22.89

Table 6: List of Cyclops species identified from different ponds.

Table 6a. MEPOM(KWESI ACHEAMPONG)

MONTH	CYCLOPS COUNT (l^{-1})	SPECIES IDENTIFIED	DOMINANT SPECIES
JUNE, 1995	22	*M. aspericornis* *M. kieferi* *M. tenuisaccus* *T. oblongatus* *M. spinosus* *Diacyclops spp.*	*M. aspericornis* *M. kieferi*
JULY, 1995	19	*M. aspericornis* *M. kieferi* *M. spinosus* *M. tenuisaccus* *T. oblongatus* *Diacyclops spp.*	*M. kieferi* *M. aspericornis*
AUG., 1995	10	*M. spinosus* *M.kieferi* *M. aspericornis*	*M. aspericornis* *M. kieferi*
SEPT., 1995	13	*M. kieferi* *T. oblongatus* *M. tenuisaccus*	*M. kieferi*
OCT., 1995	12	*M. aspericornis* *M. kieferi*	*M. kieferi*
NOV., 1995	06	*M. kieferi*	*M. kieferi*
DEC., 1995	08	*M. kieferi*	*M. kieferi*
JAN., 1996	02	*M. kieferi*	*M. kieferi*
FEB., 1996	03	*M. kieferi*	*M. kieferi*
MAR., 1996	01	*M. kieferi*	*M. kieferi*
APR., 1996	11	*M. aspericornis* *M. kieferi* *Diacyclops spp.*	*M. kieferi*
MAY 1996	08	*M. kieferi* *Diacyclops spp.*	*M. Kieferi*

Table 6b. MEPOM (MATALIGU).

MONTH	CYCLOPS COUNT (l^{1})	SPECIES IDENTIFIED	DOMINANT SPECIES
JUNE, 1995	20	*M. aspericornis* *M. kieferi* *M. tenuisaccus* *T. oblongatus* *M. spinosus* *Diacyclops spp.* *Afrocyclops spp.*	*M. kieferi*
JULY, 1995	21	*M. aspericornis* *M. kieferi* *M. spinosus* *M. tenuisaccus* *T. oblongatus* *Diacyclops spp.*	*M. kieferi* *M. aspericornis*
AUG., 1995	10	*M. spinosus* *M.kieferi M. aspericornis*	*M. aspericornis* *M. kieferi*
SEPT., 1995	13	*M. kieferi* *T. oblongatus* *M. tenuisaccus*	*M. kieferi*
OCT., 1995	12	*M. aspericornis* *M. kieferi*	*M. kieferi*
NOV., 1995	06	*M. kieferi*	*M. kieferi*
DEC., 1995	08	*M. kieferi*	*M. kieferi*
JAN., 1996	02	*M. kieferi*	*M. kieferi*
FEB., 1996	03	*M. kieferi*	*M. kieferi*
MAR., 1996	0		
APR., 1996	07	*M. aspericornis* *M. kieferi* *Diacyclops spp.*	*M. kieferi*
MAY 1996	07	*M. kieferi* *Diacyclops spp.*	*M. Kieferi*

Table 6c. TIOKROM POND.

MONTH	CYCLOPS COUNT (l^{-1})	SPECIES IDENTIFIED	DOMINANT SPECIES
JUNE, 1995	16	*M. kieferi* *T. inopinus* *T. incisus*	*T. inopinus*
JULY, 1995	12	*M. kieferi* *T. incisus*	*M. kieferi*
AUG., 1995	08	*M. kieferi* *T. inopinus*	*M. kieferi*
SEPT., 1995	18	*M. kieferi* *T. inopinus*	*M. kieferi*
OCT., 1995	13	*M. kieferi*	*M. kieferi*
NOV., 1995	09	*M. kieferi*	*M. kieferi*
DEC., 1995	05	*M. kieferi*	*M. kieferi*
JAN., 1996	02	*M. kieferi*	*M. kieferi*
FEB., 1996	04	*M. kieferi*	*M. kieferi*
MAR., 1996	01		
APR., 1996	0		
MAY 1996	0		

Table 6d. DZAKPATRA POND.

MONTH	CYCLOPS COUNT (l^{1})	SPECIES IDENTIFIED	DOMINANT SPECIES
JUNE, 1995	12	*M. kieferi* *T. inopinus* *Allocyclops spp.*	*T. inopinus*
JULY, 1995	09	*M. kieferi* *T. inopinus*	*M. kieferi*
AUG., 1995	07	*M. kieferi* *T. inopinus* *Allocyclops spp.* *Ectocyclops spp.*	*M. kieferi*
SEPT., 1995	13	*M. kieferi* *T. inopinus*	*M. kieferi*
OCT., 1995	10	*M. kieferi* *Afrocyclops spp.*	*M. kieferi*
NOV., 1995	06	*M. kieferi*	*M. kieferi*
DEC., 1995	06	*M. kieferi*	*M. kieferi*
JAN., 1996	04	*M. kieferi*	*M. kieferi*
FEB., 1996	01	*M. kieferi*	*M. kieferi*
MAR., 1996			
APR., 1996	0		
MAY 1996	0		

Table 7a. AGE AND SEX DISTRIBUTION OF DRACUNCULIASIS

(Tiokrom; 1994-1996).

AGE YEARS	M A L E S			F E M A L E S			T O T AL CASES.	%
	TOTAL	CASES	%	TOTAL	CASES	%		
0-5	4	0	0	3	0	0	0	0
6-10	7	2	28.6	2	0	0	2	1.5
11-15	13	4	30.8	11	5	45.5	9	6.9
16-20	12	4	33.3	9	6	66.7	10	7.7
21-30	21	7	33.3	6	2	33.4	9	6.9
31-40	10	2	20.0	15	3	20.0	5	3.8
41-50	2	0	0	8	0	0	0	0
>50	2	0	0	5	0	0	0	0
TOTAL	71	19	-	59	16	-	35	26.9

Sample size: 130; out of an estimated population of 180.

Table 7b. DISTRIBUTION OF DRACUNCULIASIS BY OCCUPATION (1994-1996).

(Tiokrom)

OCCUPATION	NUMBER	PERCENTAGE
Farmer	19	48.7
Trader	8	20.5
Housewife	10	25.6
Pupil	2	5.1
TOTAL	39	99.9

***39 and not 35 because some indigenes engage in more than one job.**

Table 7c. DISTRIBUTION OF DRACUNCULIASIS BY MONTH (1994-1996).

(Tiokrom).

MONTH	NUMBER	PERCENTAGE
January	1	2.9
February	9	25.7
March	8	22.9
April	12	34.3
May	3	8.6
June	0	0
July	0	0
August	1	2.9
September	0	0
October	0	0
November	0	0
December	1	2.9
TOTAL	35	100

Table 7d. SITE OF WORM EMERGENCE.

(Tiokrom).

S I T E	N U M B E R	PERCENTAGE
Hand	11	25.6
Knee	9	20.9
Ankle	21	48.8
Thigh	1	2.3
Tongue	1	2.3
Other	0	0
TOTAL	43	100

Table 8a. AGE AND SEX DISTRIBUTION OF DRACUNCULIASIS (1994-1996),

(Dzakpatra).

AGE YEARS	MALES			FEMALES			TOTAL CASES.	%
	TOTAL	CASES	%	TOTAL	CASES	%		
0-5	0	0	0	0	0	0	0	0
6-10	9	9	100	0	0	0	9	6.4
11-15	22	8	36.4	13	13	100	21	15.0
16-20	13	9	66.2	13	9	69.2	18	12.9
21-30	9	4	44.4	22	9	40.9	13	9.3
31-40	9	4	44.4	9	0	0	4	2.9
41-50	4	0	0	4	4	100	4	2.9
>50	9	0	0	4	0	0	0	0
TOTAL	75	34		65	35		69	49.4

SAMPLE SIZE: 140 out of an estimated population of 330. The indigenes were not very cooperative, hence the low sample size. This could further explain why workers of The Guinea worm Eradication Program, assemblymen and other health personel have virtually abondoned this village, hence, the persistence of Dracunculiasis in the village.

Table 8b. DISTRIBUTION OF DRACUNCULIASIS BY OCCUPATION (1994-1996).

(Dzakpatra).

OCCUPATION	NUMBER	PERCENTAGE
Farmer	31	29
Trader	27	25
Housewife	12	11
Pupil	35	33
TOTAL	106	100

Table c. DISTRIBUTION OF DRACUNCULIASIS BY MONTH (1994-1996).

(Dzakpatra).

MONTH	NUMBER	PERCENTAGE
January	4	4.8
February	13	15.5
March	31	36.9
April	18	21.4
May	13	15.5
June	0	0
July	0	0
August	0	0
September	0	0
October	4	4.8
November	0	0
December	0	0
TOTAL	83	100

Table 8d. SITE OF WORM EMERGENCE.

(Dzakpatra).

S I T E	N U M B E R	PERCENTAGE
Hand	24	17.2
Knee	40	28.7
Ankle	71	51.1
Thigh	4	2.9
Other	0	0
TOTAL	139	100

Table 9a. AGE AND SEX DISTRIBUTION OF DRACUNCULIASIS (1994-1996), MEPOM (Mataligu section).

AGE (YEARS)	MALES		FEMALES		TOTAL	
	TOTAL	CASES	TOTAL	CASES	NO.	%INFECTION
0 - 5	16	0	7	0	23	0
6 - 10	20	0	13	0	33	0
11 - 15	15	0	27	0	42	0
16 - 20	22	0	10	0	32	0
21 - 30	17	0	25	0	42	0
31 - 40	12	0	10	0	22	0
41 - 50	9	0	5	0	14	0
>50	6	0	7	0	13	0
TOTAL	117	0	104	0	221	0

Sample size: 221, out of an estimated population of <500.

Table 9b. AGE AND SEX DISTRIBUTION OF DRACUNCULIASIS (1994-1996), MEPOM (Kwesi Acheampong section).

AGE (YEARS)	MALES		FEMALES		TOTAL % INFECTION	
	TOTAL	CASES	TOTAL	CASES		
0 - 5	0	0	1	0	0	0
6 - 10	2	0	1	0	0	0
11 - 15	0	0	2	0	0	0
16 - 20	2	0	3	1	1	2.9
21 - 30	4	0	6	1	1	2.9
31 - 40	5	1	4	0	1	2.9
41 - 50	2	0	1	0	0	0
>50	0	0	1	0	0	0
TOTAL	15	1	19	2	3	8.7

Sample size: 34 out of an estimated oulation of <40.

FIGURE 1: GUINEA WORM SURVEY AREA.

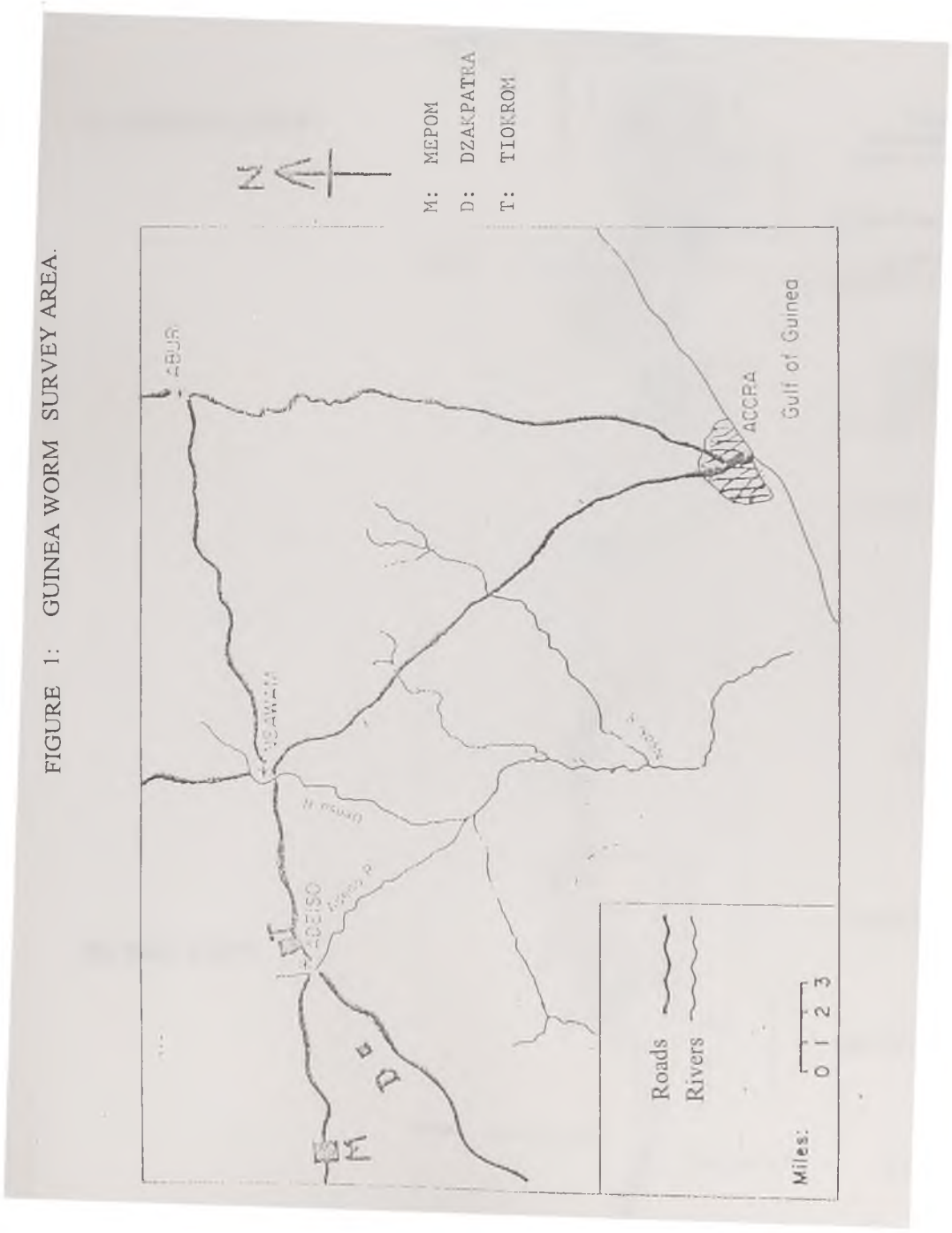


FIGURE 2: GENERALISED DIAGRAM OF A *CYCLOPS*.

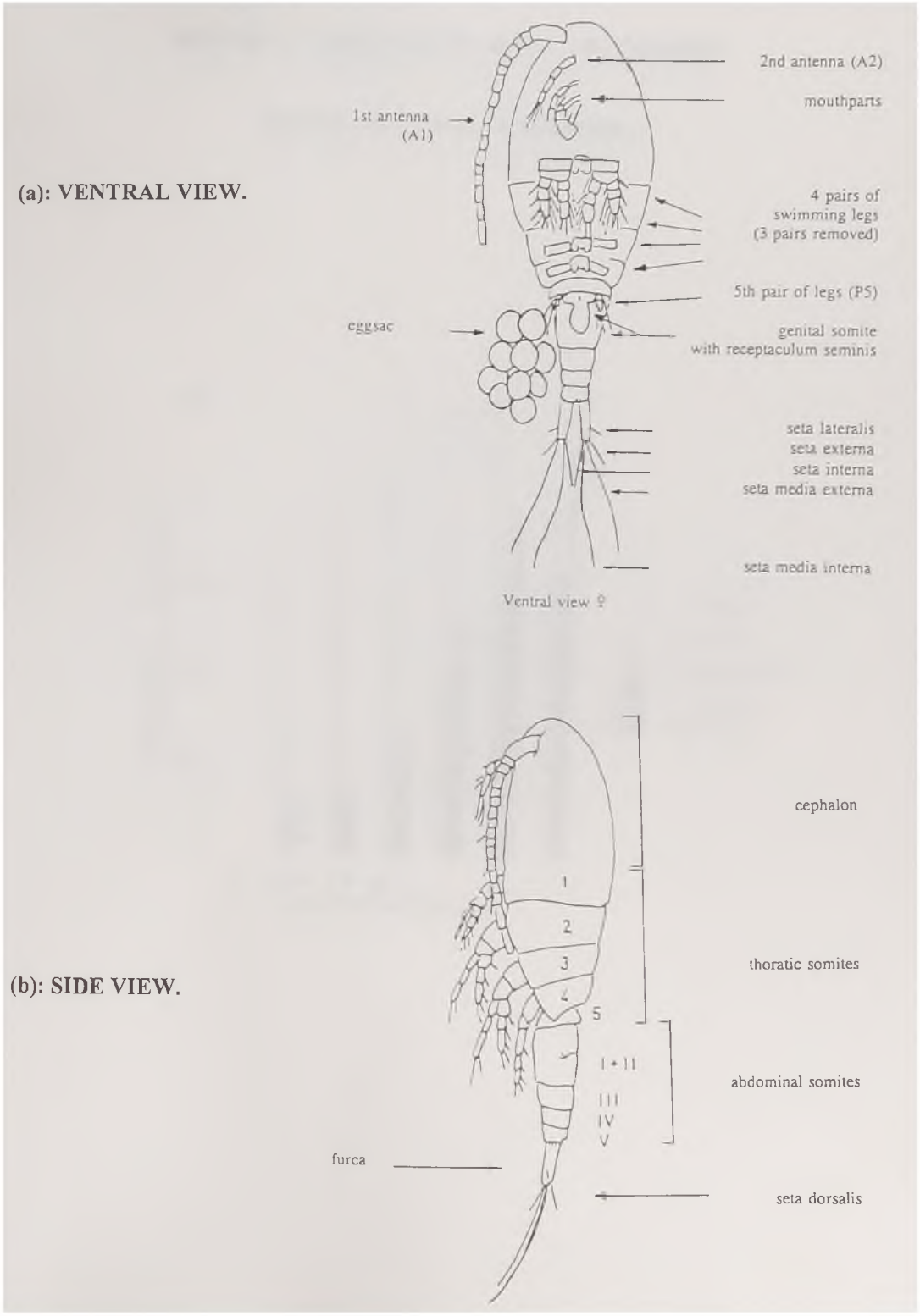


FIGURE 3: TOXICITY OF ABATE TO *CYCLOPS*.

FIGURE 3a. (24-hr EXPOSURE).

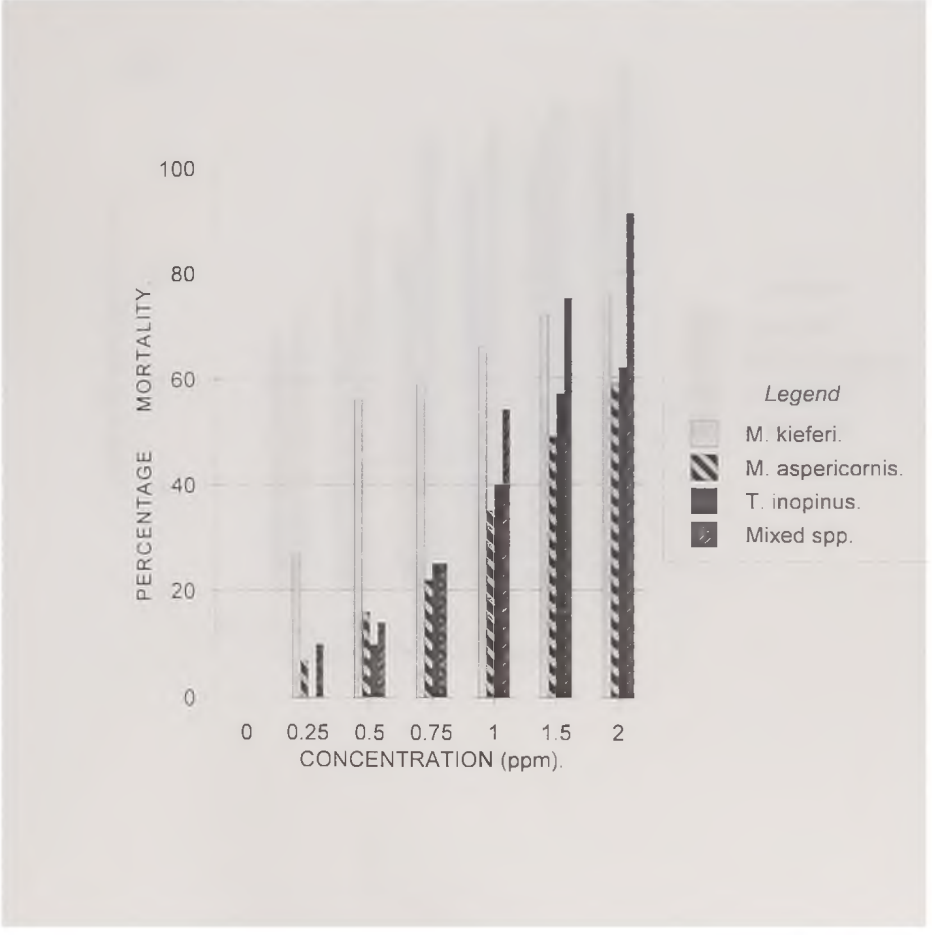


FIGURE 3: TOXICITY OF ABATE TO *CYCLOPS*.

FIGURE 3a. (48-hr. EXPOSURE).

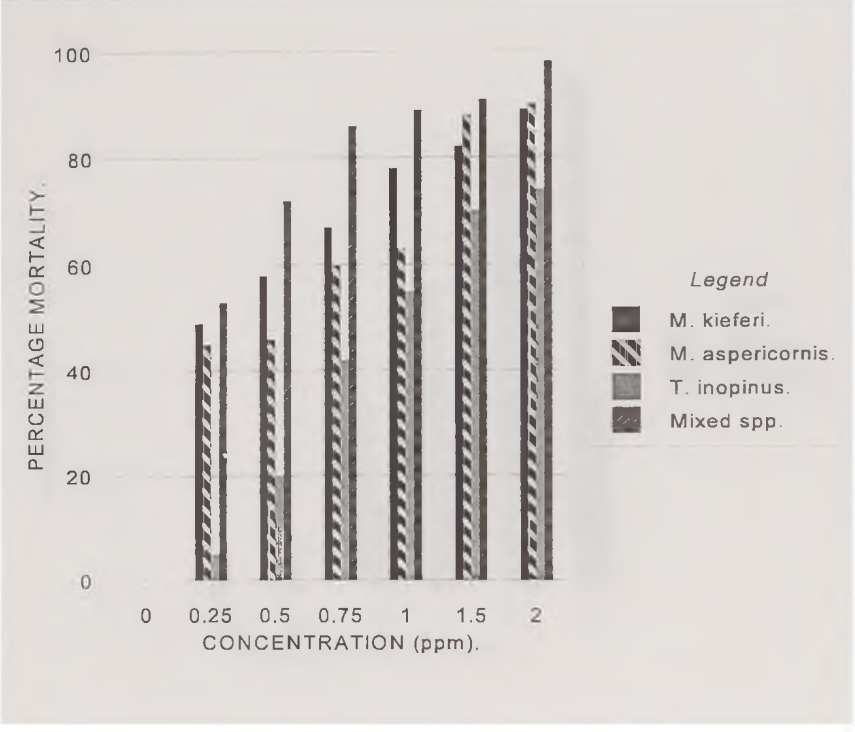


FIGURE 3c and 3d: SHOWING THE PERCENTAGE MORTALITY OF *CYCLOPS* WITH AGE/STATE OF ABATE.

FIGURE 3c. 24-hr. EXPOSURE.

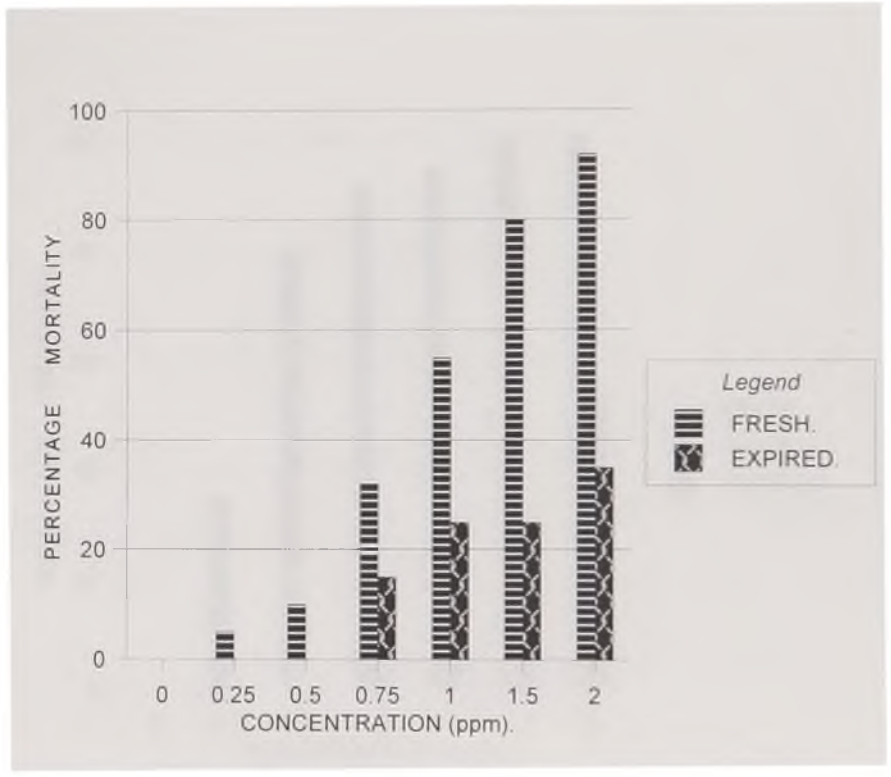


FIGURE 3d. (48-hr. EXPOSURE).

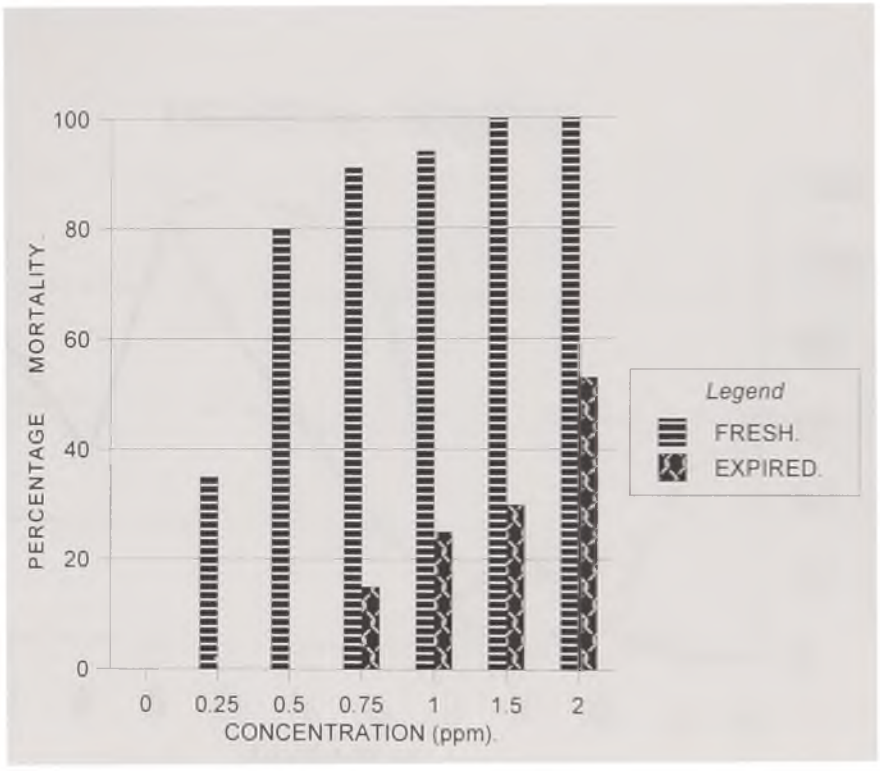
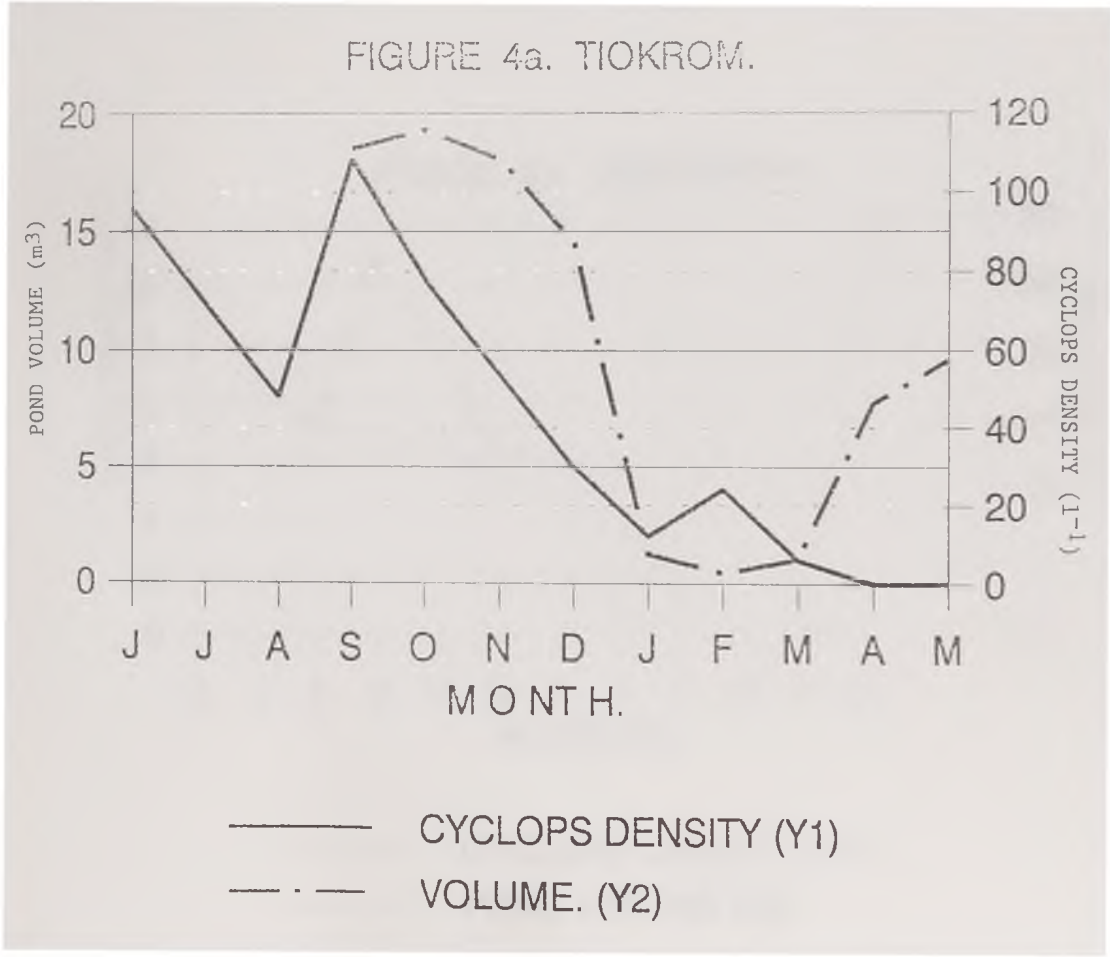
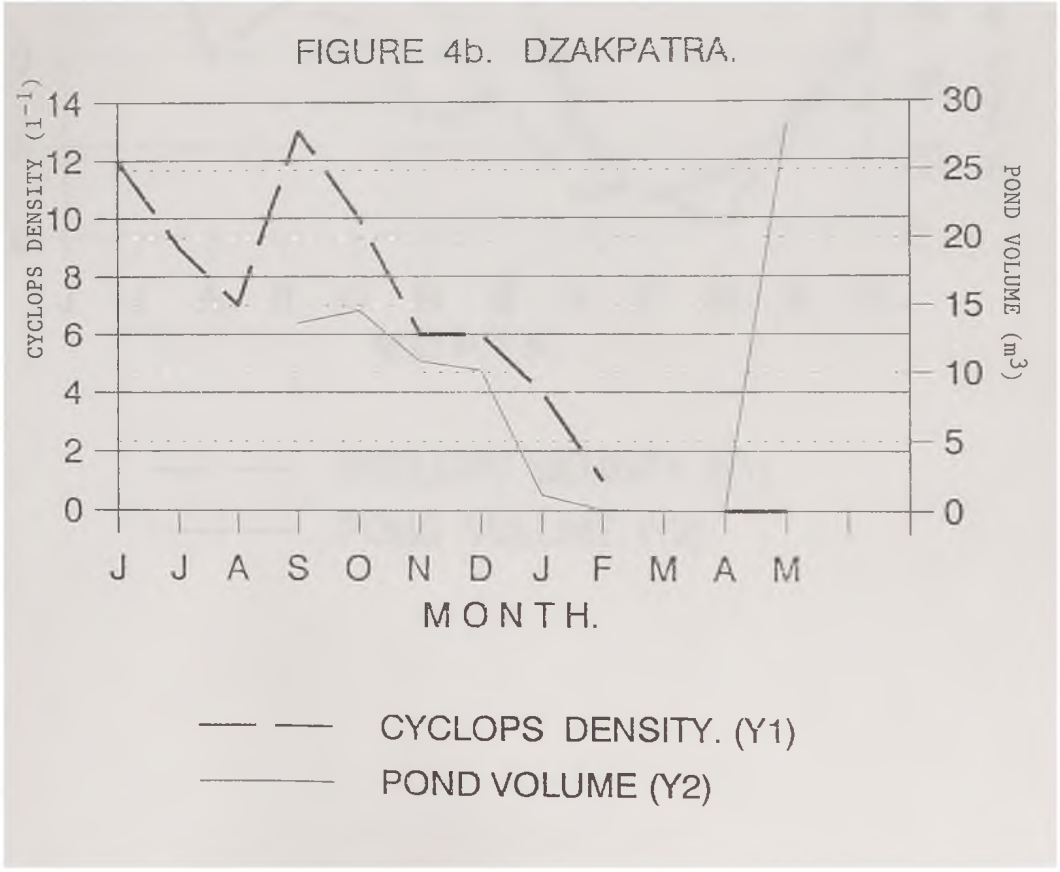
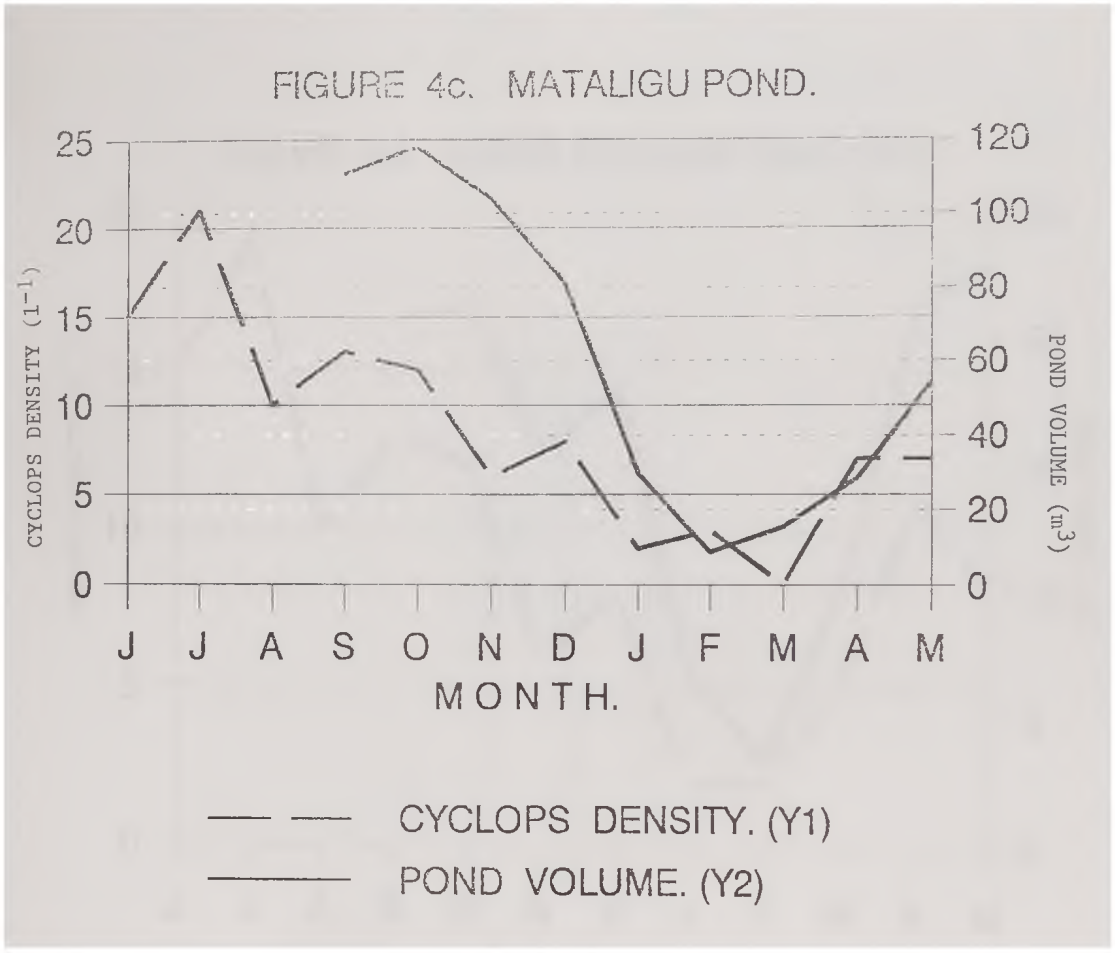


FIGURE 4: SHOWING SEASONAL VARIATION IN POND VOLUME AND *CYCLOPS* DENSITIES.







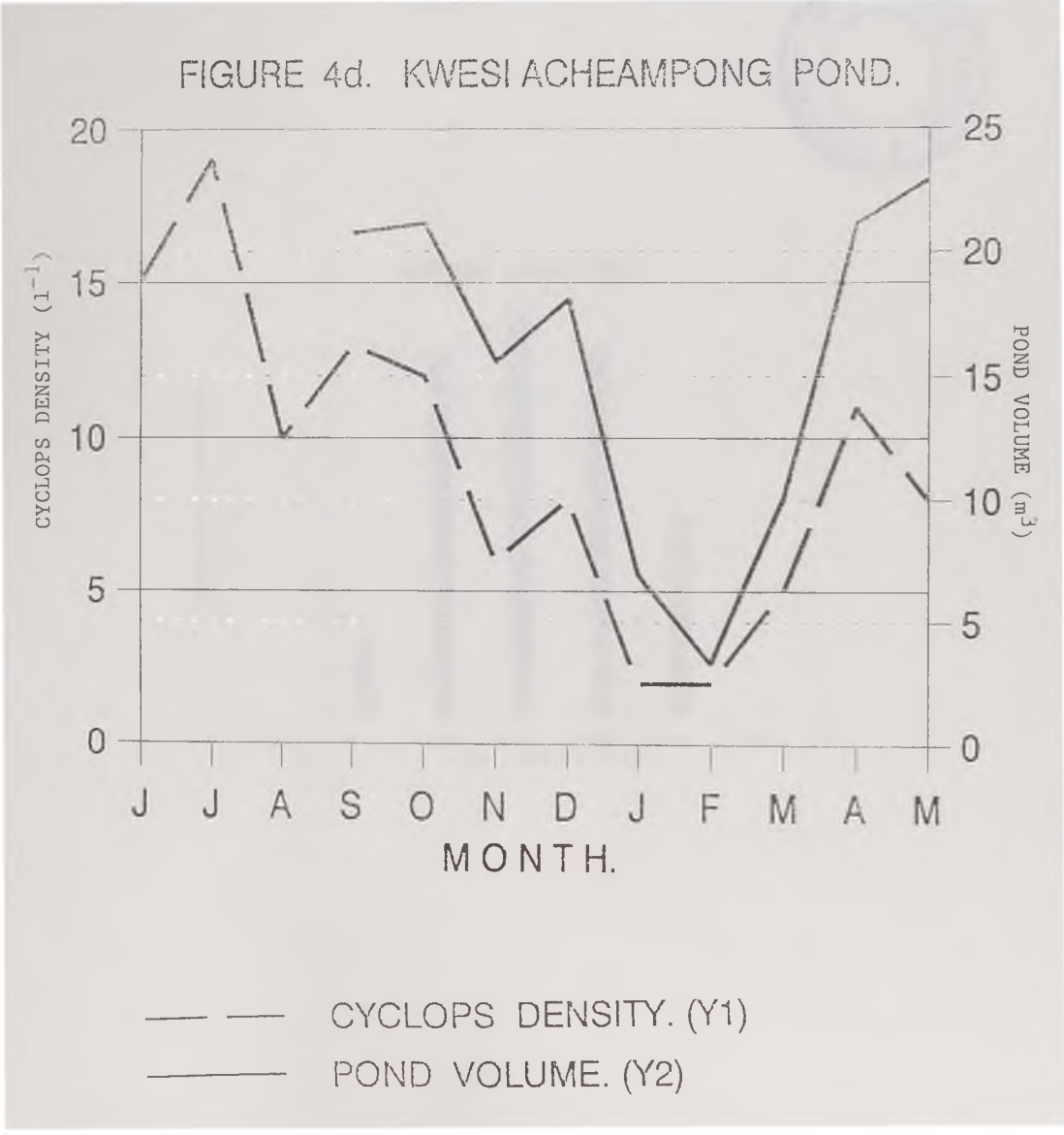


FIGURE 5a. DISTRIBUTION OF GUINEA WORM DISEASE BY AGE.

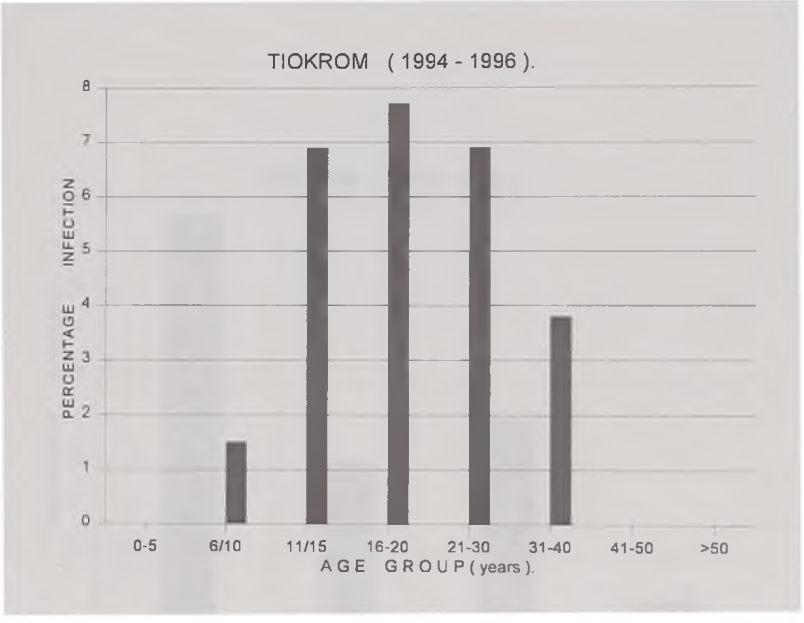


FIGURE 5b. DISTRIBUTION OF GUINEA WORM DISEASE BY OCCUPATION.

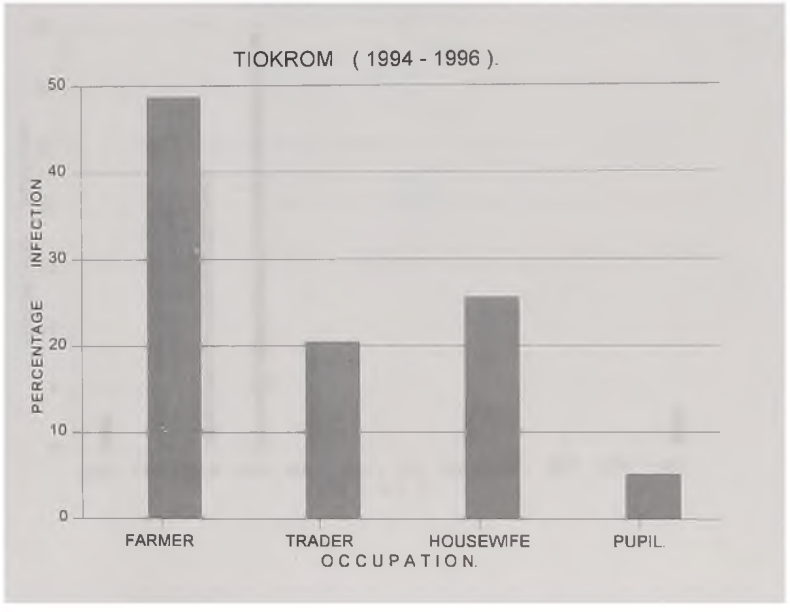


FIGURE 5c. DISTRIBUTION OF GUINEA WORM BY MONTH.

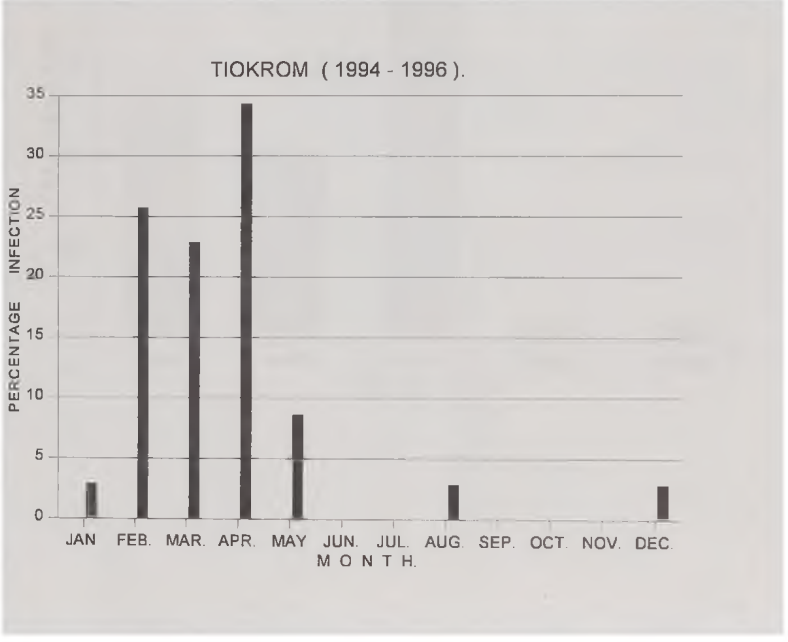


FIGURE 5d. PREFERRED SITE OF WORM EMERGENCE.

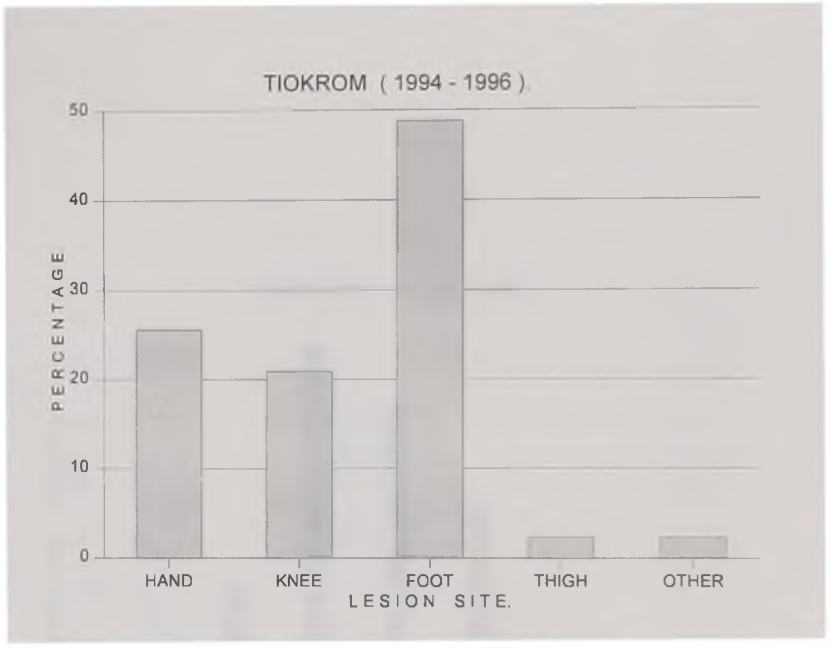


FIGURE 6a. DISTRIBUTION OF GUINEA WORM DISEASE BY AGE.

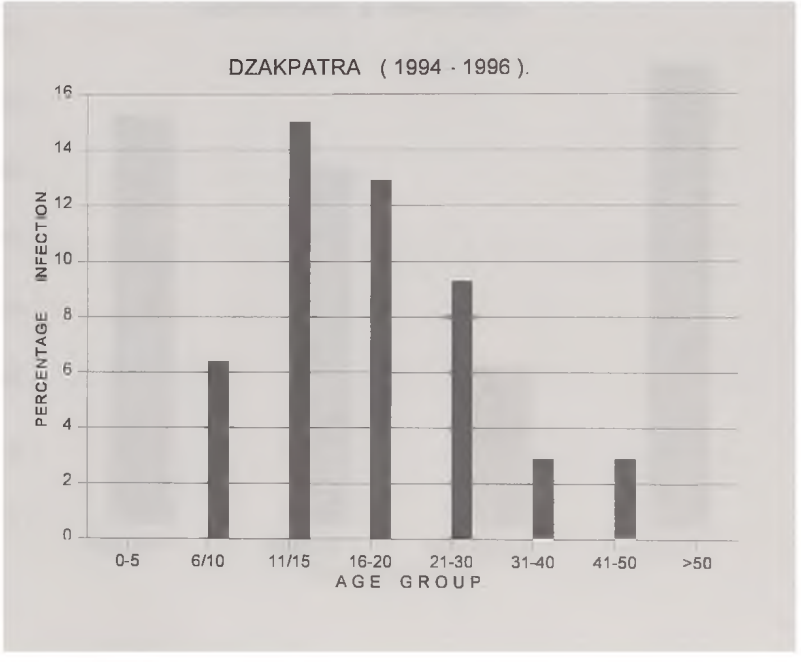


FIGURE 6b. DISTRIBUTION OF GUINEA WORM DISEASE BY OCCUPATION.

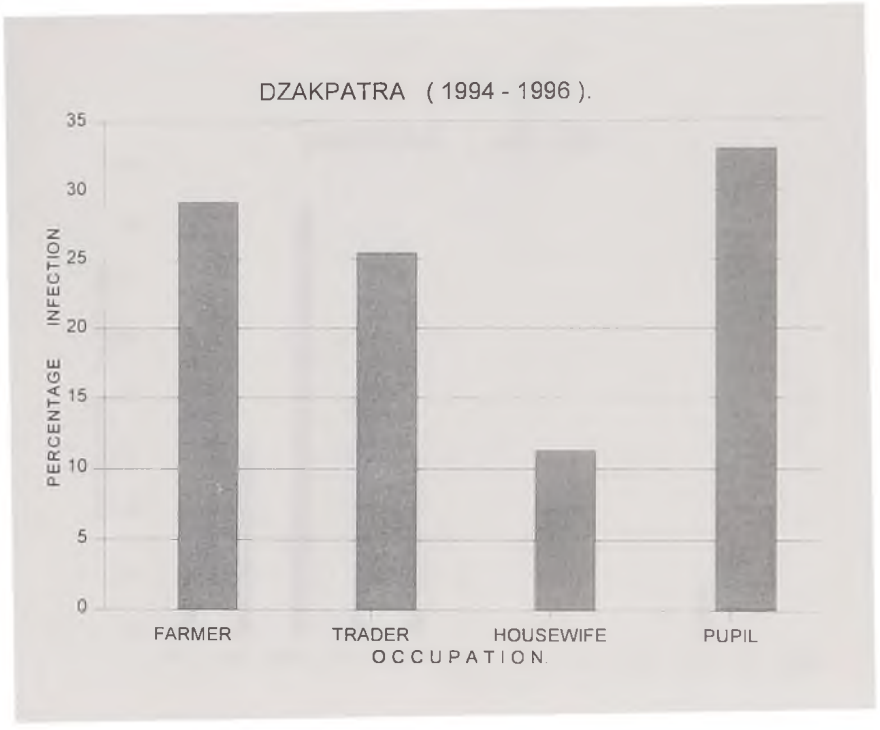


FIGURE 6c. DISTRIBUTION OF GUINEA WORM DISEASE BY MONTH.

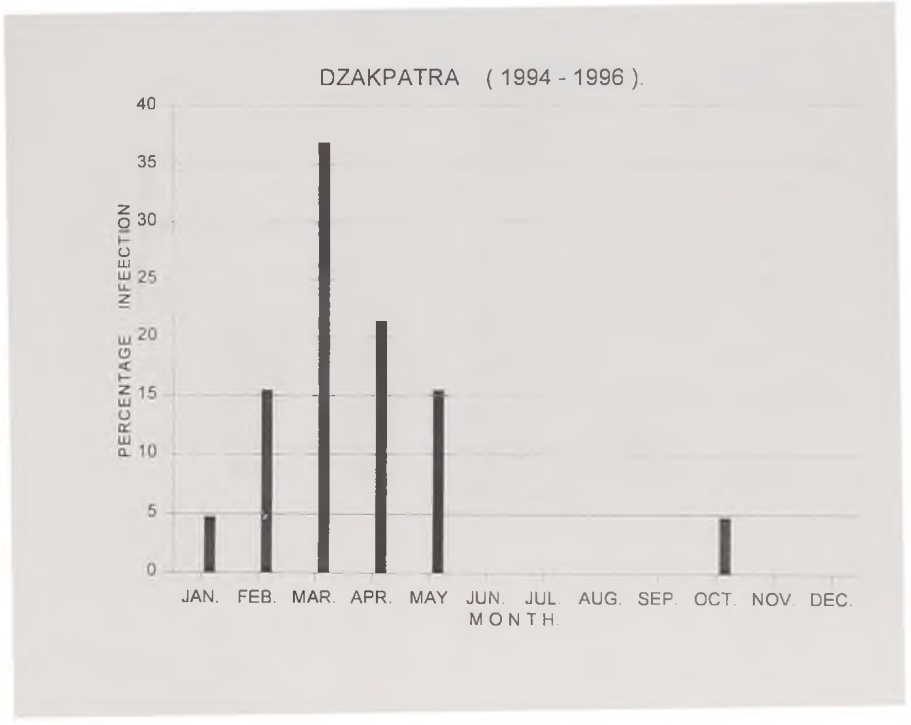


FIGURE 6d. PREFERRED SITE OF WORM EMERGENCE.

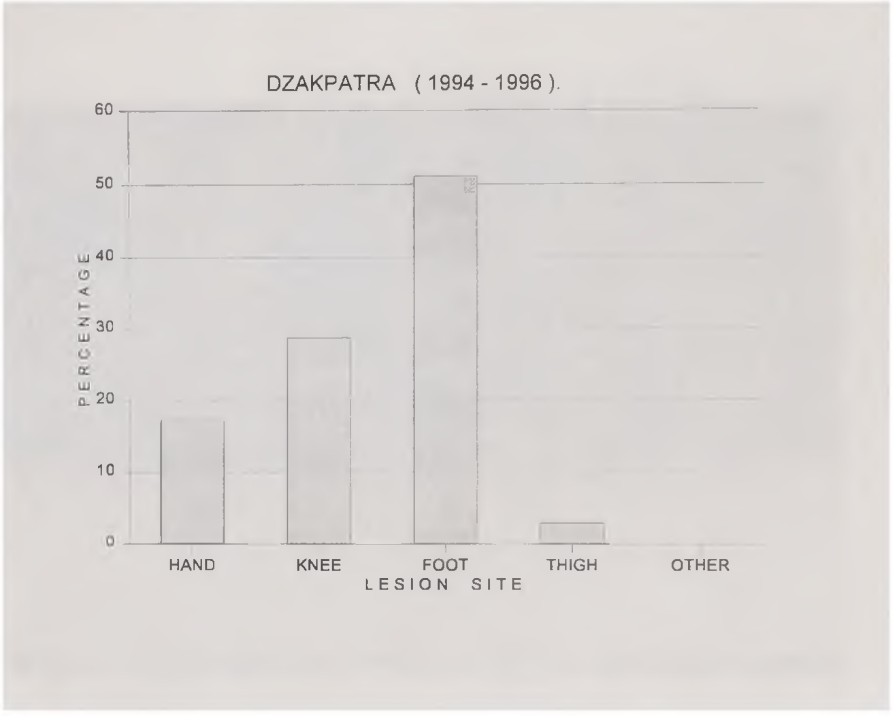
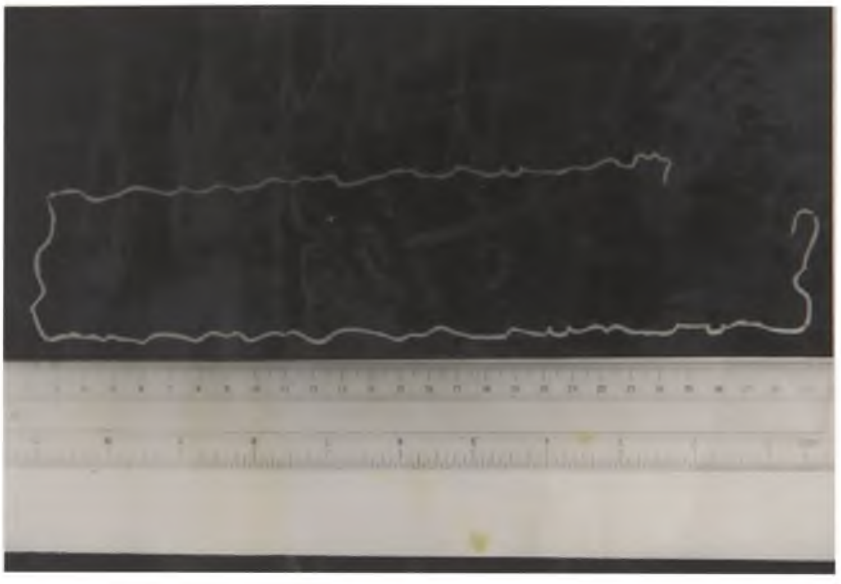


PLATE 1: FEMALE GUINEA WORM IN TWO COILS.

APPROXIMATE LENGTH: 84cm.



PLATES 2-5: PHYSICAL CHARACTERISTICS OF PONDS WITH TIME AND/OR SEASON.

PLATE 2a: TIOKROM POND.

POND AT MAXIMUM CAPACITY; JUNE - AUGUST 1995.

NOTE THE AMOUNT AND TYPES OF FRINGING VEGETATION.

PLATE 2b: POND AT MINIMUM VOLUME; JANUARY 1996.

NOTE THE DRASTIC REDUCTION IN THE WATER LEVEL AND THE ABSENCE OF FRINGING VEGETATION.

PLATE 3. MATALIGU POND (MEPOM).

PLATE 3a: POND AT MAXIMUM CAPACITY, JUNE-SEPTEMBER 1995. NOTE THE FLOATING MATS OF *PISTIA* SPP., EXCEPT AT THE CONTACT SITE.

PLATE 3b: POND AT MINIMUM VOLUME, JANUARY 1996.

NOTE THE ABSENCE OF FLOATING VEGETATION.

PLATE 4. KWESI ACHEAMPONG POND (MEPOM).

PLATE 4a: POND AT MAXIMUM CAPACITY, JUNE - AUGUST 1995.

NOTE THE *PISTIA* LOAD ON THE WATER SURFACE.

PLATE 4b: POND AT MINIMUM VOLUME, JANUARY 1996.

NOTE THE ABSENCE OF *PISTIA* LOAD AND THE DRASTIC REDUCTION IN THE WATER LEVEL.

PLATE 5. DZAKPATRA POND.

PLATE 5a: POND AT MAXIMUM CAPACITY, SEPTEMBER 1995.

NOTE THE AMOUNT OF FLOATING VEGETATION.

PLATE 5b: POND VOLUME DRASTICALLY REDUCED, JANUARY 1996.

PLATE 5c: POND COMPLETELY DRIED UP, FEBRUARY 1996.

Chapter 5

5.0 DISCUSSIONS.

The study villages for vectors of Dracunculiasis and factors that aid in the disease transmission are typical rural communities in southern Ghana, without potable water supply. The residents therefore depend solely on pond water both for drinking and for other domestic uses. These ponds are however, unreliable sources of water supply, with some drying up during the dry season. The ponds are, shallow, and the villagers wade into them when fetching water, especially in the dry season.

5.1.0 FIELD WORK.

5.1.1 Pond Morphometry and Population Dynamics of *Cyclops*.

The number of *Cyclops* species and their population density varied considerably in the various ponds throughout the period of study. It was found out that there were significant differences both geographically as well as temporally over the period of study. Thus, the calculated F-ratio for variation of *Cyclops* density between villages was 5.611 with an F-critical value of 2.892. Also, the F-calculated for variability with respect to month was 16.282 with an F-critical of 2.093. The observed trend could be attributed to a number of factors. Firstly, the amount and variety of food in the ponds could lead to the explosion or decline in numbers of the individual species and therefore the overall *Cyclops* densities. As was the case from June to August, the fall in numbers might be due to an appreciable increase in the volumes/capacities of the ponds caused by the heavy rains during this period. Also implicated were the nature and location of the ponds. With the exception of the

pond at Tiokrom, all the others could be considered as periodic streams. Thus, during the rainy season there was an inflow of water from upstream and a consequent outflow downstream. Therefore, these water bodies more or less maintained a constant volume of water during the rains, but were reduced to stagnant ponds when the rains ceased by October. A steady decline in the pond volumes occurred from October to February when there was no influx of water from the catchment areas.

These changes in the physical properties of the ponds influenced not only the density of *Cyclops*, but also the overall fauna and flora composition with month/season. The observed increases in numbers from February to June might be brought about by the availability of both organic and inorganic food materials such as cow dung (note that this was used as feed in the laboratory culture), and other animal droppings being washed into the water bodies. This loading of the ponds with animal droppings is further buttressed by the fact that domestic animals used these ponds as their main sources of drinking water in the dry season. As observed by Desfontaine and Prod'Hon (1982), there was often an increase in the prevalence of Guinea worm cases at the onset of the rains when villagers tended to collect unwholesome water from rock-pools and other small water bodies because the rivers were not yet filled with water (having dried up during the dry season). This situation provides an ideal condition for effective transmission of Dracunculiasis since man-water contact frequency increased remarkably.

Desfontaine and his colleague attributed the increase in prevalence during this period of the year to contamination of the ponds by people with active cases, since there was often a scramble for water at the collection sites. Their observation is further supported by the findings of the present investigation. Thus, the inflow of suitable and adequate food materials at the onset of the rains

leading to proliferation of *Cyclops* numbers (and probably species) was a suitable time for transmission. At this time, not only would there be adequate *Cyclops* for the transmission of Guinea worm, but also the preferred vector species as well as a suitable human behaviour pattern. These factors coincided to give the larvae a fair chance of infecting the vector species, as both the frequency of water contact by the victims and the vector numbers was increased. Thus, it was not only the contamination of the water bodies by people with active cases that accounted for the periodic increases in cases, but also the proliferation of *Cyclops* numbers and species due to adequate food materials washed into the ponds by the first rains.

Conversely, by the time the rains peaked (August) and the ponds were full to capacity, there was little or no organic inflow from the surrounding areas. Such conditions would lead to a reduction in the available *Cyclops* food, and only ponds with floating and/or submerged vegetation such as *Lemna, Pistia* and *Ceratophyllum* would tend to support high *Cyclops* densities.

Thus, whilst the decrease in densities in August could be due to increase in the volume of water in the ponds (rainfall maxima), the decrease in *Cyclops* count from October to February could be attributed mainly to the fact that the ponds were spent (i.e. *Cyclops* food material was exhausted).

The observed increases in the vector population in September and April might be explained from two perspectives. Firstly, the peak in September might be due to a fall in the water level for that brief period of no rain, and therefore the *Cyclops* population rose since there was still adequate food materials in the ponds. Secondly, the peak in April was mainly due to the influx of *Cyclops* food from the catchment area.

Another interesting observation was the fact that any physical interference with the pond substratum such a excavating might upset the *Cyclops* population dynamics, and probably other

organisms as well. This situation actually occurred in Tiokrom and Dzakpatra where the ponds were excavated in March and April respectively to enable seepage of ground water into the pond basin. The Dzakpatra pond however recorded its highest capacity in May because the villagers had damned the downstream outlet of the pond after the excavation exercise, causing the pond to fill up when the early rains came in April/May. It was also observed that this pond contained no *Cyclops* during this period. This could be attributed to the fact that any *Cyclops* eggs left in the pond basin after the excavation would not have hatched and developed to the adult stage yet. Another possible explanation would be that the removal of the soft mud from the substratum caused a change in the physico-chemical condition of the pond. Also the amount of organic matter in the water body necessary for *Cyclops* growth and reproduction would have decreased by the removal of the bottom layer of the pond which was rich in decayed and/or decaying organic matter.

5.1.2 Prevalence of Dracunculiasis in the study area.

In this study, it was found out that the complete dependence on a single source of drinking water in the dry season was a major factor that promoted Dracunculiasis transmission. The high prevalence of the disease among school children in Dzakpatra (33.0%) further augments this explanation. Thus, the physical location of the pond used as the main source of drinking water in the village played a major role with respect to the distribution pattern of the disease. This pond was located about midway along the main road linking the village to Danso where the nearest Junior Secondary school to the village was located. It could therefore be concluded that the heavy consumption of the pond water (especially after closing from school) by the school children would predispose them to heavy infections.

The results of the present survey corroborate those of Reddy *et al.*, (1969) that young children (0-5 years old) have less infections than the 6-15 year old group. The findings from the study (25% out of 26% infection in Tiokrom and 21% out of 49% in Dzakpatra), in people above the age of six years show that infection is highest among people in the working age class (16-40 years).

The finding that infection was highest in the dry season and therefore seasonal in nature also agreed with those of other surveys (Scott,1959; Brieger *et al.*, 1990 and Ilegbodu *et al.*, 1991). In this respect, as postulated by Scott (1959), climate was probably the single most important factor that determined the natural distribution of Dracunculiasis. The effect of a definite dry season, coupled with an incubation period of 8-12 months (Scott, 1959., Brieger and Rosenwieg, 1988; Smith *et al.*, 1989) could result in a marked annual periodicity in prevalence. The results obtained in the present study have therefore confirmed that Guinea worm prevalence exhibited some form of a changing cycle, at least in West Akim District of Ghana and probably all other parts of the country with a similar climate. The peak of the disease in Tiokrom was observed to occur in April whilst March recorded the peak prevalence in Dzakpatra. It is also important to note that whilst the peak prevalence of the disease could vary from one month to another even within the same village, the variable prepatent period among individuals (between 8 and 12 months) would tend to confine the transmission period to a definite time frame.

This intriguing behaviour of variability in prevalence even within a given locality means that the transmission could remain fixed to that period of "no water", but still there would be enough victims to contaminate the water sources, to maintain the cycle of transmission. This is because a group of people infected at the same period in time would suffer from the disease at different times the following year, ranging from 9-12 months post infection.

5.2.0 LABORATORY WORK.

5.2.1 Toxicity tests.

From the toxicity investigation, *Mesocyclops kieferi* and the mixture of species produced 24-hr. LC50 values of 0.53 and 0.94ppm respectively. The corresponding LC95 values are 9.15 and 2.42ppm. Manonmani *et al.*, (1989), however reported an LC50 of 0.05ppm for *M. leukarti* whilst Sastry *et al.*, (1978) observed that 0.25ppm did not affect the *Cyclops* density in a pond after a week. At a concentration of 0.75ppm, however, 25% of the *Cyclops* were dead within the same period. With a concentration of 1ppm, they observed no *Cyclops* in the pond after a week interval, and it took up to five weeks before a slow build up of *Cyclops* population was noted. Thus, they concluded that Abate effectively controlled the Indian species of *Cyclops* at 1ppm. From the present investigation, the similarity in susceptibilities of *Mesocyclops kieferi* and the composite sample could be interpreted to mean that what was considered as a mixture or a composite sample was actually made up of a greater proportion of *Mesocyclops kieferi*. This is because this species was observed to be the most common *Cyclops* throughout the period of study. The ANOVA results also showed that toxicity of Abate to

Cyclops is species specific.

Samman and Thomas (1978) also reported a 24-hr. LC50 of 0.20ppm for adult *Thermocyclops hyalinus.* This wide range in differences in the toxicities observed might be due to several factors such as species, different methods of investigation, as well as ecological and geographical conditions.

The observed 24-hr. LC50 for *Mesocyclops aspericornis* and *Thermocyclops inopinus* in the present study (1.54 and 1.36ppm respectively), could mean that these two species were relatively less susceptible to ABATE than *M. kieferi*, even though both the 24 and 48-hr. LC95 for *M. kieferi* were much higher (8.33 and 4.86ppm), when compared to 4.50 and 4.23ppm for *Mesocyclops aspericornis* an *Thermocyclops inopinus* respectively. Probit analysis of the mortality rates of these species when exposed to ABATE (**using a computer package; Startgraphics version 4.2**) showed that there were no significant differences in the mortality rate of *Mesocyclops kieferi* and the composite sample (mixture of species). There was however a statistically significant difference in mortality rates between *M. kieferi* and the mixture of species on one hand and the rest (Appendix B and C).

From these toxicity studies, the cyclopscidal potential of ABATE may be said to be very high and encouraging. The caution however is that the application in ponds used as sources of drinking water should be done depending on the prevailing circumstances. A periodic application of Abate at the evaluated 24-hr. LC50 (0.94ppm) of the chemical may be applied to ponds frequently used as sources of drinking water as a measure to control the *Cyclops* populations in the ponds. In the event of an outbreak of Guinea worm disease in a village however, a recommended dosage of 2.00ppm (the evaluated 24-hr. LC90) can be applied for that short period to wipe out most of the infective *Cyclops* that might be present in the ponds. This should however be done after informing and educating the indigenes to store enough boiled and/or filtered water for drinking (ironically, boiling and filtering drinking water is a practice the villagers rather shun or feel reluctant to do, especially those working in fields (Chippaux, 1991). Thus, water should not be fetched from these treated ponds for about three days by which time the concentration of the ABATE would have fallen to half it original value (1.00ppm) which is quite safe for consumption (Chippaux, 1991).

The use of the expired chemical by Guinea worm Eradication Programmes to control the vector should be discouraged. This is because a comparison of the effective concentrations of the Fresh and the Expired Abate showed a marked significant difference in the rates of *Cyclops* mortality both for 24 and 48-hr. durations.

5.2.2 Identified *Cyclops* species.

With respect to the *Cyclops* species in the study area, seven different species were identified (four belonging to the genus *Mesocyclops* and three to the genus *Thermocyclops*). These were: *Mesocyclops kieferi, M. aspericornis, M. tenuisaccus, M. spinosus, Thermocyclops inopinus, T. oblongatus and T. incisus*. Other genera identified were *Allocyclops, Afrocyclops, Diacyclops* and *Ectocyclops*.

Considering the numbers and consistency in appearance of the various potential vectors (*M. kieferi, M. aspericornis, T. oblongatus, T. inopinus and T. incisus*), *Mesocyclops kieferi* was highly implicated as the major vector that transmitted the disease in the study areas. This species did not only appear as the commonest *Cyclops* species in the area, but also was present

in the ponds throughout the period of study (June 1995 - May 1996), with the exception of ponds that dried up (Dzakpatra pond) or were physically tampered with (Tiokrom pond), thereby interfering with the hydrological regime of the pond. *Mesocyclops aspericornis* could be the next implicated in order of frequency of appearance, followed by *Thermocyclops inopinus*. *Mesocyclops aspericornis* was however found to be common in only one of the ponds studied (Kwesi Acheampong:- Mepom). Apart from not being prevalent in all the ponds, the appearance of this species was also found to be limited to the rainy season only. The other potential vectors were; *Thermocyclops incisus and Thermocyclops oblongatus*. This later group were not however as prevalent as the two *Mesocyclops* species:- *M. kieferi and M. aspericornis,* thus, casting doubt on their vectorial and/or transmission capacities. They were also observed to be confined to a period of considerable rainfall, when transmission was often rather low or absent altogether.

Chapter 6

6.0 CONCLUSIONS AND RECOMMENDATIONS.

The following conclusions and recommendations could be drawn from the results of the study:

(a) CONCLUSIONS.

(1) The prevalence of Dracunculiasis in West Akim District of Ghana was highest among the 16-40 year age groups.

(2) The prevalence of Dracunculiasis in West Akim District of Ghana was restricted to January to April each year, coinciding with the onset of agricultural activity.

(3) Generally, Guinea worm disease had no predilection for any particular occupation in the study area. Within a village however, the incidence of the disease was found to be occupation dependent.

(4) The possible intermediate host species of Dracunculiasis in the study area in order of importance included: *Mesocyclops kieferi* > *Mesocyclops aspericornis* > *Thermocyclops inopinus* >*Thermocyclops spinosus.*

(5) Fresh Abate at a concentration of 0.94ppm could effectively control the *Cyclops* populations in the ponds that were frequently used as sources of drinking water.

(6) Expired Abate used in the control of *Cyclops* populations in ponds often used as sources of drinking water was not found to be effective.

(7) The beliefs, values and attitudes of the indigenes could hamper control strategies, especially when the two contradict each other. This situation could lead to non-compliance with control measures and consequently maintain the disease transmission in the endemic villages.

(b) RECOMMENDATIONS.

(1) The periodic application of Abate at a concentration of 0.94ppm (≈1ppm) to the ponds that serve as sources of drinking water could effectively control the *Cyclops* populations. In the event of an out break of Dracunculiasis however, a dosage of 2ppm is recommended.

(2) The use of the Expired chemical for vector control should be discouraged or stopped.

(3) Also, a search for biological control agents as well as immunodiagnostic methods should be intensified.

(4) There is the need for the infection potentials of the *Cyclops* species implicated as potential vectors of Dracunculiasis to be investigated

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APPENDIX A

QUESTIONNAIRE FOR GUINEA WORM DISEASE (DRACUNCULIASIS) SURVEY.

1. Town/Village.....
2. Respondent No:.....
3. Age.....
4. Sex.....
5. **Educational Background**:

   None..... Prim./J. S.S..... S..S.S.....

   College..... Polytechnic..... University.....

4. **Human Behaviour:**

   (a) **Occupation:**

   Pupil..... Student..... Farmer..... Fisherman.....

   Trader..... Housewife..... Other (specify).....

   (b) How much of your work involves coming into contact with the pond water?

   None..... Small..... Half..... All.....

   © How much do you depend on the pond water? All year..... Only in the dry season....

   (d) Which other source of water do you use?

   None..... Bore hole..... River..... Rain water.....

(e) When do you often fetch water from the pond?

Morning.....Afternoon..... Evening..... Just on demand.....

(f) Which of the following do you do in the water?

Swimming..... Bathing..... Washing clothes.....

Wading through to fetch water for domestic/farm use.....

5. **Living Condition**:

How far is your house from the pond? Close..... Not close..... Far away.....

6. Have you ever been a victim of Guinea worm disease? Yes..... No.....

If yes, Year..... Month.....

From which part of you body did the worm emerge? Leg..... Hand.... .Other (specify).....

7. When was the last time a member of your family had a Guinea worm disease?

Year..... Month.....

8. **Knowledge of the Disease:**

(a) How does one get the disease?.....

(b) How can the disease be prevented?.....

(c) Have you been taught how to prevent or cure the disease? Yes.....No.....

If yes, by who?.....

9. **General comments**:

.....

.....

.....

APPENDIX B.

ANALYSIS OF VARIANCE (ANOVA): Two- Factor Without Replication.

$\alpha = 0.05$ (95% Confidence Level).

B1. Ho: *Cyclops* mortality is independent of species (24-hr.)

Source of Variation	SS	df	MS	F-calculated	P-value	F-critical
CYCLOPS SPP.	3094.13	3	1031.38	11.88106	0.000303	3.287383

B2. Ho: *Cyclops* mortality is independent of species (48-hr.)

Source of Variation	SS	df	MS	F-calculated	P-value	F-critical
CYCLOPS SPECIES.	4374.16	3	1458.056	26.840887	2.81	3.287383

B3. Ho: *Cyclops* mortality is independent of age/state of ABATE (24-hr.).

Source of Variation	SS	df	MS	F-calculated	P-value	F-critical
AGE/STATE OF ABATE	2523	1	2523	9.925256	0.025366	6.607877

B4. Ho: *Cyclops* mortality is independent of age/state of ABATE (48-hr.).

Source of Variation	SS	df	MS	F-calculated	P-value	F-critical
AGE/STATE OF ABATE	11844	1	11844	5.460356	0.042979	5.050339

B5 : Ho: *Cyclops* density is independent of village and/or pond

Source of Variation	SS	df	MS	F-calculated	P-value	F-critical
MONTH	1330.73	11	120.98	16.28218	2.6	2.093252
VILLAGE	125.06	3	41.69	5.610757	0.00319	2.891568

APPENDIX C.

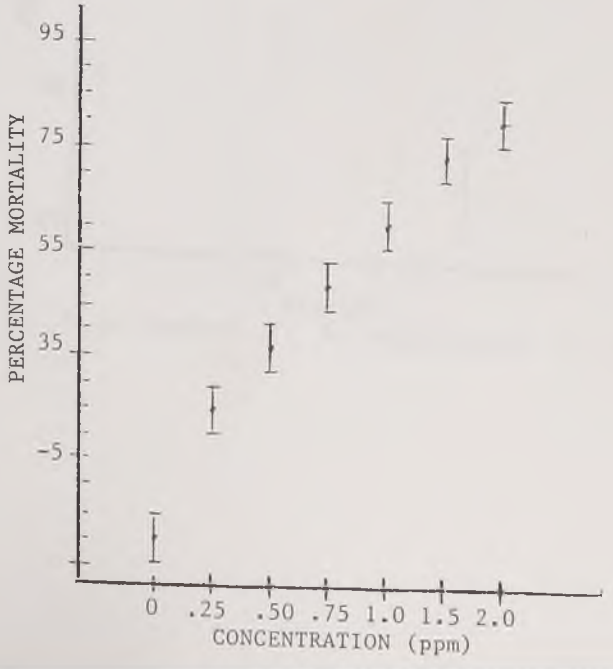
(LSD = Least Significant Difference.)

C1. MULTIPLE RANGE ANALYSIS FOR *CYCLOPS* MORTALITY BY CONCENTRATION OF ABATE.

METHOD: 95% LSD INTERVALS.

Conc. (ppm).	COUNT	AVERAGE	HOMOGENEOUS GROUPS
0.00	8	0.0000	*
0.25	8	24.500	*
0.50	8	36.500	*
0.75	8	48.250	*
1.00	8	60.000	*
1.50	8	73.000	*
2.00	8	79.875	*

(GRAPH FOR C1).
INTERVALS FOR FACTOR MEANS.



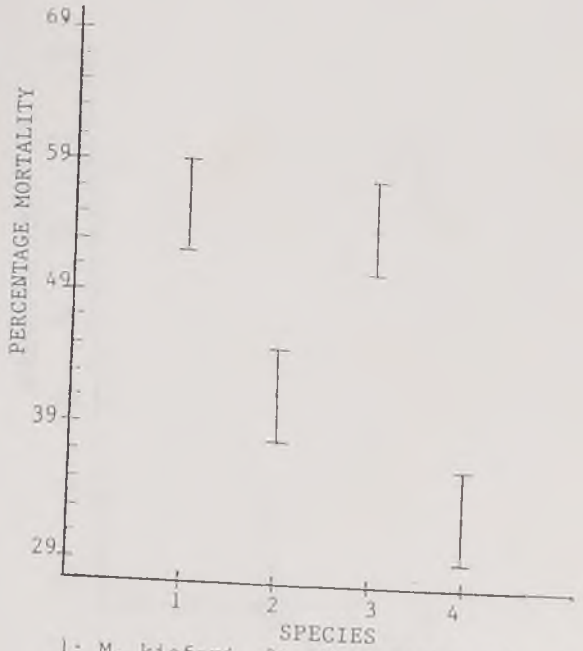
C2. MULTIPLE RANGE ANALYSIS FOR *CYCLOPS* MORTALITY BY SPECIES.

METHOD: 95% LSD INTERVALS.

SPECIES	COUNT	AVERAGE	HOMOGENEOUS GROUPS
M. kiefers	14	55.6428	•
M. aspericornis	14	41.4285	
T. inopinus	14	54.1428	•
Mixed spp.	14	32.8571	•

(GRAPHS FOR C2)

INTERVALS FOR FACTOR MEANS.



1: M. kieferi 2: M. aspericornis 3: Mixed spp. 4: T. inopinus

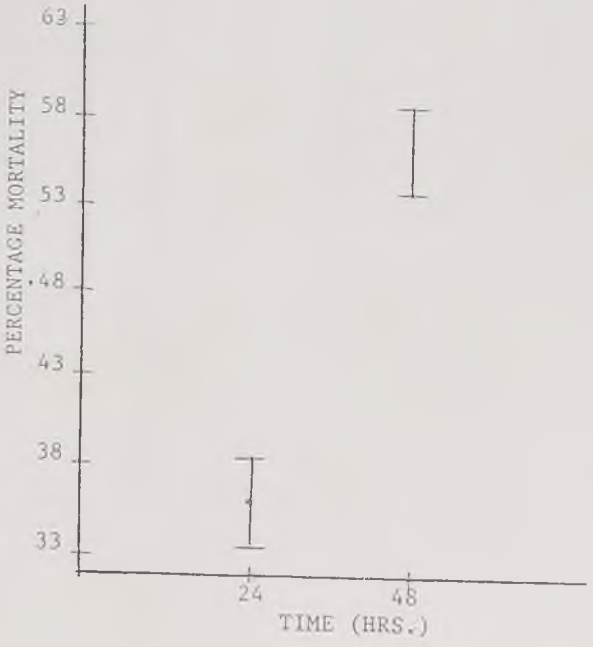
C3. MULTIPLE RGANGE ANALYSIS FOR *CYCLOPS* MORTALITY BY TIME.

METHOD: 95% LSD INTERVALS.

TIME (HRS).	COUNT	AVERAGE	HOMOGENEOUS GROUPS
24	28	35.9642	*
48	28	56.0714	*

(GRAPHS FOR C3)

INTERVALS FOR FACTOR MEANS.



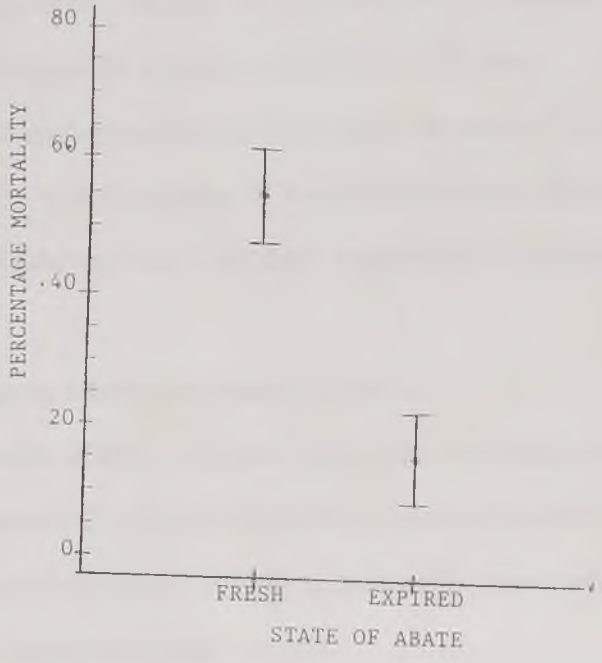
C4. MULTIPLE RANGE ANALYSIS FOR *CYCLOPS* MORTALITY BY AGE OF ABATE (FRESH OR EXPIRED).

METHOD: 95% LSD INTERVALS.

AGE/STATE OF ABATE	COUNT	AVERAGE	HOMOGENEOUS GROUPS
FRESH	14	55.0714	*
EXPIRED	14	15.9265	*

(GRAPHS FOR C4)

INTERVALS FOR FACTOR MEANS.



APPENDIX D.

FRESHWATER CYCLOPOID COPEPOIDS OF WEST AKIM DISTRICT, GHANA ; WITH AN ILLUSTRATED KEY TO SOME VECTOR SPECIES OF GUINEA WORM.

(1) Female antennules (A1), with 10 or more segments 2

(2) *Distal segment or simply segment of fifth pair of legs (P5), with 1 or 2 appendices (spines).....Subfamily: Eucyclopinae.....3

*Distal segment of P5 with 3 appendices (setae/spines)..... Subfamily: Cyclopinae.....6

(3) *P5 with 2 segments, first antenna (A1), with 17 segments.....Genus: *Macrocyclops.*

*P5 with only 1 segment, A1 with less than 12 segments. Presence of a central protuberance at the distal edge bearing the middle setae.....4

(4) *A1 as long as cephalothorax, furca without any trace of "serra".....5

*A1 with 10 or 11 segments. P5 fused to fifth thoracic segment..... Genus: *Ectocyclops.*

(5) *Furcal rami very long. Furcal index (ratio of furcal length to furcal rami) greater than 4. Genus: *Afrocyclops.*

* Furcal rami short, furcal index less than 4.....Genus: *Tropocyclops.*

(6) *P5 consists of only one segment, endopodite and exopodite of P1-P4 with 2 segments...7

*P5 consists of 2 segments, endopodite and exopodite of P1-P4 with 3 segments.....8

(7) *P5 very much reduced. The only segment present fused with fifth thoracic segment and bears a long terminal spine with setae..... .....Genus: *Allocyclops.*

(8) *The spine of the distal segment of P5 is much shorter than the setae of the same segment. Genus:.. *Diacyclops.*

*Spine and setae of distal segment of P5 approximately the same length.....9

*Spine and setae of distal segment of P5 approximately the same length.....9

(9) *Fifth leg with 2 setae inserted distally or sub-distally on free end. Genus: *Thermocyclops*.....*10*.

*Fifth leg (P5), with 2 setae, 1 inserted apically on free/distal segment. The other near the middle of inner margin.....Genus: *Mesocyclops*.....12.

(10) *protuberance of the uniting lamella of P4 armed with small teeth. Lateral wings of seminal receptacle large and recurved posteriorly.....*Thermocyclops oblongatus*.

*Protuberance of the uniting lamella of P 4smooth.....11.

(11) *Dorsal seta (on caudal ramus), about the same as length as seta externa. A1 reaching to the distal margin of second thoracic segment..... *T. inopinus*.

*Seta dorsalis at least 2x the length of seta externa, but slightly shorter than seta interna. Distal part of the long seta media interna markedly curved.....*Thermocyclops incisus*.

(12) *Inner margin of furcal/caudal rami armed with a row of setules.....13.

*Inner margin of caudal rami devoid of such setules.....15.

(13) *Setules along entire length of rami.....14.

*Setules only on proximal portion of caudal rami.....*Mesocyclops spinosus*.

(14) *Setules on rami very long, some overlapping.....*Mesocyclops aspericornis*.

*Setules on rami not very long.....*Mesocyclops tenuisaccus*.

(15) *Frontal side of basipodite of A2 without a group of small hairs next to the seta at its distal end. Lateral edge of the fith thoracic segment without fine hairs/ spinules.

Mesocyclops kieferi.