The transmission of intestinal schistosomiasis in Begemder Province, Ethiopia

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THE TRANSMISSION OF INTESTINAL SCHISTOSOMIASIS IN BEGEMDER PROVINCE, ETHIOPIA

THE TRANSMISSION OF INTESTINAL SCHISTOSOMIASIS IN BEGEMDER PROVINCE, ETHIOPIA

PROEFSCHRIFT

Ter verkrijging van de graad van Doctor in de Wiskunde en Natuurwetenschappen aan de Rijksuniversiteit te Leiden, op gezag van de Rector Magnificus Dr. A. E. Cohen, Hoogleraar in de Faculteit der Letteren, volgens besluit van het college van dekanen te verdedigen op woensdag 5 maart 1975 te klokke 16.15

door

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Aan hen die dit aangaat

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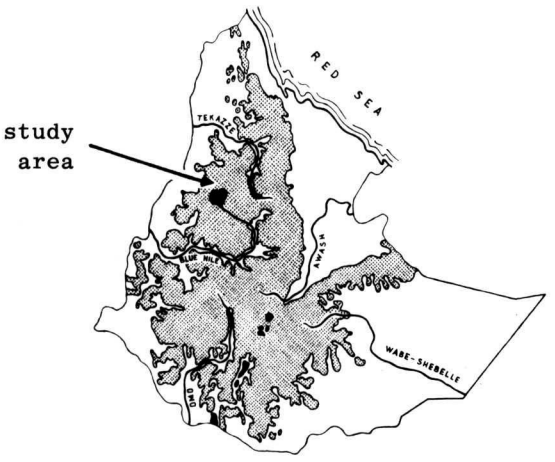


Map 1. Relief of Ethiopia

altitude more than 1500 m.

altitude less than 1500 m.

rivers

lakes

PREFACE

This thesis is a modified version of the final report on the NUFFIC project RUL/2 (Rijks Universiteit Leiden, second project).

The project was the result of a scientific cooperation between the Institute of Pathobiology of the Haile Selassie I University, Addis Ababa, and the Laboratory for Parasitology, Rijks Universiteit Leiden. All fieldwork was executed by the author and his technicians and the project was supervised by Prof. Dr. C.F.A. Bruijning and Prof. Dr. Aklilu Lemma.

The major part of the funds was provided by the Netherlands University Foundation for International Cooperation (NUFFIC). Additional funds were made available by the World Health Organization for local assistance and by the Leiden University for processing the field data.

The initial aim of the project was to perform a study on the role of baboons as reservoir hosts for schistosomiasis in the Awash Valley. Since the distribution of baboons and the area of reasonable high infection rates for human schistosomiasis did not seem to have a great overlap in the planned study area, the original research design had to be abandoned. Instead the host-parasite relationship in a stable rural area in North Ethiopia was studied.

The aims of the present study have been:

- to describe the geographical distribution of intestinal schistosomiasis in a part of Begemder Province;
- to study the man-parasite-snail relationship in the field;
- and to search for ways to reduce the intensity of transmission; efficient control of the disease with the aid of large scale application of molluscicides and mass chemotherapy, may not be accomplished until a higher level of socio-economic development will be attained.

Clearly, this general approach requires some knowledge of all parts of the life cycle of the parasite and it's hosts.For that reason this report deals with parasitological examinations and with malacological, serological, and a few behavioural observations as well. In the general discussion it will be attempted to get to a synthesis.

CHAPTER I INTRODUCTION

1.1. THE LIFE CYCLE OF SCHISTOSOMA MANSONI

Intestinal schistosomiasis is a disease caused by the tre-*Schistosoma mansoni* (Sambon, 1907). Man is the principal final host of this parasitic worm and the intermediate host is a fresh water snail. The adult worms, which are some 8-15 mm long, inhabit the portal venous system. There, the females produce large amounts of eggs, many of which are excreted with the faeces. The remaining eggs get stuck in the tissues where they die. As a result of the dead eggs bilharzial granulomas are formed which are the main cause of pathologic changes in the host.

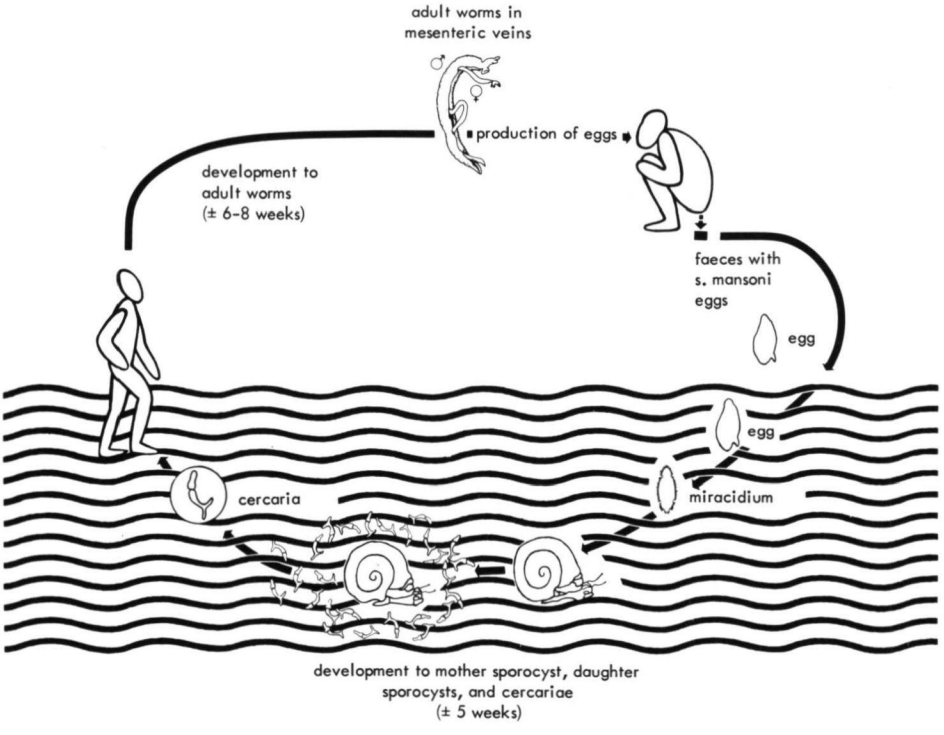


Fig. 1.1. The life cycle of S. mansoni

The excreted eggs hatch on immersion in water and the escaping miracidia can freely live in the water for several hours. If they succeed in penetrating an intermediate host snail (in Ethiopia: *Biomphalaria pfeifferi*) a mother sporocyst, several daughter sporocysts, and eventually, after some 4-5 weeks, many cercariae are produced. The phase of asexual multiplication in the snail host results in the production of large numbers of exclusively either male or female cercariae. Only snails that have been penetrated successfully by several miracidia may shed cercariae of both sexes. The free living cercariae have a short life span: most of them die within 24 hours.

Man may become infected when his skin is exposed to water containing cercariae. When the cercariae penetrate man's skin they are transformed into schistosomules and in some 40-60 days these schistosomules develop into adult worms that migrate to the portal and mesenteric veins. Then eggs are produced again.

1.2. SOME GENERAL ASPECTS OF INTESTINAL SCHISTOSOMIASIS

1.2.1. Schistosomiasis in Africa

Schistosomiasis is an old disease in Africa. Probably both *Schistosoma mansoni* and *Schistosoma haematobium* originated in Africa; possibly in Central Africa (Nelson et al, 1962; Wright, 1966). From there it spread over the continent and to the Far East, and eventually schistosomiasis patients were shipped to the New World during the slave trade period. There *Schistosoma mansoni* found a new adequate intermediate snail host. Though the parasite was not discovered until the second part of the last century, and though the clinical patterns and the public health importance of the infection were only recognised in the first decades of this century, it is certain that human infections occurred already about a thousand years B.C. because calcified schistosome eggs were found in Egyptian mummies (Ruffer, 1910).

At present schistosomiasis is generally considered as one of the most important diseases in Africa. No African country is free from endemic schistosomiasis and in many African states both *S. mansoni* and *S. heamatobium* are endemic. The total number of infected persons in the world has been estimated as at least 150 millions (WHO, 1965). It will be clear, however, that the mere number of infections does not indicate the severity of the problem. Other parasitic worms such as *Ascaris lumbricoides* and *Trichuris trichiura* are more common but do not necessarily cause greater morbidity. *S. haematobium* may cause a complex of complaints (e.g. haematuria) that was recognised by local practitioners, witchcraft doctors and patients a long time ago,

without knowledge of the causative parasite. In the case of *S. mansoni*, however, it is often very difficult for a layman and even for a well trained doctor to recognise the syndrome. Even these days there are probably vast areas in many African countries (e.g. Ethiopia) with high infection rates that have still to be discovered.

In some areas it has been attempted to estimate the yearly economic loss due to schistosomiasis. Most of these estimates refer to estimates of reduced work output and increased absenteeism on estates (e.g. Foster, 1967. Fenwick & Figenschou, 1972-a,b). In Egypt a nation-wide economic loss of 560 million U.S. Dollar per annum has been estimated (Farooq, 1967). Cost benefit calculations, however, are difficult to make: it is hard to express health of people in terms of economic loss and profit. This is particularly true for poor rural areas in which economic life is still organized in a traditional way.

1.2.2. Schistosomiasis in Ethiopia

Relatively little is known about the distribution and clinical aspects of schistosomiasis in Ethiopia. Ayad reviewed the older Italian literature which includes few systemic data (Ayad, 1956). More recently *S. haematobium* has shown to be endemic in Gewani (Russell, 1958) and in other communities in the Lower and Middle Awash Valley: Hadelguera (map 2), Melka Werer, Angelele, Cortume, and Hertale (Lemma, 1969). High infection rates for *S. mansoni* were found in Harrar (Kubasta, 1964; Lemma, unpubl. doc. 1970; Lo et al, 1973), Alemaya (Kubasta, 1964; Aram, unpubl. report 1973; Lo et al, 1973), Tensae Berhan (Duncan, unpubl. doc. 1969), Wonji (Bruijning, 1969; int. reports Inst. Pathobiology and H.V.A.), Adwa (Lemma, 1965; Buck, 1965), Zerima, Inde Selassie and other towns in Tigrae (NAMRU unit 5, Addis Ababa, pers. comm.), Gorgora (Chang, 1961; Zaphiropoulos, 1963) and Bahar Dar (Ayad, 1956; Dr. Schäufele, pers. comm.). Lower infection rates were found in the area of Lake Zwai (Ito, pers. comm.) and in Metahara (int. reports H.V.A.; Aram, unpubl. report, 1973). Recently *S. mansoni* was also reported from Jimma (Kaffa), Agarro (Kaffa) and Bati (Wollo)(Goll, pers. comm. 1974).

In Ethiopia no systemic clinical data on schistosomiasis are available and no assessment of the public health importance has been made so far. Some clinicians at the Public Health College in Gondar, the former director of the Fellege Hiwot hospital in Bahar Dar and some leading clinicians in Addis Ababa told me that they were not convinced that schistosomiasis is a serious clinical and public health problem; they get the impression that serious hepatosplenic involvement in chronic schistosomiasis is not often seen in Ethiopia. This impression, however, should be tested thoroughly.

Map 2. Ethiopia
Provinces, major rivers, and localities mentioned in this study.

A start has been made to control the disease in some areas. In the estates of the H.V.A. at Wonji-Shoa classical molluscicides are being used in combination with drug administration. In Adwa on the other hand the molluscicidal properties of crushed endod berries (*Phytolacca dodecandra*) are being tested in the field; in addition several measures have been taken to reduce man's contact with infested water, and drugs too have been used in this pilot control project. (Lemma, 1965-b). In Harrar an extensive system of piped water was introduced in the late nineteen sixties; the use of the streams just outside the town walls has been greatly reduced since, but the effect on prevalence and incidence of schistosomiasis has not yet been studied.

Chemical control as practised in Wonji and to some extent in Adwa, is probably not feasible in most rural areas because of the high recurrent costs.

1.2.3. Schistosomiasis in Gondar area

Not much has been published on the occurrence of intestinal schistosomiasis in Gondar area. The older Italian literature (reviewed by Ayad, 1956) will not be considered; only the results of the more recent work will be summarized in this section.

In Bahar Dar, at the southern part of Lake Tana, 23 out of a sample of 44 persons were found to be infected (Ayad, 1956). According to the files of the Fellege Hiwot Hospital in Bahar Dar *S. mansoni* ova were found in 104 of approximately 8.000 routine stool examinations that were done in 1962 (Ethiopian Calendar 1)) (1.3 %). Most positive persons were living in the section of the town near the Ras Hotel.

Three surveys have been performed in Gorgora, at the Northern shore of Lake Tana (Chang, 1961; Zaphiropoulos, 1963; Buck et al, 1964). These surveys indicate a fair transmission rate of *S. mansoni* in Gorgora, and it was assumed, and partly proved, that the infection was transmitted by *B. pfeifferi* which was present, though not abundant along the shores of Lake Tana at Gorgora. Examining direct faecal smears Chang found an infection rate of 22.8 % among 202 schoolchildren. Zaphiropoulos, probably also using direct smears, found 19.9 % of 241 children to be positive for *S. mansoni*. For some months Chang did not find any *B. pfeifferi* and during some other surveys along the shores of the Lake at Gorgora he found a few (no snails were infected). Zaphiropoulos on the other hand, found 265 *B. pfeifferi*. One hundred forty nine were crushed, and 18 (12 %) were shown to be infected. Buck and coworkers used the M.I.F. concentration method in addition to a direct smear. Among 50 children *S. mansoni* eggs were detected in 25. According to various serological techniques the infection rate in this group of children varied from 63-92 %.

An analysis of the 20,676 routine stool examinations that were performed at the Gondar Public Health College Hospital (Chang, 1962) showed an infection rate for *S. mansoni* of 1.8 %. A later review of the stool examinations at the same hospital in Gondar gave similar infection rates (Molineaux, 1967; Schaller, 1971).

1) Note: 1962 Ethiopian Calender coincides with the period September 1969 till September 1970, Gregorian Calender. Henceforward "Ethiopian Calender" will be abbreviated as "E.C.".

According to the files of the Public Health Training Centres of Addis Zemen, Gorgora, and Kolla Duba (all 1961 E.C.) the infection rates for *S. mansoni* were at most 0.2 %, 7.7 % and 2.0 % respectively (Polderman, unpublished data).

1.3. A GENERAL DESCRIPTION OF THE AREA UNDER INVESTIGATION (maps 3 and 4)

1.3.1. The country

The area that is studied in this report has natural borders almost all around. Just north of Gondar, the capital of Begemder Province, the area is bordered by the high mountain massif of Woggera (± 2,200 m.- over 3,000 m.) which culminates in the Semien mountains (up to 4,600 m.). These mountains extend to the south into the districts of Belessa, Debre Tabor and Gaynt. From the Gondar-Bahar Dar road these districts can be seen as a steep ridge of mountains a few kilometers to the east of the road. To the west, the natural border consists of the edge of the highland plateau; in the north-west there is a steep escarpment; in the south-west there is a more gradual slope down towards the plains along the Sudan border. The most western end of the highland plateau is formed by Quara awraja (district), a 'peninsula' of the plateau protruding into the lowlands. To the south the border of the area consists of Lake Tana, a shallow lake of some 60 km long and some 45 km wide. The maximum depth is probably not more than 12 m.

The area separated from the surroundings by these natural boundaries may be considered to consist of 3 different zones: the shores of Lake Tana (alt. ± 1,840 m)(photos 1, 2 and 3); the alluvial plains north of Lake Tana (1,840 m.)(photo 4) and the remaining undulating area (1,850-2,200m)(photos 6, 7, 8).

The characteristics of these zones will be discussed elsewhere (chapter 2). Both Chiwahit and Jenda, the communities in which the greater part of the present study was carried out, are located in the undulating area. Unless otherwise mentioned I will refer to this undulating area in the following chapters.

Volcanic rocks cover the highland plateau surface to considerable depths. Although no active volcanos remain in the area today, several hot springs are still to be found (near Chilga, Chewa Duba, and Aleffa). The soils north of Gorgora are mainly fine-textured, often stony and light brown to dark grey in colour. Most soils in the area are moderately to strongly acid (pH below 6) or slightly acid (pH 6.1-7.3)(Murphy, as cited by Simoons, 1960). Medium or high amounts of magnesium, potassium and often of phosphorus were found (Murphy, as cited by Simoons, 1960). The Dembia plains and most parts of the hills are considered to be fertile or very fertile by the local population.

The countryside is dry and open in 'summer', and luxuriant and green during and after the rains. The whole area consists of rather heavily populated agricultural lands (photos 4, 6) . The population density is greatest in the Dembia plains. In some of the marshy parts of the plains (e.g. around Sarweha river, west of the Gondar-Gorgora road) people keep large herds of cattle; otherwise most land is cultivated, the main crops being teff (*Eragrostis teff*), wheat, barley, maize and pulses.

There are only few motorable roads. A chain of roadside towns has been established along the main roads Gondar-Gorgora and Gondar-Bahar Dar, which were constructed during the Italian occupation (1936-1941) and in the nineteen-fifties respectively. Apart from the old capital of Gondar, these roadside towns are the main centres of trade. The towns are easily recognised in the landscape as patches of eucalyptus trees in an otherwise open country (photo 13).

Villages off the main road generally consist of little pockets of 'tukuls' protected from the outside world by some dense vegetation of eucalyptus, acacias, figs, bamboos, or candelabra euphorbias (photo 31). These pockets of tukuls may be scattered over a wide area which together form a village. These villages often consist of several subvillages, depending on the number of churches.

The hilly area is drained by numerous small streams and rivers. Some of these streams flow into Lake Tana, others join the Atbara river, a tributary of the Nile, and some of the smaller streams vanish in the marshes north of Lake Tana.

1.3.2. The people and the organization of life

It is supposed that in ancient times the Ethiopian highland plateau was occupied by Caucasoid peoples who spoke Cushitic languages and who were absorbed by the aboriginal population (Trimmingham, 1952). Around 1,000 B.C., and at several times after that, Semitic peoples invaded the plateau and profoundly changed language, culture, and racial characteristics. Even though the present day Amhara, the main tribe in the Gondar area, speak Amharińa, a semitic language, Trimmingham estimates that the genetic contribution of the Cushites was far more important. The Galla invasions from the sixteenth century onwards brought another wave of Semitic blood, this time mixed with Bantu blood. Though the influence of Galla invasions was more profound in southern and central Ethiopia, the Galla added much to the Amhara way of life and genetic structure in Begemder Province.

In the highland part of Begemder Province the dominant ethnic group is the Amhara. Some other ethnic groups in the area are of the same Ethiopian physical type; they cannot be distinguished from the Amhara. These groups include the Jabarti, or native moslims (Trimmingham, 1952), the Falasha or Ethiopian Jews and the Wayto.

They all speak Amhariña. The Wayto are a small group of Moslim hunters and fishermen along the shores of Lake Tana. Because of their small numbers they are of little importance to our studies. The Falashas cannot be recognized and generally they will not admit to being Falasha. Jenda used to be one of their centres but towards the end of the last century, and in the course of this century, most Falashas have been converted into Ethiopian Orthodox Christians. The Jabarti will always confess their religion. Many of them are living in Gondar, Chiwahit, and all other roadside towns but some are living in the countryside, generally clustered together (e.g. in Guzara near Emfraz and in Chenker). In Gondar many Jabarti, as well as foreign Moslims, are living together in an exclusively Moslim suburb Addis Alem.

The Kamant, who are living in Chilga and Woggera, on the border of our study area, are partly Agow-speaking. They were less influenced by the Semitic Galla invasions but they cannot be distinguished from the Amhara. Generally they will not admit to be no Coptic Christian.

Besides the native Ethiopian Moslims a fair number of recently immigrated and second generation Arabs are living in Gondar and the roadside towns. Most of them are Yemenites, but there are also Saoudi Arabians and some Libians. They can generally be recognized as foreigners; they have a lighter skin, and they speak Arabic rather than Amharic. They are far less numerous than the Jabarti; only in Gondar itself are there many of them.

The principal, and most respected, occupation in the whole area is farming. Most farmers live in the rural areas and villages. The roadside towns are centres for trade: goods are sold and bought during the weekly market. Both government schools and government administration are concentrated in these towns which often have a population of somewhere between 1,000 and 5,000 inhabitants. Except in Gondar and Azozo there is no piped water available in the province (74,000 square kilometers, 1,4 million inhabitants) and only in recent years have a few roadside towns in the province got electricity during the night time. Except in Gondar there is no factory in the province and there are no well planned agricultural projects.

Gondar, the capital of Begemder Province, with a population of about 36,000 inhabitants (Eth. Stat. Abstr., 1971), is a former capital of the Ethiopian empire. It is still an important centre of religious, administrative and economic life. The Public Health College of the Haile Selassie I University is located in Gondar. Some 15 years ago five Public Health Training Centres were established in roadside towns in the surroundings (Addis Zemen, Dabat, Gorgora, Kolla Duba and Gondar). Four of these Health Training Centres are still functioning. Thus, health facilities in the area between Gorgora and Gondar were comparatively good and are still so, even though Gorgora Health Centre has been closed down.

1.3.3. The climate

The region between Gondar and Lake Tana has a typical Ethiopian highland climate. The temperatures are pleasant and seldom too high in day time, and the nightsare cool but not often really cold. In this part of the Ethiopian highland the big rains pour down between June and September; the little rains are not very pronounced or absent. Towards the end of the dry season the earth gets very dry and often deep drought cracks are formed: ideal hiding places for the thousands of grass rats (*Arvicanthis niloticus*) that can be seen during this time of the year. In many places the first rains are entirely absorbed in the dry ground and it is only later that the rainwater is gathered efficiently by the streams and rivers. Part of the big rains occurs as thunderstorms which are of a very local character.

Table 1.1. The climate in Bahar Dar
(source: Eth. Stat. Abstr.)

	1967	1968	1969	1970
Average yearly maximum temperature (°C).	25.6	25.8	26.5	26.5
Average yearly minimum temperature (°C).	10.2	10.4	11.8	10.5
Total amount of rain in mm.	1494	1608	1619	1652

Table 1.2. Temperatures and rainfall at Gondar airport
(means over the period June 1968-May 1973)
(source: meteorological station, Gondar airport)

	Mean Max. Temperature	Mean Min. Temperature	Rainfall in millimeters
January	27.3	10.4	2
February	29.4	12.9	3
March	29.4	14.5	41
April	29.7	15.9	50
May	28.0	15.1	94
June	25.3	14.1	113
July	22.9	13.4	311
August	23.1	12.9	216
September	24.7	12.4	105
October	26.0	12.2	59
November	26.6	11.8	28
December	26.6	10.2	8
yearly	26.6	13.0	1,030

Only few official climatic data on the area are available. Some data from the Ethiopian Statistical Abstracts are quoted in table 1.1. Regrettably, no formal information is available on Gondar or Gorgora, but with the kind permission of the meteorological station of the Gondar airport (station of the Civil Aviation Administration, Ministry of Communication) lists with daily temperatures and precipitation were copied. This meteorological station is located on the flat hills a few kilometers north of the northernmost tip of the Dembia plains (map 3), along the road 5 km south of Azozo at an altitude of 1,970 m. The results of these observations are summarized in table 1.2.

On the compound of our field station in Chiwahit (altitude 1,900 m.) a maximum-minimum thermometer and a raingauge were erected. The temperature was read at 1.50 m. in a white painted weather box with slatted blinds. The results of these observations are summarized in Table 1.3. and in Fig. 1.2. Unfortunately, no thermometer was available from October to December 1972.

Table 1.3. Temperatures and rainfall in Chiwahit

	1971			1972			1973		
	max. temp	min. temp	rain	max. temp	min. temp	rain	max. temp	min. temp	rain
January				29.0	11.3	00	32.2	11.5	00
February				29.7	11.0	00	33.9	12.8	00
March				31.5	13.9	00	34.4	15.4	13
April				31.3	15.1	31	33.1	15.6	24
May				30.0	15.5	90	28.9	15.2	151
June	-	-	149	26.4	14.6	122	28.4	14.1	153
July	-	-	377	23.4	14.1	277	24.6	13.6	269
August	-	-	221	23.4	13.2	188	24.3	13.8	215
September	-	-	89	24.7	13.5	71			
October	25.4	11.4	37	-	-	67			
November	26.3	10.3	17	-	-	25			
December	26.9	8.3	00	-	-	00			

During the months in which observations were made both in Chiwahit and at Gondar airport near Azozo it appeared that the monthly maximum temperature was 1.1° C higher in Chiwahit whereas the monthly mean minimum temperature was about 0.3° C higher in Azozo. The monthly rainfall in Chiwahit and Azozo was about the same.

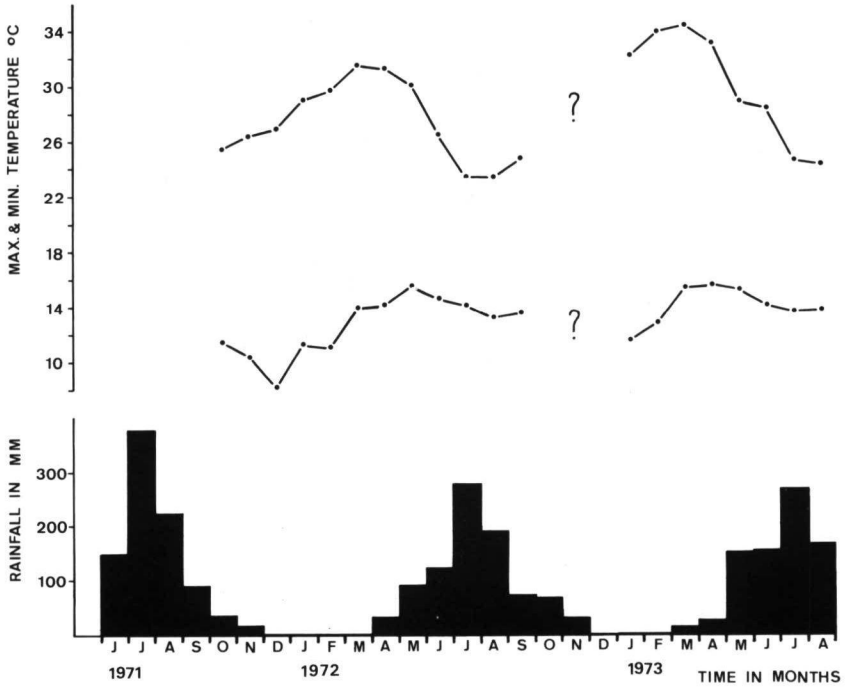
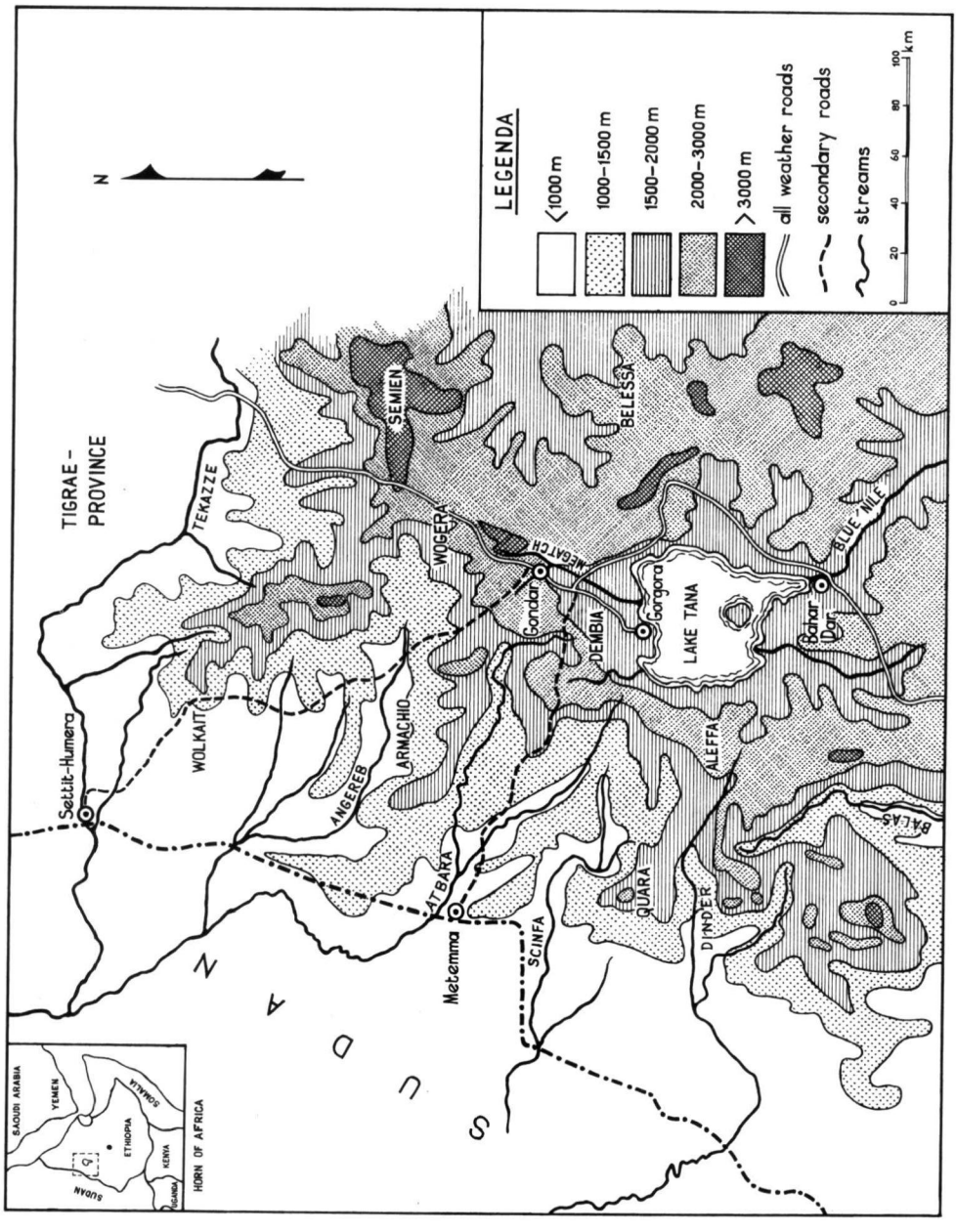


Fig. 1.2. The climate of Chiwahit



Map 3. North West Ethiopia

CHAPTER II THE GEOGRAPHICAL DISTRIBUTION OF S. MANSONI

2.1. INTRODUCTION

Before a study of the dynamics of schistosome transmission in a particular community can be undertaken, one should be acquainted with some general characteristics of the endemic area in which that community is situated. Migratory movements of people are extremely common in what are seemingly stable areas (e.g. Ruyssenaars et al, 1973) and these movements interfere with detailed studies of a closed ecosystem (i.e. a particular community including its sources of water supply) unless the intensity of transmission is the same inside and outside the system.

Since there is frequent interchange of people between communities in this part of Begemder Province, it is essential to study the occurrence of schistosomiasis in the neighbourhood of the communities in which a study of the dynamics of schistosome transmission will be carried out. For that reason, the geographical distribution of *S. mansoni* was studied in the area around Chiwahit and Jenda (map 4).

Relevant questions in this section are:
- what is the prevalence of *S. mansoni* in various communities ?
- what is the distribution of the intermediate host ?
- which are the factors that determine this distribution pattern ?

2.2. A DESCRIPTION OF THE STUDY AREA

In paragraph 1.3.1. it was suggested that the highland plateau region that is studied here may be divided into three zones: 1) the shores of Lake Tana, 2) the alluvial plains, and 3) the undulating area (map 4). In this section a fourth region will be investigated as well: the hot lowlands along the Sudan border, west of the highlands (map 3).

The shores of Lake Tana (photos 1, 2) are either rocky, sandy with shingle and bolders, or swampy with bushes of papyrus reeds. In the swampy areas it is difficult to reach the water. In those areas villages are generally located a long way from the actual shores (e.g. Acherra Mariam, and Alloha, south east of Chach), and people do not, or only seldom, go to the Lake. Instead, water is obtained from artificial wells or from the bigger streams (see next paragraph).

In the rocky places (e.g. Mangi) the houses are built on the plateau high above the water. During most of the year (perhaps 9 months) water from small streams and wells is easier to obtain than the lake water. In Mangi, people depend on the lake during the last months of the dry season when the streams and wells contain only very little or no water. Many housewives wash their clothes in the lake throughout the year.

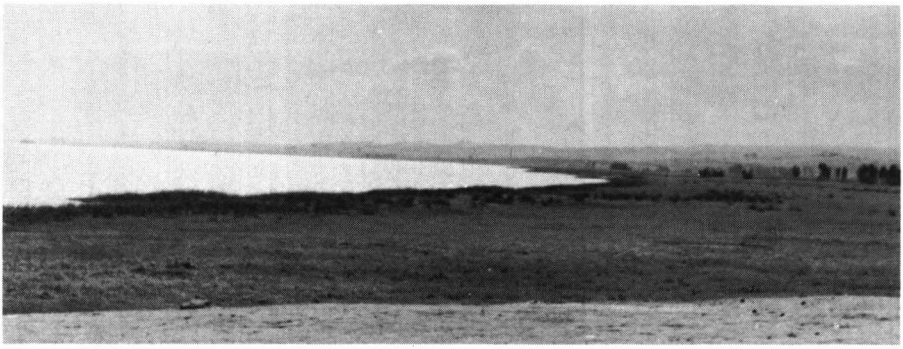


photo 1. The marshy shores of Lake Tana near Delghi.

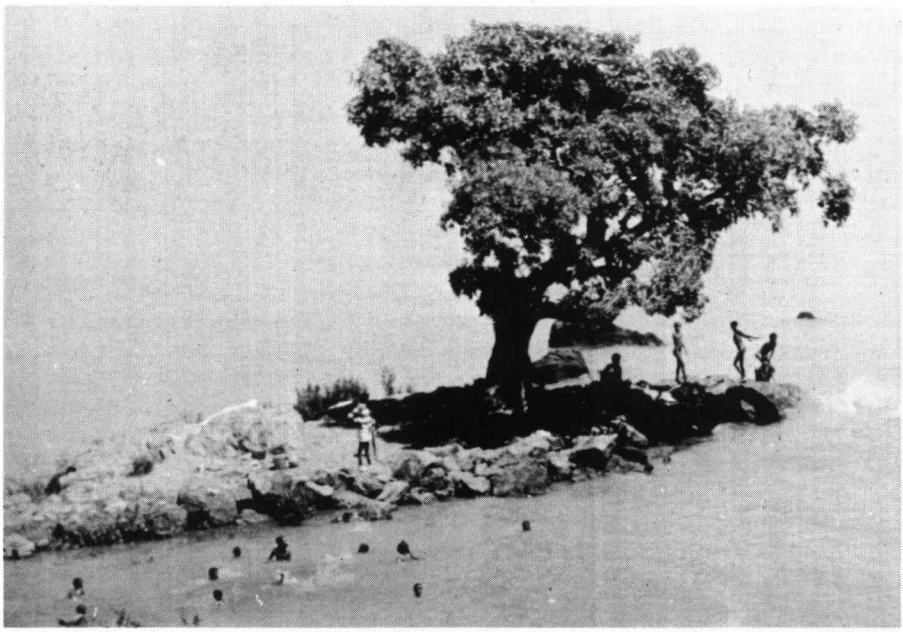


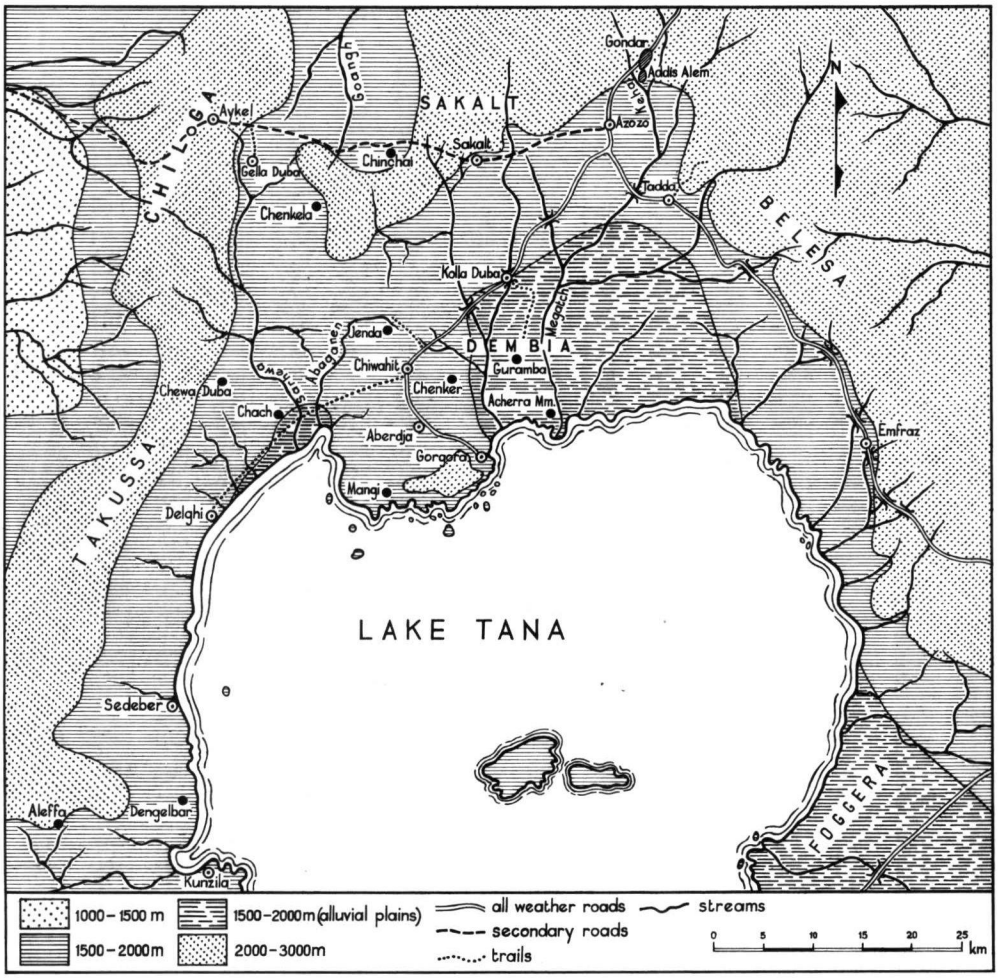
photo 2. Lake Tana at Gorgora. The children swimming are mainly boys.

Some towns (Gorgora, about 1,7000 inhabitants; Delghi, about 2,000 inhabitants; and Kunzila, perhaps 1,500 inhabitants) are located on sandy or stony belts on the shores of the Lake. These towns have small harbours for the 'Navigatana'-steamer that passes twice a week. The inhabitants are completely dependent on the lake for their water supply. There is no piped water and there are no functioning pumps. In Gorgora, and probably also in other towns, boys catch little fish with simple angling-rods. Since most Amhara despise fish as unclean food during most of the year, fishing is not a common activity, though there are said to be a few professional fishermen in Gorgora. Elsewhere along the shores, however, (e.g. in Mangi) Waito fishermen and farmers go regularly into the Lake for fishing (photo 3). Local commerce by water and transport of people and goods to the monastery islands in the lake for instance are greatly dependent on the 'tanqua's': reed boats in which the 1-3 passengers are continuously exposed to the lake water.

The densely populated and fertile Dembia plains (photo 4) are traversed by several typical lowland streams: slow flowing muddy streams sometimes with high mudwalls and with very little vegetation growing in them or along their borders (photo 5). During the rains the rivers get swollen and in some years parts of the Dembia plains and the plains around the mouth of Sarweha and Abaganen are transformed into virtual swamps. Then the water

photo 3. A (Waito) fisherman in Lake Tana near Mangi. The method of fishing results in long exposure times.

may enter many huts. Before the onset of the activities of the Malaria Eradication Service, this area was feared because of malaria. The area is inhabited by farmers and their families. They sell their crops in the weekly markets of the roadside towns, so they have a lot of contact with the area described in the next paragraph. Agriculture is of a primitive type; there are no irrigation schemes and no functioning agricultural cooperatives. Each group of huts has a partly protected well of its own. Every few years new wells are dug; they contain relatively clean water.



Map 4. The study area
The black dots refer to villages and rural areas that were included in our study. The 'towns' that were surveyed are represented by ⊙ (see also table 2.1.)

photo 4. The alluvial plains North of Lake Tana (in the distance: Guramba).

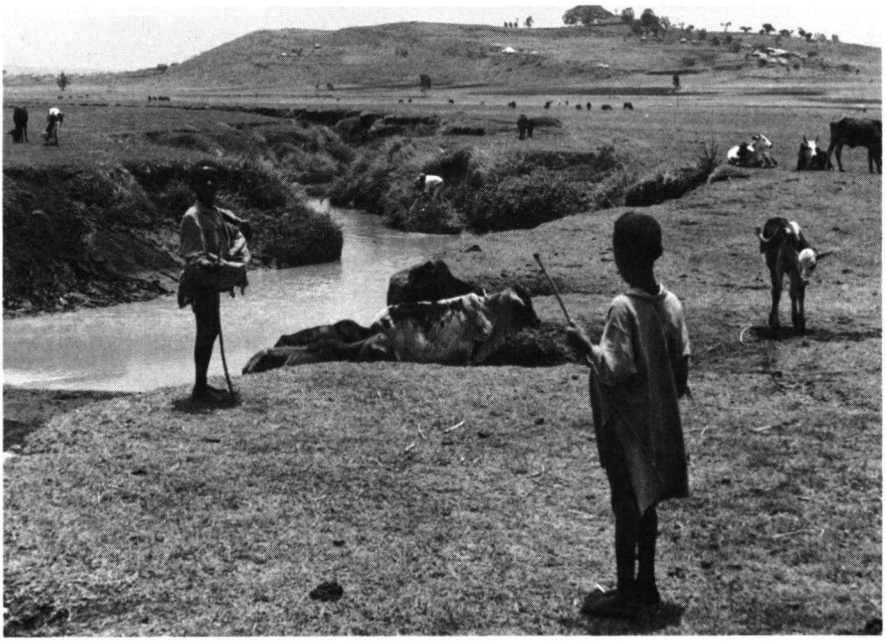


photo 5. The Sarweha near Chach; one of the muddy, slow flowing rivers in the plains North of Lake Tana.

photo 6. Air photo of the undulating country near the airport south of Azozo.

The undulating area around Lake Tana and the Dembia plains consist of a mainly agricultural area with many old villages (photo 6, 7, 8). The people are dependent on the small streams for their water supply. Some 15 years ago several towns in this area were provided with handpumps but most of them are no longer functioning. For obvious technical reasons most roads in this part of the province cross the undulating area rather than the marshy plains or the higher mountains. Most towns have been built along these motor roads. A more detailed analysis of the characteristics of this area that may be of relevance for schistosome transmission will be given in the next chapters.

The lowland border area between Metemma and Settit Humera (photos 9, 10, 11) has been rapidly developed in recent years due to the introduction of cash crops (sesame, cotton, sorghum). During the harvest season many labourers from Tigrae and Begemder provinces migrate into this area. The water supply and the health- and sanitary facilities are completely inadequate for this influx of labourers. The crops are grown without irrigation and, apart from some large rivers, the amount of available water is very limited. A few large lowland rivers (Atbara and Tekazze)

cross the savannah-type land, and many farmers have to collect water from those rivers in drums many kilometers away from their farmlands. In contrast to the areas mentioned above which have mean yearly temperatures varying between 15° and 20° C., the average yearly temperature here is between 25° and 30° C. though no accurate data are available.

photo 7. Air photo of a typical village near Azozo. Note the very small size of the stream where the people get their water from.

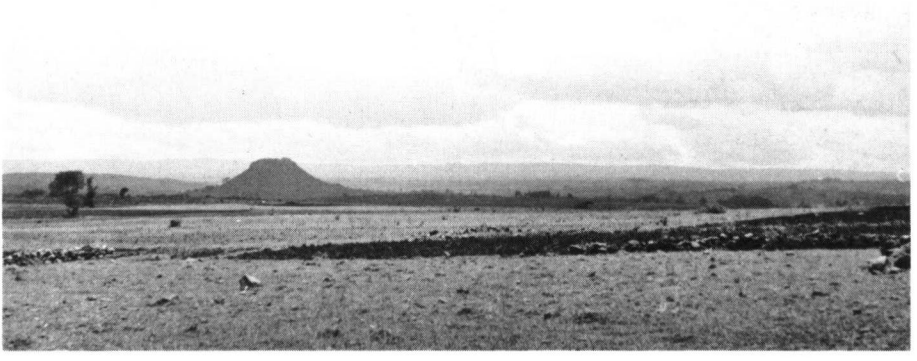


photo 8. The undulating area west of Chiwahit. The characteristic mountain (Gibgibba) is an "amba", a mountainous relict in an onther-wise eroded country.

photo 9. The Negade-Bahir, one of the rivers crossing the Aykel-Metemma road (altitude about 900 m).

photo 10. The rapidly expanding town of Settit-Humera, the centre of rich sesame, sorghum-, and cotton cultures (altitude about 500 m.).

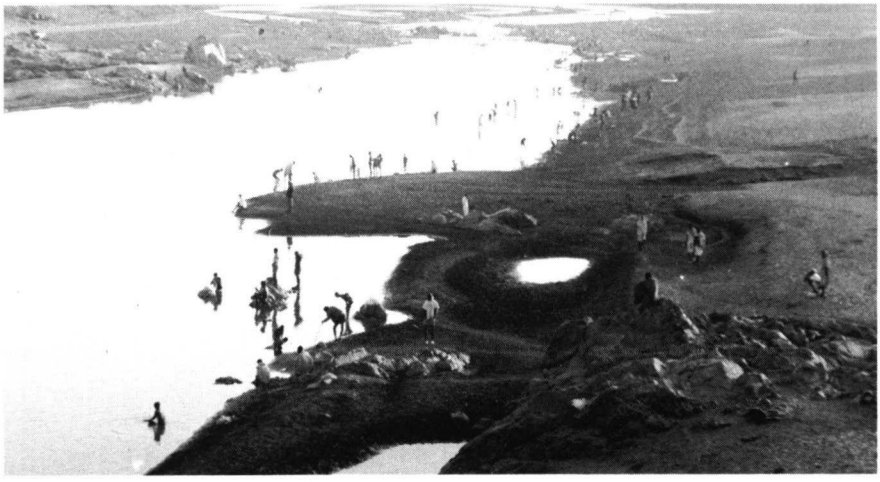


photo 11. Settit-Humera. For its water supply the town is entirely dependent on the Tekazze river.

2.3. MATERIALS AND METHODS

Parasitological surveys were performed in a number of towns, villages, and rural areas. If a school was present in a particular community, some fourty schoolchildren who were born in that town were selected for parasitological examination. In order to include children of different ages in the sample, the children were selected from different classes (e.g. from the first, third and fifth grade). If no school was present, house to house surveys were performed and in some cases children who happened to present themselves were examined. Thus no random sampling was achieved.

Plastic cups in 6 different colours were distributed and faeces were produced instantly in almost all cases. From each child about two grammes of faeces were collected and stored in 7.5 % formalin. Most faecal samples were examined with Ritchie's concentration method (Ritchie et al, 1960), (appendix 3); in some cases, however, due to shortage of chemicals, a simple sedimentation method was used (appendix 3). From each sample one slide was examined. If no *S. mansoni* eggs were found with the sedimentation method, another slide was examined. No information on the quantitative egg-output was gathered in this way.

In the areas where parasitological data were collected, streams, pools or the shores of Lake Tana were checked for the

presence of *B. pfeifferi*. A simple sweep net was used for these snail collections. Since in most cases only one or a few snail surveys were performed in a particular area, the information on presence or absence of *B. pfeifferi* should be interpreted with care.

2.4. RESULTS

2.4.1. Prevalence of the parasite

In the period between April 1971 and November 1972 a number of stool specimens was collected in each of 32 communities. Out of the 1,495 collected samples *S. mansoni* ova were found in 684. In table 2.1. the infection rates for different communities are summarized. For the purpose of a rough localization of the transmission sites, only the 981 children who were born in that community or its immediate surroundings are considered in the table. (In a few cases some children who came 6-10 years ago to their present dwelling place had to be included in the sample).

2.4.2. Occurrence of the intermediate host

The intermediate host, *Biomphalaria pfeifferi* (photo 20), was most abundant in the very small streams in the undulating area just below the springs from which these streams originate. These little streams contain water throughout the year though they may be reduced to merely a series of isolated little pools by the end of the dry season (see chapter 4, photo 21). The flow rate of these streams is negligible except during the heavy rains. Several to many adult *B. pfeifferi* were found among others in the following streams: all streams crossing the Chiwahit-Gorgora road; Ayenkura-, Shenkura-, Dakmit- and Adesa streams (crossing the Azozo-Aykel road at 6, 19, 26 and 47 km. respectively); little streams near Maconta Yessus; Abo stream and Falasha-Cheka near Chenkela Abo and Chenkela Yessus respectively; Serauka stream just outside Aykel, Angacha river (just outside Tadda); a tributary of Goangh-river (just beyond Gella Duba), all streams around Chiwahit, Atakelt stream near Jenda etc. Chalguaye-, AmbaZena- and Chigaro-stream around Chiwahit and Atakelt stream near Jenda are typical examples of this type of little streams: snails were present in almost all pools during all samplings throughout the year. For a detailed analysis of these snail populations, see chapter 4.

In the larger streams in the border area between the hilly zone and the plains, the seasonal fluctuations in the numbers of snails are more pronounced (Dirma at Kolla Duba, photo 12; Keha at Addis Alem, photo 13; Demazzo at Azozo). The muddy streams in the plains (Dirma, Megatch, Abaganen and Sarweha) did not seem

Table 2.1. Geographical distribution of **S. mansoni** *infections among children in the age class 7-15 years*
(In this table only those children were considered who were born in the same locality or who came a long time ago)

name of the locality	sampled group	exam. method	sample size and number of positives ♂	♀	% positives
Gondar					
Gondar T. Work school	schoolchildren	R	22/ 1	20/ 2	7
Gondar Meseret school	schoolchildren	R	26/ 1	17/ 1	5
Addis Alem	schoolchildren	S	18/16	45/34	79
Shores of Lake Tana					
Gorgora	schoolchildren	R	29/18	28/26	77
Mangi	house to house	S	4/ 0	7/ 1	9*
Delghi	schoolchildren	R	9/ 0	19/ 2	7
Sedeber	house to house	S	7/ 0	5/ 1	8*
Kunzila	schoolchildren	S	5/ 1	19/10	46
Dembia plains					
Guramba Bahta	house to house	R	4/ 1	3/ 0	14*
Acherra Mariam	house to house	R	13/ 0	12/ 2	8
Northern hills					
Azozo	schoolchildren	S	14/ 8	25/17	64
Tadda	schoolchildren	S	21/13	20/11	59
Emfraz	schoolchildren	R	14/ 7	21/15	63
Sakalt	schoolchildren	R	17/ 7	19/ 7	39
Behona & Chinchai	accidental	R	4/ 1	18/ 3	18
Gella Duba	schoolchildren	R	15/10	15/ 8	60
Aykel	schoolchildren	R	14/ 1	23/ 2	8
Chenkela Abo & Yessus	house to house	R	17/10	18/13	66
Kolla Duba	schoolchildren	S	25/15	31/16	55
Jenda	house to house	R	25/23	19/16	89
Chiwahit	accidental	R	21/15	43/36	80
Aberdja	house to house	R	3/ 3	2/ 1	80*
Chenker	house to house	S	8/ 6	18/11	65
Southern hills					
Chewa Duba	house to house	R	10/ 1	13/ 3	17
Chach	shepherds	R	0/ 0	17/ 3	18*
Maconta Yessus	accidental	R	3/ 1	7/ 0	10*
Dengelbar	accidental	S	12/ 0	18/ 0	0
Aleffa	accidental	S	13/ 0	11/ 0	0
Zana Abo & Mariam	accidental	S	5/ 0	8/ 0	0*
Quara	accidental	S	12/ 0	12/ 0	0
Lowlands near the Sudan border					
Metemma	schoolchildren	R	6/ 0	18/ 2	8
Settit Humera	schoolchildren	R	13/ 0	21/ 0	0

Legend
under 'examination method' : 'R' stands for 'Ritchie's concentration method'
'S' stands for 'Simple Sedimentation method'.
under 'sample size and number of positives': e.g. 22/1 means 22 stool specimens were examined. **S. mansoni** *eggs were found in one.*
under 'percentage positives' : the asterisks refer to inaccurate percentages, corresponding with small sample sizes.

to harbour many *B. pfeifferi*. The results of the present surveys are summarized in table 2.2.

The shores of Lake Tana were investigated at several spots, but most regularly at Gorgora because of its accessibility and its high prevalence of *S. mansoni* among children. The results are summarized in table 2.3.

In Gorgora the shores were always checked beyond the former Imperial Palace and near the Malaria Eradication Service building. Sometimes the stretch of shore along the Navigatana maintenance buildings was included in the survey. Since the use of nets is not practical in this habitat we simply searched for snails in the very shallow water. In general this was done by one or two persons during 15-30 minutes. Other molluscs that were found included: *Lymnaea natalensis, Bulinus truncatus, Gyraulus costulatus, Bulinus forskali, Bellamya unicolor, Anisus natalensis* and *Melanoides tuberculata*.

Table 2.2. B. **pfeifferi** *in some medium-sized streams*

name of river	date of snail survey and abundance of B. pfeifferi				
Goangh (Aykel road)	05/11/71	13/12/71			
	0	0			
Dirma (Aykel road)	01/12/71	30/12/71	15/09/72		
	0	0	0		
Dirma (Kolla Duba)	12/10/72	12/12/71	18/12/72	28/02/73	30/03/73
	0	0	0	3	3
cont.	19/05/73	28/07/73			
	0	0			
Dirma (near mouth)	09/12/71	25/03/72			
	0	0			
Keha (Addis Alem)	28/03/72	03/05/72	16/07/72	12/09/72	16/12/72
	4	2	0	1	3
cont.	27/02/73	17/03/73	18/05/73	27/07/73	
	4	2	1	1	
Demazza (Azozo)	10/10/71	10/12/71	10/05/72		
	0	0	3		
Abaganen (Delghi-track)	11/12/71	15/06/72			
	0	0			
Sarweha (Delghi-track)	11/12/71	15/06/72			
	0	0			
Megatch (Acherra Mm)	09/12/71				
	0				

Legend to table 2.2.

0: no B. **pfeifferi** *were found*
1: very few B. **pfeifferi** *were found (<10 snails per hour searching)*
2: few B. **pfeifferi** *were found (1-10 snails per 5 minutes)*
3: quite some B. **pfeifferi** *were found (2-20 snails per minute)*
4: many B. **pfeifferi** *were found (>20 snails per minute)*

photo 12.
The Dirma river at Kolla Duba

Table 2.3. **B. pfeifferi** *along the shores of Lake Tana*

locality	abundance of B. pfeifferi				
Gorgora	27/09/70	10/01/72	25/03/72	15/05/72	05/07/72
	1 †	0	1	1	3
	31/07/72	15/08/72	05/09/72	01/10/72	12/10/72
	2	0	0	0	1j
	18/12/72	28/02/73	18/03/73	19/05/73	28/07/73
	0	0	1	0	2
Kunzila	09/01/72				
	0				
Sedeber	09/01/72				
	0				
Delghi	11/12/71	05/07/72			
	0	0			
Mangi	21/03/72				
	2j				
Wawa	15/10/71				
	3				

Legend to table 2.3.
the same as for table 2.2.
1j, 2j: very few, or few; but only juveniles
1 † very few, only dead snails

Only little time was available to study the occurrence of *B. pfeifferi* in the lowlands and in the streams descending from the western escarpment. A few juveniles were found in the rivers half way down the escarpment on the way to Settit-Humera (7/6/72, mainly in Genet river), no *B. pfeifferi* were found in any of the rivers that are crossed by the Chilga-Metemma road (photo 9), and no snails were found in the Tekazze-river (Settit-Humera, photo 11) nor in the Atbara (7 km north of Metemma).

Except on a few occasions the collected snails were checked for infection. *B. pfeifferi* that shed brevifurcate cercariae were found in the following streams: AmbaZena, Chalguaye, and Chigaro (near Chiwahit), Atakelt (near Jenda), Melkem Weha (between Chiwahit and Gorgora), Dakmit (near Sakalt) and Keha (near Addis Alem). In all cases the furcate cercariae were proved to be *S. mansoni* cercariae (see chapter 5).

2.5. DISCUSSION

The comparatively low prevalence of *S. mansoni* among children found by both Chang and Zaphiropoulos in Gorgora (see paragraph 1.1.3.) may be the result of the use of less sensitive techniques than those used in our studies. The very high prevalence that was found in the present study and to a lesser degree in Buck's survey may appear rather unexpected since few *B. pfeifferi* and no infected *B. pfeifferi* were found in the course of our studies. Apparently we failed to recognize either the right focus of transmission or the right time. Theoretically it is possible that many children acquired their infection elsewhere; e.g. in the nearby hilly area. This does not seem very likely, however, for two reasons. Firstly, the nearest infested streams in the hilly area are several kilometers outside Gorgora; many of the infected children are young and it is not likely that they go there very often. Secondly, there is a marked difference in infection rate between boys and girls ($p<0.05$). Since *B. pfeifferi* is not very abundant and since the cercariae from the probably very low numbers of infected snails are diluted in a large amount of water, the cercarial densities are probably low or zero during the greater part of the year and never very high. Rather long exposures to the lake water are probably required to attain a high prevalence in a group of the population. Among boys these long exposure times are common since they often swim in the lake (photo 2). Girls do swim sometimes, but not nearly as often. In the undulating area, on the other hand, the transmission patterns are apparently such that the infection rates are similar among boys and girls (see chapter 3).

More direct evidence for schistosome transmission in the lake is given by Chang in a cycloprinted paper (Chang, 1961):

"During October-November 1959 thirteen of the sixteen Intern Health Officers and Sanitarians at the Gorgora Training Health Centre were swimming along the northern shores of Lake Tana, and six of them developed symptoms after 8-12 weeks that have been diagnosed as *S. mansoni* ". Unfortunately, detailed information on this observation is lacking.

In Kunzila the situation may well be comparable to Gorgora, but fewer data were collected. In the other communities along the lake side no transmission takes place at present, or only a very low transmission. The two infected boys from Delghi may have got their infection either in the lake or elsewhere. In Mangi 18 men (17-50 years old) who had always lived in the area were examined. Though 8 of them said they fished in the lake very regularly, and one of them was actually observed while fishing professionally (photo 3), none of them was infected.

Unlike our findings in Gorgora Chang states: "*Biomphalaria* shows a constant presence in small numbers ..." (Chang, 1961). He found low numbers of *B. pfeifferi* between January and May and somewhat higher numbers in the other months. No observations were made during the rains (June-September). Out of a total number of 149 *B. pfeifferi* Zaphiropoulos found 18 *B. pfeifferi* shedding cercariae (Zaphiropoulos, 1963).

In general we found low numbers of *B. pfeifferi* or no snails at all at the shores near Gorgora. Moreover, most specimens were juveniles. The high number of *B. pfeifferi* that were found in early July 1972 consisted mainly of juveniles. None of these snails was infected. On July 31st a few big adult *B. pfeifferi* were found in little depressions containing water a little off the main body of the lake water. In these tiny dips the adult snails were breeding: numerous newborn *B. pfeifferi* (max. diameter less than 2 mm) and several egg masses were found. Two weeks later not a single snail could be found. It seems that the rocky and sandy shores of Lake Tana are not a favourable habitat for *B. pfeifferi*. Yet, sometimes a fair number of *B. pfeifferi* were found, mainly at the beginning of the rains. These snails may have been washed into the lake from the streams in the hilly area where *B. pfeifferi* is very common, or they may have come from other parts of the lake shore.

The transmission of *S. mansoni* along the shores appears to be of a very focal character: the infectivity of the water is in general probably low except during short periods in some particular foci.

Probably no transmission takes place in the Dembia plains. It is very likely that the three infected children acquired their infection in nearby highly endemic areas. The reasons for the probable absence of endemic schistosomiasis are the practice of digging new wells every few years and the unfavourable habitats for snails in the rivers.

Even though the altitude of the hilly area seems very high for *S. mansoni* transmission, this area appears to be highly

endemic. The high prevalence of *S. mansoni* in the roadside towns compared to the rural areas off the mainroads (table 2.1.) may suggest a recent introduction of the disease. This however, does not seem very likely for two reasons. Firstly, many parts of the roads along which the towns are located are built on watersheds with streams draining to either side of the road. So, many of the most favourable snail habitats happen to be situated close to the roads and the roadside towns. Secondly, for several centuries the area has been the centre of the Ethiopian Empire. Many armies used to cross the area in all directions, there was an influx of Galla tribesmen from the south, and Moslim merchants entered it from the north. So, before the construction of the roads, the area has by no means been an isolated district.

The great difference between the prevalence among school-children from Gondar city and Gondar's Moslim suburb Addis Alem is probably due to the presence of a well-organized system of piped water in Gondar and the complete dependence of the population of Addis Alem on the Keha and Angereb rivers which were shown to be infective.

In Aykel(Chilga), which is only some 5 km from the highly endemic market town Gella Duba, the transmission seems to be almost or completely absent. Yet, the streams around Aykel town

photo 13. Addis Alem, the Moslim suburb of Gondar, located at the foot of the hills to the North of the Dembia plains. The people collect their water from the Keha river.

look very similar to the ones around Chiwahit for instance, and many *B. pfeifferi* were actually found just downstream the main washing place in Serauka stream (22/12/71). Unfortunately no climatic observations are available, but the low temperatures caused by the high altitude (± 2,200 m) and accentuated by its location on the top of a narrow, draughty ridge of mountains, may well prevent *S. mansoni* from becoming established in Aykel streams, even though the intermediate host snails are present. Similar situations with flourishing populations of *B. pfeifferi* but no parasites are found in many parts of the Ethiopian highlands e.g. near Wolencomi (2,200 m) and ChaCha (2,740 m) as studied by Arram (1973).

Only one trip was made into Aleffa and Quara, west of Lake Tana by Aberra Kumsa and Berhanu Gebru (July 1972). After a first chain of hills (Takussa in the north and Aleffa in the south) the track goes down into Scinfa valley and afterwards up again to Quara. In the streams flowing into Lake Tana and in some small streams on the other side of the Takussa watershed some *B. pfeifferi* were found, but not in Scinfa river, nor in its bigger tributaries, nor in the streams around Zana Mariam and Salia in Quara. As summarized in table 2.1. all collected stool samples from the southern hills were negative for *S. mansoni*. It is not clear why the endemic area between Gella Duba, Gondar and Gorgora does not extend to the south and west into Aleffa and Quara.

The prevalence of *S. mansoni* in the lowland centres Metemma and Settit-Humera was found to be low. In these lowland districts no snails were found during our surveys (October and November 1972). This does not mean, however,that no snails may be found in the other months of the year. The smaller highland tributaries of both Tekazze and Atbara river harbour many *B. pfeifferi*. Particularly Atbara river north of Metemma, with its luxuriant vegetation along the shores might harbour *B. pfeifferi* at other times of the year. The same holds true for tributaries of Atbara and Tekazze that were not visited.

Six out of twenty schoolchildren (30 %) at Settit Humera school who were born in the nearby lowland district Wolkait were positive for *S. mansoni*. In Metemma area the aboriginal Gumis tribesmen can easily be distinguished from the recent highland immigrants. Two out of eight Gumis schoolboys (25 %) who were born in Metemma area, and who had almost certainly never been on the highland plateau, had *S. mansoni* eggs in their stools. According to the files of the Health Centre in Settit Humera, approximately 7 % of the outpatients of the Health Centre was positive for *S. mansoni* (direct smear). This suggest the existence of a very high prevalence among seasonal labourers (the Health Centre in the highly endemic Gorgora, using the same techniques, recorded a similar infection ate of 7 % amont its outpatients; see paragraph 1.2.3.). Such a high infection rate

among older persons could be explained by the fact that the great majority of the outpatients were seasonal labourers from Tigrae and Begemder provinces. In parts of both provinces *S. mansoni* is known to be highly endemic (see this report par. 1.2.2. and 1.2.3.).

Thus the situation in the lowlands can be summarized as follows: endemic schistosomiasis is likely to exist in the lowlands to the west and north-west of Gondar. In recent years many thousands of infected seasonal labourers have migrated and still continue to migrate into the formerly sparsely populated area. So, in the near future, with a further development of the area, more attention should be paid to the possible spread and to the impacts of the disease.

2.6. SUMMARY

The shores of Lake Tana, and the hills, the plains and the lowlands north and west of Lake Tana, were surveyed for the prevalence of intestinal schistosomiasis and its intermediate host. The small streams in the hills around Lake Tana appeared to be the main transmission sites for *S. mansoni*. In some communities in this area infection rates of over 80 % were found among children between 7 and 15 years of age. Transmission at the shores of Lake Tana seems to be very localized. The risk of increasing transmission of *S. mansoni* in the economically important lowlands along the Sudan border was discussed.

photo 14. The sign that was placed near the shore of the Lake at Gorgora in the early nineteen-sixties. The effect is shown on photo 2.

CHAPTER III THE PREVALENCE OF SCHISTOSOMA MANSONI IN CHIWAHIT

3.1. INTRODUCTION

The principal question in the understanding of transmission dynamics, and in fact the principal question that should be posed prior to any control project is: "Which factors determine why some people are infected and others are not ?"

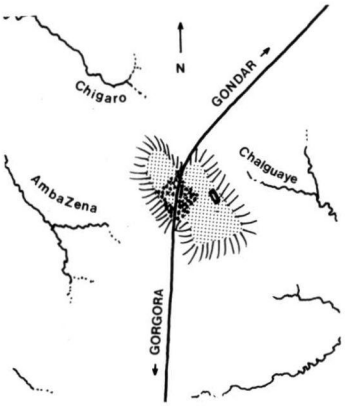
The prevalence of the infection in a community is determined by the people's history of exposures, by transmission intensity and by the defence system of the individual host. This chapter is concerned with a bare description of the prevalence of *S. mansoni* in the population of the roadside town of Chiwahit, and with several characteristics of the population of Chiwahit, such as sex, religion, patterns of migration, and occupations. The chapters 4 and 5 are dealing with factors that determine the level of transmission in Chiwahit whereas the possible role of man's defence system will come up for discussion in the last chapter.

It is not easy to determine the prevalence of *S. mansoni* infections accurately. The traditional parasitological examination take a lot of time and are not very sensitive. In 1971, when most stool specimens required for these studies were collected, no simple quantitative stool examinations method that could easily be used in our situation, was known to the author. Bell's method (Bell, 1963) is very time-consuming, and Kato's method (Kato, no date; Martin and Beaver, 1968), though simple and much quicker, required examination of fresh specimens. At the time of the survey, unfortunately, our financial situation and skilled technical assistance were minimal, therefore, the large-scale survey had to be based on formalin-preserved stool samples examined with traditional methods. In a comparative study at the Institute of Pathobiology in Addis Ababa, the home-laboratories for these studies, Ritchie's alcohol-buffered ether-formalin concentration method has been reported to be the best method in the given situation (Duncan et al, 1970). Therefore, this method was adopted in the present studies.

In addition, in one quarter of the town Immuno Fluorescent Antibody Tests were performed. Serological tests do not only provide information on the situation of the patient at the moment of drawing blood: persons who do not harbour living worms but did

photo 15. Air photo of Chiwahit and its surroundings. (the course of the streams is accentuated by pen.)(photo kindly made available by the Mapping and Geography Institute of the Ethiopian Government).

so some time ago will still show a positive test. Therefore the history of the patient's contact with the disease is a very important factor. Since it appeared that many of the present inhabitants of Chiwahit migrated to Chiwahit a short time before (table 3.3.) **only little attention was paid to serological tests** in Chiwahit. This additional diagnostic method was used more extensively in Jenda (chapter 6).



Sketch map of the neighbourhood of Chiwahit. This sketch shows the same area as photo 15. The town of Chiwahit is located on the plateau in the centre of the picture.

3.2. THE LOCAL SITUATION

3.2.1. The town of Chiwahit

The present town of Chiwahit is located on a small plateau (about 50 acres) lifted some 35 meters above the surroundings (photos 15, 16). It started its existence as a Highway Authority camp in about 1954 (Messing, 1972). Until that time the weekly market for the area was in Aberdja, 8 km south of Chiwahit, on the main road to Gorgora. Nowadays Chiwahit has the main market for grain, oilseeds and cattle in Dembia. It attracts people from all over Dembia and from Takussa, Chilga, Sakalt, Belessa, and even from **Gaynt and Debre Tabor**.

As most roadside towns, the outer parts of the town are densely planted with eucalyptus trees whereas the centre of the town consists of a huge market place, surrounded by little shops and traders' houses (photos 17, 18, 19). During the rains the town gets very muddy; then it is often difficult to get from the mainroad through the muddy verge into the actual town. It is easy to understand why those who do wear shoes in the dry season don't during the rains !

photo 16. The town of Chiwahit, situated on a low flat hill.

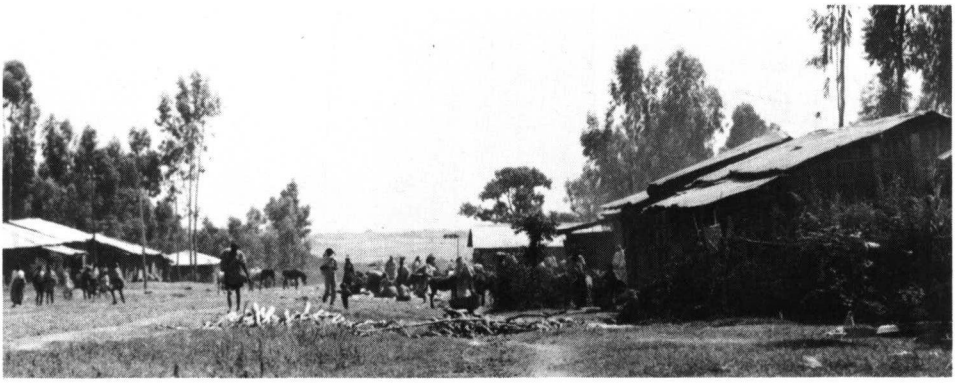


photo 17. Chiwahit, the centre of town along the main road.

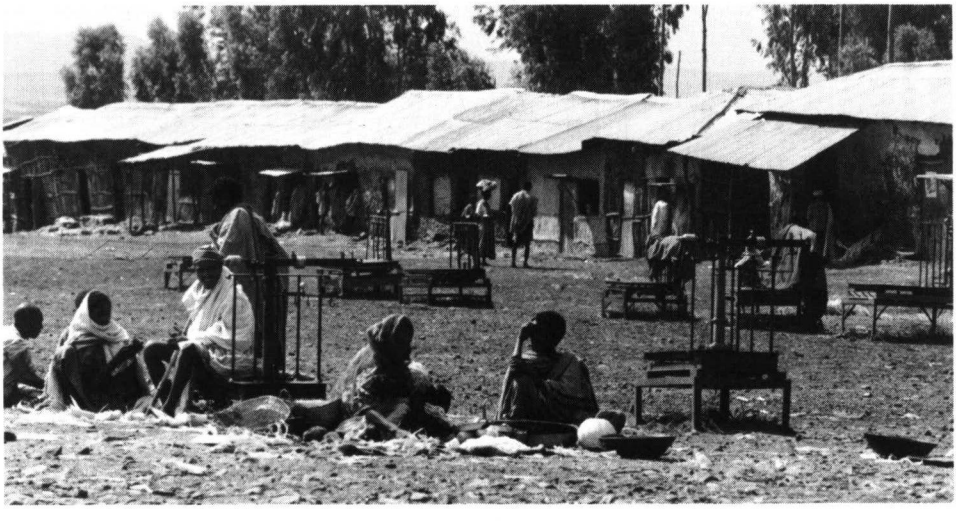


photo 18. Chiwahit, the market area on a normal day.

The communicational and educational facilities Chiwahit offers have been improved significantly since Messing wrote in 1962: "Telephone, there is none, but local government has collected contributions towards telephone and claims that 103 poles have been purchased". Today there is a telecommunication office with a telephone, there is a big 'chica' 1) schoolbuilding with 6 classromms (± 320 children) and money for a new building has been collected already.

Once a week a Health Officer, a sanitarian and a nurse from Gorgora or Kolla Duba hold a clinic in the small health station, and the health officer gives some lessons to the schoolchildren.

There is an Ethiopian orthodox church in Chiwahit and since 1971 also a small mosque. The daily bus service from Gondar to Gorgora has a stop in Chiwahit and in addition quite a few old private small buses go down from Gondar to Chiwahit and back again. Chiwahit is the principal town of the mikitil wereda 2) of Chiwahit that extends southwards to Gorgora ; wereda 2): Kolla Duba; awraja 2): Gondar . The mikitil wereda gez 3) (Ato Gosa Merid up to spring 1971, Ato Kebede Belay from then onwards) also serves as mayor of Chiwahit town.

3.2.2. The people of Chiwahit

In 1962 Messing estimated the population of Chiwahit at about 2,000. According to Ato Gosa (former mayor of Chiwahit) it was just over 2,000 in 1970, and according to our counts and estimates it was about 2,200 in 1971.
It was attempted, though not achieved, to study a 100 % sample of the town's population. In effect only some 75-80% of the people were included in this study. The demographic data in this section refer to information that was obtained from this sample. The error involved by not including the remaining 20 % will be discussed below.

The population has all characteristics of that of a North-Ethiopian roadside town. There is a great surplus of women, many of them being divorced farmer's wives who have settled in the town to make a livelihood. They are tallabrewers 4), prostitutes and servants. Many of them are also petty traders (peppers, onions,

Note: 1) 'chica': a construction of wattle and daub, generally used in the construction of local huts.
2) 'mikitil wereda', 'wereda' and 'awraja': administrative divisions of the province.
3) 'gez': governor.
4) talla is the local beer that is prepared and sold by tallabrewers.

wood, and cow-dung for burning etc.) and in their spare time they spin cotton for the town's weavers. Because of the high number of single tallabrewers the mean household size is rather small: 2.9 (calculations based on our inquiry) compared with the Ethiopian mean household size of about 4.53 (Eth. Stat. Abstr.: number of persons per household in rural areas: 4.65, in urban areas: 3.65; for Begemder province the figures are: 4.4 and 3.3 respectively). According to another survey the mean size of the households in Begemder province (towns + rural areas) is approximately 3.3 (Russell, 1967).

photo 19. Chiwahit's weekly market on monday.

From table 3.1 and fig. 3.1. it will be seen that the surplus of women is mainly caused by the agegroup of 16-32 years, and to a lesser extent by the older women. Among christians between 16 and 32 years of age the surplus of women is even more pronounced: 16.7 % being male and 83.3 % female: brewing talla is an entirely Christian occupation.

Most moslim women, many older Christian women and some of the younger women are housewives. It is the task of the housewive to prepare food, to buy and sell little items necessary for cooking, to draw water and to wash clothes. These activities are also performed by the tallabrewers, but they have to go to the streams more often to collect water. A comprehensive list of the occupations in Chiwahit is given (table 3.2.).

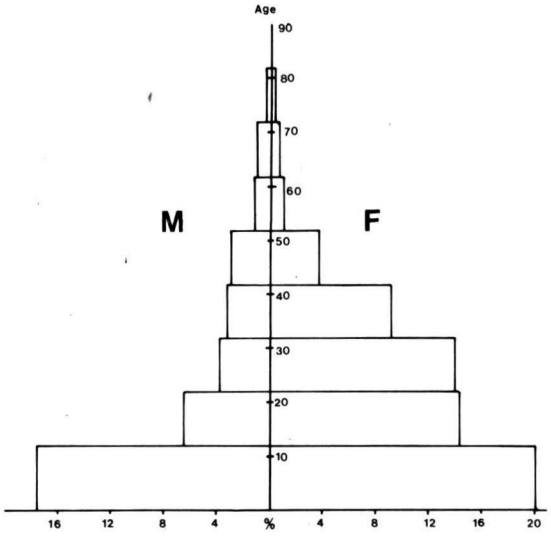


Fig. 3.1. Population pyramid for Chiwahit
(based on a sample of 1676 people, see par. 3.3.2)

There is a relatively high number of schoolchildren living in the town because children from "the countryside" are often living with relatives in order to attend school. According to Russell's survey 35 % of the population of Begemder province is younger than 15 years (Russell, 1967).

More demographic details will be given as required in the following sections of this chapter. Here it is only attempted to give a general impression of the character of the town.

All persons in Chiwahit that were included in the sample were asked for their birthplace, and for the length of time they had been living in Chiwahit. Though the localization of all these birthplaces produced a considerable number of problems since no recent maps exist, the results are summarized in the maps 5 and 6 and in table 3.3.

Table 3.1. Sex distribution per age-group

age	male	female	total
1- 6	124 (43.7%)	160 (56.3%)	284 (16.9%)
7-15	239 (49.2%)	247 (50.8%)	486 (29.0%)
16-32	103 (20.2%)	408 (79.8%)	511 (30.5%)
> 32	146 (37.0%)	249 (63.0%)	395 (23.6%)
total	612 (35.9%)	1064 (64.1%)	1676 (100 %)

Table 3.2. Frequency of various occupations in Chiwahit

occupation	%
females	
1 talla brewers / sellers	30.9
2 housewives	29.1
3 servants and daily workers	8.8
4 merchants	2.4
5 others, none, unknown	2.7
males	
6 merchants	9.8
7 daily workers	3.2
8 farmers	3.5
9 clothmakers, tailors	3.3
10 technicians and craftsmen	1.7
11 others, none, unknown	4.4
	100

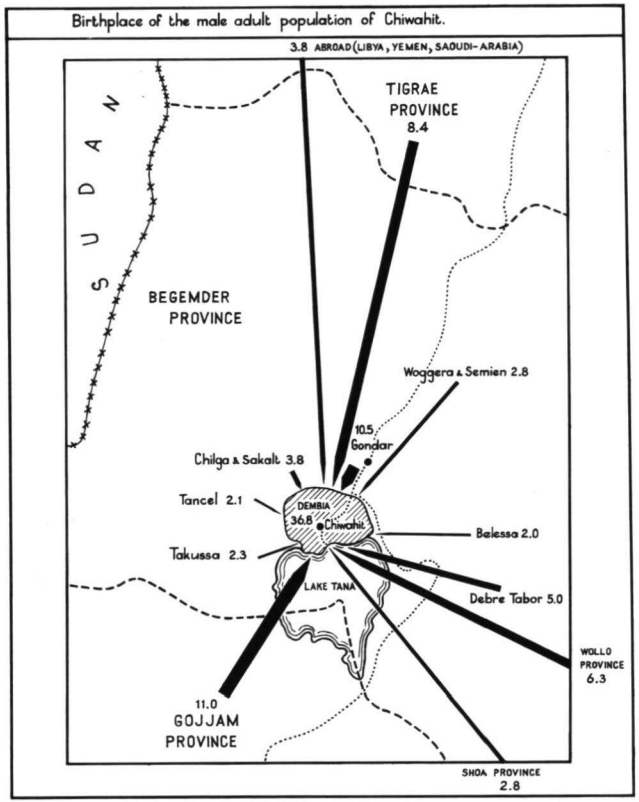
Category 5 includes old women, a few disabled women, a nun, a 'chica shum' (administative authority) and a couple of women that did not answer our questions. Category 10 includes both technicians in the millhouse and some carpenters, tanners, silversmiths and a blacksmith. Category 11 includes 7 teachers, 2 priests, 11 policemen and soldiers, 5 workers at the Malaria Eradication Service and the Ministry of Agriculture-Office, some Chica shums, butchers, barbers, a 'doctor' and a 'pharmacist' etc.; the old and disabled men, and a few who did not answer our questions properly.

In our sample 80.3 % of the persons was Christian; the remaining said to be Moslim. The majority of the Moslims are Ethiopian Moslims (Jabartis), but there is also a fair number of Arab Moslims. Most of the Arabs were born in Ethiopia, but seven of them were immigrants from abroad who came in the nineteen-thirties.

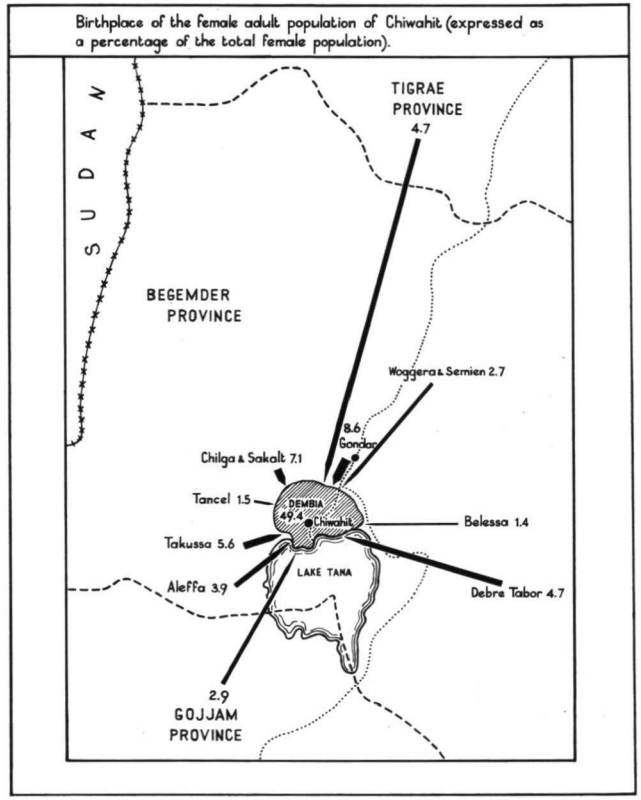
Even though the total population of Chiwahit has not significantly increased during the last 10 years, it appears from these data that the turnover of the population in Chiwahit is high. More women than men were born in Chiwahit or its immediate surroundings. The most important male occupation in Chiwahit is trading , and traders are usually very mobile, so this difference is easily understandable.

Table 3.3. The length of time people have been living in Chiwahit.

type of immigrants	percentage of the population
those who came to Chiwahit less than 2 months ago	3.0
those who lived in Chiwahit for less than 5 % of their life-span, but for more than 2 months	9.0
those who lived in Chiwahit for more than 5% but less than 20% of their lives	20.3
those who lived in Chiwahit for more than 20% but less than 50 % of their lives	29.6
those who lived in Chiwahit for more than 50% of their lives but who were not born in Chiwahit	10.3
those who were born in Chiwahit, including those who came to Chiwahit before their third year of age	27.8



Map 6. Immigration of males into Chiwahit



Map 5. Immigration of females into Chiwahit

(based on our sample of 1812 people)

Since the population of Chiwahit proved to be far less stable than expected, a compararive study was performed in the more stable farmer's village of Jenda, some kilometers off the main road (see chapter 6).

3.2.3. The water supply

In 1958 handpumps were constructed at the wells of Amba-Zena, Chigaro, and Cahlguaye, outside Chiwahit. The pump at AmbaZena has been working off and on for many years, but has been out of order for the last few years. At Chalguaye water could be collected from a tap at the end of a tube that came down from a decapitated well. The amount of water produced at this tap is minimal however (photo 24) and the tap is generally locked except during a few hours in the morning. Very often the tap broke down, and the water seeped away freely. At Chigaro well there is a similar construction that has been out of order for a long time, but it was still possible to collect water from a concrete lined waterhole. In 1972 the device was repaired by the Public Health College in Gondar. Now clean water can be obtained from 2 taps. Even though this well is the farthest from Chiwahit town (about 15 minutes walk over a narrow stony trail) the numbers of visits to this well have increased considerably since the reparations (see chapter 5).

The great majority of people, however, depend on water that is collected from the streams and pools (photos 21, 23, 25-30). The subject of water collections and water contacts will be dealt with in more detail elsewhere (chapter 5).

3.2.4. The sanitation

It is not customary in Chiwahit to have a latrine or a toilet. Faeces are generally produced at the roadside, just outside the houses, or in the backyards of the houses. Most people, however, prefer the shade of the eucalyptus trees in the outer parts of town. The Health Officers and sanitarians from Gondar and Gorgora have tried to persuade people to dig pit latrines (pit in the ground, no roofing), and they actually assisted in doing so. Nevertheless, only a small proportion of the houses has a latrine of its own and even among those few latrines several appeared to be in disorder (full, overgrown) or out of use for no good reason. As far as is known to the author there are three roofed latrines in the town: one belonging to the school, one to the health station which was rarely used, and one to our field station which was built by us.

In one quarter of Chiwahit and among a group of fifty 1st grade schoolchildren an inquiry was made concerning the numbers of latrines. The results of our questions are summarized in the tables 3.4. and 3.5.

Table 3.4. Numbers of latrines among 79 houses in Chiwahit, Quarter A

	Chr.	Mols.	total	
all persons of the household agree that there is a latrine	18	5	23	(29%)
all persons of the household agree that there is no latrine	41	7	48	(61%)
some persons of the household say there is a latrine, others say there is not	7	1	8	(10%)

Table 3.5. Numbers of latrines in the homes of 50 school-children

	Chr.	Mosl.	total
latrine present	10	5	15 (30%)
no latrine present	29	6	35 (70%)

The high proportion of disagreement as to whether or not a household has a latrine of its own gives an impression of the irregular way in which latrines are generally used and of the inaccuracy of the answers: people know they ought to have a latrine, so they are inclined to pretend to have one.

3.3. MATERIALS AND METHODS

3.3.1. The inquiry

The intention of the Chiwahit survey was to make all persons answer a list of questions (appendix 2) and produce a small amount of stool for parasitological examination.
of stool for parasitological examination.

The questions regarding the size of the household served to estimate the proportion of people that was missed in our survey (see paragraph 3.3.2.).

The estimate of age produced considerable confusion. Very few persons know their birth date and most do not know how old they are. Women often don't bother to try to remember their age, instead they simply say 30 or 40. In general men estimated their ages more accurately than women. In a group of 117 persons the ages were registered twice with an interval of 7 weeks. The differences between the first and the second estimate are presented in table 3.6.

Because people tend to round off their ages to the nearest 5 or 10 (see fig. 3.2.) the age intervals in the following paragraphs are chosen e.g. from 23-32 rather than from 20-30.

Table 3.6. Errors in the estimates of the ages

type of persons	sample size	deviation in years of the second age-estimate from the first one							
		0	1	2	3	4	5	5-10	> 10
boys 4-15 years	18	11	3	2	1	1			
men 16-32 years	13	8	1	2		2			
men over 32	11	6	2	1				1	1
girls 4-15 years	39	12	17	6	2	1	1		
women 16-32 years	21	8	3	3	3		3		1
women over 32	15	7	1	1	1	1	3	1	
total	127	52	27	15	7	5	7	2	2

The inquiry into the history of the persons was confined to the place of birth and the length of stay in Chiwahit (see paragraph 3.2.2.). This means that persons who were born in a non-endemic area and who came to Chiwahit only a short time before may well have had a long history of contact with the infection in former dwelling places. Unfortunately, in our studies it was not possible to take complete histories of every person's movements during his whole life. Thus, the endemicity of *S. mansoni* in the people's birth place will only give a rough impression of the frequency of contacts with the disease before these persons came to Chiwahit.

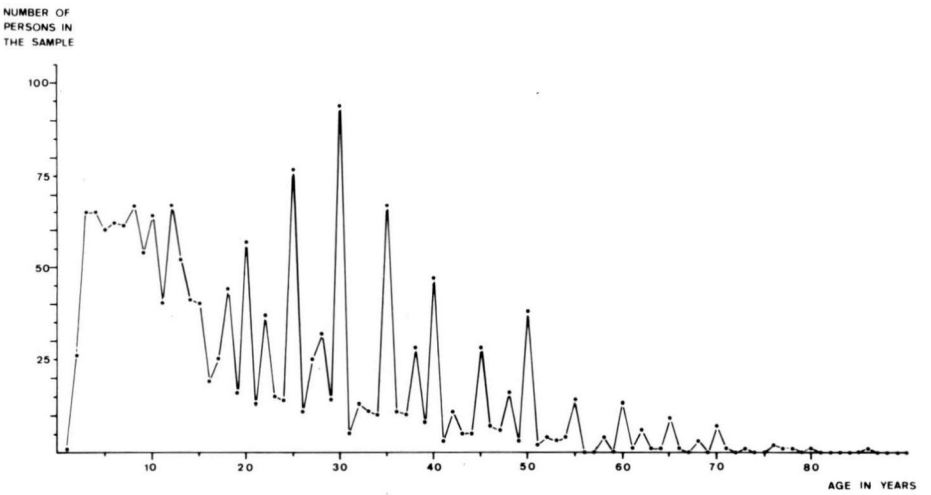
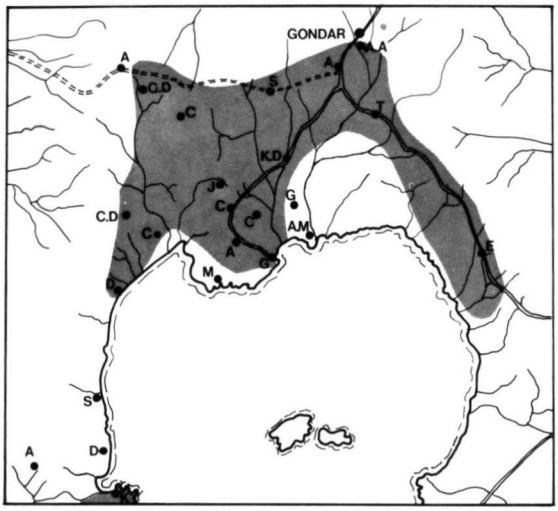


Fig. 3.2. Age-frequency distribution among the people that were included in the sample

In the following paragraphs those persons who were born in villages located in the shaded area of map 7 will be considered to be born in endemic areas. In addition, people from Adwa and Bahar Dar are considered to come from endemic areas. All persons from other birth places are considered to be born in areas for which the endemicity is unknown, low, or zero.



Map 7.

The area that will be considered to be highly endemic for **S. mansoni**
(for the full names of the communities, see map 4)

The information on the different consistencies of the stool samples was not used because the criteria proved not to be well enough defined.

The information on the water-contact patterns proved very unreliable. This subject will be discussed in chapter 5.

3.3.2. The sample size

The information we obtained in answer to the question on the size of the household enabled us to estimate the number of persons that should have been included in our survey but which we did not encounter. In addition, a number of houses proved to be locked on the occasion of several visits: an estimate was made of the number of households that was entirely missed in this way, and of the mean size of those households. Thus, the total population of Chiwahit (including Chalguaye 'suburb') was estimated to be about 2,200.

According to the Eth. Stat. Abstr. about 8 % of a town's population is younger than 3 years; for Chiwahit the number of infants under 3 is probably a little bit less due to the great surplus of single women, say 7 %, or 144. Only 32 infants under

three were included in the sample. Of the remaining 2,200-(144-32) = 2,088 people, only 1,812 (87 %) were registered in our system. Among these 1,812, answers to our inquiries and adequate stool samples were received from 1,676 persons. The remaining 136 persons were not included in our final analysis because no proper stool sample was delivered (37), because one or more questions were not answered properly (19), because the stool-specimen got lost or because the microscopical examination was considered to be unreliable (24), or because some persons came to Chiwahit less than 2 months ago (56).

The sample of 1,676 persons on which our analysis is based is not a proper random sample. The number of infants is underestimated as has been pointed out above; the number of school-children is overestimated since the schoolteachers did not permit refusals. The number of elderly women is probably somewhat underestimated: they were most reluctant to cooperate. Often women required their husband's permission to cooperate, and since more Moslim traders were missed than Christians, more Moslim women refused to cooperate than Christian women. Some traders (mainly Moslims) travel around from one village to another attending all weekly markets; we failed to include some of them in the sample.

In spite of these sampling errors, the sample will be considered to represent the population adequately in the following sections.

3.3.3. The collection of stool samples

Little plastic cups (from the plastic factory, Addis Ababa) were handed over to the people after they had answered all the inquiry questions. About three quarters of the people produced a sample of stool instantly. With the remaining quarter an appointment was made as to the time of collection of the cups. It proved to be advantageous to use cups of different colours; in this way the risk of accidental mixing up of the stools was reduced. As soon as feasible 2 grammes of stool were weighed on a simple balance and transferred to a bottle with 10 ml of 7.5 % formalin.

3.3.4. The parasitological examinations

Ritchie's alcohol buffered formalin-ether concentration method was used in this study as the diagnostic method for helminth ova detection. Prior to the normal procedure the faeces-formalin suspension was divided into two equal parts: one part for a second examination whenever necessary, and one part for the present examination. The suspension of approximately 1 gramme of stool in formalin was mixed thoroughly in 200 ml tap-water before being filtered over a double layer of cheesecloth.

Ritchie's concentration method (Ritchie et al, 1960) is described in appendix 3.

3.3.5. The collection of bloodsamples

From most people older than 3 years in quarter A of Chiwahit one to three heparinized capillary tubes of blood were drawn by means of fingerpricks. At Chiwahit school and in Jenda (see chapter 6) blood was collected in the same way. Since no hand-centrifuge nor electricity were at our disposal the tubes were set upright for several hours. Thus 20-30 microliter of serum were obtained. The tubes with sera were labelled, packed and sent to Holland within 1-3 days. Within 5-7 days after the collection the sera were stored at -20° C. at the Laboratory for Parasitology, Leiden, Holland.

3.3.6. The Immuno Fluorescent Antibody Tests (IFAT)

The indirect I.F.A. tests were performed essentially according to the methods as described by Ambroise-Thomas and by Deelder (Ambroise-Thomas, 1969; Deelder, 1973). Cryostat sections (6 microns) of adult male *S. mansoni* worms embedded in Guinea-pig abdominal muscles were used as the antigen substrate. No female worms were used because of the auto fluorescence of the ovaria. The conjugated immunoglobulins were diluted to 1/20 (SwAHu/FITC; Nordic, Tilburg, Netherlands) or to 1/10 (SwAHu/IgM/FITC). Microscopical examination was performed with a fluorescence microscope equipped with a quartz-iodine lamp (12V, 100W), a KP490 primary filter (Leitz) and a K510 secondary filter (Leitz).

A detailed description of the IFA-technique is given in appendix 4.

3.4. RESULTS

3.4.1. Results of the parasitological examinations

The overall prevalence data for some helminths as they were found in our survey are given in table 3.7.
The infection index with helminths is remarkably high with an average of 1.7 helminth-species per host, according to our methods. Ritchie's method (pH 7) is known to be a poor one for hookworm detection (Ritchie et al, 1960), and the majority of *Taenia* infections will have been missed, so the average number of helminth species per host is probably much higher.

Ascaris lumbricoides	76.2%
Schistosoma mansoni	42.2%
Trichuris trichiura	37.1%
Strongiloides stercoralis	7.0%
Hookworm	4.6%
others	6.5%

Table 3.7. Prevalence of helminth infections in Chiwahit

For *S. mansoni* the results of the parasitological examinations are summarized according to various categories of the population in the charts 1-5. Although the whole sediment of the formalin-ether sediment was examined, the methods used in examining the faecal samples are not reliable in a quantitative sense. For that reason the charts will not deal with counts of eggs but only with fractions of people who are positive and negative for *S. mansoni*.

Key to the charts. The charts are constructed such that in each chart one variable, e.g. sex or age, is tested under different sets of conditions. The percentages of persons that are positive in each group are depicted in the right hand part of the charts. The numbers of persons in each group is given in brackets. When less than ten persons per group were available, the percentage is given as a small black point instead of a bigger dot. For the sake of clarity dots under the same set of variables are connected with a solid line, and provided with a reference number (e.g. 1.3.b. for the comparison of the infection rate of male and female Moslims in Chiwahit).

For sex, age, religion and section of the town in which people are living, the answers from the inquiry were used. The occupations are classified according to the system given in table 3.2. The endemicity is determined in accordance with map 7. The time during which people have lived in Chiwahit was expressed in two different ways. In Chart 4A recent immigrants are those who have lived in Chiwahit for less than 20 % of their lives and former immigrants are those who have lived in Chiwahit for more than 20 % of their lives. In Chart 4B the length of time during which people have lived in Chiwahit is expressed in years.

For the Charts 1, 3, 4A and 4B the difference between the infection rate of the two categories that were compared was tested statistically with the normal approximation of Fisher's test for 2x2 tables. The P-values are represented as follows:

. stands for $0.05 < p < 0.1$
.. stands for $0.01 < p < 0.05$
... stands for $p < 0.01$

In Chart 2 the difference was tested between the infection rate of each set of four age groups and the infection rates of the four age groups given in (2.1.a.). For chart two χ^2-tests were used.

Although the original data are given wherever possible, the charts are not strictly systematic: too much space would be required for rather useless data.

A correct statistical analysis of the correlation is difficult since none of the variables, age, occupation, religion, etc. are independant among themselves. Multi-variate analysis of the variance is not feasible since there are too many yes-or-no answers and the distribution of the other variables cannot easily be transformed into normal distributions.

DISCUSSION OF THE RESULTS PRESENTED IN THE CHARTS

Chart 1 Infection rate and sex

When the right hand part of the first chart is considered it can be seen at the first glance that the higher prevalence of infections in males compared with females (1.1.a.)($p < 0.01$) is not consistently found in all subsamples. The difference between the infection rates of males and females is more pronounced in some subsamples than in others. In other words, the difference of (1.1.a.) is not entirely, or perhaps not at all, causally related with the sex but rather with variables that are linked with sex and considered separately in this chapter.

From (1.2.a-d.) it can be seen that the correlation between the infection rate and the sex is very marked in infants and children but absent in older people.

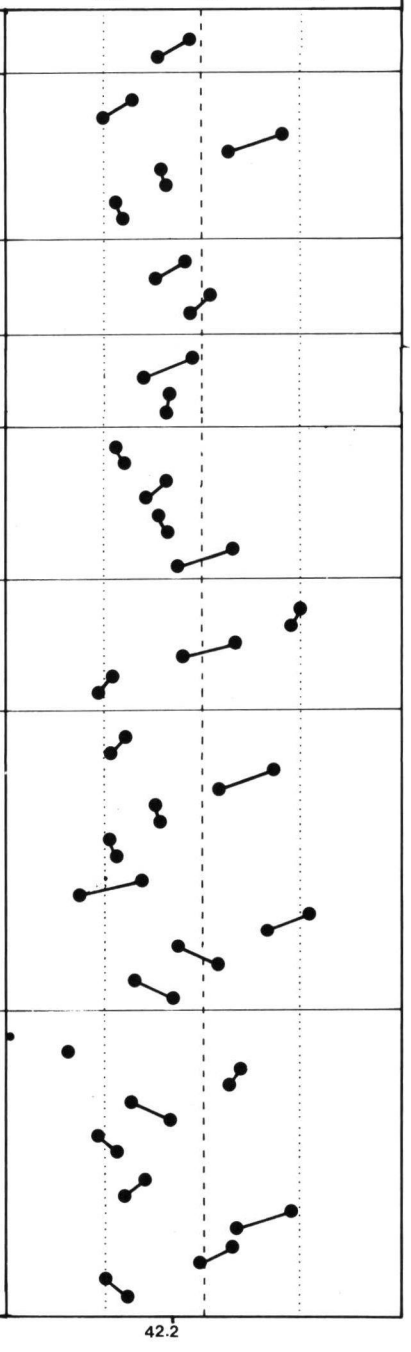
When all males and females are split up according to their religion (1.3.a-b.), the picture of (1.1.a.) remains the same so the infection rate is higher among males than among females irrespective of religion.

When subsamples are drawn on the basis of religion and age (1.7.a-h.) it appears that in Christians the role of the factor 'sex' is only recognizable in children between 7-15 years of age ($p < 0.01$). Among Moslims the infection rate is higher in boys than in girls but among adult Moslims the reverse is true there the infection rate is higher among females ($p > 0,1$)

Since Moslim infants are not very numerous and since the prevalence of infections in adult female Moslims is higher and not lower than in adult male Moslims, the difference between the infection rates of (1.1.a.) would seem to be attributable to the high infection rate in boys of 7-15 years of age compared with girls. How could this difference be explained ?

CHART 1 Infection rate and sex

break down of the total population by:		SEX		% pos.	P-value	
1. OVERALL		M	(612)	47.2	•••	a
		F	(1064)	39.4		
2. AGE	1- 6 years	M	(124)	32		a
		F	(160)	25		
	7-15 years	M	(239)	70	•••	b
		F	(247)	56		
	16-32 years	M	(103)	40		c
		F	(408)	41		
	older than 32	M	(146)	28		d
		F	(249)	30		
3. RELIGION	Christians	M	(450)	46	•••	a
		F	(896)	38		
	Moslims	M	(162)	52		b
		F	(168)	47		
4. SECTION OF THE TOWN	section A+B	M	(315)	48	•••	a
		F	(482)	36		
	section C+D	M	(266)	43		b
		F	(574)	42		
5. IMMIGRANTS						
recent immigr. from non-endemic areas		M	(99)	28		a
		F	(198)	30		
" " from endemic areas		M	(44)	41		b
		F	(165)	36		
former immigr. from non-endemic areas		M	(149)	39		c
		F	(252)	41		
" " from endemic areas		M	(320)	58		d
		F	(449)	44	•••	
6. OCCUPATIONS	schoolchildren	M	(200)	75		a
		F	(114)	73		
	non-schoolchildren	M	(53)	59		b
		F	(89)	40		
	infants	M	(117)	27		c
		F	(156)	24		
7. RELIGION AND AGE						
Christians, 1- 6 years		M	(95)	31		a
		F	(123)	27		
	7-15 years	M	(178)	68		b
		F	(203)	54	•••	
	16-32 years	M	(71)	38		c
		F	(354)	39		
	older than 32	M	(106)	26		d
		F	(216)	28		
Moslims,	1- 6 years	M	(29)	35		e
		F	(37)	19		
	7-15 years	M	(61)	77		f
		F	(44)	66		
	16-32 years	M	(32)	44		g
		F	(54)	54		
	older than 32	M	(40)	33		h
		F	(33)	42		
8. AGE, for former Christian immigrants						
from non-endemic area,	1- 6 years	M	(9)	0		a
		F	(19)	16		
	7-15 years	M	(32)	59		b
		F	(39)	56		
	16-32 years	M	(16)	31		c
		F	(63)	41		
	older than 32	M	(47)	23		d
		F	(78)	28		
from endemic areas,	1 - 6 years	M	(81)	35		e
		F	(94)	29		
	7 -15 years	M	(129)	72	••	f
		F	(124)	58		
	16-32 years	M	(21)	57		g
		F	(123)	49		
	older than 32	M	(16)	25		h
		F	(49)	31		



From (1.6.a-b.) it appears that the infection rate is much higher in schoolchildren than in non-schoolchildren (7-15 years of age) ($p < 0.01$). This holds true for both boys and girls. More boys than girls go to school (76 % and 46 % respectively) which explains the comparatively high infection rate in boys. The question remains why the infection rate is higher in schoolchildren then in non-schoolchildren, but that matter will be discussed with the analysis of chart 5.

In the sections A+B of the town of Chiwahit there is a difference between the infection rates of males and females, but this is not so in the remaining part of the town (1.4.a-b.). These differences can be fully explained by the fact that in the sections A+B 22.8 % of the population consists of schoolchildren, in the sections C+D this is only 11.5 %. Furthermore, there are more adult Moslim women in the sections C+D than in the sections A+B (17.2 % and 9.6 % respectively).

When different groups of immigrants are considered (1.5. a-d.), the role of the factor 'sex' is only clearly recognizable among the former immigrants from endemic areas. This category happens to include the majority of the children. The importance of patterns of immigration will be discussed elsewhere.

Little information is gained when all males and females are split up into smaller categories (1.8.a-h.).

Conclusions

- The correlation of the infection rate with sex, as presented by (1.1.a.) appears to be primarily the result of the fact that the infection rate is higher in schoolchildren than in non-schoolchildren. Of minor importance is the observation that the infection rate is higher in Moslim infants than in Christian infants.
- The prevalence of infections among adult Moslims is higher in females than in males.

Legend to chart 1

M : Males
F : Females
The P-values refer to normal approximations of Fisher's 2 x 2 table.
. : 0.05 < p < 0.1
.. : 0.01 < p < 0.05
... : p < 0.01

CHART 2 Infection rate and age

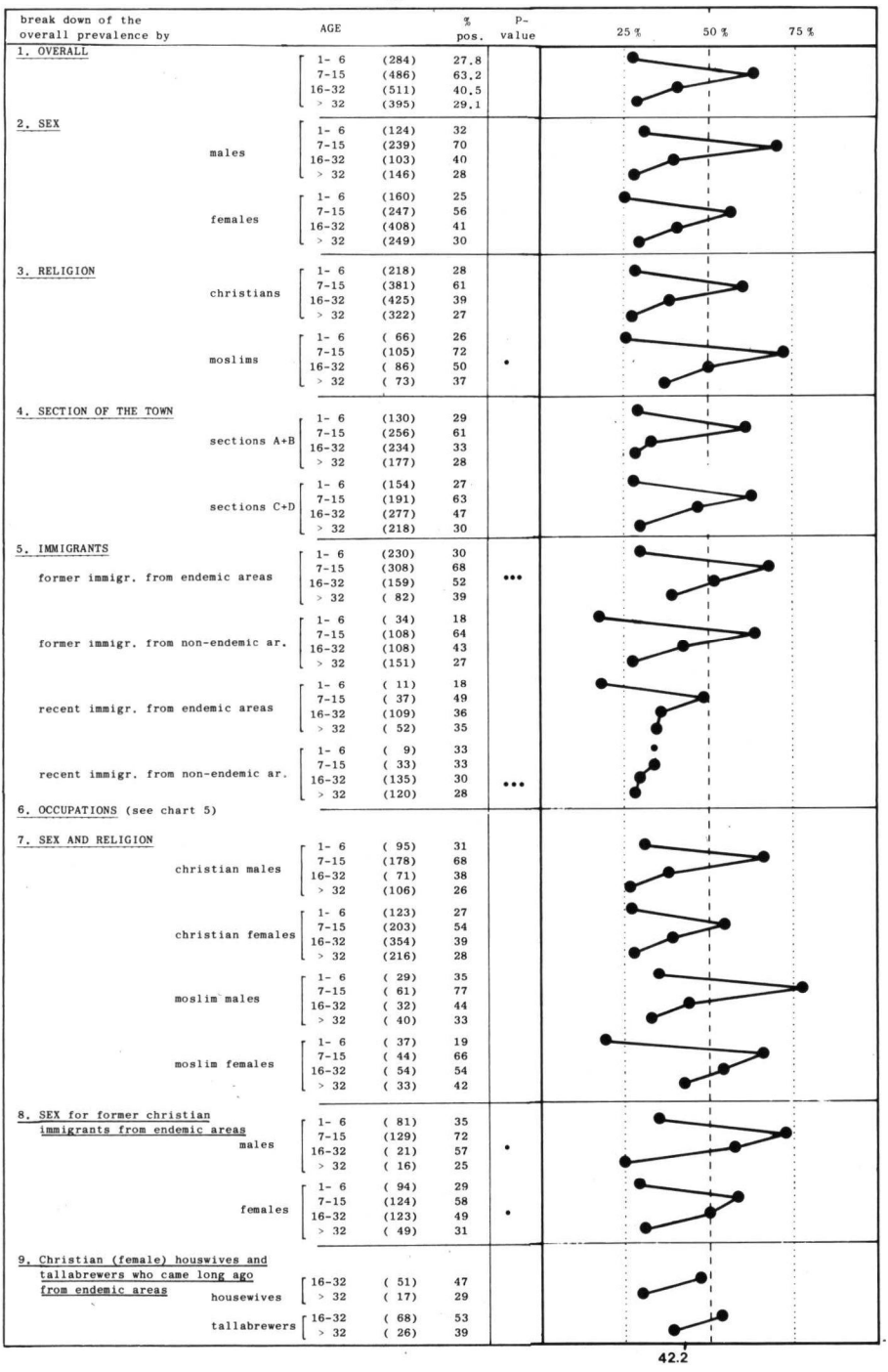


Chart 2 Infection rate and age

At different ages the infection rates are significantly different (2.1.a.) ($p < 0.01$). This remains true all through chart 2, for all categorizations except for the recent immigrants from non-endemic areas. Among the recent immigrants from endemic areas the peak prevalence is still comparatively low. More detailed age-prevalence relationships are given in the figures 3.3., 3.4. and 3.5; again the same pattern is confirmed.

Conclusion

- The prevalence of *S. mansoni* is age-dependent.

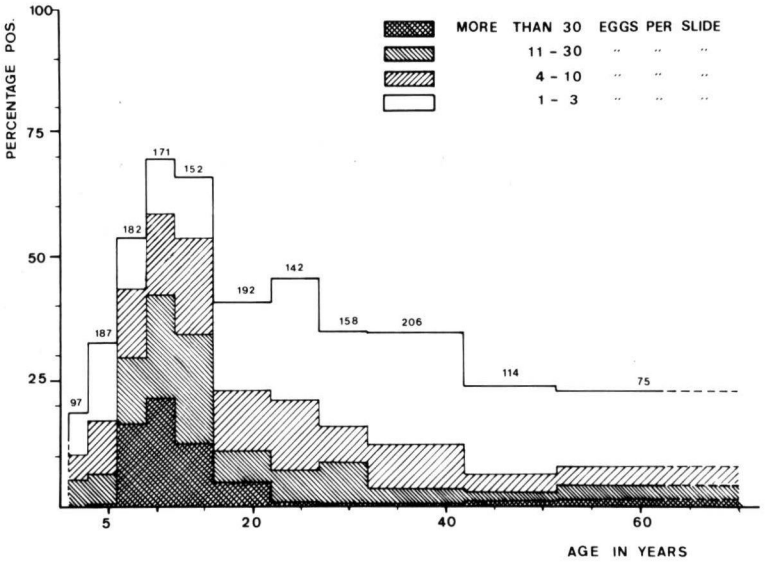
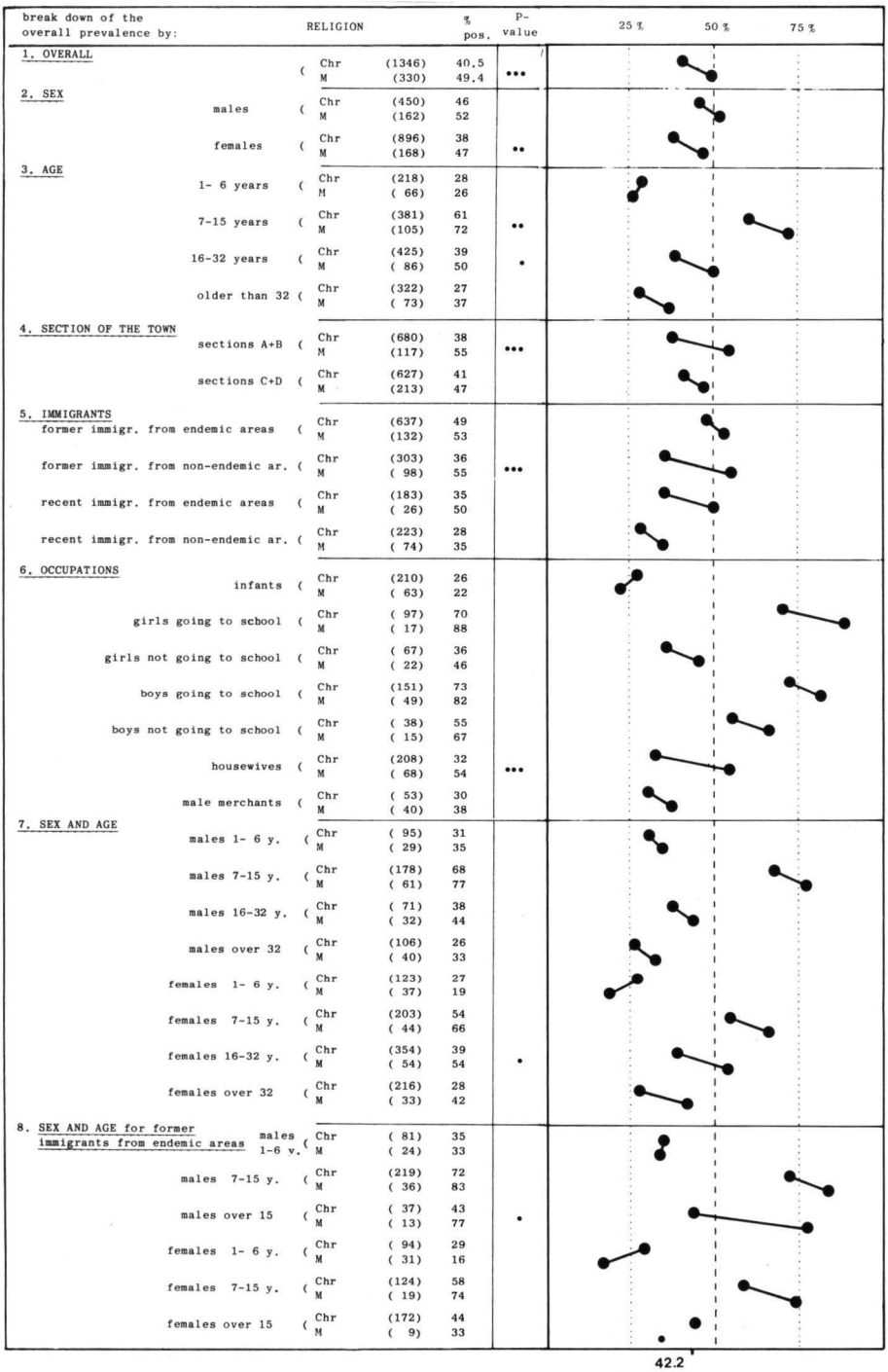


Fig. 3.3. **S. mansoni** *infections in different age-groups*
The figures on top of the histogram indicate the sample ***size per age group.***

Legend to chart 2

P- values refer to χ^2 *-tests for 4 variables comparing the age-prevalence relationship of each category with the age-prevalence relationship of 2.1.a. (4 degrees of freedom).*
., .., ...: as for chart 1.

CHART 3 Infection rate and religion



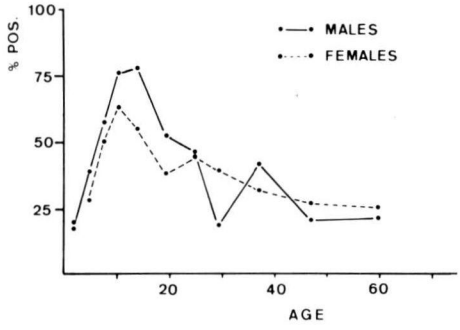


Fig. 3.4. **S. mansoni** *infections per sex, per age*

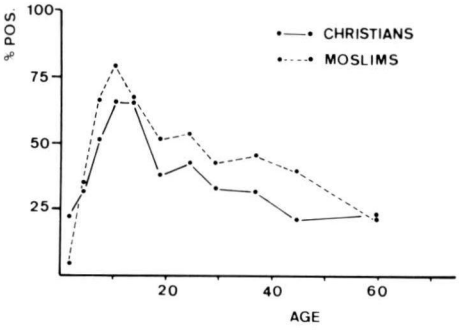


Fig. 3.5. **S. mansoni** *infections per religion, per age*

Chart 3 Infection rate and religion

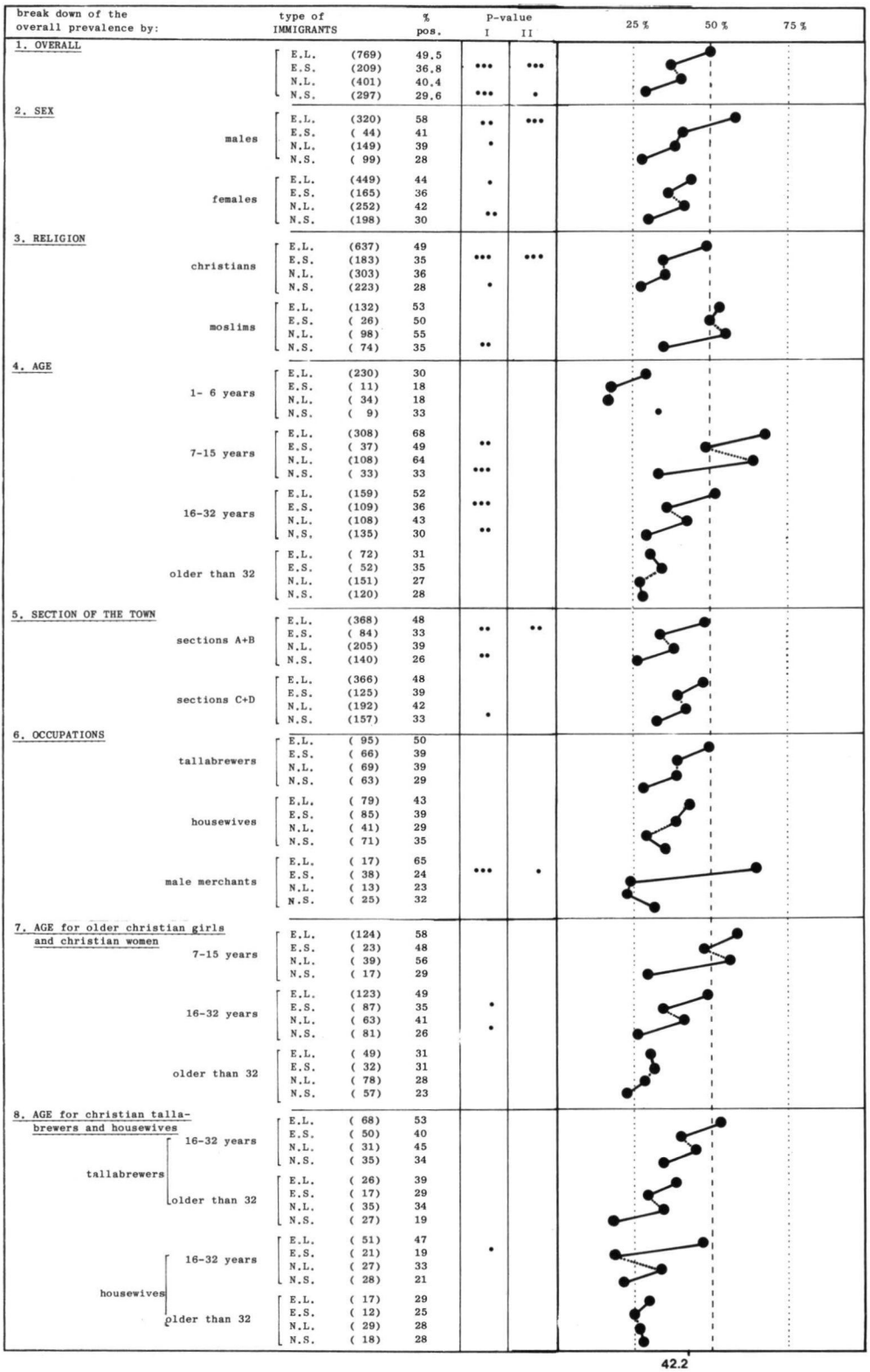
Comparison of the overall infection rates among Christians and Moslims (3.1.a.) shows that the prevalence of infections is higher in Moslims ($p < 0.01$). A brief examination of the right hand part of the chart indicates that this remains true for most subsamples but not for all. All categories in which the difference between the infection rates is not consistent with the overall picture (3.1.a.) appear to refer to infants (i.e.: 3.3.a.; 3.6.a.; 3.7.e.; 3.8.a.; 3.8.d.). In children of 7-15 years of age and in adults, on the other hand, the higher prevalence of *S. mansoni* infections among Moslims is more pronounced than in the overall picture (3.3.b-d. and 3.1.a.). In adult women the difference between the infection rates of Christians and Moslims ($0.05 < p < 0.1$) is larger than in adult men ($p > 0.1$).

It is a common finding that the infection rate in Moslims is higher than in Christians and this difference is generally believed to be a result of the religious washings of the Moslims (e.g. Farooq et al, 1966; Lo et al, 1973). These washings, however, are not practiced very often in this part of Ethiopia, and when they are practiced it is a male activity. Alternative explanations for the high infection rate among Moslim women cannot

Legend to chart 3

Chr. : Christians
M. : Moslims
The P-values refer to normal approximations of Fisher's 2 x 2 test.
., .., ... : as for chart 1.

CHART 4A Infection rate and patterns of immigration



easily be found. Possibly they have more contact with infested water than the other groups of adults. This possibility will be tested in chapter 5. It is also possible that Moslims are more susceptible to the infection than Christians. However, in the introduction (paragraph 1.3.2.) it has been shown that the majority of Moslims are Ethiopian Moslims having the same racial characteristics as the Ethiopian Christians and most Arabs living in Chiwahit are males.

To a foreign observer a striking difference between Christians and the Moslims in Chiwahit is the relative wealth of the Moslims. They are richer, have better houses, more servants, and they look cleaner. There could be a causal relation between wealth and prevalence of infections but such a correlation is difficult to study since wealth cannot readily be measured by a foreigner.

Conclusions

- The prevalence of *S. mansoni* infections is higher in Moslims than in Christians except for children under 6 years.
- The difference is more marked among adult females than among adult males.
- No explanation could be given for the religion-related differences in the infection rates.

Legend to chart 4A

E.L. : Immigrants who were born in an area endemic for schistosomiasis and who came to Chiwahit long ago, and those who were born in Chiwahit itself.
E.S. : Immigrants who were born in an area endemic for schistosomiasis and who came to Chiwahit short ago.
N.L. : Immigrants who were born in an area not endemic for schistosomiasis (or in an area of which the endemicity is uncertain) and who came to Chiwahit long ago.
N.S. : Immigrants who were born in an area not endemic for schistosomiasis (or in an area of which the endemicity is uncertain) and who came to Chiwahit short ago.
The P-values I refer to normal approximations of Fisher's 2 x 2 test when comparing the infection rates of E.S. and E.L. or of N.S. and N.L.
The P-values II refer to normal approximations of Fisher's 2 x 2 test when comparing the infection rates of E.L. and N.L. or of E.S. and N.S.
., .., ... : as for chart 1.

CHART 4B Infection rate and patterns of immigration

break down of the overall infection by:	length of residence in Chiwahit		% pos.	P-value I	P-value II	25 % 50 % 75 %
1. AGE						
children	≤ 2	(71)	45.1			a
	3- 5	(74)	63.5	•••		
	> 5	(297)	70.4			
adults	≤ 2	(243)	27.6			b
	3- 5	(177)	40.7			
	6-10	(269)	40.9	•••	••	
	>10	(244)	32.0			
2. SEX OF CHILDREN						
males	≤ 2	(33)	49			a
	3- 5	(36)	61	•••		
	> 5	(179)	79			
females	≤ 2	(38)	42			b
	3- 5	(38)	66	•		
	> 5	(118)	58			
3. RELIGION OF CHILDREN						
christians	≤ 2	(57)	49			a
	3- 5	(53)	62	••		
	> 5	(232)	67			
moslims	≤ 2	(14)	29			b
	3- 5	(21)	33	••		
	> 5	(65)	83			
4. BIRTH PLACE OF CHILDREN						
endemic area	≤ 2	(36)	53			a
	3- 5	(31)	65			
	> 5	(174)	69			
non-endemic area	≤ 2	(35)	37			b
	3- 5	(43)	63	•••		
	> 5	(44)	80			
5. SEX OF ADULTS						
males	≤ 2	(56)	27			a
	3- 5	(42)	41			
	6-10	(66)	35			
	> 10	(80)	31			
females	≤ 2	(187)	28			b
	3- 5	(135)	41			
	6-10	(203)	43	•••	••	
	> 10	(164)	32			
6. AGE OF ADULTS						
16-32	≤ 2	(190)	29			a
	3- 5	(123)	46	•••		
	6-10	(144)	47			
	> 10	(83)	46			
older than 32	≤ 2	(53)	23			b
	3- 5	(54)	30			
	6-10	(125)	35		•	
	> 10	(161)	25			
7. SEX AND AGE OF ADULTS						
males 16 - 32	≤ 2	(35)	23			a
	3- 5	(23)	44	•		
	6-10	(21)	43			
	>10	(18)	56			
males > 32	≤ 2	(21)	33			b
	3- 5	(19)	37			
	6-10	(45)	31			
	>10	(62)	24			
females 16 - 32	≤ 2	(155)	30			c
	3- 5	(100)	46			
	6-10	(123)	47	•••		
	>10	(65)	43			
females > 32	≤ 2	(32)	16			d
	3- 5	(35)	27			
	6-10	(80)	38	•		
	>10	(99)	25			
8. RELIGION OF ADULTS						
Christians	≤ 2	(203)	26			a
	3- 5	(143)	39			
	6-10	(221)	38	•••		
	>10	(207)	33			
Moslims	≤ 2	(40)	38			b
	3- 5	(34)	47			
	6-10	(48)	56			
	>10	(37)	35			
9. BIRTH PLACE OF ADULTS						
end. area	≤ 2	(111)	34			a
	3- 5	(81)	37			
	6-10	(117)	52	•		
	>10	(107)	36			
non-end. area	≤ 2	(132)	22			b
	3- 5	(96)	44			
	6-10	(152)	33	••		
	>10	(137)	29			
10. BIRTH PLACE AND AGE						
16 - 32 end. area	≤ 2	(98)	35			a
	3- 5	(59)	42			
	6-10	(78)	54	••		
	>10	(56)	46			
16 - 32 non-end. area	≤ 2	(92)	23			b
	3- 5	(64)	48			
	6-10	(66)	38	•••		
	>10	(27)	44			
> 32 end. area	≤ 2	(13)	31			c
	3- 5	(22)	23			
	6-10	(39)	49			
	>10	(51)	26			
> 32 non-end. area	≤ 2	(40)	20			d
	3- 5	(32)	34			
	6-10	(86)	29			
	>10	(110)	25			

42.2

Charts 4A and 4B Infection rate and patterns of immigration

The pattern of *S. mansoni* infections in Chiwahit is determined by past exposures to infected water rather than by present exposures. Relevant factors of the people's past include the time during which the people have been living in Chiwahit, the characteristics of the former dwelling place, and birth place and behavioural changes in ageing people. Unfortunately, all of these variables could not be recorded accurately. Instead, in chart 4A, people are classified as being first of all an inhabitant of Chiwahit (those people who had lived in Chiwahit for more than 20 % of their life-span) or as being a recent immigrant (those people who had liven in Chiwahit for less than 20 % of their life-span). In chart 4B the infection rates are related to the actual length of the people's residence in Chiwahit (expressed in years).

An overall comparison of the four groups of immigrants (4A. 1.a.) indicates that the infection rate is higher in those people who came long ago than in those who came recently to Chiwahit. This is true for immigrants who were were born in endemic areas as well as for those from non-endemic areas (in both cases: $p < 0.01$). The infection rate is higher in people who were born in endemic areas than in people who were born in non-endemic areas.

These observations hold true for most subsamples as presented in chart 4A. The exceptions refer to older people (4A.4.d., 4A.7.c.; 4A.8.d.) and to the occupational groups of housewives and male merchants (4A.6.b.; 4A.6.c.). The numbers of male merchants (4A.6.c.), however, are too small to draw firm conclusions, and the category of the housewives (4A.6.b.)includes many older women.

In the categories in which age is not considered, the interpretation of the chart is difficult since the group of former immigrants from endemic areas contains disproportionately many schoolchildren among whom the infection rate is comparatively high. Furthermore, the picture is complicated by the presence of the infants among whom the classification as 'recent immigrants'

Legend to chart 4B

The P-values I refer to normal approximations of Fisher's 2 x 2 test when comparing the infection rate of those who came less than 2 years or 2 years ago with that of those who came 3-10 years ago (for children : more than 2 years ago). The P-values II refer to normal approximations of Fisher s 2 x 2 test when comparing the infection rate of those who came 3-10 years ago with that of those who came more than 10 years ago.
., .., ... : as for chart 1.

and 'former immigrants' is not really appropriate. For that reason the infants were not included in chart 4B.

In chart 4B the actual length of the people's residence in Chiwahit is expressed in years. A residence time of 3-5 years has quite a different meaning for young children and for adults, so for that reason children and adults will be considered separately in this chart.

In all cases except two (4B.7.b.; 4B.10.b.) the prevalence of infections was lower in the immigrants who came less than 2 years ago than in those who came 3-5 or 6-10 years ago and the two aberrant subsamples include only small numbers of people. The relatively low infection rate in the very recent immigrants reflects the observation on the high prevalence of *S. mansoni* infections in Chiwahit as compared to many other areas in the province (see chapter 2).

Neither in children nor in adults is there a clear and consistent difference in the infection rates between those people who came 3-5 years ago and those who came 6-10 years ago.

The prevalence of infections in adults who have lived in Chiwahit for more than 10 years (4B.1.b.) is lower than in adults who lived in Chiwahit for 3-10 years. This holds true for males and for females (4B.5.a-b.), for Christians and for Moslims (4B. 8.a-b.), for old adults, but not for young adults (4B.6.a-b.). Although not statistically significant, the decline in the infection rate among older persons (older than 32 years) who have lived in Chiwahit for more than 10 years as compared with those who lived in Chiwahit for only 3-10 years, is of some relevance since this decline might reflect a partial acquired resistance against schistosome infections. Apart from the length of residence in Chiwahit, both groups of immigrants are very similar: the occupational and sex distributions, and the mean ages (46 and 44 years respectively) of both groups of immigrants are almost the same.

Among children who have lived in Chiwahit for more than about 3 years the effect of the endemicity of schistosomiasis in the children's birth place is not noticable any more (4B.4.a-b.), but the infection rate in children as well as among adults who came to Chiwahit 2 years ago or less, is higher among those who were born in areas emdemic for schistosomiasis than among those from non-endemic areas (4B.9.a-b.).In adults this difference remains also visible in the immigrants who came 3-10 years ago and even in those who came more than 10 years ago. The latter difference is partly due to the fact that - among those who came to Chiwahit more than 2 years ago - the group of subjects originating from non-endemic areas includes many older persons (> 32 years) compared with the group of persons born in endemic areas (59 % compared with 37 %). In chart 2 it has been shown that the infection rate is clearly age-dependent. When the effect

of the endemicity of schistosomiasis in the people's birth place is considered per age group (4B.10.a-d.) the differences in the infection rate appear to be small.

Conclusions

- The infection rate is lower among immigrants who came to Chiwahit less than about 3 years ago than among those who have lived in Chiwahit for a longer period of time.
- Neither among children nor among adults is there a consistent difference in the infection rates between those people who came 3-5 years ago and those who came 6-10 years ago.
- The infection rate tends to be lower among those older adults who have lived in Chiwahit for more than 10 years than among those who lived in Chiwahit for 3-10 years.
- The effect of the endemicity of schistosomiasis in the people's birth place cannot be recognised any more when the people have lived in Chiwahit for some 3 years or more.

Chart 5 Infection rate and occupation

The prevalence of *S. mansoni* infections in some occupational groups is higher than in others. It is possible that this could be explained by differences in the patterns of life which are inherent in the various occupations. For instance it might be expected that among the tallabrewers who go to the streams very often the infection rate is higher than among the tailors and merchants who hardly ever go there. It is also possible, however, that differences in prevalence among various occupational groups may be reduced to differences in age (see comments on chart 2) or to historical factors (see comments on chart 4A and 4B).

There is a higher prevalence among the schoolchildren than among the non-schoolchildren. There are several partial explanations possible for this finding.

(1) Stools from the schoolchildren, and from the other children and adults in Chiwahit, were not prepared for microscopical examination by the same person. A part of the relatively low prevalence in non-schoolchildren, infants and adults might be explained by our failure to achieve a strict standardization in our techniques. However, the estimates of the error (see paragraph 3.5.1.) do not justify the hypothesis that the difference should be explained entirely by this possible error.
(2) There are more recent immigrants among the non-schoolchildren than among the schoolchildren (19.7 % compared to 7.3 %).
(3) At school children are taught to be clean. Chiwahit school was directed for several years prior to and after our surveys by a very active and competent headmaster. The children's

CHART 5 Infection rate and occupation

Occupations	Overall		all groups except recent immigrants from non-endemic areas	
	number	% pos.		
infants up till 6 y.	(273)	25	(265)	25
female schoolchildren	(114)	73	(110)	74
female non-schoolchildren	(89)	40	(79)	43
male schoolchildren	(200)	75	(189)	77
male non-schoolchildren	(53)	58	(52)	59
tallabrewers	(293)	40	(230)	43
housewives	(276)	38	(205)	38
servants	(83)	29	(55)	34
female merchants	(23)	26	(16)	25
none, unknown, others (fem.)	(27)	22	(18)	28
male merchants	(93)	33	(68)	34
daily workers	(30)	43	(22)	45
farmers	(33)	39	(26)	35
clothmakers	(31)	32	(15)	47
technicians, craftsmen	(16)	25	(13)	31
none, unknown, others (male)	(42)	24	(16)	19

break down by:	RELIGION			
	christians		moslims	
infants up till 6 y.	(210)	26	(63)	22
female schoolchildren	(97)	70	(17)	88
female non-schoolchildren	(67)	36	(22)	45
male schoolchildren	(151)	73	(49)	82
male non-schoolchildren	(38)	55	(15)	67
tallabrewers	(293)	40	(0)	-
housewives	(208)	32	(68)	54
servants	(78)	29	(5)	20
female merchants	(8)	25	(15)	27
none, unknown, others (fem.)	(24)	17	(3)	67
male merchants	(53)	30	(40)	37
daily workers	(29)	41	(1)	100
farmers	(33)	39	(0)	-
clothmakers	(6)	17	(25)	36
technicians, craftsmen	(13)	15	(3)	67
none, unknown, others (male)	(38)	24	(4)	25

break down by:	AGE					
	1-15 years		16-32 years		older than 32	
infants up till 6 y.	(273)	25				
female schoolchildren	(114)	73				
female non-schoolchildren	(89)	41				
male schoolchildren	(189)	76	(11)	63		
male non-schoolchildren	(53)	58				
tallabrewers			(184)	45	(105)	30
housewives			(173)	39	(94)	33
servants	(32)	32	(32)	34	(19)	16
female merchants			(8)	37	(15)	20
none, unknown, others (fem.)			(13)	23	(13)	23
male merchants			(37)	40	(55)	27
daily workers			(13)	38	(16)	50
farmers			(12)	44	(21)	29
clothmakers			(11)	27	(20)	35
technicians, craftsmen			(5)	40	(11)	18
none, unknown, others (male)			(15)	27	(25)	20

abdomens were inspected weekly: if the children appeared to be dirty they were whipped, and if the following week they were still not clean the parents were called to account. Non-schoolchildren, on the other hand, were not very clean in general; they don't like washing and a less frequent exposure might be expected.

Tallabrewers have a slightly higher prevalence of *S. mansoni* infections than housewives, and the difference is slightly larger when only Christians are considered. A relatively small fraction of the female servants is infected; this is remarkable since the dirty work such as the collection of water is often done by them. The prevalence among male merchants in our survey is only slightly lower than the overall prevalence of *S. mansoni* among adults even though many of these merchants hardly ever go to the streams; they have only very rare contact with the infested waters around Chiwahit (see chapter 5). The same holds for the tailors among whom a surprisingly high percentage is infected when the recent immigrants from non-endemic areas are excluded. The infection rate rate among farmers (exept the recent immigrants from non-endemic areas) is only slightly higher than among Christian merchants. The numbers of persons in these categories, however, are very small. The prevalence among the occupational groups 'none, unknown, and other's is rather low in both males and females. At least partly this could be explained by the composition of these groups; they include the old, retired and disabled people.

Conclusion

No clear correlation could be found between the characteristics of various occupations and the prevalence of *S. mansoni*.

The role of the section of the town

The part of the town in which people are living may be an important factor to take into account since most people from the sections A and B go to Chalguaye stream for their water, and practically all people from the sections C and D go to AmbaZena or Chigaro stream (children who are living in the sections C or D are often seen around Chalguaye since the school is located near to the spring of Chalguaye stream). In chapter 5 it will be shown that the infectivity of the Chalguaye stream is generally much higher than in the AmbaZena and Chigaro.

In the 16-32 year age group the prevalence is higher in the sections C+D than in A+B (chart 2). This difference is mainly due to the fact that most Moslims are living in sections C and D.

Apparently (according to the data given in the charts 1-4 and the original data) the part of the town in which people are

living does not explain a substantial part of the overall variance of *S. mansoni* infections in Chiwahit. A sixth chart on the role of the section of the town does not introduce any new insights. The results of these parasitological examinations will be discussed in paragraph 3.5.2. and in chapter 7, general discussion.

3.4.2. Results of the serological examinations

The results of the serological examinations on 159 people from Chiwahit (all from section A) are presented in table 3.8. and in figure 3.6.

Out of the 79 persons whose stools were positive for *S. mansoni* (Ritchie's concentration method) 75 were also positive (reciprocal titer $\geq$ 8) on serological examination. The four false negative I.F.A. tests were from 2 children of 3 years of age, one from a girl of 7, and one from a woman of 40 years old.

In April 1973 165 blood samples were collected at Chiwahit school by Dr. Hiatt and our assistants. For technical reasons no first grade children were included. The samples were examined by the author in Leiden. Out of the 165 blood-samples only three were negative. Two of the negative children excreted a few eggs during the same survey, the third one was consistently negative in 4 stool examinations in 2 consecutive years (1972 & 1973). The mean reciprocal titer of the remaining

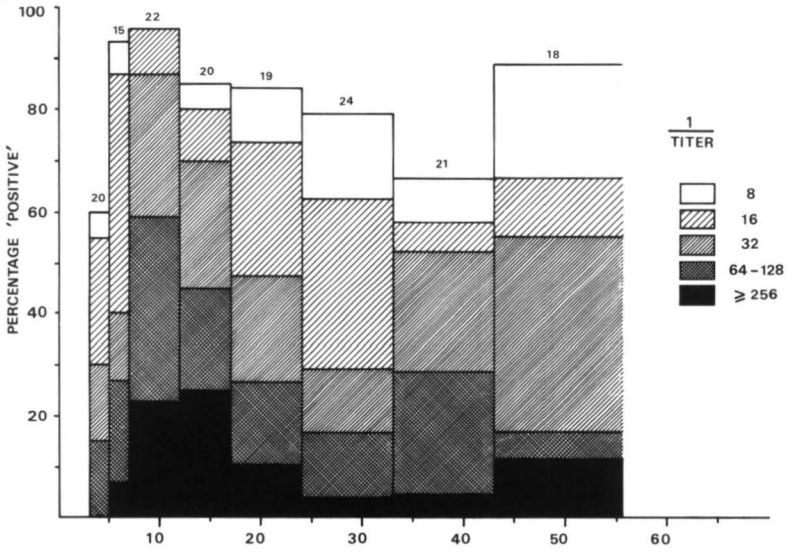


Fig. 3.6. The titers in I.F.A.-tests on 159 human sera from Chiwahit
The figures on top of the blocks refer to the number of people that was examined per age-group.

Table 3.8. Results of I.F.A.-tests for Chiwahit section A

Age	Number of IFA-tests	reciprocal titer ≥ 8	percentage "positive"
3- 5	20	12	60
6- 7	15	14	93
8-12	22	21	95
13-17	20	17	85
18-24	19	16	84
25-33	24	19	79
34-43	21	14	67
over 43	18	16	89
total	159	129	87

schoolchildren was 128. In 22 children the reciprocal titer was 512 or more

3.4.3. Physical examination of some schoolchildren

In cooperation with Dr. Ph. Eastman and Dr. W.J. Terpstra a small group of 121 schoolchildren was examined for hepatomegaly and splenomegaly. The age of all children was between 6 and 16 years. No detailed physical examination was done, and no other attempts were made to assess the clinical symptomatology of *S. mansoni* infections in this community. The figures presented in table 3.9. do not have the pretention to elucidate the problem of the medical importance of *S. mansoni* infection in Chiwahit; they merely provide some preliminary information on the subject. Some more data on liver enlargements are given in chapter 6, and the relevance of the results is discussed in the chapters 6 and 7.

Table 3.9. Hepatomegaly rate at Chiwahit school

grade	number examined	number of enlarged livers
1	27	4
2	15	2
3	-	-
4	28	2
5	24	3
6	27	0
total	121	11

In two cases the liver came lower than 2 cm below the lower costal margin. In the remaining 9 children the livers were just palpable or they extended just below the lower costal margin at exhalation. All children with enlarged livers were positive for *S. mansoni* at parasitological examination. In many non-endemic areas, however, the hepatomegaly rate is not significantly lower.
So, for the time being, there is no reason to suspect any causal relation between the schistosome infections and the hepatomegalies.

Though outbreak of malaria are still common during the rains, no splenomegalies were registered among the 122 schoolchildren.

3.5. DISCUSSION

3.5.1. Discussion of the methods; analysis of the errors

At the Institute of Pathobiology in Addis Ababa the routine procedure of Ritchie's concentration method included the filtration of 10 ml faeces-formalin suspensions, containing about 1 gramme of stool, through a double layer of wet cheesecloth. This filtration system is rather inefficient; more eggs will pass the cheesecloth when thinner suspensions are used. Therefore, in our experiments the faecal suspension was mixed thoroughly with some 200 ml tapwater before being filtered. Then the suspension was left in a conical glass for sedimentation during 30 minutes. The supenatant was decanted, and the sediment was used for the normal Ritchie-procedure. In some preliminary experiments this method appeared to increase the egg recovery, but no detailed comparative studies were performed because of lack of time.

For the standardization of the technique it is important that both the concentration procedure and the microscopical examination are strictly controlled. Ideally, both parts should be performed by the same technician all through the period of the study. Moreover it is important that the faeces-formalin suspensions are not stored too long before being examined in order to reduce changes of the specific gravity of the eggs. Unfortunately, neither of these requirements could be fulfilled because of the practical situation in the field. Technicians were not always available, and several of them joined us and disappeared again soon after. Because the chemicals were not always at our disposal a simple sedimentation method had to be used sometimes (see appendix 3). In some other cases the examination of the samples had to be postponed too long.

Table 3.10. The execution of the stool examination methods

number of the survey	type and date of the survey	preparation of egg concentrate by technician:	micr. exam. by techn.	method	date exam.
1	schoolchildren Ch. (4/71)	A	X	R	6-71
2	Chiwahit town (sections B,C,D) (3,4/71)	B	X	R	6,7-71
3	Chiwahit town (section A) (8/72)	C	Y	R	9-72
4	schoolchildren Chiwahit (3/72)	C	Y	R	11-72
5	schoolchildren Chiwahit (3/73)	C	Y	R	7-73
6	Jenda (chapter 6) (9/72)	C	Y	R	11-72
1',2'	repeated exam. of sp. collected at surveys 1 & 2	C	Y	S	8,9-72
3'	repeated exam. of Chiwahit section A-survey (3)	C	Y	S	8,9-72
4'	repeated exam. schoolch. Chiwahit 3/72-survey (4)	C	Y	R	11-72
5'	repeated exam. schoolch. Chiwahit 3/73-survey (5)	C	Y	R	7-73
6'	repeated exam. schoolch. Jenda 9/72-survey (6)	C	Y	R	12-72

In order to evaluate the stool examination techniques used at their true worths, several cross checks with the same or different methods were performed. The methods that were used and the persons by whom the methods were performed are summarized in table 3.10.

The errors, i.e. the number of "false negative" results, can be approximated as follows:

1. Some stool specimens that were considered to be positive in the first examination (method L) were repeated with method K. Let p be the fraction that is also positive on second examination.
2. Some other stool specimens that were found to be negative in the first examination (method L) were repeated with method K. Let q be the fraction of "negatives" that transpires to be positive upon second examination.
3. Due to the shortcomings of method K, q is underestimated. If a hypothetical 'perfect' method K' was used (recovery potential 100 %), the real fraction of stools that was negative on first examination and that appears to be positive on second examination is $Q = \frac{1}{p} \cdot q$.
4. In the epidemiological survey (1st exam., method L) the fraction of negatives (n) was overestimated. The actual fraction of negatives is $N = n(1 - Q)$.
5. The "recovery potential" of method L is: $R.P. = \frac{1 - n}{1 - N} \cdot 100$.

Example 1

42 samples from Chiwahit town (sections B,C,D) that were positive for *S. mansoni* (method 'BXR', i.e. the eggs were concentrated by technician B, and the microscopical examination done by technician X; Ritchie's concentration method was used; see table 3.10.) were tested once again (method CYS). Only 25 were positive, so the 'recovery potential' of method CYS ('p') was approximately 60 %. 260 negatives (method BXR) were tested once again (CYS). 36 appeared to be positive this time.

So, $q = \frac{36}{260} = 0.14$.

An ideal CYS method (recovery potential 100 %) would have revealed $\frac{42}{25} \cdot \frac{36}{260}$ negatives. So, Q = 0.23. In the original survey in Chiwahit 65 % of the non-schoolchildren + adult population of Chiwahit was negative for *S. mansoni*. The fraction of true negatives will therefore be:

N = 0.65 (1 - 0.23) = 0.50, and the recovery potential of method BXR was:

$$R.P. = \frac{1 - 0.65}{1 - 0.5} \cdot 100 = 70\ \%.$$

Example 2

Both in 1972 and in 1973 stools from schoolchildren in Chiwahit were examined with the same method performed by the same persons (CYR). Out of the 140 children who were positive on first examination and whose stools were examined for a second time (CYR) 119 (85 %) were positive for a second time. Out of the 118 negatives of the first examination that were repeated, 55 (46.6 %) proved to be positive on second examination, so

$$Q = \frac{140}{119} \cdot \frac{55}{118} = 0.55.$$

On first examination 128 out of 412 (31.1 %) of the schoolchildren were negative. The real percentage negatives N is estimated to be: N = n (1 - Q) = 0.31 (1 - 0.55) = 0.14.
The recovery potential of the method calculated in this way is:

$$R.P. = \frac{1-0.31}{1-0.14} \cdot 100 = 80.2\ \%.$$

When the same method is used twice the same recovery potential should be found. In this case, indeed, the difference between the first and the second calculated recovery potential was not very large (80 % and 85 % respectively).

The recovery potentials are calculated for those surveys in which fair numbers of negative and positive first examinations were repeated. The results are listed in table 3.11.

Table 3.11 suggests that the methods as they were used were most sensitive among infants and children. For the 7-15 age class this is well understandable since the egg outputs are much higher in this group than in adults (see fig. 3.3.). Possible explanations for the relative accuracy of our methods for the examination of infants' stool samples refer to the different consistency and the small daily amount of infants' faeces.

Table 3.11. Recovery Potentials for Ritchie's method as used in this survey

number of survey (see table 3.9.)	procedures 1st exam	2nd exam	1	2	3	4	percentage positives on first exam.	R.P. second exam.	R.P. first exam
1	AXR	CYS	-	-	27	10	74	60	82
2	BZR	CYS	42	25	260	36	35	60	70
4,5	CYR	CYR	140	119	118	55	69	85	80
2a	BXR	CYS	-	-	158	2	28	60	86
2b	BXR	CYS	-	-	29	9	60	60	75
2c	BXR	CYS	-	-	82	14	40	60	70
2d	BXR	CYS	-	-	91	11	29	60	67

Legend to table 3.11

column 1 *Stools that were positive on first examination and that were examined once again (by the same or another procedure).*

column 2 *Number of repeated positives that were positive on the second occasion.*

column 3 *Stools that were negative on first examination and that were examined again (by the same or another procedure).*

column 4 *Stools that were negative on first examination but in which S. mansoni eggs were found on the second examination.*

row 2a *People from Chiwahit sections B,C,D in the age class 1 - 6 years.*

row 2b *People from Chiwahit sections B,C,D in the age class 7 -15 years (excluding schoolchildren).*

row 2c *People from Chiwahit sections B,C,D in the age class 16-32 years.*

row 2d *People from Chiwahit sections B,C,D in the age class 32 and over.*

row 1, 2, 4, 5 see table 3.10.

The calculations as made above only intend to give a rough approximation of the errors. A major criticism could be leveled at the way in which the recovery potential of the second examination is calculated: those stools that were positive in the first survey do not represent a random sample of all positives but a selected group of positives with relatively high numbers of eggs. Yet, some impression is gained on the accuracy of the stool-examination methods in this chapter.

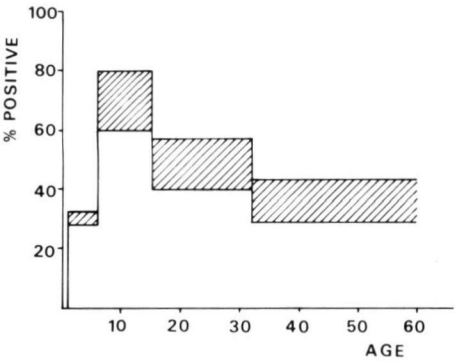


Fig. 3.7.

Age-prevalence histogram
The shaded parts depict the fraction of 'actually positive' stools that were 'false negatives' according to our stool examinations.

Though the whole sediment obtained with Ritchie's concentration method was examined for *S. mansoni* eggs it is doubtful to what extent the egg counts represent the actual egg output of the host. Dr. R.A. Hiatt examined some 90 stool-samples from Chiwahit schoolchildren with two quantitative methods (Bell's method and Kato's method) (R.A. Hiatt, pers. comm., 1973, report in preparation). Stool specimens that were collected at the same time from the same children were also examined by our technicians with Ritchie's concentration method. The coefficient of correlation of the results of Bell's method and Ritchie's method as used by us was 0.66 after logarithmic transformation.

Because of the unreliability of the quantitative value of the egg counts and because of the complications involved in processing the data, the numbers of eggs that were found in the stools were excluded from consideration in the analysis of the relative role of the various variables that were studied in this chapter.

No attempts were made to assess the accuracy of the serological tests as described in the paragraphs 3.3.6. and 3.4.2. The experience at the Leiden Laboratory for Parasitology shows that the errors are not more than about titer.

3.5.2. Discussion of the results

Before drawing conclusions from the parasitological findings it is of importance to consider the apparently large discrepancy between the 'stool-prevalence' and the 'IFA-prevalence'. Several factors are thought to be responsible for this difference.

1) The IFA-prevalence is a "period-prevalence" rather than a "point-prevalence"; it is expected to be higher than the stool-prevalence since past infections may still be the

cause for a positive test. Unfortunately, it is not known how long specific anti-schistosome antibodies remain demonstrable in the blood.

2) The high IFA-prevalence may be partly due to cross reactions with animal schistosomes. To some extent this will have happened since *S. bovis* is present in the area. Regular surveys of the streams around Chiwahit, however, have shown that both the intermediate host snail of *S. bovis (Bulinus 'truncatus')* and the parasite itself are very rare compared to *Biomphalaria pfeifferi* and *S. mansoni*. It is very unlikely - from an epidemiological point of view - that the disturbing influence of cross-reactions with *S. bovis* is of great significance: people who become exposed to *S. bovis* cercariae will probably have been in contact with *S. mansoni* cercariae long before.

3) As has been mentioned in section 3.5.1., the stool—prevalence for various groups of people has been underestimated because of the errors in the coprological methods. When stool-prevalence and IFA-prevalence are compared the corrected stool-prevalence (as presented in figure 3.7.) should be used rather than the uncorrected data.

4) I.F.A. tests may be positive if performed on sera from patients who do not excrete *S. mansoni* eggs but who do harbour adult schistosomes. This situation may occur when the worms have shifted to other locations (e.g. to the pulmonary artery) and in unisexual infections (i.e. infections with exclusively either male or female worms). The latter possibility will be considered in some more detail.

Blackie in Rhodesia, examining cadavers judged to be lightly infected, reported a long time ago that "it was rarely possible to recover more than 5 or 6 parasites from a given case" (Blackie, 1932, as cited by Cheever, 1968). More recently Cheever did a post mortem study on a large number of human cadavers in Brazil. Out of 83 "asymptomatic" subjects that were perfused at autopsy, 23 were found to harbour less than 5 worm pairs. Very few unpaired worms were found and the sex ratio of the worms was approximately 1:1.

In the area in which Cheever performed his study clinical complications and Symmers' fibrosis are frequently observed. In Chiwahit the epidemiological and clinical situation seems different: in sentinel mice, exposed to the natural bodies of water around Chiwahit, the sex ratio among the worms is about 6 males to 1 female (see paragraph 5.2.2.3.), and severe clinical cases are rarely or never observed (see paragraph 1.2.2.).

In Chiwahit the mean egg counts were very low in older people (fig. 3.3.). Since the number of eggs per gramme of

faeces has been found to reflect the worm burden in a nearly linear relation (Cheever, 1968), the low egg counts are probably the result of the low number of worm pairs that inhabit the portal system of the older people in Chiwahit. If the worm loads are extremely low (e.g. 1-3 worms per person), the chance of mating is small or zero. The mean worm load in a population of susceptible human hosts should be just over 4 in order to give rise to a mean burden of one worm pair per individual host, provided that 1) the life expectancy of unmated worms is the same as that of mated worms, 2) the life expectancy of female worms is the same as that of male worms, 3) the sex ratio among worms is 1:1, and 4) male and female worms, if both present, never fail to mate.

If the first condition is not met, i.e. if the life expectancy of unmated worms is shorter than that of mated worms fewer unisexual infections are to be expected. If the second, third or fourth condition are not met, an even higher rate of unisexual infections may be expected. Unfortunately, nothing is known about the life expectancy of unmated worms compared to that of mated worms; but there are indications that male worms live longer than female worms (Hairston, 1965a); the sex ratio among worms in sentinel mice was certainly not 1:1 for Chiwahit area, and Cheever's data suggest that few worms fail to meet a partner - if present.

In figure 3.8. the egg count frequencies are presented for various age groups. In this figure the proportion of the population is estimated which is likely to harbour at least one worm if the lowest egg counts (1-3 eggs per slide) are supposed to reflect infections with more than the minimal number of worms (e.g. 3, 4, or even more).

These considerations in combination with figure 3.8. suggest that in older people the majority of stool-negative individuals might harbour some unpaired worms. These unpaired worms will probably cause a positive I.F.A. test.

As in paragraph 3.5.1., these considerations only serve as approximations in order to gain a better understanding of how the charts 1 - 5 might be interpreted.

The particular age-prevalence relationship as represented in figure 3.3., could be explained in two alternative ways: either by the notion that behavioural patterns in relation to contact with infested water change drastically in the course of life (the transmission-related explanation), or by the (gradual) development of a defence system of the host (the immunity-related explanation).

The first explanation can be tested by comparing the infection rates and the water contact patterns of particular groups of the population. The second explanation is more difficult to test. The observation that the infection rate tends to become somewhat lower among people who have lived in Chiwahit

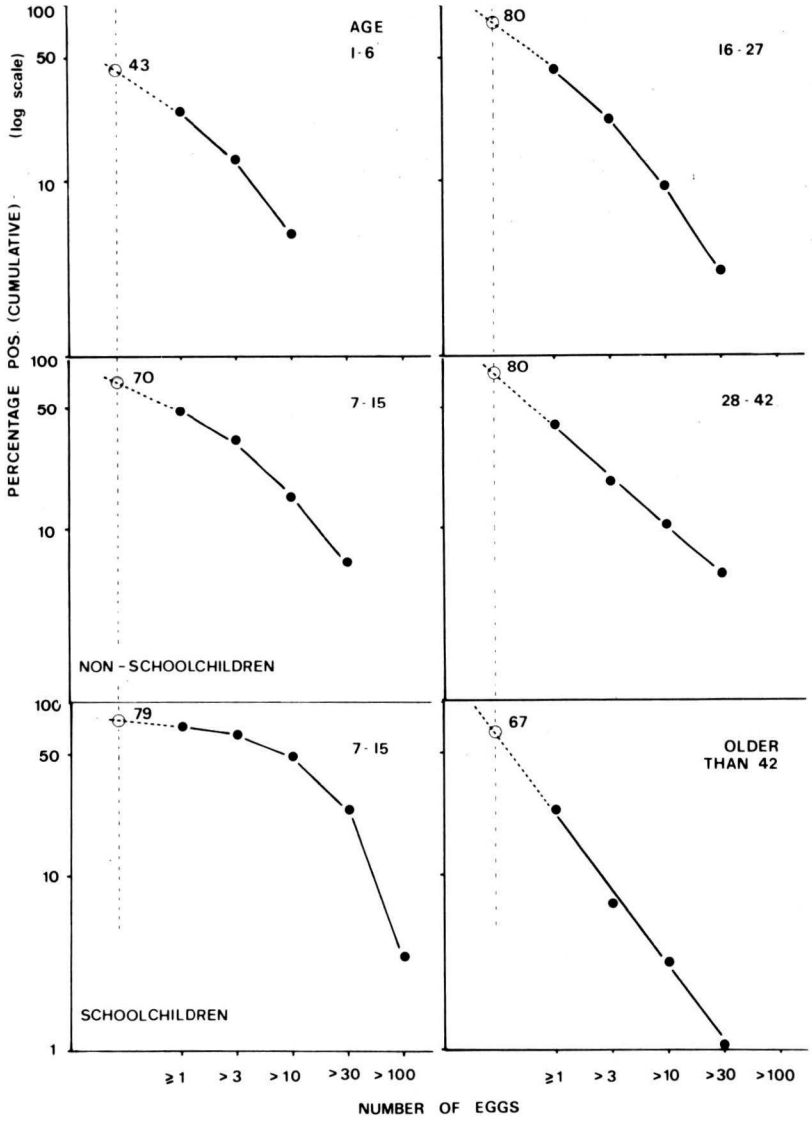


Fig. 3.8. Cumulative frequency of various egg counts per age group

The thin dotted lines indicate a hypothetical mean worm load of one adult worm per person. The actual position of this dotted line is unknown. It may well be that it ought to be moved a little to the right or to the left, but that does not really change the picture. The open circles and the accompanying figures depict the hypothetical percentage of the people that harbours at least one worm.

for at least 10 years suggests that an acquired immunity has developed among these people. This relatively low infection rate, however, may well be caused by quite another factor which escaped attention in the analysis of the charts. The demonstration of the role of an acquired resistance is probably bound to depend on indirect proof: on the gross inadequacy of the transmission-related explanation.

Clearly, a thorough analysis of the factors that determine the intensity of transmission is required before the relative role of both explanations can be discussed.

3.6. SUMMARY

In this chapter the prevalence of *S. mansoni* infections in Chiwahit was studied in different groups of the population. Both a serological and a coprological method were used.

The results of the Immuno Fluorescent Antibody Tests indicated that the great majority of people older than about 6 years is, or has 'recently' been infected with *S. mansoni*. Using Ritchie's concentration method a typical age-prevalence relationship was observed with a peak prevalence in children of 10-12 years of age. A careful analysis of the infection rates among various categories of the population lead to the following conclusions:

- Though no formal analysis of the variance could be performed, age appeared to be the major factor to explain the total variance of *S. mansoni* infections in Chiwahit.
- The infection rate among schoolchildren is higher than among non-schoolchildren.
- The infection rate is higher in Moslims than in Christians. This difference is most marked among adult women; it is absent among infants.
- The infection rate is lower among immigrants who came to Chiwahit less than about 3 years ago than among those who have lived in Chiwahit for a longer period.
- The effect of the endemicity of schistosomiasis in the people's birth place cannot be recognised any more when the people have lived in Chiwahit for some 3 years of more.
- The infection rates were similar among people with occupations that require frequent exposures to infested water and among people with other occupations.

The seeming discrepancy between the serological and the coprological tests was discussed but the final interpretation of the findings and the search for the mechanisms leading to the particular prevalence distribution are postponed to the general discussion (chapter 7).

CHAPTER IV THE INTERMEDIATE HOST

photo 20. **Biomphalaria pfeifferi** *(Krauss), (2 times natural size)*

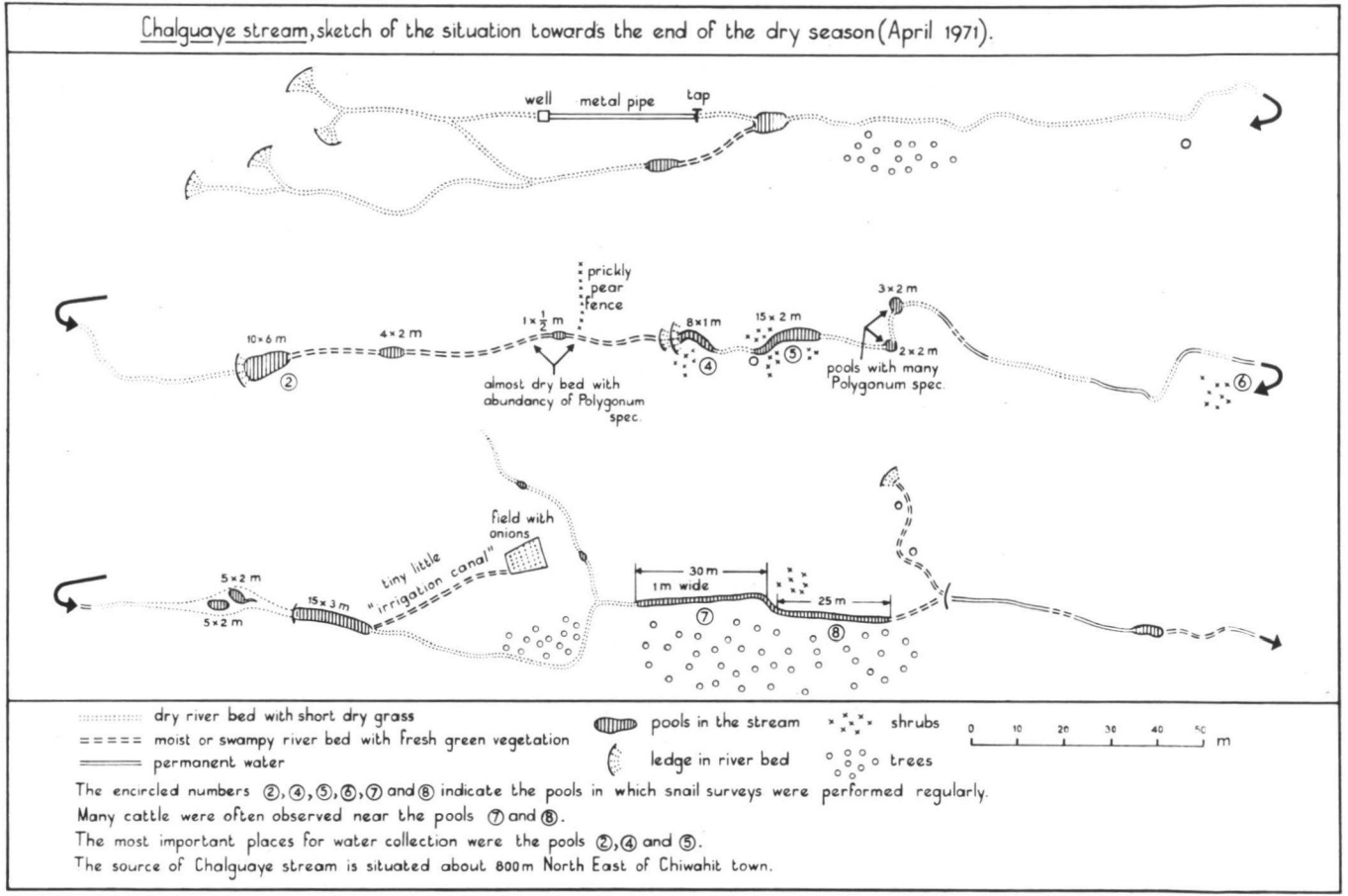
4.1. INTRODUCTION

In a general description of the epidemiology of intestinal schistosomiasis in Chiwahit the description of the biology of the intermediate host is an essential part. In this chapter we will deal entirely with the situation in the three streams from which people in Chiwahit obtain their water: AmbaZena, Chalguaye and Chigaro. Data on the snail populations in Atakelt stream near Jenda will be given in chapter 6. The population biology of *Biomphalaria pfeifferi* itself can only be considered briefly. More attention will be paid to the schistosome infections in the intermediate host.

The topographical location of the streams is shown on the aerial photo (photo 15 and corresponding explanatory map). AmbaZena stream is the biggest, and it is used most frequently by Chiwahit's population (see chapter 5). Chalguaye is used second most. Chigaro is not used very often, and those women and children who do go to Chigaro collect their water from the well and only rarely from the Chigaro stream.

AmbaZena, Chalguaye, and Chigaro originate from wells just below the rim of the little plateau on which Chiwahit is situated. The altitude of Chiwahit town is 1,900 m. and the springs of the streams are some 25 m. lower. The catchment areas of the streams are small; they are mainly fed by underground water. The water volume and the flow velocity are thus rather independent of the

Map 8. Sketch map of Chalguaye stream



precipitation. Even though the vertical fall of the streams that we are studying is quite large, the flow rate is negligible. For instance, the volume of flow of water in January 1972 was 0.16 litre per second in the last and biggest pool of Chalgaye that was studied. Except during and shortly after the heavy rainstorms in July, August and September, the streams are not continuous but are rather a series of isolated pools with muddy patches, luxuriant vegetation, or even short dry grass in between. For the Chalguaye stream a detailed map has been drawn (map 8) and photos of a series of pools are given (photo 21) to illustrate these characteristics. The general appearance of the other streams is very similar.

For the snail populations the main consequences of this type of water body are: 1) great fluctuations in snail population densities related to the amount of precipitation may not be expected; 2) during the dry season immigration and emigration in each of the pools are probably factors of little importance; infected snails are likely to remain in the same pool which is of considerable importance to the transmission of *S. mansoni* and to our studies on transmission.

The water temperature was recorded in the deepest pool (16) for a 48 hour period at different depths. The results are shown in fig. 4.1. At the depth of 80 cm the temperatures were the same as at 40 cm. Most pools, however, were only 10-50 cm deep.

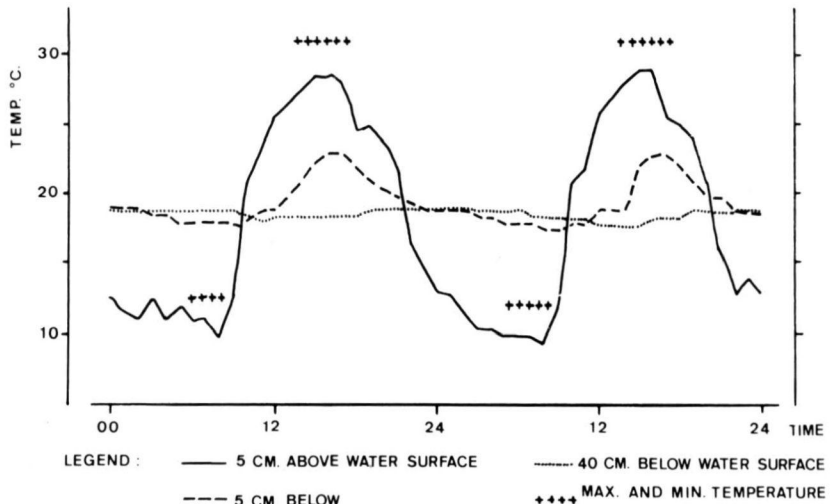
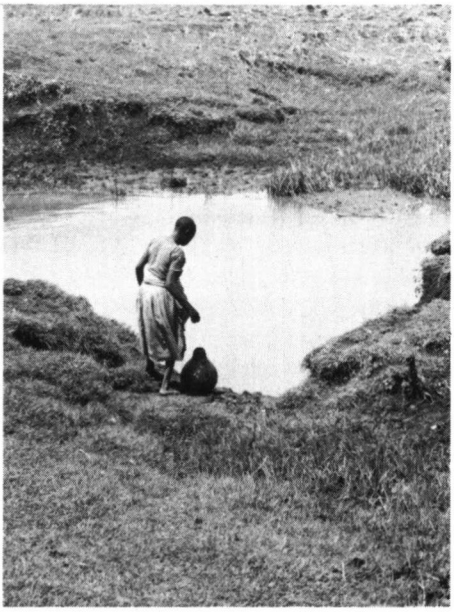
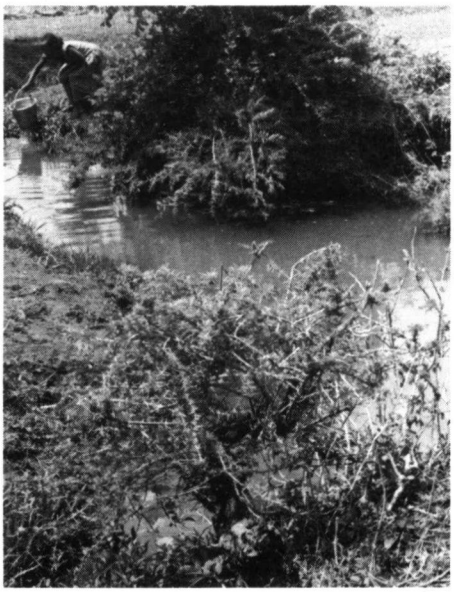


Fig. 4.1. Water temperatures at different depths and air temperatures at the water surface, and in Chiwahit town (pool 16)(April 1972).



21-a. pool '2',rather muddy, often used for drawing water.

21-b. pool '4',small but clear, often used for washing clothes and drawing water.



21-c. favourite pool for washing clothes and drawing water.

21-d. pool '6',shallow, dense vegetation, rarely used.

photo 21. The pools of Chalguaye stream that were surveyed monthly.

21-e. pool '7',far from town, rarely used.

21-f. pool '8',far from town but sometimes used for washing and bathing (by children).

The vegetation varies slightly from one pool to another, but in most places *Graminae, Polygonum* and *Scirpus* were dominant. In some places very few plants were present: the vegetation was trampled down by the water collectors or washed away during the rains.

In North Ethiopia *Biomphalaria pfeifferi* is known to be the intermediate host of *Schistosoma mansoni*. In our studies this was confirmed many times. Therefore, in the following paragraphs, we will solely deal with populations of *B. pfeifferi* (photo 20). In Chalguaye stream, which has a muddy substratum along the whole length that was studied, *B. pfeifferi* was the only abundant species; some *Gyraulus costulatus* and some *Lymnaea natalensis* were found in most surveys, but only very few *Lymnaea truncatula* and *Bulinus 'truncatus'*. In more rocky places of the AmbaZena and Chigaro numerous *L. natalensis* and fewer *B. pfeifferi* were found. Some *G. costulatus* and a few *B. truncatus* and *L. truncatula* were found. Only in two of the pools in Chigaro did we regularly find a few *B. 'truncatus'*, some of which turned out to be infected with *Schistosoma bovis* on a few occasions (chapter 5).

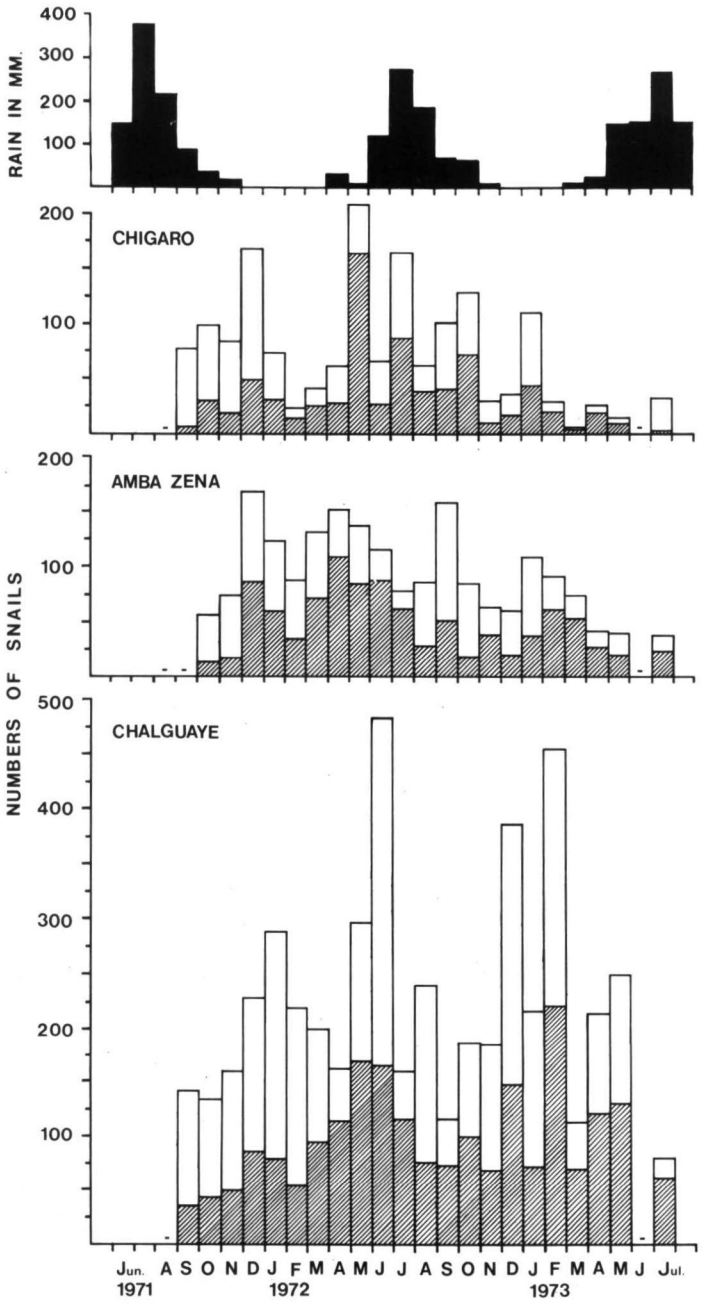


Fig. 4.2. Seasonal fluctuations of the numbers of snails

□ *number of snails < 10 mm.*
▨ *number of snails ≥ 10 mm.*

4.2. METHODS

In each of the three streams some pools were selected for monthly snail-surveys; these snail surveys were continued for 22 months: from September 1971 until July 1973. In a down-stream sequence the pools were numbered as follows: Chalguaye: 2, 4, 5, 6, 7, 8; AmbaZena: 14, 15, 16, 17, 18, 19; Chigaro: 21, 22, 23, 24, 25. During each survey the same sites within each pond were selected for sampling.

In each survey all pools were sampled three times for 20 seconds, using a simple sweepnet. Whenever possible, the snail collections were done by the same person. The whole net's content was transported in plastic bags to the laboratory in Gondar. There snails were searched for by two technicians. With a plastic ruler all snails were measured to the nearest millimeter. All snails were exposed to an artificial source of light for several hours to check wether or not they were shedding cercariae.

No specific attention was paid to the occurrance of egg masses in the streams. After measuring and examination all snails were returned to their pools.

4.3. RESULTS

4.3.1. Population biology

1. seasonal variation of snail densities

The results of the monthly snail surveys are summarized in figure 4.2. The monthly numbers of snails do not show clear seasonal variations and the peak numbers for each of the streams are not found at the same times.

A better picture of the seasonal fluctuations of the snail populations can be obtained when the numbers of snails in different age classes are considered seperately. The monthly counts of old snails ($\geq$ 11 mm), very old snails ($\geq$ 13 mm), and juvenile snails ($\leq$ 5 mm) are summarized in fig. 4.3. and fig. 4.4. Among the old and very old snails there was a gradual increase in numbers during the dry season of 1971-1972, and a decrease from the beginning of the rains onwards, but this pattern was more marked in Chalguaye and Chigaro than in AmbaZena. In the course of the next dry season there was a similar increase in numbers of old snails, but this process collapsed between the surveys of December and January. The peak number of old snails was not reached in the May survey but earlier, probably due to the early onset of the rains. For some reason this pattern was only recognized in Chalguaye in 1972-1973, and not in Chigaro nor in AmbaZena.

The numbers of juvenile *B. pfeifferi* (up till 5 mm) were highly variable. There was a sudden increase in numbers just before the rains of 1972 in the pools 7 and 8 of Chalguaye but

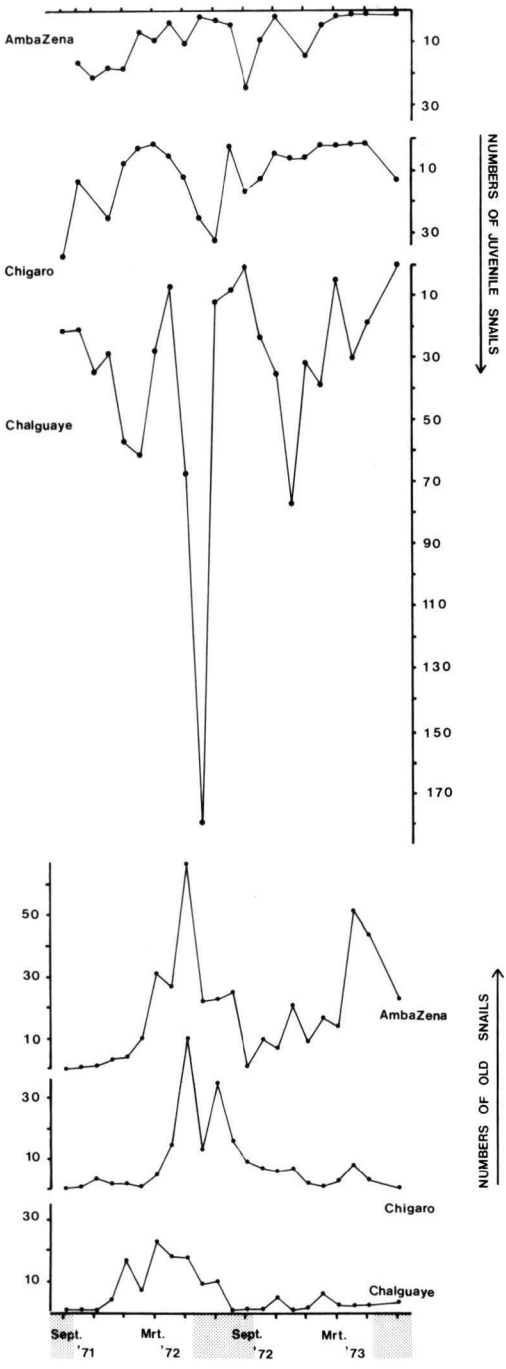


Fig. 4.3.
Number of juvenile and number of very old snails per stream

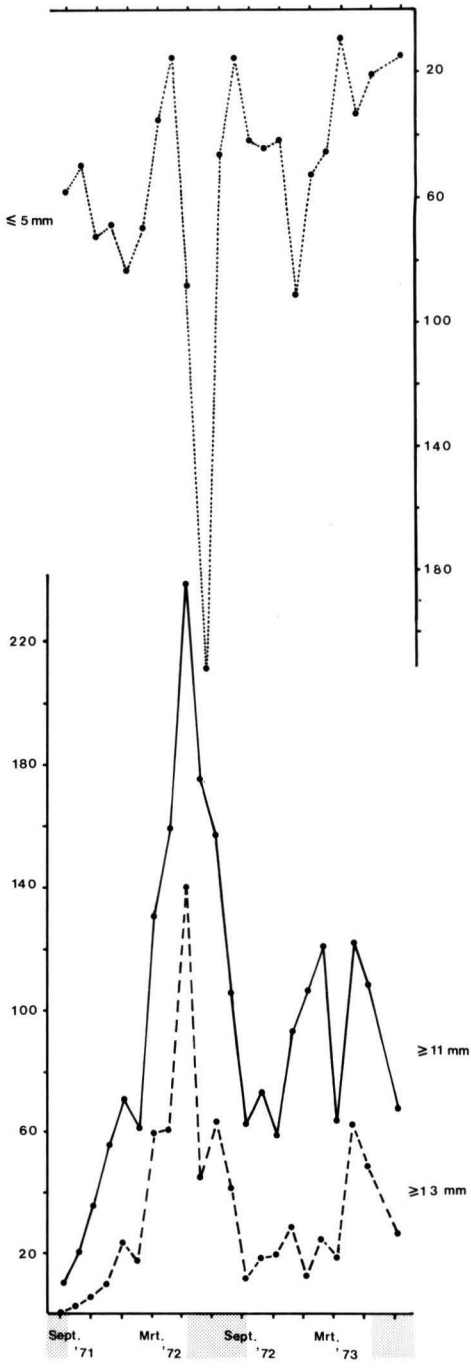


Fig. 4.4.
Total numbers of juvenile, old, and very old snails

not in any of the other pools. The peaks in numbers of juvenile snails are not clearly related to peaks in numbers of adult snails as might be expected. It is interesting to note that the peaks in numbers of juvenile snails and the corresponding 'birth explosion' did not coincide in the different pools (fig. 4.5.). Clearly distinghuishable peaks in numbers of juvenile snails were only registered in some pools. In the pools not mentioned in fig. 4.5. we never found more than a few juveniles. So, numbers of juvenile snails do not seem to be mainly regulated by the rains.

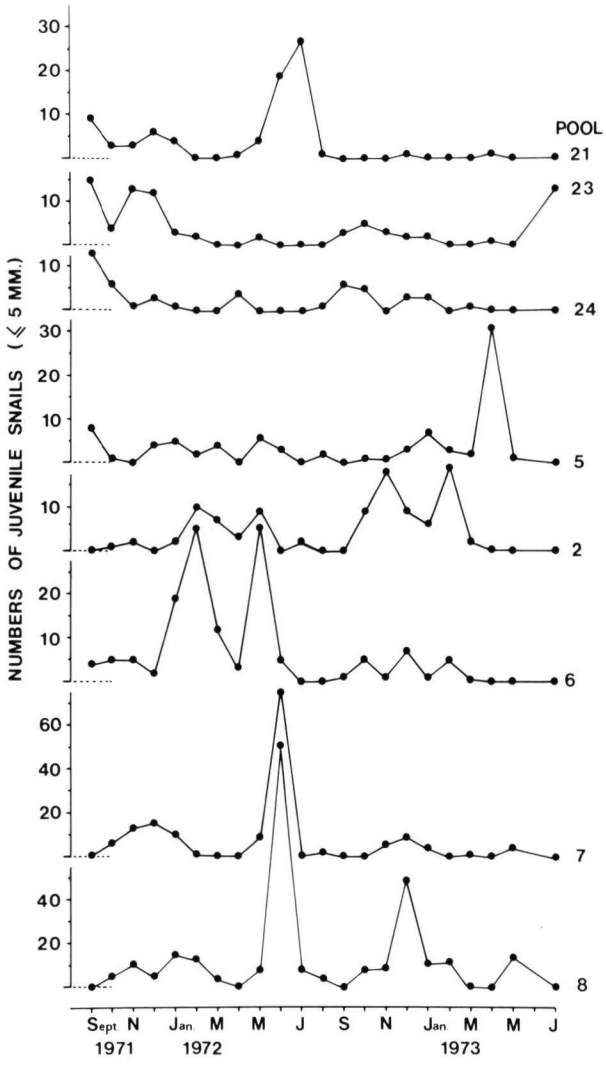


Fig. 4.5. Seasonal fluctuations of the numbers of juvenile snails

2. Growth of the snails

Up to now we have been using the terms 'old snails' and 'very old snails' in a rather indeterminate way. The actual estimation of the age is based on the - non linear - relation between size and age. Since the growth of snails is affected by environmental factors such as temperature (Sturrock, 1966), the age - size relationship should be determined for the particular area of investigation itself. Therefore a growth curve (i.e. the graphical representation of the best estimate for the age of snails in each size class) was constructed for *B. pfeifferi* in the streams around Chiwahit.

Sturrock, Meuleman, and Aram have constructed growth curves for *B. pfeifferi* in the laboratory (Sturrock, 1966 ;Meuleman, 1972; Aram, 1973). The sizes of the snails that were collected around Chiwahit cannot be explained very well by either of these growth curves: we found too many 'very big' snails (13 mm and more). A field growth curve for *B. pfeifferi* has been constructed for some streams not far from Addis Ababa (alt. 2,200 m and 2,750 m.)(Aram, 1973) but again the curve did not fit our data.

Though it was not one of the principal aims of this study to go into the subject of snail population in great detail, it was attempted to construct a growth curve for the snails in the Chiwahit area. Rather rough size measurements had to be used for the snails were only measured to the nearest mm. Since the pools that are considered here are all small, harbouring only small numbers of snails, data from all pools had to be combined. It has been shown already that - in the dry season - each pool should be considered as a separate entity with its own characteristics. It is not to be expected that growth, natality and mortality are the same in all pools. Yet an attempt was made to achieve an overall impression of the growth, and later of the mortality rates in the area as a whole.

The construction of the growth curve for *B. pfeifferi* in Chiwahit area (fig. 4.6.) is based on the comparison of the monthly growth of clearly distinguishable cohorts from the monthly size-frequency histograms. The selection of cohorts that can be used for this purpose is dependent on a number of limiting conditions:

- the number of snails per pool should not be too small;
- observations during the rainy season should not be used (immigration and emigration from and to other pools; temporarily reduced growth-rate in unfavourable climatic situations (Aram, 1973);
- juvenile snails should not be used: monthly snail collection intervals are too long for these rapidly growing snails; moreover, errors in the recovery of these young snails are relatively large;

- Cohorts which show a reduction in size instead of a growth should not be used;
- infected snails should be omitted because of possible temporarily increased growth or gigantism (Sturrock, 1966).

When these considerations are taken into account, 10 cohorts could be selected for snails between 7 and 12 mm. The mean monthly growth of these cohorts was 1.48 mm.

Due to the small numbers, the growth of bigger snails had to be determined in another way. In September 1971 the biggest snails in Chalguaye were 11 mm. Only after 6 months had the biggest snails reached a diameter of 16 mm. During these 6 months there was a gradual increase in size (table 4.1.). The same was observed in Chigaro stream: in September 1971 the biggest *B. pfeifferi* were 10 mm, and it was not until March 1972 that the first snails of 15 mm were found. These findings suggest a mean monthly growth of approximately 3/4 mm for *B. pfeifferi* between 10 and 16 mm.

Table 4.1. The growth of the biggest snails in Chalguaye stream (1971 - 1972).

(10/4 means: 10 snails were found, 4 of which were shedding S. mansoni *cercariae).*

size in mm	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mrch.	Apr.	May
11	10/4[1]	7/2	11/1	5	11	8/1	25	21	33/1
12	-	1	5/3	9/1	9/1	11/2	11	24	29
13	-	1	1/1	2	3	7/1	9/1	16	38/3
14	-	-	-	1	1	1	12/2	8	17/2
15	-	-	-	-		2/2	6	3	11
16	-	-	-	-		-	4/1	-	1/1

When the results from both approaches are combined an approximate growth curve can be constructed (fig. 4.6.). This growth curve, however, only describes the monthly growth of snails of a particular size. The exact age of snails of a certain size could not be determined with our methods. Comparison with other authors (Aram, 1973; Sturrock, 1966) showed that snails of 5 mm diameter will be 6-12 weeks old. Therefore, in our study snails of 5 mm were assumed to be 2 months old.

Clearly, the streams and pools around Chiwahit were not the ideal habitat for the construction of a field growth curve, but the choice of the study area was imposed on us since the corresponding epidemiological work had to be done in Chiwahit.

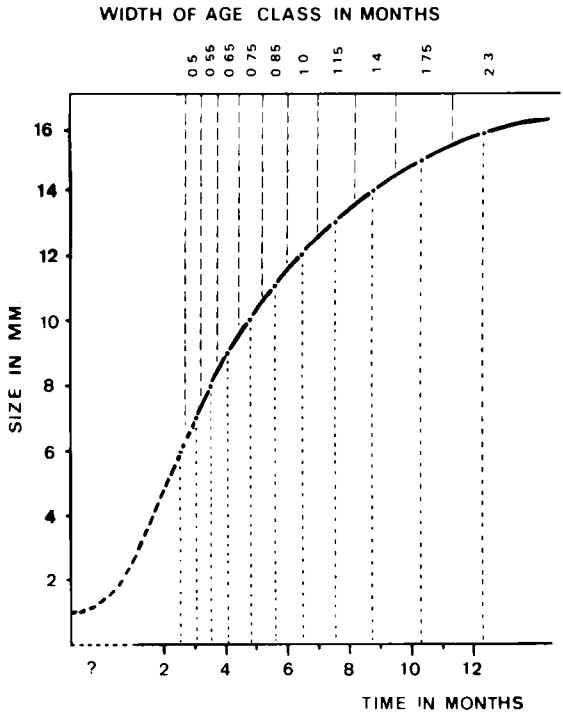


Fig. 4.6.

Growth curve of

B. pfeifferi

3. Mortality (and natality)

In general the mean monthly mortality rate is calculated by comparison of the numbers of snails in a certain size class in one sample, and the numbers of snails of the size to which last months cohort may expected to have grown (in conformity with the growth curve, see paragraph 4.3.1.2)(Webbe, 1962; Aram, 1973). The monthly mortality rate is equal to the loss of snails per initial number of snails.

To calculate mortalities in this way offers some problems in our area since the sample size in each of the pools was often too small to permit this type of calculations for seperate pools. A calculation of the monthly mortality rates for the combined monthly snail counts, using the numbers of snails from all 17 pools together, appeared to produce rather erratic results. Instead, the mean monthly mortality was approximated in another way. This approach is only permitted (as an approximation) since

1) the observations were continued during two seasonal cycles;
2) the observations were continued during a period which is long compared to the mean life span and even to the maximum life span of the snails;
3) the populations of adult snails are comparatively stable (4. 3.1.1.).

A size-frequency histogram for all snails caught in the streams during 22 snail surveys is given as fig. 4.7. Using the growth curve of figure 4.6. the size-frequency histogram can be converted into an age-frequency diagram (fig. 4.8.). The number of snails of $2\frac{1}{2}$-4 month of age is surprisingly low which should probably be attributed to the relevance of three factors. The number of snails of 1 cm. has been overestimated (as shown in fig. 4.7.) and the number of very small snails (< 5 mm) has probably been underestimated (small and fragile snails can easily be missed when searching in large amounts of mud and vegetation). Since the number of snails per age class in fig. 4.8. has been

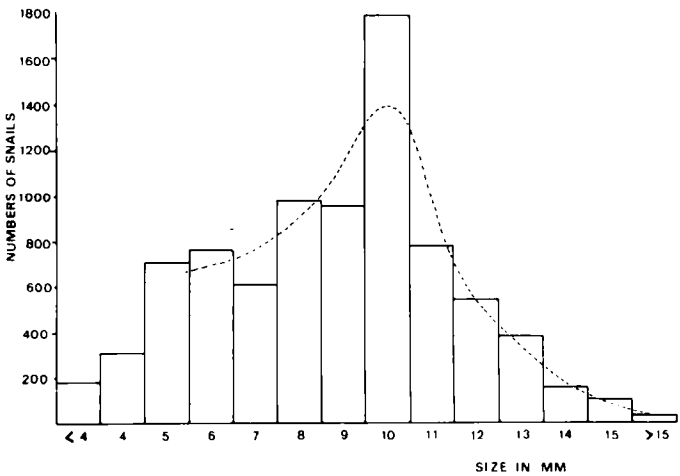


Fig. 4.7. Size-frequency distribution of B. pfeifferi

calculated as

$$\frac{\text{the number of snails of size y}}{\text{width of the age class corresponding to snails with size y}},$$

the number of young snails (< 5 mm) in fig. 4.8. will be underestimated when the width of the ageclasses corresponding to each class is overestimated. On page 91 it has been shown, in fact, that the growth curve is fairly inaccurate for the young snails.

From 10 mm onwards the decline in numbers of snails per age class is very regular. In figure 4.9. it is shown that this monthly reduction in numbers is exponential. The slope of the straight line of figure 4.9. shows that the mean monthly survivorship is 53 %; so the mean monthly mortality rate is 47 %, for *B. pfeifferi* of 10 mm and bigger, in this particular area.

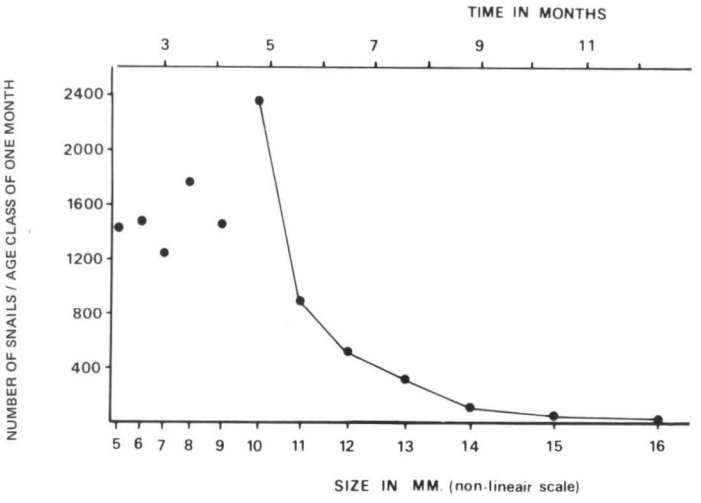


Fig. 4.8. Age-frequency distribution of **B. pfeifferi**

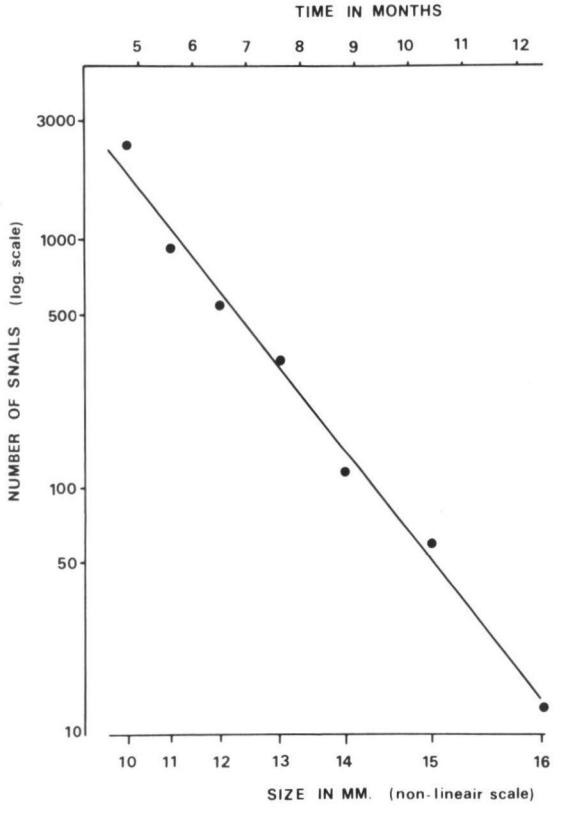


Fig. 4.9. Age-frequency distribution of **B. pfeifferi**

It is more common to express mortalities as mean daily mortalities. The daily mortality can be calculated as follows.

$1x = e^{-xd}$ where 1x = the proportion of snails surviving to age x
x = the number of days between sampling (i.e. 30)
d = the mean daily mortality rate

So, $0.53 = e^{-30d}$, and the mean daily mortality rate is equal to 2.2 %.

The mortality rates were calculated as mean mortality rates over the whole year. It has been demonstrated already (fig. 4.3.) that the mortality of adult snails is much higher during the rains than during the dry months.

In the calculations in these paragraphs snails with demonstrable infections were excluded. Of course prepatent infections that could not be detected without snail crushing procedures could not be excluded. Since the percentage of snails that shed cercariae is never very high (paragraph 4.3.2.), this error may not be very large.

Because of lack of time it was not attempted to determine natality rates in the field nor in the laboratory. It is only of some importance to note that the time of the occurrence of numerous juvenile snails is unpredictable, and has no readily apparent relation to the numbers of adults (fig. 4.5.).

4.3.2. S. mansoni infections among snails

Out of the 8,497 *B. pfeifferi* caught during 22 surveys over a period of almost 2 years, 200 were found to shed "mammalian type" cercariae (2.4 %). Mice were exposed to cercariae from 29 of these infected snails ('mono-infections'). In 26 cases adult *S. mansoni* developed (see paragraph 5.2.2.4.). Therefore, *B. pfeifferi* shedding "mammalian type" cercariae will be referred to as *B. pfeifferi* shedding *S. mansoni* cercariae or as snails with patent *S. mansoni* infections.

1. Seasonal variations of the infection rate

There appear to be seasonal fluctuations in both the number and the percentage of infected snails (fig. 4.10.). In snails that are younger than the length of the prepatent period of *S. mansoni* in snails, no infections will be recognized with our cercariae-shedding-tests. Therefore, it is more realistic to compare the number of infected snails with the number of snails that could have been infected, i.e. the numbers of snails ≧ 6 mm. (see table 4.2.).

Apart from the extremely high number and percentage of infected snails that was found in the pools 4 and 5 in July 1973 there was an increase in both number and percentage of infected snails just after the rains, followed by a gradual decrease.

The interpretation of these seasonal fluctuations requires some preliminary notes on the faecal pollution of the streams around Chiwahit and on the peoples' behaviour.
These matters will be discussed in more detail in chapter 5.

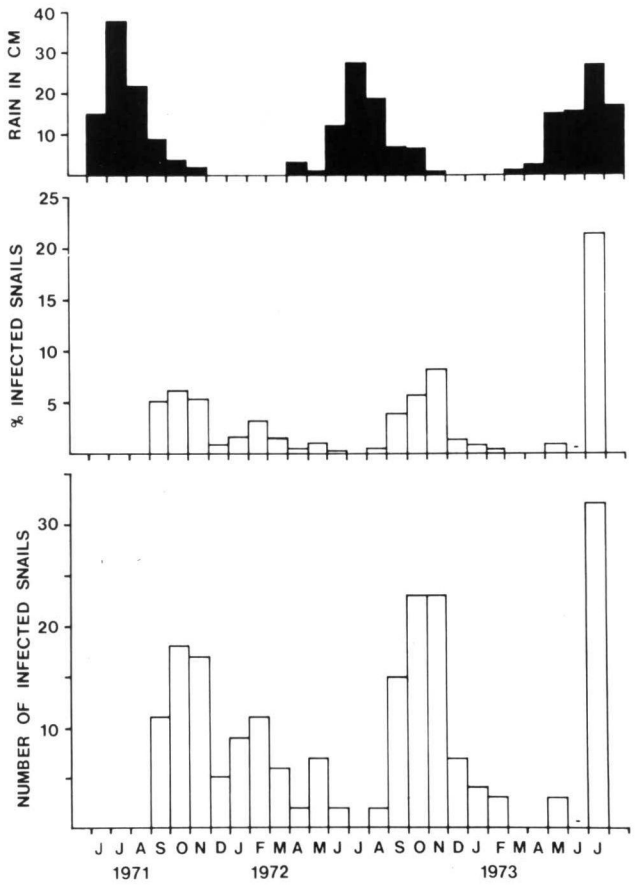


Fig. 4.10. Seasonal fluctuations of the number of infected snails

For their water supply, people of Chiwahit are entirely dependent on a few little pools in the riverbeds of the three streams (e.g. photos 23 and 29). In order to keep these pools clean they take good care of them. People certainly avoid de-

Table 4.2. Seasonal variations of the infection rate

Month	total number of snails	number of infected snails	percentage of infected snails	numbers of snails equal to or bigger than 6 mm.	percentage of infected snails among those that are ⩾ 6 mm.
Sept. 1971	218	11	5.1	160	6.9
Oct.	289	18	6.2	240	7.5
Nov.	318	17	5.4	246	6.9
Dec.	559	5	0.9	491	1.0
Jan. 1972	485	9	1.9	402	2.2
Feb.	330	11	3.3	261	4.2
Mrch.	371	6	1.6	336	1.8
Apr.	376	2	0.5	362	0.6
May	640	7	1.1	552	1.3
June	665	2	0.3	444	0.5
July	400	0	0.0	354	0.0
Aug.	386	2	0.5	371	0.5
Sept.	372	15	4.0	330	4.6
Oct.	398	23	5.8	354	6.5
Nov.	278	23	8.3	239	9.6
Dec.	481	7	1.5	390	1.8
Jan. 1973	433	4	0.9	381	1.1
Feb.	574	3	0.5	529	0.6
Mrch.	190	0	0.0	183	0.0
Apr.	281	0	0.0	248	0.0
May	304	3	1.0	285	1.1
June	-	-	-	-	-
July	149	32	21.5	136	23.5
TOTAL	8497	200	2,3 %	7294	2,7 %

The shaded parts depict the time of the big rains

fecating and urinating in or close to these pools. They do not swim or wash their bodies in those pools very often (children do so sometimes near pool 8; adults and children sometimes wash themselves between the pools 16 and 19 or farther downstream). Faeces dry out very quickly in the dry season, and consequently eggs of *S. mansoni* - if present - soon die (chapter 5)(Chernin and Antolics, 1973; Upatham, 1972). Therefore, the risk of faecal contamination of the streams is not very great during this season. During the rains, on the other hand, moist human faeces is often washed down into the streams. At the beginning of the rains the soil is still very dry and most precipitation is absorbed before it gets to the streams.

1971–1972 pool	Aug.	S	O	N	D	J	F	M	A	M	J	Jul.
2	-	1^{13}	9	3^{19}	12	2^{32}	1^{31}	46	55	52	36	19
4	-	1^{29}	14	6^{36}	2^{43}	1^{36}	12	4^{23}	22	2^{55}	13	10
5	-	4^{36}	11	8	26	17	6^{16}	18	11	5^{77}	2^{30}	35
6	-	1^{27}	2^{30}	16	30	66	76	74	26	46	29	15
7	-	2^{26}	2^{30}	35	61	32	2	3	11	31	186	49
8	-	2^{16}	5^{40}	46	56	1^{105}	82	35	37	31	190	30
14	-	-	6	1	3	11	9	14	8	-	17	10
15	-	-	1^{17}	1^{17}	20	2^{14}	3	17	16	40	25	20
16	-	-	1	4^{11}	18	1^{35}	33	43	88	65	55	29
17	-	-	10	0	5	15	12	31	2^{17}	12	10	1
18	-	-	1^{30}	20	5	0	13	1^{14}	7	15	7	4
19	-	-	9	33	106	2^{49}	18	12	15	5	3	4
20	-	15	3^{29}	1^{27}	58	17	1	26	32	57	59	156
22	-	0	2	2	2^{4}	2	1^{1}	1	0	0	6	3
23	-	31	14	40	1^{60}	31	9	0	2	21	0	2
24	-	31	4^{48}	2^{24}	25	30	1^{8}	1^{13}	29	23	1	0
25	-	0	6	1	21	0	2^{5}	1	0	5	0	0
total	-	11^{218}	18^{289}	17^{318}	5^{559}	9^{485}	11^{330}	6^{371}	2^{376}	7^{640}	2^{665}	0^{400}
1972–1973												
2	7	3^{25}	8^{29}	66	61	2^{47}	165	60	2	9	-	5
4	12	6	2^{15}	8	2^{7}	17	1^{2}	2	5	12	-	10^{11}
5	41	13	6	1^{3}	18	42	58	19	135	1^{78}	-	22^{55}
6	26	29	19	12	18	9	15	3	7	8	-	6
7	11	1^{2}	1^{49}	2^{30}	104	40	156	20	14	89	-	3
8	141	39	3^{65}	11^{66}	5^{178}	2^{57}	158	8	53	2^{52}	-	2
14	46	3^{29}	7	4	6	44	10	19	2	9	-	4
15	2^{19}	4^{45}	7	10	35	8	34	18	24	14	-	7
16	5	36	41	0	6	13	14	27	4	9	-	0
17	16	40	17	5	11	24	14	7	4	2	-	17
18	0	5	3	0	6	16	0	3	5	6	-	7
19	0	3	10	8^{44}	0	4	2^{19}	0	3	0	-	3
21	32	3	7	1^{5}	4	31	2	0	4	0	-	0
22	3	1^{3}	7	4	3	7	2	0	2	2	-	0
23	5	11	34	8	10	17	5	0	7	5	-	32
24	5	24	1^{37}	11	15	24	17	4	12	5	-	0
25	15	3^{39}	7^{43}	2	3	28	3	0	1	3	-	0
total	2^{386}	15^{372}	23^{398}	23^{278}	7^{481}	4^{433}	3^{574}	0^{190}	0^{281}	3^{304}	-	32^{149}

It has been pointed out by several authors (e.g. McDonald, 1965) that minimal amounts of faeces containing *S. mansoni* eggs may be enough for a successful snail infection. It seems unlikely that people collecting water or washing clothes, do not contaminate the pools with *S. mansoni* eggs. Once in a while children will defecate in the water, fall in one of the ponds, wash or rinse dirty underwear, etc. Then, some snails may get infected. If indeed snail infections in the dry season depend on that type of 'sanitation hazards', a clustered pattern of infections among the snail populations in various pools, at different times, may be expected. Under this hypothesis a more random distribution of infected snails would be expected after the rains, from September to November. This hypothesis is tested below.

In table 4.3. the numbers of infected snails and the total numbers of snails are given for each of the pools during each of the surveys. When the infection rates during the months September-November are compared with the infection rates during the period February-July (table 4.4.), the overall infection rate during the post-rain months is almost 4 times as high as that during the months of the dry season (table 4.4.). (The months December and January were not included in these considerations since it is uncertain whether infected snails that were found in this period contracted their infection in the rains or later). Yet,the monthly infection rate per infected pool is about the same during both periods. So the relatively high infection rate in the post-rain months is caused by a high number of pools being infected rather than by a high number of infected snails per infected pool. When the very high infection rates in the pools 4 and 5 in July are not included in these considerations, the picture does not change substantially.

Table 4.4. Infection rates during the post rain months (Sept. - Nov.) and in the dry season

	total number of snails	number of inf. snails	% of inf. snails	total number of snails per infected pool	no. of inf. snails	% of inf. snails in inf. pools
Sept.-Nov. '71+'72	1873	109	5.82	1061	109	10.3
Feb.-July '72+'73	4280	66	1.54	621	66	10.6
(Feb.-June '72+'73)	3831	34	0.89	555	34	6.1

← *Table 4.3. Total number of snails (small figures) and number of infected snails (big figures) per pool per month*

In the dry months the highest infection rates were found in the pools that are used most often for water collection and for washing clothes (pools 2, 4, 5, 19). Only in pool 14 few infected snails were found though it is frequently visited by water collectors.

If indeed the infection of snails in the dry months is dependent on occasional 'sanitation hazard' at localized spots, a gradual decline in numbers of infected snails from that population should be observed. In table 4.5. the results are listed of our observations in those pools where at one time or another in the dry season five or more infected snails were found. The decline in numbers of infected snails might be considered as an exponential decline (see fig. 4.11.). The slopes of the straight lines (when plotted on a logarithmic scale) suggest monthly survival rates of 42 %, less than 17 %, 40 %, and 47 % respectively.

Table 4.5. The dying away of infected snails from some pools

	1st observation		2nd observation		3rd observation		4th observation	
pool	date	number of inf. B.pf.	date	number of inf. B.pf.	date	number of inf. B.pf.	date	number of inf. B.pf.
4	29/10/71	6	02/12/71	2	04/01/72	1	31/01/72	0
5	31/01/72	6	01/03/72	0				
5	01/05/72	5	01/06/72	2	05/07/72	0		
8	28/10/72	11	04/12/72	5	03/01/73	2	02/02/73	0

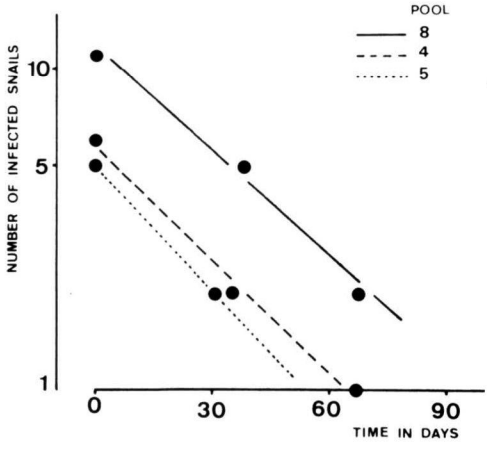


Fig. 4.11.

The decrease in numbers of infected snails in the heavily infested pools during the late dry season.

Though this analysis is based on very small numbers of infected snails, and though our sampling methods were certainly not perfect, it is remarkable that the monthly survival rates for infected snails are similar in 3 out of 4 cases (mean 43 %), and slightly lower than the survival rates for uninfected snails (53 %).

Rather than using this analysis to estimate survival rates and mortality rates of infected snails, the data do tend to confirm our hypothesis of the way in which snails become infected in the dry months and in the post-rain period.

2. Age-Prevalence distribution of infected snails

As in the study of *S. mansoni* infections in man, a better understanding of the processes of acquiring and losing infections may be gained by the analysis of infection rates in different age groups of the snails. The basic data for this analysis are given in table 4.6. and figure 4.12.

In laboratory experiments it has been shown that the life expectancy of infected snails is shorter than that of uninfected snails (e.g. Sturrock, 1966; Meuleman, 1972). The same is probably true for snails in their natural habitats. For that reason the fraction of infected snails will only increase with the snails' age as long as the rate of acquisition of the infection is greater than the rate of loss (by death, and perhaps also by curing) of the infection.

Table 4.6. Size-frequency distribution of infected snails

diameter in mm.	number of uninfected snails	number of infected snails	percentage of infected snails
< 4	183	0	0.0
4	317	0	0.0
5	708	0	0.0
6	782	1	0.1
7	608	2	0.3
8	974	2	0.2
9	948	7	0.7
10	1783	53	2.9
11	775	29	3.6
12	541	48	8.2
13	382	28	6.8
14	159	14	8.1
15	107	9	7.8
> 15	30	7	18.9
total	8297	200	2.4

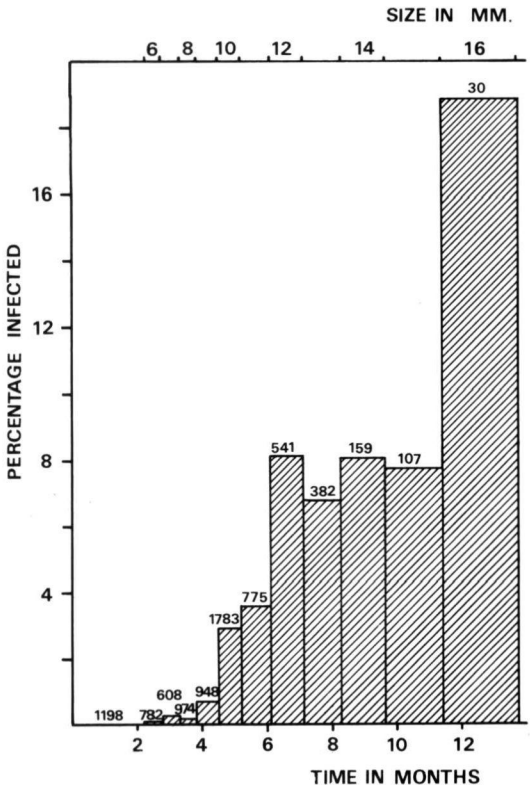


Fig. 4.12.

Size-frequency distribution of infected snails

Mathematically such a process of two opposing forces can be simulated by choosing different values for both rates. For human age-prevalence curves this has been done by Münch for various infectious diseases (Münch, 1959) and by Hairston for schistosomiasis (Hairston, 1965-b). More recently these "catalytic models" have been used for the analysis of infections in the intermediate host snails *B. nasutus productus*, *B. pfeifferi*, and *B. glabrata* (Sturrock and Webbe, 1971; Sturrock, 1973-a,b). Using this type of mathematical models it is possible to calculate the approximate daily rate of acquiring and losing *S. mansoni* infections in a snail population.

Münch listed the basic conditions which have to be fulfilled before this type of analysis may be employed. Unfortunately, it would seem that - in my opinion - two major conditions cannot be met. These conditions are: 1) "forces of infection have not varied greatly over a fairly long period - long enough to include the oldest age band in this study" (Münch, 1959); 2) the age of the infected individual should be known.

As to the first assumption: the oldest snails (e.g. 10 months and older) have been subject to infection for many months but the force of infection was not constant during these

10 months. Sturrock & Webbe's solution to use only data from snail collections in one month does not solve this problem. Regarding the second assumption: clearly, the age of uninfected snails can be approximated adequately. It has been shown, however, (Sturrock, 1966; Meuleman, 1972) that gigantism or temporarily accelerated growth occurs in *B. pfeifferi* infected with *S. mansoni*.
According to Sturrock's and Meuleman's data the difference in mean size between infected (patent infections) and uninfected snails was 1-2 mm. This means that the age of infected snails is highly overestimated when the growth curve (fig. 4.6.) is used for the estimation of the age. The disproportionately high infection rate in snails of 16 mm (fig. 4.12.) should probably be attributed to the overestimate of the age of the infected snails of this size. The remarkably low infection rate in snails of 8 and 9 mm could be explained similarly.

4.3.3. Snail densities and absolute numbers of snails

Up till now we have been dealing with snail densities in arbitrary units: the numbers of snails per collection. For estimates of the infectivity of the water the actual numbers of snails and infected snails per m^3 of water or per m^2 shoreline are of major importance.

Though the results of our attempts to estimate the total numbers of snails in some pools are certainly inconclusive, the data of three properly performed capture-marking-recapture experiments are summarized in table 4.7.

Table 4.7. Estimation of snail densities

pool	4	5	5
date 1st collection	08/05/72	08/05/72	22/06/72
number of marked snails that were returned to the pool	52	128	359
date 2nd collection (3.20")	16/05/72	16/05/72	28/06/72
total number of snails caught in 2nd collection	43	88	122
number of painted snails caught in 2nd collection	5	12	23
calculated population size	447	940	1904
percentage recovery in standard sampling time (3.20")	9%	9%	6%
perimeter of the pool in meter	16	38	38
number of snails per meter shoreline	28	25	50
bottom surface of the pool in m^2	16	50	50
number of snails per m^2 bottom surface	28	19	38
volume of the pool in m^3	4.6	16	16
number of snails per m^3	97	59	118

In fact, this type of estimate of the snail densities should have been repeated several times for each of the 17 pools. This was not done because of time shortage. From the data we did collect we get the impression that the snail densities were neither extremely high nor very low (comparative data are given by Aram, 1973; Pellegrino & de Maria, 1966 etc.).

4.4. DISCUSSION

4.4.1. Discussion of the methods

Accurate quantitative sampling procedures are generally considered to be very difficult to achieve. Several devices have been constructed (e.g. Dazo, 1965) and all of them have their disadvantages.

The time-restricted sampling method that was used in this study has been discussed by Olivier and Schneiderman, and has been used, among others, by Webbe, by Sturrock, and by Aram (Olivier and Schneiderman, 1956; Webbe, 1962; Sturrock, 1972-a,b; Aram, 1973). In our studies no comparative sampling methods were used to evaluate the efficiency and consistency of the time-restricted sampling procedure.

Though it was tried to standardize the procedures as much as possible, it is realized that for instance the efficiency of the method changed in the course of the year due to the changing appearance of the pools (amount of water, vegetation, accessibility, etc.).

4.4.2. Discussion of the results

The relatively small effects of the rains on the total numbers of snails that was found (fig. 4.2.) was thought to be related to the particular topographical characteristics of the habitat. Unfortunately, no regular studies were made farther downstream from Chalguaye, Chigaro and AmbaZena. On some odd occasions few or no *B. pfeifferi* were found a couple of kilometers downstream in the Chigaro and Chalguaye. The same holds for Atakelt stream near Jenda (chapter 6). In chapter 2 it has been shown that in the bigger streams that collect water from streams like Chalguaye, Chigaro and AmbaZena, the presence of *B. pfeifferi* is very irregular and generally less abundant. The apparently favourable conditions of the habitats just beyond the wells compared to the habitats farther downstream are probably dependent on both physical and chemical factors. Chemical factors, however, were not studied in the streams around Chiwahit.

Though the mean daily water temperature is definitely lower than 25^{0} C. (the temperature that is generally used in experimental

work on *B. pfeifferi* and that is considered to be the approximate optimum temperature (Sturrock, 1966), *B. pfeifferi* in the streams around Chiwahit appears to display a prosperous growth, and large maximum diameters are attained. According to the experimental growth curves of Sturrock (25° C.), the mean diameter of *B. pfeifferi* at the age of 4 months is about 9 mm (R.F. Sturrock, 1966) or 10 mm (B.M. Sturrock, 1966).

At 19° C. *B. pfeifferi* of the same age are about 4 mm smaller (B.M. Sturrock, 1966). According to Aram (lab. experiment 25° C.), the mean diameter at 4 months was just over 8 mm, and just over 6 mm among *B. pfeifferi* in some streams in the neighbourhood of Addis Ababa (field experiment, temperature 13-23° C. with an average of 15° C.)(Aram, 1973). The snails that were grown by Sturrock and by Aram did not grow bigger than about 13 mm.

According to our field data the mean size at the age of 4 months is approximately 9 mm. About 3½ % of the total snail population has a maximum diameter of 14 mm and over. When the low mean water temperatures at this altitude are taken into account (see fig. 4.1.), it appears that the populations of *B. pfeifferi* are thriving in these habitats around Chiwahit.

In a "pool area" of some little streams in the neighbourhood of Addis Ababa, the daily percentage mortality rates of adult *B. pfeifferi* were calculated to be 0.73 and 1.27 during the dry season (Aram, 1973). These mortality rates are lower than those found in our studies (4.3.1.3.).

In Tanzania, working on *B. nasutus productus*, Webbe found daily percentage mortality rates of around 2.4 % in observations that lasted several months but not a whole year (Webbe, 1962). Sturrock, studying *B. glabrata* in St. Lucia found daily mortality rates between 0.0 and 1.7 % in growing populations, between 1.7 and 4.6 in stable populations, and between 4.7 and 7.5 % in decreasing populations. The overall mean daily mortality rate was 3.4 %.

Webbe and Aram based their calculations on observations during parts of the year only. Naturally the mean daily mortality is higher when observations in the less favourable rainy season are included in the calculations - as was done by Sturrock and in this study. Compared with the results of the above cited authors which were partially concerned with other species in other areas, the mortality rates that were found in our studies may be considered to be average or rather low.

Observations on the infection rates among snails were discussed in the sections 4.3.2.1. and 4.3.2.2. Using Münch's catalytic models it has been calculated by Sturrock that the mean daily mortality in populations of *B. glabrata* in St. Lucia was slightly higher in infected than in uninfected snails (240 death per week per 1000 infected snails) compared to a daily mortality of 3.4 % among uninfected snails (Sturrock, 1972[a]; Sturrock, 1972[b]). The data presented in this chapter (fig. 4.11.) are not at variance with Sturrock's findings.

4.5. SUMMARY

Permanent populations of *B. pfeifferi* were found in the streams around Chiwahit. Though the rains' disturbing influence on the populations of adult snails was clearly visible, the total number of snails was not clearly correlated with the seasonal fluctuations in the precipitation or temperature. The habitats in the small streams just beyond the wells were shown to be favourable habitats for *B. pfeifferi*: growth of the snails was fast, the maximum diameter large, and the life expectancy 'normal' or good.

The highest infection rate among snails was observed in the months following the big rains. Towards the end of the dry season fewer infected snails were found, but their distribution both in time and in space, was more clustered than during the post-rain period. The implications of these findings were discussed.

The infection rate was much higher in big snails than in the smaller ones. The size - frequency distribution of infected snails was analysed, and the use of catalytic models for this type of analysis was criticized.

CHAPTER V THE TRANSMISSION OF S. MANSONI

5.1. INTRODUCTION

In the previous chapters both the human and the snail populations and the prevalence of the parasite in man and in the snails have been described. In this chapter an attempt is made to describe some aspects of the dynamic phases of the process of infection of the final and the intermediate host.

The incidence of infections in the final host depends on:

- A1 - the density of cercariae and their spatial distribution;
- A2 - the frequency of contacts with infested water, and the type and duration of these contacts;
- A3 - the host-finding efficiency and the skin penetration efficiency of the cercariae;
- A4 - the defence mechanisms of the final host.

The incidence of patent infections of snails depends on:

- B1 - the density of miracidia and their spatial distribution;
- B2 - the density of susceptible snails and their spatial distribution;
- B3 - the host finding and penetration efficiency of the miracidiae;
- B4 - the defence system of the snail host;
- B5 - the mortality of the snail host in the prepatent period.

Only some of these factors will be discussed in the following paragraph; due to lack of time it was not attempted to measure cercarial densities by cercariometric methods. Instead, the joint effect of the factors A1, A3, and A4 was determined for mice (paragraph 5.2., experimental mouse exposures). The exposure time of man and the type of activities near infested water have been estimated and recorded in a number of cases (paragraph 5.3.: man's exposure to infested water). Though initially it was tried to estimate the combined result of the factors B1, B3, B4 (and B5) by the use of sentinel snails, this part of the project had to be abandoned because of technical problems with breeding mice. Only a few remarks will be made on the faecal pollution of the water and on the occurrence of infected snails in the natural situation (paragraph 5.4.).

The role of animal reservoirs and the occurrence of *Schistosoma bovis* will be discussed in the paragraphs 5.5. and 5.6.

5.2. EXPERIMENTAL MOUSE EXPOSURES

White mice were used to demonstrate the infectivity of water in three different situations: in the streams around Chiwahit, in the local houses, and in the laboratory to check the identity of cercariae.

5.2.1. Methods and materials

In the streams around Chiwahit groups of 6-12 white mice (obtained from the Imperial Central Laboratory and Research Institute, Addis Ababa) were exposed together in one "tanqua" (Amharic for boat). This floating exposure cage (fig. 5.1.a, photo 22) was made of wire mesh, and was covered with a lid of the same material. The floaters were cut from the polystyrene packing material wrapped in nylon mosquito gauze. During the exposures the tanqua was protected from direct sunlight by an umbrella, held by one of the junior technicians. On a few occasions the exposure was interrupted for some minutes because of mice fainting away.

Every few months the overall infectivity of each stream was estimated by exposing one group of mice (about 10 weeks old) to 5 different pools on 5 consecutive days. Thus, the exposure time was 5 hours per mouse. On each day, when the mice were exposed to one particular pool, the "tanqua" was kept in 2 or 3 different parts of the pool (mainly along the banks; in the middle of the pools protection from the sun was difficult).

For the exposure of mice to household water, stored water was collected from the local houses. A similar type of tanqua was constructed for these experiments (fig. 5.1.b). People from a number of houses in quarter B of Chiwahit were asked to hand in their stored household water 1). The water from each house was transferred from the original container into an enamel bucket. The volume of the water was measured, and notes were made as to the time and place of the water

Note 1): In Chiwahit water is precious and its worth is not generally expressed in terms of money. Therefore, people had to be provided with a full jar of clean water in exchange. For this purpose a regular water-fetching-donkey-service was set up between Chigaro well and the field laboratory. The water was chlorinated before distribution.

Fig. 5.1-a.

Exposure cage for exposing mice to the streams

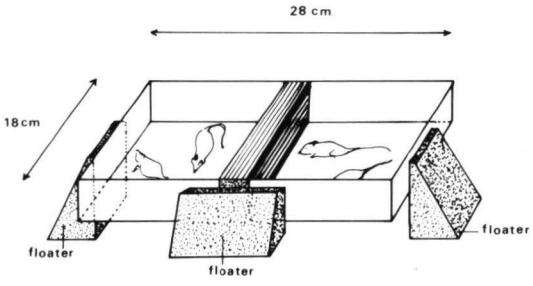
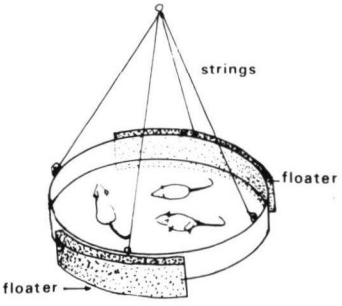


Fig. 5.1-b.

Exposure cage for exposing mice to household water in a bucket



collection. Groups of 6-12 mice were exposed to water from many houses in succession. Each exposure lasted 10 minutes. Household water that was claimed to be collected from the tap at Chalguaye well was not used in the experiments.

In the laboratory mice were exposed to cercariae from single infected snails from the streams around Chiwahit and from other streams as well. By immersion in shallow plastic bowls, they were exposed to suspensions of about 100 cercariae in some 20 ml water (exposure time: 30 minutes).

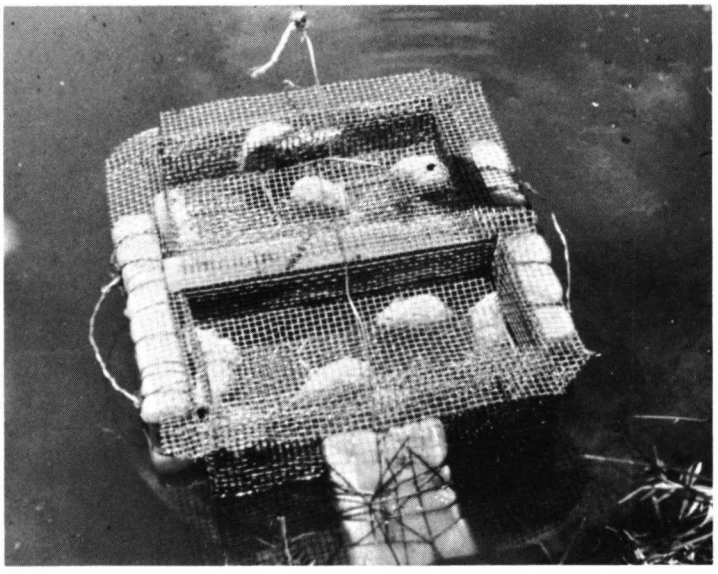


photo 22. The "tanqua" (amharic for boat), a simple floating device to expose mice to natural bodies of water.

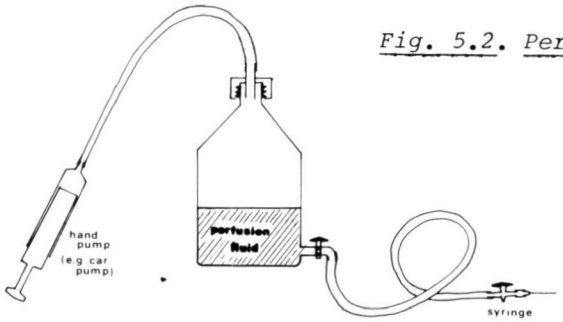


Fig. 5.2. Perfusion unit

Seven to ten weeks after the exposure the mice were sacrificed and perfused according to the system of DuVall & de Witt (1967). The vena porta was cut, a syringe was inserted in the aorta dorsalis and then the perfusion fluid (8½ g NaCl + 7½ g Na-citrate per liter tap water) was injected into the portal system by pressure (fig. 5.2.). Perfused mice were thoroughly rinsed in tap water for the detection of young worms. Schistosomes obtained from the perfused mice were collected in conical sedimentation glasses and counted.

When the perfusion was not performed fully satisfactorily, or when mice died prior to the perfusion date, the mice were dissected carefully. The presence of liver granulomas was always recorded.

Due to the sub-optimal mouse breeding conditions (the temperature was sometimes too high, and well balanced food or fresh carrots, supplementing wheat and barley meals, were not always available) mortality among both infected and uninfected mice was sometimes fairly high. During the exposures, however, the mortality was very low. Even during the multiple exposures to household water no mice died.

5.2.2. Results

5.2.2.1. Exposures to the streams

The shedding of cercariae by infected snails often shows a marked daily rythm (Webbe & Jordan, 1966; Pellegrino & de Maria, 1966). Mouse exposures to natural bodies of water should therefore be performed at a fixed time of the day. In order to obtain the highest worm yields it is wise to perform the experiments during the period of optimal infectivity of the water. In Tanzania a peak transmission was recorded between 9 A.M. and 2 P.M.; from 4 P.M. onwards low infection rates in sentinel mice and very low worm loads were recovered (Webbe and Jordan, 1966). In Brazil the transmission appeared to continue throughout day time and even up till midnight (Pellegrino and de Maria, 1966).

Following a preliminary experiment that was performed at the beginning of the regular mouse exposures, one systematic experiment was executed in pool 5 of Chalguaye stream. This pool is often used for washing clothes and fetching water. During 5 consecutive days 4 groups of mice were exposed repeatedly at particular times of the day: one group 5 times from 6.30 to 7.00 A.M., one group 5 times from 10.30 to 11.00 A.M., one group 5 times from 14.30 to 15.00 P.M., and the last group 5 times from 18.30 to 19.00 P.M. For each group of mice the total exposure time was $2\frac{1}{2}$ hours. Before the

Table 5.1-a. The infectivity of pool 5 at different times of the day

five exposures between 10/5/1972 and 14/5/1972 at 4 different times:				
	6.30-7.00 A.M.	10.30-11.00 A.M.	14.30-15.00 P.M.	18.30-19.00 P.M.
exposure time in minutes	5 x 30	5 x 30	5 x 30	5 x 30
number of exposed mice	8	7	7	7
number of mice surviving exposure	8	7	7	7
number of mice perfused after 8 weeks	8	7	7	7
number of infected mice	2	7	7	5
total number of S.m. worms	4	559	219	192
mean worm load per mouse	0.5	79.9	31.3	38.0
standard deviation for worm loads	-	30.2	15.7	26.8
no. of mice with gran.liver	1	7	7	4

Table 5.1-b. Observations on the densities of snails in pool 5 in May 1972

dates of 4 snail-surveys in pool 5	1 / 5	8 / 5	16 / 5	1 / 6
number of infected snails	5	6*	4*	2
total number of collected snails	72	128*	88*	28
infection rate among snails	6.9%	4.7%	4.5%	7.1%
snail density in pool 5 according to table 4.7. (par. 4.3.3.) 59 snails/m^3				
density of infected snails in this pool at this time: 3.5 infected B. pf./m^3				

* *The total number of snails is comparatively high because, in this case, the snail collection time was longer than the standard time of 3x20 seconds.*

experiment and shortly after, snails were collected from this pool with our routine methods (par. 4.2.), and the absolute snail densities were estimated with a capture-recapture experiment (see par. 4.3.3.). The results of these experiments are summarized in the tables 5.1.a. and 5.1.b., and in fig. 5.3.

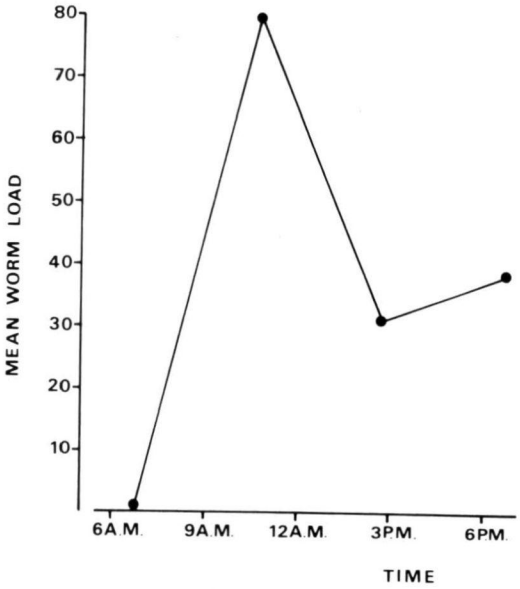


Fig. 5.3. The mean worm load in mice that were exposed to pool 5 at various times of the day

Discussion and conclusions

The transmission of *S. mansoni* is most intense during the second exposure (10.30-11.00 A.M.) but remains high until dusk and perhaps even longer. Early in the morning the transmission is low. Even though the snail density and the infection rate among snails in this pool are not very high, the infection rate among mice and the mean worm load of the exposed mice is extremely high. Between 10.30 and 11.00 A.M. the mean worm load per hour exposure was equal to 32.0. Compared to the results of other investigators (Pitchford & Visser, 1962 ; Webbe, 1965; Webbe & Jordan, 1966; Pellegrino & de Maria, 1966; Pesigan et al, 1958; Sturrock, 1973) this is a very high value.

Table 5.2. Exposures of sentinel mice to the streams around Chiwahit. →

The figures in the shaded parts refer to the means of the numbers of male worms, female worms, juveniles and the percentage infection rate among the mice.

CHALGUAYE					AMBAZINA					CHIGARO					TOTAL
exposure date	number of ♂worms	number of adult ♀worms	number of juvenile ♀worms	granulated liver	exposure date	number of ♂worms	number of adult ♀worms	number of juvenile ♀worms	granulated liver	exposure date	number of ♂worms	number of adult ♀worms	number of juvenile ♀worms	granulated liver	mean infection rate among mice (in %) & mean worm load
9-13 Sept.'71	8	6	-	+	15-19 Sept. '71					8-14 Sept.'71	1	-	-	-	
	13	6	-	+		6 mice:NEGATIVE					2	1	-	-	
	7	7	-	+							1	-	-	-	
	29	32	-	+								1	-	-	
	13	9	-	+									-	-	
	17	17	-	+									-	-	
	9	9	-	+									-	-	
	16	10	-	+									-	-	
	28	29	-	+									-	-	
	15.4	13.9	-	100%		-	-	-	0%		0.5	0.3	-	50%	50% 10.0
7-11 Dec.'71	1	-	-	+	19-24 Dec.'71	-	-	-	-	14-18 Dec.'71	-	-	-	-	
	4	2	-	+		1	-	-	-		1	-	-	-	
											-	1	-	-	
	1.7	0.7	-	100%		0.3	-	-	33%		0.2	0.2	-	40%	58% 1.0
3-7 Apr.'72	-	-	1	-	29 Mrch-2 Apr.'72					24-28 Mrch.'72					
	-	-	1	-		13 mice: NEGATIVE					13 mice: NEGATIVE				
	-	-	1	-											
	10 mice: NEGATIVE														
	-	-	0.2	23%		-	-	-	0%		-	-	-	0%	8% 0.1
1-5 July'72	-	-	-	-	6-10 July'72	no observation				24-28 July'72	-	-	-	-	
	5 mice: NEGATIVE										5 mice: NEGATIVE				
	-	-	-	0%							-	-	-	-	0% 0.0
11-15 Sept.'72	3	3	-	+	6-10 Sept.'72	1	1	-	+	24-28 Sept.'72	1	1	-	+	
	1	1	3	+		3	-	-	+		1	1	-	+	
	1	3	-	+		1	-	-	+		1	-	-	-	
	3	1	-	+		1	-	-	+		-	1	-	-	
	1	3	-	+		2	-	-	+		-	-	-	-	
	2	2	4	+		1	-	-	+		-	-	-	-	
	2	-	1	+							-	-	-	-	
			7	+											
	1.3	1.6	2.1	89%		1.0	0.1	-	57%		0.4	0.5	-	50	65% 2.3
14-18 Nov.'72	5	5	-	+	24-28 Nov.'72	1	-	-	+	26-30 Nov.'72	5	1	-	+	
	1	3	-	+		3	1	-	+		2	1	2	+	
	2	2	-	+		5	1	-	+		2	1	-	+	
	2	1	-	+		7	1	-	+		2	-	-	-	
	1	-	-	+		6 mice: NEGATIVE					2	1	-	-	
	2	2	-	+							4	-	-	-	
	3	1	-	+							4	1	1	+	
	4 mice: NEGATIVE										5 mice: NEGATIVE				
	1.5	1.3	-	64%		1.6	0.5	-	45%		1.7	0.4	0.3	55%	55% 2.4
Jan. '73	3 mice: NEGATIVE				Jan. '73	4 mice: NEGATIVE				Jan. '73	no observation				0% 0.0
2-6 July'73	10	13	-	+	7-11 July'73	1	1	-	+	July '73	no observation				
	15	50	-	+		2	1	-	+						
	9	10	-	+		1	1	-	+						
	5	7	-	+		1	-	-	+						
	9.8	20	-	100%		0.5	0.5	-	67%						83% 15.4

The infectivity of the water of this pool, during this particular period, at this particular time of the day (10.30-11.00) could be expressed as follows: at a density of infected snails of 3.5. per m^3 of water, the worm load in mice was about 32 per 25 cm^2 exposed skin (one mouse) in a multiple exposure experiment that lasted 5 times 30 minutes (for comparison: a man's hand has a surface of about 400 cm^2).

I think it is unwise - for the time being - to transform these figures to the infectivity per cm^2 of mouse skin per minute exposure since the worm load is probably not a linear function of the various variables (Upatham and Sturrock,1973).

In chapter 4 the seasonal fluctuations of the numbers of infected snails were studied. An attempt was made to confirm the results of chapter 4 by exposing sentinel mice at different times of the year to each of the streams. The results of these mouse exposures are summarized in table 5.2. and figure 5.4.

The results of the mouse exposures do confirm the results of the snail surveys: the highest infection rates and worm loads were found after the rains and in July 1973 (following the early onset of the rains in 1973). The highest worm loads were found among mice exposed to Chalguaye stream which is in agreement with the results of the snail collections. The impression gained from the mouse exposure experiment in pool 5 (first part of par. 5.2.2.1.) was confirmed: at some particular times of the year the infectivity of the water appeared to be very high in at least one stream, and probably more specifically, in particular pools of one stream.

Though the numbers of mice that were exposed were small compared with the numbers mentioned in the work of other authors (e.g. Sturrock, 1973, exposing over 12,000 mice), the results are thought to be satisfactory because of the comparatively small 1) standard deviation of the worm loads per group of mice (see table 5.1., and 5.2.). Because of this low standard deviation and the positive correlation that has been found between the infection rate among mice and the worm load (Webbe, 1965; Sturrock, 1973), the present experimental set up with long exposure times and small numbers of mice is considered to be an efficient one (in this particular situation).

note 1) The standard deviations mentioned in the tables 5.1. and 5.2. are considered to be 'low' since even under well-controlled laboratory conditions the worm loads of experimentally infected mice may vary considerably.

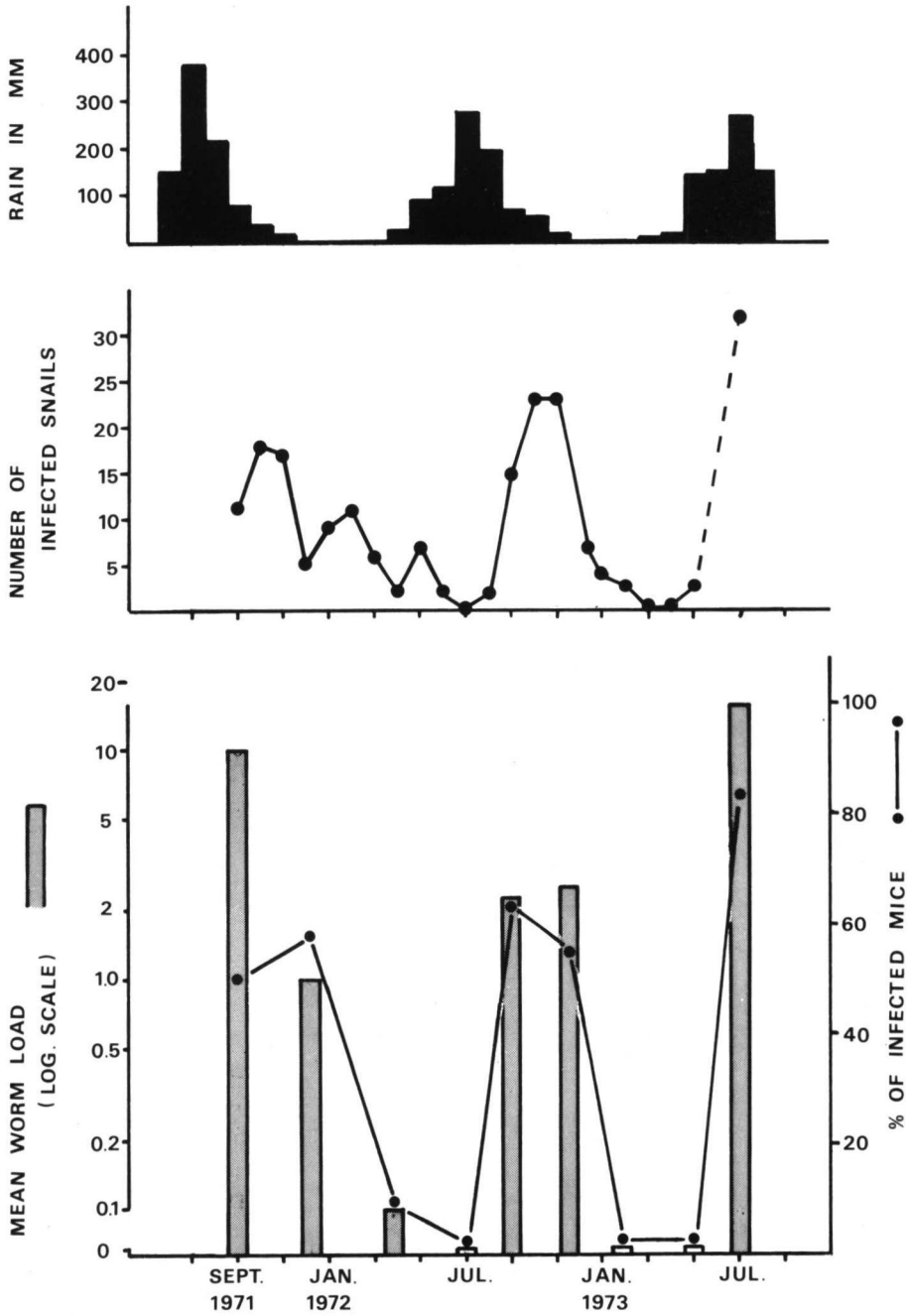


Fig. 5.4. Comparison of the amount of rain, the numbers of infected snails, the percentage infection rates in sentinel mice, and the mean worm loads in sentinel mice, over a period of 22 months

5.2.2.2. Mouse exposures in the local houses

In October 1972, groups of mice were exposed repeatedly to household water from a number of houses. The results are summarized in table 5.3. Thirty eight percent of the water jars were said to have been filled longer than 4 hours before at Chalguaye: according to the vague indications of the owners of the jars mainly filled at pool 2, pool 4 and pool 5, and at some places in between.

Altogether 630 l. of water was collected during the dangerous time of the day. These 630 l. gave rise to 10 *S. mansoni* worms in mice, i.e. one per 63 liters. The infectivity of Chalguaye stream at the time of the experiment was high as determined by the numbers of infected snails in the routine snail surveys of October and November: both times the overall infection rate for Chalguaye was 7.5 %; further details were given in table 4.3. The mean worm load of mice exposed to Chalguaye stream was 5.0 in the middle of September and 2.6 in the middle of November.

It is well known that *S. mansoni* cercariae can survive for as long as two days (Belding, 1965), and that they may remain infective for at least several hours. The results of this experiment indicate that cercariae that were produced some hours before at a distance of about 1 kilometer from the houses, and that were brought to town in various types of jars, were in fact still able to infect mice. These cercariae, that are brought into the town, may play an important role in the transmission of schistosomiasis in Chiwahit by infecting those people who do not go to the streams. The quantitative role that is possibly played by this mode of transmisssion will be discussed in chapter 7.

Table 5.3. Mouse exposures in the local houses

	experiment		
	A	B	C
date of the experiment	2-7/10	18/10	19/10
number of water-pots that were emptied in our mouse-exposure bucket	93	24	28
total exposure time per mouse (in minutes)	93x10	24x10	28x10
total amount of water used in the experiment	725 liter	163 l.	171 l.
amount of water collected before 9 A.M.	297 liter	77 l.	55 l.
amount of water collected after 9 A.M.	423 liter	86 l.	116 l.
number of mice that was exposed	12	6	6
number of mice that was perfused	12	6	6
number of infected mice	3	0	1
number of worms that was recovered	7	0	3

5.2.2.3. Mouse exposures in the laboratory

In a number of cases it was attempted to infect white laboratory mice with cercariae from single infected snails. These experiments were performed to identify the '*S. mansoni*-type' cercariae. The results of these mouse exposures are summarized in table 5.4.

Table 5.4. Mouse exposures with cercariae from individual snails

exposure date	snail from pool	number of worms		granulated liver
		male	female	
4 / 1	2	23	-	-
1 / 5	4	10	4	+
1 / 5	4	17	8	+
1 / 5	5	37	-	-
1 / 5	5	3	4	+
1 / 5	5	15	9	+
11 / 5	5	33	-	-
1 / 5	5	31	-	-
1 / 5	5	2	2	+
20 / 6	5	-	13	-
20 / 6	5	-	-	-
20 / 6	5	2	1	+
5 / 9	15	10	-	-
5 / 9	15	12	-	+[1)]
5 / 9	22	1	-	-
5 / 9	25	25	8	+
5 / 9	25	52	5	+
6 /10	2	12	9	+
6 /10	4	100	-	-
6 /10	4	41	-	-
6 /10	24	37	-	-
6 /10	21	-	4	-
6 /10	25	2	5	+
6 /10	8	-	-	-
6 /10	8	104	-	-
1 /11	19	-	-	-
1 /11	19	6	-	-
1 /11	19	22	19	+
1 / 11	19	10	9	+

1) female worms must have been present for eggs were found in the liver.

Discussion and conclusions

Of the 29 mice that were exposed to cercariae from single snails (excluding a few mice that died before the 7th week after exposure) *S. mansoni* worms were recovered from 26 mice. Three mice were negative at perfusion. In some cases only very few worms were recovered (on one occasion one single male worm, once 4 worms, and once 6 worms). Since it is a common phenomenon that some mice are not readily infected in laboratory experiments, it may be concluded that probably all or practically all '*S. mansoni*-type' cercariae are actually *S. mansoni* cercariae.

It is remarkable that in 13 out of the 26 successful infections both male and female worms were recovered at perfusion. Following the first mixed male-female infections which were found as a result of exposures to cercariae from individual snails, rigorous precautions were taken to avoid mixture of cercariae from different snails. Yet, the rate of bisexual infections remained at the same high level. No difference in the proportions of unisexual and bisexual infections was found during the post rain period compared with the dry season.

In a hypothetical situation in which two miracidia develop into mature sporocysts in each snail, not more than 50 % of the snails will shed both male and female cercariae. This maximum of 50 % will be reached when the miracidial sex-ratio is 50 %-50 %. From table 5.4. it appears , however, that there is an excess of snails shedding male cercariae : 11 of the 13 unisexual infections refer to mice infested with male schistosomes only, and the total number of male schistosomes that was recovered at perfusion was about six times as high as the number of females (607 males and 100 females). The combined findings of a sex ratio among the schistosomes of 1:6 and of a rate of bisexual infections of 50 % suggests that the mean number of mother sporocysts, so the mean number of successful miracidial penetrations of the snail, will have been approximately four 1)

note 1). When all infected snails contain 3 fully developed mother sporocysts the fraction of snails shedding both male and female cercariae can be calculated as:

$$p^{(3)}_{bisex.} = 3.\left(\frac{1}{6}\cdot\frac{5}{6}\cdot\frac{5}{6}\right) + 3.\left(\frac{1}{6}\cdot\frac{1}{6}\cdot\frac{5}{6}\right) = 0.42$$

and when all infected snails contain 4 fully developed mother sporocysts:

$$p^{(4)}_{bisex.} = 4.\left(\frac{5}{6}\cdot\frac{5}{6}\cdot\frac{5}{6}\cdot\frac{1}{6}\right) + 6.\left(\frac{5}{6}\cdot\frac{5}{6}\cdot\frac{1}{6}\cdot\frac{1}{6}\right) + 4.\left(\frac{5}{6}\cdot\frac{1}{6}\cdot\frac{1}{6}\cdot\frac{1}{6}\right) = 0.59$$

→

Similar high proportions of snails with bisexual infections were found by McClelland studying *B. nasutus productus* in Tanzania (McClelland, 1965). McClelland explained the phenomenon in two ways. He suggested "it is due to the habit of both snails and miracidia to concentrate at the bottom and periphery of the container" (in laboratory experiments). Furthermore it was considered that a heavy mortality as the result of parasitization might have occurred among young snails (McClelland, as cited by Webbe, 1965).

The rather low prevalence of infections among snails and the unexpectedly high rate of multiple infections in individual snails represent contradictory observations which are not readily explicable. If this pattern was due to a high mortality of young infected snails such a massive slaughter should have been reflected in a high mortality in those snails. This, however, is not the case, as has been pointed out in paragraph 4.3.1.3. Alternatively, the clustered distribution of both snails and miracidia (human stools) may be the major explanation for the high number of multiple snail infections. This explanation, however, is not in agreement with the observations of paragraph 4.3.2.1.: the percentage of multiple snail-infections was about the same in the dry months as in the post-rain months.

For the time being, no satisfactory explanation of the high rate of multiple infections can be given. A more detailed study of this subject may well produce important information on the dynamics of snail infections in the field.

5.3. MAN'S EXPOSURE TO (INFESTED) WATER

The various types of water contact that might be related to the high prevalence of *S. mansoni* in Chiwahit do not remain unchanged throughout life. Both past and current patterns of exposure will have their bearing on the present status of infection of a subject.

The most important components of these exposures are:
-1- the collection of water at the streams plus all associated activities,
-2- washing clothes plus associated activities,

note 1, p. 118, cont.

In a more natural system in which the sporocysts are distributed randomly over the population of infected snails, the rate of bisexual infections will be lower, the actual rate being dependent on the frequency distribution of the sporocysts.

-3- various activities at home, using water from the (infested)streams,
-4- swimming and bathing,
-5- various activities outside Chiwahit.

The relative importance of past infections has been discussed briefly in chapter 3; accurate information on this subject, however, is difficult to obtain.

In the following sections the present exposure patterns of various groups of the population will be discussed.

5.3.1. Methods

Inquiries were made on the individuals' habits of drawing water and washing clothes (see appendix 2). However, the results of these inquiries do not fit the actual observations on the frequencies of water contacts. The answers to the inquiry will not be considered in these paragraphs for they are thought to be less reliable than our actual observations.

These observations were made at two different 'levels':

1) large scale counts that did not reveal any information on the nature of the various behavioural patterns, and
2) accurate observations on the way people wash their clothes and draw their water; the latter observations were only done on a small group of people.

1) All people that returned from the streams to the town were counted during the observation days. The type of activity (collecting water, washing clothes), the sex, and the religion were registered, and the age of all persons was estimated. Cycloprinted froms were used for thse observations (appendix 5). Observations along each stream were continued for 7 consecutive days; each day the observations started at dawn (6 A.M.) and lasted until dusk (7 P.M.) without interruption.
The observations were done by one or two technicians from Chiwahit town itself. Both of them knew many inhabitants, their religion, and their age. The technicians' observations and their counts were checked regularly by the author. The religion of adult men and women can easily be recognized by the people's clothes. In children, however, this distinction can often not be made. We overcame this problem by the fortunate situation that our observers knew most children and their religion.

2) In a number of cases detailed observations were made on women and girls while collecting water. All activities of the observed women and children were registered with the aid of a tape recorder, and the actual exposure time of the persons to the water was recorded in seconds. Unfortunately, the process of washing clothes was registered less accurately because of the complexity of the activities.

For practical reasons, the activities that involve contact with (infested) water at home and outside Chiwahit were not studied in any detail. Only some general remarks and descriptions will be given.

photo 23.
Drawing water. Note the careful way in which the woman fills her tin.

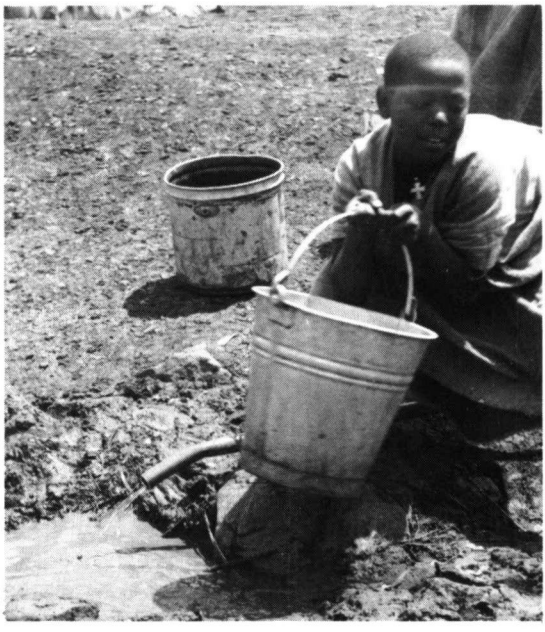


photo 24.
The spring of Chalguaye stream; up till October 1972 the only source of clean water for Chiwahit.

5.3.2. Results

5.3.2.1. The collection of water at the streams

Table 5.5.a. shows that the daily variation in the number of visitors is not very large within one week. Most visitors were registered on Sundays because of Chiwahit's weekly market on Monday mornings. The favourite streams of the individual water collectors tend to remain the same. In the long run, however, there may well be more important variations in the choice of the stream.

During a week's observation in March 1972 the total number of females visiting AmbaZena was 3715 (from Sunday to Saturday 728, 467, 507, 516, 517, 410, and 510 respectively). These higher counts were due to the facts that

Table 5.5.a. Numbers of female water carriers

	Su	Mo	Tu	We	Th	Fr	Sa	weekly total
AmbaZena (19-25 Nov. '72)	495	357	346	338	406	361	424	2727
Chalguaye (27 Nov.-3 Dec. '72)	334	328	354	318	347	361	319	2361
Chigaro (24-30 Okt. '72)	336	263	274	263	309	248	329	2022
Total for 3 rivers	1165	948	974	919	1062	970	1072	7110

Table 5.5.b. Numbers of female water carriers, additional observations

A m b a Z e n a	
Saturday	Sunday
25/11 : 424	19/11 : 495
23/12 : 481	24/12 : 561
6/ 1 : 416	7/ 1 : 557

C a l g u a y e	
Saturday	Sunday
2/12 : 319	3/12 : 334
16/12 : 260	17/12: 304
30/12 : 303	31/12 : 335

Table 5.6. Numbers of female water carriers at different times of the day
(based on the observations referred to in table 5.5.a.)

	girls up to 15 years old	women older than 15 years	total females
before 9 A.M.	480 (20,7%)	1465 (30,6%)	1945 (27,3%)
between 9 A.M. and 5 P.M.	1329 (57,4%)	2321 (48,4%)	3650 (51,3%)
after 5 P.M.	508 (21,9%)	1007 (21,0%)	1515 (21,3%)
total	2317 (100%)	4793 (100%)	7110 (100%)

1) the tap at Chigaro well was not yet functioning in March 1972,
2) towards the end of the dry season there is more water left in AmbaZena, the biggest stream, than in Chigaro and Chalguaye.

On 6 Saturdays and 6 Sundays some additional observations were made along the Chalguaye and AmbaZena (table 5.5.b.). Again, the counts along each stream were quite similar in the three comparable observations.

During the big rains, from July until September, most people collect rainwater from the corrugated roofs of the town-house. Depending on the previous days' amount of rain, very few to the average number of people are counted along the river during these months. Due to the large daily fluctuations no accurate counts were made during these months.

Table 5.6. shows that almost 75 % of the females collect their water after 9 A.M. - the highly infective period of the day (see paragraph 5.2.2.1.). More women than girls go early in the morning.

When the numbers of women and girls in different age classes are compared (table 5.7.), about one third of the female water carriers appears to be younger than 16 years. The number of women that is living in Chiwahit can be approximated by multiplying the numbers of women (per age class) who were registered in our census (par. 3.3.2.) by 5/4 (20 % of the people were not included in our census).

Table 5.7. The age of female water carriers
(based on the observations referred to in table 5.5.a.)

age class	AmbaZena weekly	Chalguaye weekly	Chigaro weekly	total 3 rivers weekly	number of females in Chiwahit population	water-collection frequency per person per week
	number / %	number / %	number / %	number / %		
4 - 6	56 / 2.1	12 / 0.5	67 / 3.3	135 / 1.9	135	1.0
7 -15	843 / 30.9	738 / 31.3	601 / 29.7	2182 / 30.7	309	7.1
16-22	412 / 15.1	598 / 25.3	368 / 18.2	1378 / 19.4	214	6.4
23-32	822 / 30.1	595 / 25.2	647 / 32.0	2064 / 29.0	296	7.0
33-42	405 / 14.9	280 / 11.9	261 / 12.9	946 / 13.3	191	5.0
more than 42	189 / 6.9	138 / 5.8	78 / 3.9	405 / 5.7	120	3.4
total of all ages	2727 / 100	2361 / 100	2022 / 100	7110 / 100	1265	5.6

Using the total numbers of women and girls that are living in Chiwahit, the mean weekly number of water collections per person can be calculated (table 5.7.). The water collection frequencies appear to be about the same for girls and women between 7 and 32 years of age. Older women go to the streams (slightly) less often.

From table 5.8. it appears that the fraction of Moslim water collectors is highest along the AmbaZena, and lowest at Chigaro well. Among children the percentage of Moslim girls is about the same along each of the streams. Both among women and among girls the water collection frequency per

Table 5.8. The religion of female water carriers (per age-group) (17 observation days)

		Age		
		≤ 15	> 15	total
AmbaZena	Total number of watercarriers	899	1828	2727
	number of Moslim watercarriers	80	222	302
	% of Moslim watercarriers	8.9	12.1	11.0
Chalguaye	Total number of watercarriers	750	1611	1354
	number of Moslim watercarriers	66	84	150
	% of Moslim watercarriers	8.8	5.2	6.4
Chigaro	Total number of watercarriers	668	1354	2022
	number of Moslim watercarriers	53	47	100
	% of Moslim watercarriers	7.9	3.5	4.9
Total	percentage of Moslim watercarriers	8.6	7.4	7.8
	% female Moslim in Chiwahit's population	19.9	13.3	15.8
water collection frequency per person per week				
	- Christians	5.9	6.2	6.1
	- Moslims	2.3	3.2	2.8
	- Total	5.2	5.8	5.6

Table 5.9. The age distribution of adult Christian and Moslim female water carriers (17 observation days)

Age	Amb. + Chalg. + Chigaro number and % of Christians		Amb. + Chalg. + Chig. number and % of Moslims	
16-22	1307	(28.5)	71	(30.9)
23-32	1967	(42.9)	97	(42.2)
33-42	916	(20.0)	48	(20.9)
> 42	391	(8.5)	14	(6.1)

person is higher among Christians than among Moslims, which is probably due to the fact that the richer Moslim women often employ (Christian) servants for the tiring work of drawing water. This is less common among Christians.

Table 5.9. shows that the age distribution among female water collectors is about the same for Christians and Moslims.

Adult men do not go to the streams around Chiwahit very often. If they do go there, it is mostly professionally, with a donkey carrying two big canvas sacks. One donkey load of water (about 60 l.) is sold in the town for 25 Ethiopian cents (U.S. $ 0.12). These professional water carriers go down to the streams many times a day. There are about 8 of them in Chiwahit.

The results of weekly counts of male water carriers are summarized in table 5.10. The numbers are too small to permit a frequency analysis per religious group and per time of the day as given for the females.

Out of the 171 boys who collected water from the Chalguaye, 80 did so on Friday. This disproportionally high activity on Friday is related to the weekly cleaning of the school on that day, which requires much water.

Out of the 298 male water carriers (age up till 15) 58 (10.5 %) were registered as Moslim; of the 383 adult male water carriers 67 (17.5 %) were recognized as Moslim. Among the male inhabitants of Chiwahit 24.5 % are Moslims in the 1-15 age class, and 28.9 % are Moslims in the adult men. Therefore just as among females, Christian men and boys go more often to the streams to fetch water than Moslim men and boys. Table 5.10. shows very clearly that adult men only very rarely go to the streams to collect water in the regular way. Practically all male water car-

Table 5.10. Numbers of male water carriers

Age	AmbaZena		Chalguaye		Chigaro		Total	
	A	B	A	B	A	B	A	B
4- 6	2	-	1	-	1	-	4	-
7-15	90	-	171	1	32	-	293	1
16-22	3	93	6	107	1	8	10	208
23-32	5	56	4	73	1	5	10	134
> 32	-	8	-	13	-	-	-	21
all ages	100	157	182	194	35	13	317	364

Legend A: collecting water with a jar, gourd, or bucket
B: collecting water professionally by donkey.

riers are professional water transporters. When the professional water carriers are excluded, the weekly water collection frequencies for males in different age classes are 0.03, 0.98, 0.06, and 0.00 for the age groups 1-6, 7-15, 16-32, and older than 32 respectively.

The results of the comparison of the weekly water collection frequencies with the infection rates in the various groups of the population are presented in figure 5.5. The results will be discussed at the end of this chapter and in the general discussion, chapter 7.

The process of collecting water

In this section the way in which people have contact with (infested) water will be described as far as the collection of household water is concerned. Since the presence of the observer with his taperecorder tended to disturb the normal pattern of behaviour of the water collectors, the main observer was joined by a couple of technicians to create a more relaxed atmosphere: they talked together and with the visitors, they helped the women to put the heavy water pots on the women's heads etc. In that way they screened the presence of the observer and his taperecorder.

> Except for a few older women, most women and girls go to the streams in small groups. With a tin can or a half gourd water is scooped from the pool into a larger container: a big gourd, a bucket, a kerosine can or a clay jar. Women go down to the water, scoop half a gourd of water, test whether the water looks clean enough, and wash the little scooping-gourd for a few seconds with their hands. Then the large container is washed with one or two scoops of water. The container is taken down to the water, the woman squats besides the water, and starts filling the container with gourdfuls of water (photo 23). While filling their container most women try to keep their feet dry. Sometimes, however, it appears easier to stand with one or two feet in the water. In general, this phase of collecting water is executed carefully in order not to stir up the mud. Sometimes even the hand in which the scooping gourd is kept remains dry during this process. More often some fingers or the whole hand get wet every now and then. Some women prefer to fill their containers by pushing them under water rather than by scooping in such a careful way. When the container is almost filled it is pulled higher up the banks. There it is filled up to the brim. Subsequently women often go back to the water to fetch some more for washing their hands and feet. Women mostly do so in the morning, but less often in the afternoon. A tiny amount of water is used for this practice. Sometimes the face is also washed. Finally, an old piece of cloth is rolled up, on top of which the water container is balanced on the head. Clay jars are sometimes carried on the back.

Apart from these activities which belong strictly to the collection of water, a few other activities are often to be observed along the rivers before or just after the actual water-collection. These are: 1) closing cracks in old water containers with moistened mud, 2) urinating, and less often (and less visible) defecating, 3) looking for eucalyptus twigs or another sort of vegetation to cover the surface of the water in the container (to reduce loss of water by spilling; usually those twigs are brought from the town).

While this description fits the majority of women, the others collect their water in a similar but slightly different way.

Quantitative observations

The movements of 37 people were recorded during water collection activities at the streams. Twenty three of them were Christian women (older than 15 years). Among the remaining 14 there were 8 Christian girls, 3 Moslim women, 1 Moslim girl, and 2 Christian boys.

Since the chance of infection is likely to depend on the exposure time, on the exposed surface, and on the amount of water to which one's skin is exposed, these factors had to be taken into account in the observation. The results of the observations are summarized in table 5.11.

We have to be careful with the interpretation of the observations on these small numbers of persons. No conclusions should be drawn from the figures on "others": three Moslim women, one Moslim girl, and two Christian boys.

However, it appears that the amounts of water involved in the exposure are small and the exposure times are short. In girls the exposure time seems to be shorter than among women; the actual scooping time is shorter because girls do not stand so often in the water (greater body suppleness), and because they wash their legs, hands, and faces less often while fetching water. While observing these activities one is struck by the careful way in which infants and little girls attempt to imitate their mothers (photo 25).

photo 25

Little girls start their household duties at an early age; they perform an almost perfect immitation of their mother's water-collection behaviour.

Table 5.11. Quantitative observations on the contact with water while fetching water

	1	2	3	4	5	6	7	8	9	10	11	12
Chr. women	23	6'16"	86"	21	26"	5	314	13"	12	0,5	4"	4
Chr. girls	8	5'08"	38"	6	-	-	-	6"	4	0,25	-	-
others	6	8'42"	77"	4	5"	1	19	3"	1	0,1	-	-
all observed persons	37	6'47"	74"	31	17"	1	266	10"	17	0,4	2½"	-

Legend:
1. *number of persons*
2. *duration of stay at the river side from arrival until departure (in minutes and seconds)*
3. *actual time that was spent filling the jar*
4. *number of persons who did actively collect water*
5. *average time during which people stood with one or two legs in the water*
6. *number of persons that stood with one or two legs or feet in the water*
7. *average of the exposure times (as mentioned under 5) multiplied with the estimated exposure surface (in square dm x sec)*
8. *average time during which feet, hands of faces were washed*
9. *number of persons that washed parts of their bodies*
10. *average of the estimated volumes of water that were used for washing as mentioned under 8 and 9 (in l.)*
11. *average time during which people conducted water through their hands (like a funnel) while pouring water from the scooping gourd into the container*
12. *number of persons that used their hands in the way as mentioned under 11.*

The times are expressed in minutes (') and seconds ("). The averages are always calculated over the total number of persons who took part in the activity.

A general impression which happened to be supported by the recorded observations is that boys do not help their mothers very often when the latter collect water. Even if they accompany their mothers to carry some home, they often do not scoop at all, and do not get wet. (Both boys that were observed carefully just stared at their mothers without helping). In discussions with schoolchildren boys and girls agreed that in general girls are cleaner than boys; boys do not wash their hands and faces as often as girls and they don't go to the streams as often.

The mean time during which people were actually scooping water (column 3) does not describe the time of contact with water. Many women are very successful in keeping dry. In some cases we observed their hands still being dry at the end of the scooping phase.

Even though fairly accurate observations were performed at the streams, it is still very difficult to estimate the total mean exposure time during the collection of water. If we add up means from columns 5, 8, and 11, we get 43" for Christian women, 6" for Christian girls , and ± 30" for all observed drawers of water together. This figure underestimates the exposure time since some less important activities (such as washing of the container) were not included in table 5.11.

In conclusion, the mean total exposure time during the collection of water could be estimated to be less than 1 minute, irrespective of the amount of water to which one is exposed, and to the area of the skin surface that was exposed.

5.3.2.2. Washing clothes along the streams

The other important part of the human behaviour that may create opportunities for intensive transmission of *S. mansoni* is the washing of clothes. Again our technicians counted all people who came back from the streams after having washed clothes, and again the sex, religion and age of them were noted. The results of these counts are summarized in the tables 5.12. - 5.15.

Table 5.12. shows that most washing of clothes is done along AmbaZena. Practically all Moslims go to this stream.

Table 5.13. shows a great variability in the numbers of Christian washing women on Saturdays. These fluctuations are caused by the numerous holy days of the Ethiopian Coptic

Table 5.12. Numbers of women washing clothes, by age, religion and stream

	Christians			Moslims			Amb.+Chalg.+Chig.		
Age	Amb.	Chalg.	Chig.	Amb.	Chalg.	Chig.	Chr.	Mosl.	Total
< 7	-	-	-	-	-	-	-	-	-
7-15	17	13	5	8	-	-	35	8	43
16-22	13	14	5	11	-	-	32	11	43
23-32	25	5	7	25	-	-	37	25	62
33-42	5	3	3	14	1	-	11	15	26
> 42	4	2	1	3	1	-	7	4	11
total	64	37	21	61	2	-	122	63	185

church. Since the Saturdays of minimal clothes washing activity (25/11/'72 for AmbaZena and 2/12/'72 for Chalguaye) were the essential days in the weekly counts of table 5.12, the weekly totals from table 5.12. should be corrected for these large weekly fluctuations.

The approximate mean frequencies of washing clothes for Moslims and Christians are given in table 5.14. Since the Christian/Moslim ratio in Chiwahit town is 80 %/20 % it may be conlcuded that there is no significant difference in the washing frequencies between Christian and Moslim women.

Table 5.13. Numbers of women washing clothes on three saturdays and three sundays

AMBAZENA			CHALGUAYE		
date	numbers of Chr.	Mosl.	date	numbers of Chr.	Mosl.
Sat. 25/11/'72	58	18	Sat. 2/12/'72	18	0
Sat. 23/12/'72	94	20	Sat. 16/12/'72	33	0
Sat. 6/ 1/'73	104	9			
Sun. 19/11/'72	30	20	Sun. 3/12/'72	12	1
Sun. 24/12/'72	39	36	Sun. 17/12/'72	10	0
Sun. 7/ 1/'73	22	18	Sun. 31/12/'72	10	0

Table 5.14. Approximate weekly mean numbers of women washing clothes

	Christians	Moslims	Total
AmbaZena	150	63	213
Chalguaye	45	1	46
Chigaro	21	-	21
Total	216 (77%)	64 (23%)	280 (100%)

Table 5.15. Numbers of men washing clothes
(7 observation days per stream; see table 5.5.a.)

Age	Christians			Moslims			Amb.+Chalg.+Chig.		Total
	Amb.	Chalg.	Chig.	Amb.	Chalg.	Chig.	Chr.	Mosl.	
≤ 15	7	6	4	15	-	-	17	15	32
> 15	5	-	-	8	-	-	5	8	13
Total	12	6	4	23	-	-	22	23	45

Sometimes people start washing their clothes early in the morning but only rarely is a woman finished before 10 or 11 A.M. So the majority of women washing clothes is busy at the streams during the highly infective period of the day.

Men do not wash clothes very often, but Moslim men and boys tend to participate in this activity more often than their Christian companions (table 5.15.).

For several categories of the Chiwahit population the prevalence of *S. mansoni* infections has been given in chapter 3, and in this chapter the frequency of washing clothes was considered. The results of both observations are compared in fig. 5.6. (p. 141). The conclusions of this comparison will be discussed in par. 5.7.

The process of washing clothes

Observing the organization of life in a small North Ethiopian town it will readily be noted that by far the largest numbers of people wash their clothes on Saturdays and Sundays. Among Christians Saturdays are favourite, Moslims wash their clothes preferably on Sundays.

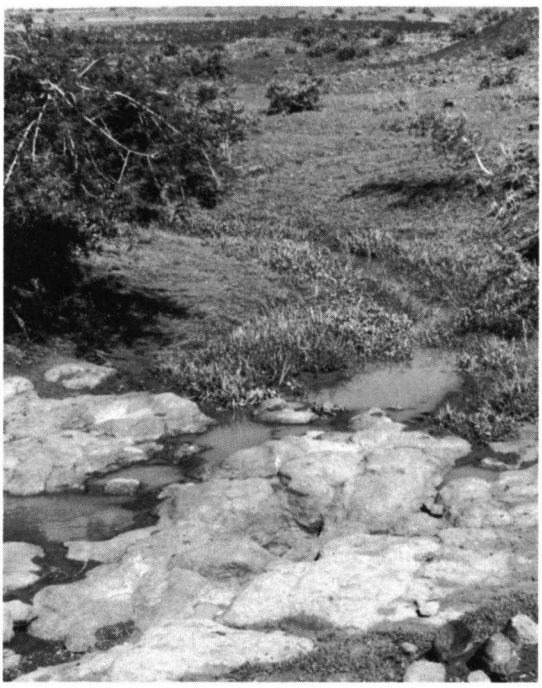


photo 26.

The principal washing place of Chiwahit, some 15 minutes walk from the centre of town. Note the eroded rocky bottom.

The washing of clothes is a social event; people go down to the streams together and they help each other. Some women are 'lazy', others very active; some seem to be 'specialized' in the actual washing, others in rinsing; women with little children are allowed to take it easy, they are helped by the others, etc. For that reason an estimate of the average exposure time per person is not easy to achieve.

Along the streams around Chiwahit, people wash their clothes in two different ways. Sometimes women use the rocky bed of the stream as a scrubbing board (photo 26); in that case the clothes are rinsed by trampling on them with bare feet. Then the women stand in the slow flowing stream for a considerable length of time. Around Chiwahit the only suitable rocky place for this washing procedure (just beyond pool 19, AmbaZena) has a maximum depth of some 15 cm. Women who wash their clothes at other places along the streams use the bottom parts of big kerosene barrels instead of the rocky bed of the stream (photo 27). Time and again fresh water from the stream has to be scooped into the barrels. Again the clothes are rinsed by trampling on them in the bottom of the partly filled barrel.

photo 27.
Washing clothes in the bottom sections of old kerosene drums.

The complete procedure of washing clothes takes a long time: often as long as 3 hours, and sometimes even longer. During this time the clothes are also (partly) dried in the sun, while people wash their arms, legs and faces as described in the previous section. Some women wash their whole bodies in the stream (photo 30), or on the banks of the stream; others take advantage of the situation to wash their children (photo 29).

For washing clothes people use a lot of soap ("Omo", "Rol", or a cake of soap of an Ethiopian brand). On Saturdays and Sundays the wash-places can be recognized by an intense smell of soap. The water downstream from the washing places has a scum of dirt and soap, and the water in the washing places themselves often looks white with soap. Nevertheless, we did not find any dead snails in these places.

On Saturday 28 October 1972 a group of 7 women was observed at pool 5 of Chalguaye. All of them brought a kerosene washing bassin. Four of them arrived at 10.48 A.M., and the other three came at 11.07 A.M. Sometimes friends joined them, and sometimes some of them disappeared for a while. Following some preparative work, they started washing some 8 minutes after arrival. Three of them were finished with

photo 28. Men rarely participate in the washing of clothes; the helpful farmer on this picture washes and rinses clothes in a cow skin.

the actual washing at 1 P.M.; the remaining three went on for another 20 minutes. By 1.25 P.M. the last clothes were spread out in the sun. The first two women returned to the town at 1.38 P.M., and the others followed 10 and 22 minutes later.

Two women thoroughly washed their bodies. They squatted in the washing basin, soaped their whole bodies, and used about 6 liter of water each. Four women washed their faces, arms and legs, and the last woman did not wash herself at all.

Between 10.48 A.M. and 2.00 P.M. 28 buckets of water, 33 kettles of water, and 23 little bowls of water were collected. This was estimated to be about 350 liter, i.e. 50 liters per person.

Though the activities of the women were not accurately recorded very often, they were observed superficially very regularly. It seems to the author that the description as given above (including the washing times involved and the amounts of water that were used) is a fairly typical description of the events at a washing place.

In the situation where people wash their clothes in the stream the risk of infection is probably higher due to the greater amounts of water involved. On these places, however, no quantitative observations were made.

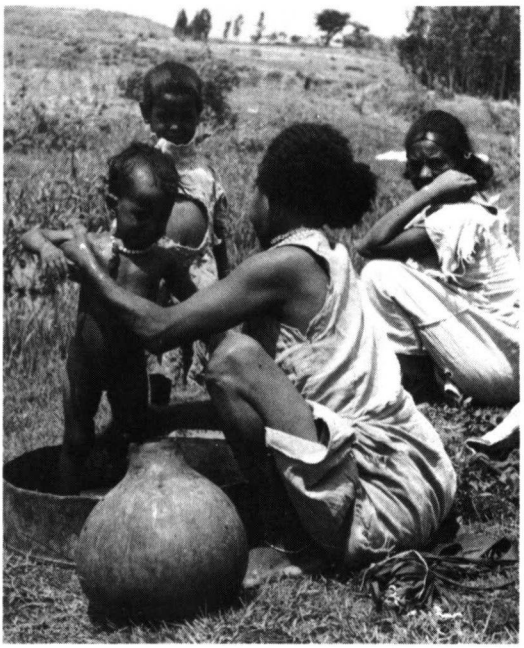


photo 29.
When the clothes are drying in the sun children may be washed.

photo 30.
Sometimes women and men wash their entire bodies in the stream.

5.3.2.3. Water contacts at home

In section 5.2. it has been shown that the household water that was stored in the local houses had not entirely lost its infectivity. The impact of this observation is entirely dependent on the way in which this water is used by the inhabitants. The household water is used for different purposes including washing clothes at home, washing hands before and after each meal (cutlery is unknown), washing face and hands early in the morning after getting up, brushing teeth with a little twig, preparing coffee, tea, and local beer (talla). The relative importance of these activities, the exposure times, and the actual risk to contract a schistosome infection at home are difficult to estimate.

5.3.2.4. Bathing and swimming

Sometimes people are observed while bathing their entire bodies in the streams (photo 30), but this activity does not seem to be performed very regularly by most persons. It is observed most often on Saturdays when the clothes that have been washed are drying in the sun. Then the women and children sit down in the bottom parts of the kerosene barrels or in the stream itself and are washed by their friends or mothers. Only few men were observed in the streams during washing activities. Inquiries were made on the habits of bathing but the answers appeared very unreliable.

Children sometimes go to the streams to swim and play in the water. Several schoolchildren (boys as well as girls) were considered to be good swimmers by their schoolmates, and one can only become a 'good swimmer'

when one has at least some training. Swimming is performed most often between September and December (the most dangerous months) because only then there is enough and temptingly clear water. Yet we did not observe these swimming children very often.

In adults and in children the frequent religious bathings in the short month of Pagome (in September) might be of some importance. On five consecutive days all Christians are supposed to wash their whole body in the streams. These washings, however, are generally performed before 6 A.M. and only some children tend to come a little later. Since the infectivity of the water is very low in the early hours, this habit is not likely to be of major importance.

Since the frequencies of bathing and swimming are difficult to estimate, the importance of these activities in the transmission of schistosomes remains uncertain although it is hardly conceivable to be a factor of major importance.

5.3.2.5. Water contacts outside Chiwahit

Merchants and farmers and to a lesser extent the other inhabitants as well will be exposed from time to time to infested water in the neighbourhood of Chiwahit. Farmers, when ploughing their fields, often wash their feet in the little streams between their plots of land and their houses in Chiwahit. Some merchants travel around in the area visiting the weekly markets in Kolla Duba, Gondar, Emfraz, etc. Often they stay overnight in those towns. Clearly they can become infected in those towns in which high infection rates were found (chapter 2).

Housewives and tallabrewers, craftsmen and clothmakers and probably also some others tend to visit the weekly markets in the neighbourhood once in a while for buying all sorts of goods. Quite regularly people travel around to visit relatives in the 'countryside'; they often stay with them for a few days.

The frequency of these trips, and the risk of exposure to schistosome infections are very difficult to estimate.

5.4. FAECAL POLLUTION OF THE WATER

In paragraph 3.3. it has been described that the number of latrines in Chiwahit is very limited. Most people prefer to defecate under the protection of the eucalyptus trees. In these places large amounts of faeces and accompanying flies can be found. On a smaller

scale this also holds good for the trees, prickly pear fences, and stone walls in the neighbourhood of the water collection places and washing places.

In the dry season the faeces dry out very quickly and the schistosome eggs, if present, will probably soon die (Chernin & Antolics, 1973). In the rainy period, on the other hand, the faeces remain moist for a long time. During the heavy rainstorms of July, August, and September these faeces, including the living *S. mansoni* eggs, may be expected to be washed down into the streams. There the escaping miracidia will probably infect the intermediate snail host.

In order to check this hypothesis rain water that flowed down the Chiwahit school - Chalguaye trail was collected and examined by a salt flotation method (18 August 1972). Twenty liters of this muddy 'rainwater' were left for sedimentation in a jerrycan for one hour. Most of the supernatant was poured off and the remaining 1½ liters were filtered over nylon mosquito gauze and a double layer of cheesecloth respectively. Following sedimentation in conical glasses, decanting of the supernatant, centrifugation (1½ min. 2000 rpm) and decanting of the supernatant again, the sediment was shaken with a saturated NaCl solution. The flotate was examined on six slides. The results are presented in table 5.1.6.

Table 5.16.

Microscopical examination of rainwater flowing down from Chiwahit into Chalguaye stream

1st slide:	1 hookworm egg
	10 hookworm larvae (early stage rhabditiform larvae)
	1 hookworm larva (late stage rhabditiform larva)
2nd slide:	10 hookworm larvae (early stage rhabditiform larvae)
3rd slide:	8 hookworm larvae, (early stage rhabditiform larvae)
4th slide:	4 hookworm larvae, (early stage rhabditiform larvae)
	2 Ascaris lumbricoides eggs
5th slide:	no eggs, nor larvae,
6th slide:	no eggs, nor larvae.

Only very few *Ascaris* eggs and no *Trichuris* or *Schistosoma* eggs were found. This is probably due to the procedure that was used. The important observation, however, is the abundant presence of hookworm larvae which suggests an intense faecal contamination of the water flowing into the streams. The observations on the seasonal fluctuations of the numbers of infected snails (chapter 4) and our attempts to explain these seasonal variations (par. 4.3.2.) are supported by the present observations.

Our attempts to infect 'clean snails' with the rainwater that flowed down from the town into the streams failed due to technical problems in breeding snails in the laboratory.

5.5. RESERVOIR HOSTS

Due to lack of time no systematic search for reservoir hosts was aimed at. The grass rat (*Arvicanthis niloticus*) which is known to be highly susceptible to *S. mansoni* infections in the laboratory can be found in such overwhelming numbers in the area that we could not resist a brief examination of their role as possible reservoir host. According to fairly old literature (Kuntz & Malakatis, 1955; Gear et al., 1966) the grass rat has not been found naturally infected. Only recently natural infections of grass rats have been described in Egypt (Mansour, 1973).

In March and June of 1972 thirty seven grass rats were trapped along the AmbaZena and the Atakelt stream (near Jenda). The examination of faecal specimens from the colon of 10 rats revealed 52 *Ascaris lumbricoides* eggs, 12 *Trichuris trichiura* eggs, and 5 *S. mansoni* eggs. Many of the eggs looked a trifle abnormal. Since many rodents use human stools as a part of their diet, these eggs may have been produced by parasites of the human host. All 37 rats were dissected carefully. One rat harboured a male, and one harboured a female *S. mansoni* worm; the livers were not granulated.

So, in this area, *A. niloticus* appears to be a reservoir host of *S. mansoni*. The importance of this reservoir for the transmission of schistosomiasis, however, is probably small.

5.6. THE OCCURRENCE OF SCHISTOSOMA BOVIS

The occurrence of *S. bovis* is of considerable importance to any study in which serological tests are used as a tool for *S. mansoni* diagnosis since cross reactions are commonly found.

It has been mentioned (chapter 4) that snails of the *Bulinus truncatus* group have been found in Chigaro stream. *B. truncatus* spec. is known to be the intermediate host of *S. bovis* in Ethiopia (Lo, 1971). One hundred and fifty one samples of dung originating from about 50 cows and oxen were examined microscopically. In 120 samples (79.5 %) ova of *Fasciola* spec. were found. *S. bovis* eggs, however, were absent. This observation is not a guarantee for the absence of *S. bovis* from the area because light infections with a low egg production can easily be missed in the massive

amount of daily dung production (Lo, 1971; Terpstra, pers. comm.).
On some occasions a few *B.'truncatus'* were found to shed furcate cercariae. In mice that were exposed to these cercariae in the laboratory adult *S. bovis* worms developed, and typical *S. bovis* eggs were found in both liver and faeces. On one occasion a few *S. bovis* worms were recovered from mice that were exposed to the Chigaro stream (April 1971, preliminary exposure experiment).

Though present in the Chigaro, *S. bovis* is probably not a very common parasite in the area since the snail host was only very rarely found and since the infection rate of cattle was apparently low or even absent in Chiwahit.
Although the presence of *S. bovis* infections in the area indicates that the results of the I.F.A. tests shouls be interpreted with care, the number of false positive I.F.A. tests due to cross reactions with *S. bovis* is probably very low since it is unlikely that a large proportion of Chiwahit population contracts a *S. bovis* infection while escaping a *S. mansoni* infection.

Though cercariae of other trematodes were produced by some specimens of *B. pfeifferi* that were caught around Chiwahit, these are not likely to produce cross reactions with *S. mansoni* (Lee & Berrios-Durán, 1973).

5.7. DISCUSSION

The main errors in the results of the mouse exposure are probably caused by the premature death of exposed mice and by the fact that the small and slender female worms that are recovered from unisexual infections in mice, can easily be overlooked at perfusion. In the authors opinion, the experiments were performed properly and satisfactory results were obtained though the numbers of mice were fairly small.

The accuracy of the observations on the human behaviour was much poorer. Among children the religion cannot easily be recognised and the estimation of the age is always very difficult and unreliable. Often male water carriers do not participate in the actual collection of water. Moreover, the calculation of the water-collection frequencies and cloth washing frequencies was based on the numbers of people (per category) that are living in town. These numbers are not known, but they had to be estimated. In some cases we will have over-estimated these numbers, in other cases they will have been underestimated. In spite of these approximations and errors it is thought that the observations produce a

useful description of the people's behaviour as far as contact with (infested) water is concerned.

In the first part of this chapter it has been shown that the infectivity of the streams around Chiwahit was high at some times of the year at some particular places. Washing clothes, requiring prolonged exposure times, and probably resulting in the most efficient transmission of schistosomiasis, is only performed by a relatively small number of people, each week, and probably it is the same individual women who wash clothes regularly whereas others do so only very rarely. Fetching water, on the other hand, is done by a large proportion of the population.

The relative importance of the exposure time and the cercarial density in the transmission of *S. mansoni*, was discussed by Upatham and Sturrock (Upatham and Sturrock, 1973). The results of their laboratory experiments (exposing white mice to *S. mansoni* cercariae shed by *B. glabrata* from St. Lucia) suggested that "exposures of less than 1 minute carry little risk of infection at low cercarial concentrations. Repeated exposures will probably not increase the risk substantially, and it will only rise if the cercarial concentrations rise". They mentioned the observations that fiels cercarial concentrations were generally low on St. Lucia. "It therefore seems reasonable to infer that for most of the year on St. Lucia, fording and collecting domestic water are activities of little importance in the transmission of *S. mansoni*. Washing clothes, bathing and swimming (....) are probably much more important".

For Chiwahit this view on the transmission of schistosomiasis would suggest that the washing of clothes will be the most important activity all through the year. During the months September-December, however, when the cercarial concentrations may become very high in certain places, also brief contacts with infested water (for instance while collecting water) may be of great consequence in the transmission of *S. mansoni*. For those who fetch water and who regularly wash their clothes as well, the latter activity will certainly be of greater consequence to the transmission of schistosomiasis, but those who are not frequently exposed for prolonged periods of time may become infected while fetching water (at least during certain periods of the year).

On St. Lucia it has been shown that there is a close correlation between the prevalence of *S. mansoni* infections and the number of observed water contacts in each group expressed as a percentage of the total observation for each sex (Jordan, 1972). In Chiwahit, on the other hand, there is certainly not a clear correlation between the frequency of collecting water or the frequency of washing clothes and the infection rate (fig. 5.5. and 5.6.). The frequencies of collecting water and washing clothes are much higher in women

Fig. 5.5. Comparison of the frequency of collecting water and the infection rate in various categories of the population

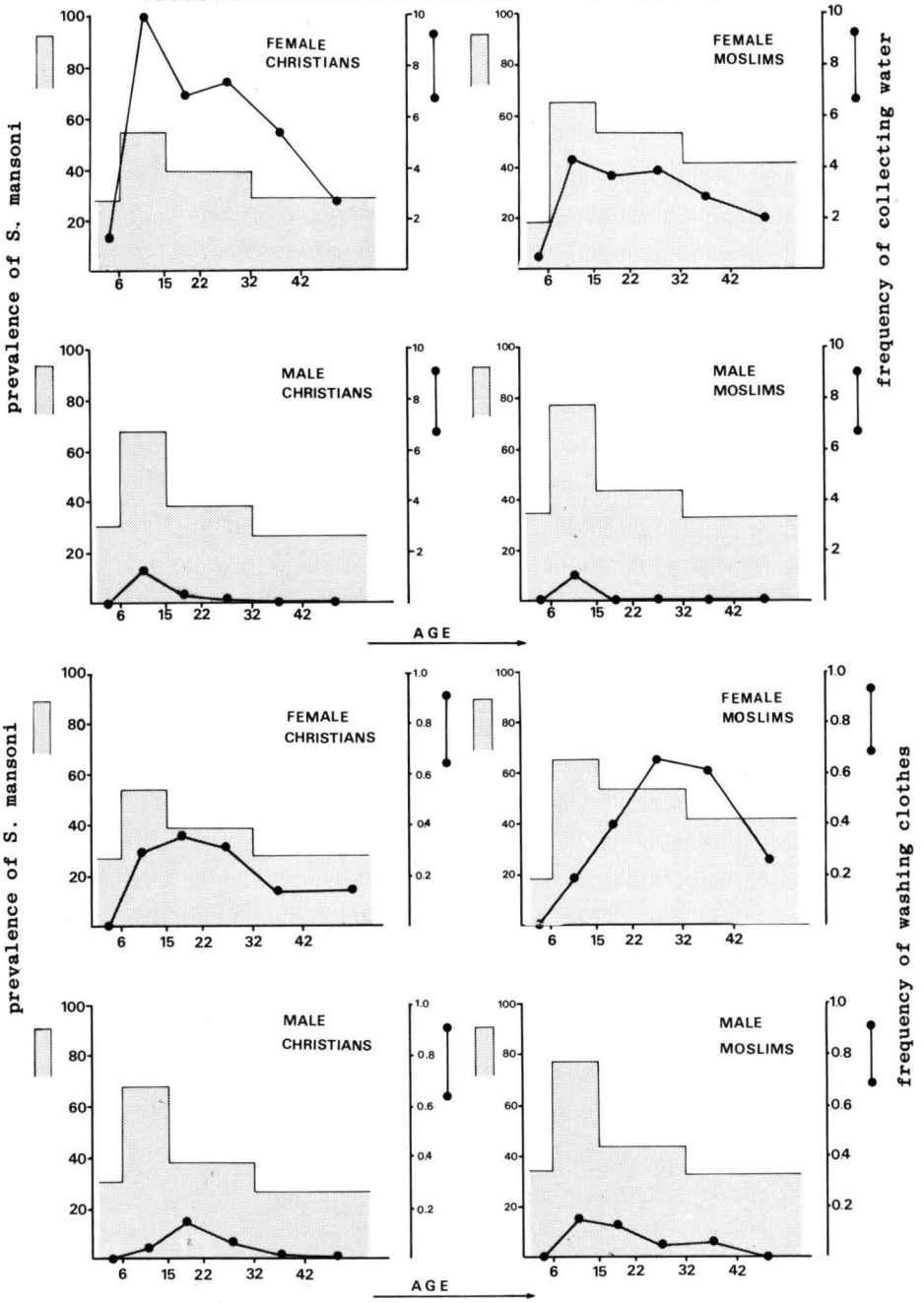


Fig. 5.6. Comparison of the frequency of washing clothes and the infection rate in various categories of the population

than in men; yet their infection rates do not differ very much. The peak prevalence in the age group 7-15 corresponds only vaguely with peaks in activities near infested water.

The water contacts inside the houses will not be of crucial importance to the women and girls who collect water, but for the old and disabled and for the babies who do not go cutside Chiwahit itself, the infested water that is stored inside the houses will probably be the only source of infection.

The exposures to infested water outside Chiwahit may certainly be of some importance but it has been shown that the prevalence of *S. mansoni* is comparatively high in Chiwahit itself. Most women who live in Chiwahit spend the greater part of their time in or around the town and their exposure time to infested water farther away from Chiwahit will certainly be comparatively short. For men, on the other hand, the relative importance of exposures outside Chiwahit may be more important: when coming back from weekly markets in the neighbourhood (e.g. from Chewa Duba on Saturdays) they often wash their bodies in little streams in the area beyond the scope of our observations.

Theoretically it is possible, of course, that the principal activities that determine the infection rate in people were missed in our observations. For instance, in par. 5.3.2.4. it was mentioned that schoolchildren do sometimes swim in the streams although we only observed them doing so on some very rare occasion, and when people wash their entire body they certainly try to escape the eye of a foreign scientist. So, without any doubt, our observations were incomplete. However, it is hardly conceivable that a major part of the exposures to infested water consisted of types of exposures which we failed to observe.

The absence of a correlation between the exposure to infested water and the infection rate as described in this chapter (and to some extent in chapter 3, chart 5) suggests that either the role of the present day exposure pattern is masked by the effects of former exposures, or the infection-pressure is such that even those subjects who do not often get exposed to the infested streams still have a fair chance to become infected. There is some evidence both for the former and for the latter explanation, and both explanations will probably be true, to some extent. In the general discussion (chapter 7) it is attempted to estimate the relative importance of both.

5.8. SUMMARY

In this chapter it has been shown that the infectivity of the streams around Chiwahit is generally low, but may become very high at some spots during certain periods. The seasonal fluctuations of the infectivity of the water as reflected by the numbers of infected snails (chapter 4) were confirmed by the regular exposures of sentinel mice to each of the streams.

Exposures of sentinel mice to cercariae from single infected snails revealed that most infected snails harbour more than one mother sporocyst. The mean number of mother sporocysts per infected snail was shown to be more than two, perhaps about four.

Adult *S. mansoni* worms could be recovered from mice that were exposed to household water that was stored in the local houses. The worm loads, however, were low. The possible impact of this observation on the epidemiology of schistosomiasis in this town was discussed(summarized in the fig. 5.5. & 5.6.).

The most important aspects of the people's exposure to infested water were observed and recorded but there appeared to be no correlation between the frequencies of collecting water or washing clothes and the infection rates in several groups of people.

A couple of grass rats (*Arvicanthis niloticus*) that were caught along the streams around Chiwahit and Jenda appeared to harbour adult *S. mansoni* worms.

It was shown that *Schistosoma bovis* is present in the area, but it does not seem to be very common.

CHAPTER VI SCHISTOSOMIASIS IN JENDA

6.1. INTRODUCTION

Most of the observations mentioned so far are based on fieldwork in one small town and its streams. Since several of our conclusions could not be tested thoroughly, a brief study of some aspects of the transmission of *S. mansoni* was planned in another community in the neighbourhood of Chiwahit.

In the course of chapter 3 it was shown that the population of Chiwahit was not nearly as stable as expected. The relationship between infection rate and age was affected by the recent introduction of uninfected subjects from non-endemic areas whose history of contact with schistosomiasis was not known. The results of serological tests (I.F.A.T.) were thought to be of doubtful significance in older people and in recent immigrants whose histories were not known. The situation in Chiwahit, moreover, was complicated by the presence of people of many different occupations and by the presence of many Moslims in addition to the Coptic Christian majority.

In this chapter the results will be discussed of work that was executed in the rural area of Jenda.

6.2. THE LOCAL SITUATION

Jenda is a farmers village located about one hour's walk north west of Chiwahit. The altitude, temperatures, precipation and soil type are the same as in Chiwahit. The old village used to be a stronghold of the Falashas (the Ethiopian Jews). For that reason the 'Catholic mission to Jews' (British) established a mission on the other side of Atakelt stream (Kobela) in 1863. The tukuls of Jenda are scattered over a low hill that extends over several kilometers from east to west. The total number of inhabitants is not known to the author but will be between 500 and 1,000.

Most inhabitants were born in Jenda: often in the same group of houses in which they are still living. Out of the 117 males who answered our inquiry, 110 had lived in Jenda for more than 15 years; all boys under 15 were born in Jenda. Among females the figures were 139 and 121 respectively. The 'recent immigrants' (those who had lived in Chiwahit for less than 15 years) were excluded from our final sample.

photo 31. Jenda, an old farmers' village, a few kilometers off the main road.

The occupations that were met (according to our inquiry) among the 'former immigrants' and native people from Jenda are listed in table 6.1. In order to achieve a homogeneous sample the nine adults with 'other' occupations were not included in our studies.

The number of boys is fairly low. This is due to the fact that more boys than girls are living in Chiwahit or Kolla Duba to attend school, and to the continuous absence of many cowherd boys.

Some people in Jenda collect their household water from Atakelt stream, which is quite similar to the streams around

females	housewife	49
	others	5
	schoolchildren	12
	non-schoolchildren	36
males	farmers	61
	others	4
	schoolchildren	4
	non-schoolchildren	18
infants		42

Table 6.1. Occupations in Jenda

Among the 5 women who said they were not housewives, there were 2 tallamakers, 1 spinster, and 2 old women without profession. Among the 4 men who said they were not farmers, there were 3 weavers (all over 60 years of age) and 1 blacksmith.

Chiwahit and originates from a well near the east of Jenda. Others go to a well just south of Jenda or to another to the west. From a preliminary stool survey in Jenda we got the impression that the prevalence of *S. mansoni* was lower among people who visit either of the wells than among those who used the Atakelt for their water supply. This impression was confirmed by Dr. Hiatt, (pers. comm; report in prep.). For that reason only inhabitants from the houses that were situated close to Atakelt were studied in our survey, all of them admitting to use the Atakelt for their water supply.

All people that were subjected to our inquiry were Christians (there are hardly any true Falashas any more; they have all been converted).

There are no latrines in Jenda.

In summary, the sample on which the data in the following sections are based is a very homogeneous one: all people have lived in Jenda for many years, they are all Christians, they are all either a child or a farmer or a housewife, and they all use water from the same stream.

6.3. MATERIAL AND METHODS

1. Parasitological examinations

   Ritchie's method was used as described elsewhere (3.3.3., 3.3.4., and appendix 3). In this study of Jenda all stool specimens that were found to be negative for *S. mansoni* were examined once again with the same method (stool sample from the same day, concentrated separately).
2. Micro Immuno Fluorescent Antibody Tests were performed as described in par. 3.3.6. and appendix 4.
3. Physical examinations on a subsample of 130 subjects were done by Prof. Ch. Leithead from the Medical Faculty of the H.S.I.U. in Addis Ababa.
4. The snail surveys were performed in the same way as described in par. 4.2. Ten pools were chosen for regular snail collections.
5. Mouse exposures were performed as described in par 5.2. Each day one group of mice was exposed to 2 pools: 30 minutes in each pool. As in the streams around Chiwahit, the total exposure time per group was 5 hours.
6. Observations on man's contact with infested water were not made for two reasons: 1. the water-contact patterns of farmers is difficult to study, 2. there is not one well-defined entry to the streams since the village is not located above the spring but parallel to the Atakelt.

parasite	% positive
A. lumbricoides	36.5
S. mansoni	68.9
T. trichiura	3.2
S. stercoralis	1.4
Hookworm	1.8
others	4.5

Table 6.2. Prevalence of helminth infections

6.4. PARASITOLOGICAL EXAMINATIONS: RESULTS AND DISCUSSION

In comparision with the results for Chiwahit the infection rates of *T. trichiura* and to a lesser extent of *A. lumbricoides* are remarkably low. This difference might be caused by the greater concentration of people and their garbage and faeces in Chiwahit. However, the prevalence of *S. mansoni* is higher in Jenda. The numbers of people that were studied in Jenda were too small to permit an analysis of the correlation with the several factoors of possible importance as given in the charts of chapter 3. Instead the results will be summarized in a few histograms and tables.

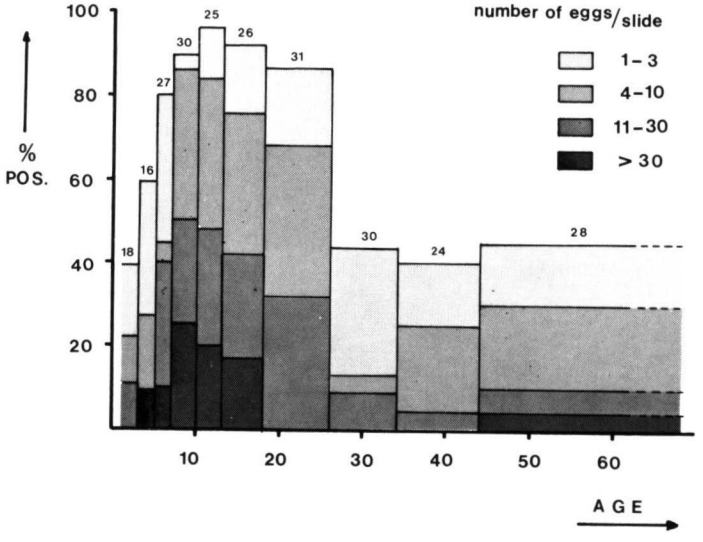


Fig. 6.1. **S. mansoni** *infections in different age-groups (Jenda)*
The figures on top of the histogram indicate the sample size per age-group.

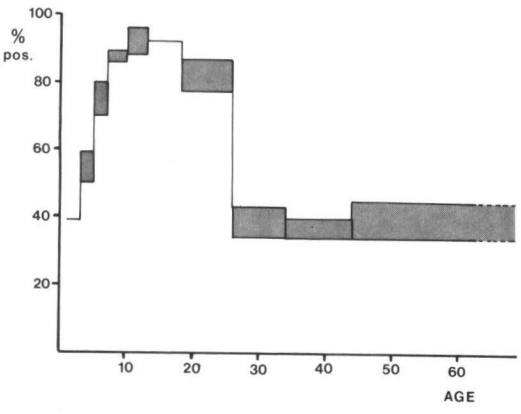


Fig. 6.2.

Age-prevalence histogram
The shaded parts depict the samples that were negative on first examination but positive on second examination.

Table 6.3. Infection rates in different age classes for males and for females

Age	females		males		total	
	numbers	%	numbers	%	numbers	%
1- 6	(9/20)	45.0	(13/24)	54.2	(22/44)	50.0
7-15	(46/51)	90.2	(27/29)	93.1	(73/80)	91.3
16-32	(14/27)	51.9	(26/26)	100.0	(40/53)	75.5
> 32	(7 /19)	36.8	(11/26)	42.3	(18/45)	40.0

Table 6.4. Comparison of the infection rates in Jenda and Chiwahit
1): all groups of immigrants,
2): those who have lived in Chiwahit for 5 years or more.

		Age	Jenda		Chiwahit		
				% pos.		% pos.	
males	infants	1- 6	(13/24)	54.2	(39/124)	31.5	1)
	boys	7-15	(27/29)	93.1	(141/179)	78.8	2)
	farmers	16-32	(26/26)	100.0	(5/ 12)	44.4	1)
	farmers	> 32	(11/26)	42.3	(6/ 21)	28.6	1)
females	infants	1- 6	(9/20)	45.0	(40/160)	25.0	1)
	girls	7-15	(46/51)	90.2	(68/118)	57.6	2)
	housewives	16-32	(14/27)	51.9	(25/ 63)	39.7	2)
	housewives	> 32	(7/19)	36.8	(14/ 54)	25.9	2)

Comparision of fig. 6.1. with fig. 3.3. shows that in Jenda the peak prevalence is higher and that the infection rate of *S. mansoni* remains higher in older age groups. This difference is partly due to the fact that in Jenda all negative stools were examined a second time. In fig. 6.2. the data on the age-specific infection rates are given for the first examination separately. The age-specific infection rates for males and females separately are given in table 6.3.
The numbers of schoolchildren are too small to compare the infection rate of schoolchildren with the infection rate of children who do not attend school.

A comparison of the infection rates in the occupational groups of housewives and farmers is identical to the comparison of females and males (older than 15 years of age) (table 6.4.). The statistically significant difference in the infection rates of housewives and farmers is difficult to interpret: as pointed out elsewhere the water contact behaviour of farmers can not easily be studied.

The difference between the infection rates of *S. mansoni* in Chiwahit and Jenda is partly but not entirely due to minor differences in the techniques. To some extent the abundant presence of recent immigrants in Chiwahit may explain the difference. Behavioural factors are not likely to be of great importance since the occupations of the housewives and of the farmers are quite similar in Chiwahit and Jenda. Among non-schoolchildren the way of life is also very similar in the two places. It might be of importance that the Atakelt stream is closer to most houses in Jenda than the Chalguaye, AmbaZena and Chigaro are to Chiwahit.
Another factor that might be of crucial importance is the infectivity of the water. In the following paragraphs, however, it will be shown that there are not more snails in the Atakelt than in the Chalguaye, and that the infection rate among snails in the Atakelt was not higher than in the streams around Chiwahit. Exposures of sentinel mice to the Atakelt suggest that the infectivity of this stream is certainly not higher than the infectivity of the streams around Chiwahit (observations in 1972) (par. 5.2.2.1. and par. 6.7.).

So again, we fail to understand why the infection rate in one group of people (Jenda) appears to be higher than in another group of people (Chiwahit).
Again we get the impression that the infection rate of *S. mansoni* in man cannot be predicted on the basis of a mere multiplication of chances as proposed in several mathematical models.

6.5. SEROLOGICAL EXAMINATIONS; introduction, results and discussion

The use of serological diagnosis of *S. mansoni* infections in epidemiological surveys has been the subject of contradictory opinions. In some cases infections that could not be diagnosed with parasitological methods were easily found with serological tests. Laboratory experiments and routine examinations of patients' sera (e.g. in the Laboratory of Parasitology, Leiden) have shown a high specificity and sensitivity of the test (Ambroise Thomas, 1969; Bruijning, 1965; Deelder, 1973). In the epidemiology of schistosomiasis, however, this test has not been used very often. This is partly due to the high rates of cross reactions with animal schistosomes that were sometimes found (Sadun & Biocca, 1962; Blackburn and Ma, 1970).

In areas where *S. bovis* is absent more reliable results may be expected. Clarke, in Rhodesia, has used the I.F.A. test in addition to a skin test and a stool examination method. Following a peak prevalence at the age of about 20 years, the prevalence declined in older age groups according to the stool examinations; in the skin tests it remained at the same very high level, while it went down slightly in the I.F.A. test (Clarke, 1966). No antibody titers were determined in this study and the specificity of the method was not tested.

The I.F.A. test has been reported to be sensitive and easy to perform in the Gezirah area, Sudan (Ambroise-Thomas et al, 1972), but the number of specimens examined was very small in this study, and the specificity was not tested.

In a recent dissertation (Tewarie, 1972), a good correlation between the results of stool examinations and of I.F.A. tests was found for human stool specimens and sera from Surinam.(The I.F.A. tests for this study were performed at the Laboratory of Parasitology, Leiden).

In St. Lucia, on the other hand, the rates of false negative I.F.A. tests were very high (18 %-37 %) (Warren et al, 1973), and in Ethiopia too, the I.F.A. test has produced very poor results: "In contrast to other tests where the results of immunologic procedures and stool examinations were closely associated, the reactions of the fluorescent antibody tests were independent of the presence or absence of *S. mansoni* eggs in the stool specimens of the individuals tested." (Buck et al, 1964).

It has been described that significantly raised antibody levels as detected with the I.F.A. test may persist for a considerable time (Ambroise Thomas, 1969). This is only partly due to the long life span of the worms. In a comparative study of the antibody response of the various specific classes of antibodies it has been shown for malaria infections in human volunteers (Collins et al, 1971) that the IgG

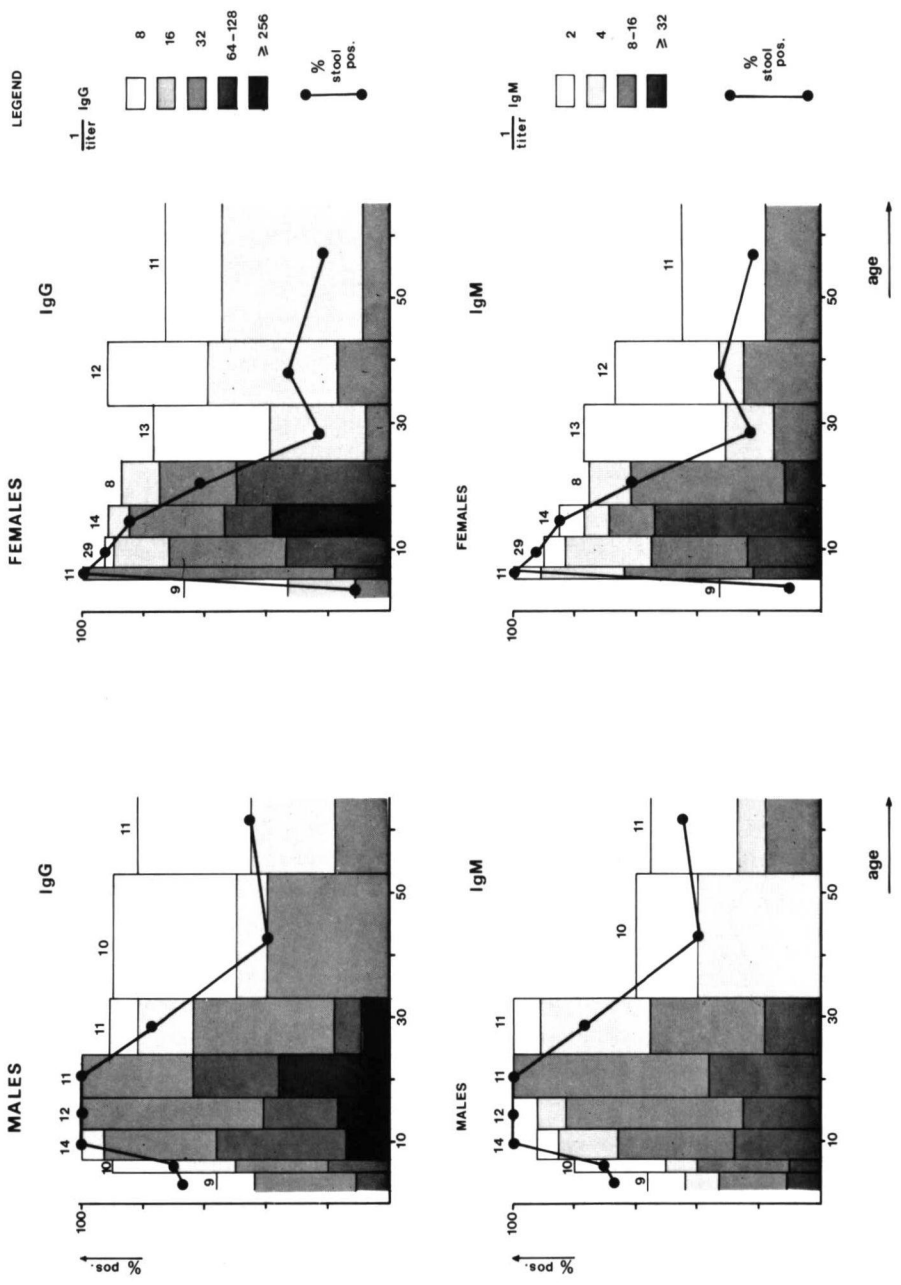


Fig. 6.3. The IgG-, and IgM-titers in I.F.A.-tests on 195 human sera from Jenda

response rose to the highest level and persisted for the longest time. The IgM response was more transient and returned to near inoculation levels in a relatively short ime. For schistosomiasis very few data on specific IgM titers are available. Deelder compared the results of the I.F.A. technique with specific antisera in experimental mouse infections and in a group of 20 human sera (Deelder, 1973; Deelder et al, 1975, in press). In the experimental mouse infections the IgM titer was not a transient one but the experiment had to be discontinued 22 weeks post infection.

In Jenda the I.F.A. test was not used as the principal diagnostic tool but rather as a way to achieve a better understanding of the results of the stool examinations. We did not aim at a correct diagnosis for individuals.

For sera from Jenda both an anti heterologous pooled IgG, and a specific anti IgM conjugate were used in the I.F.A. tests. The results are summarized in the figures 6.3. and 6.4. In both figures the results are compared with the results of the parasitological examinations on the same individuals.

The question of the lowest titer that may still be considered to represent a specific response is subject to discussion. Laboratory experience with the I.F.A. tests (performed in the same way, with the same conjugates) suggests that this critical titer is somewhere between 1/8 and 1/16 for pooled IgG (Laboratory of Parasitology, Leiden, pers. comm.). Ambroise Thomas, using the same method but a different conjugate found the same critical levels (1/10; Ambroise Thomas, 1969). According to the experiments of Ambroise Thomas the rate of false positive reactions is about 5 %. In routine examinations in the Laboratory of Parasitology in Leiden false positive reactions on patients' sera are extremely rare (Mr. de Vries, pers. comm.).

From an epidemiological point of view it may sometimes look like an arbitrary choice to consider 1/8 rather than 1/16 as the critical titer. For a correct appreciation of the situation in the older people, however, the question is more acute since a high proportion of these people shows titers of 1/8 and 1/8-1/16. In table 6.5., therefore, the results of both parasitological and the IgG and IgM determinations are compared for those individuals in whom low titers or no *S. mansoni* eggs were found.

If a titer of 1/8 is still considered as 'positive', 8 out of 135 (5.9 %) parasitologically confirmed positive cases were negative in serological examination (IgG). Out of the 66 stool negatives, definitely positive I.F.A. tests (titer 16) were found in 28 subjects. In 6 cases a titer of 1/8-1/16 was found, and in 13 cases the titer was 1/8. The remaining 19 stool negative subjects were also negative upon serological examination.

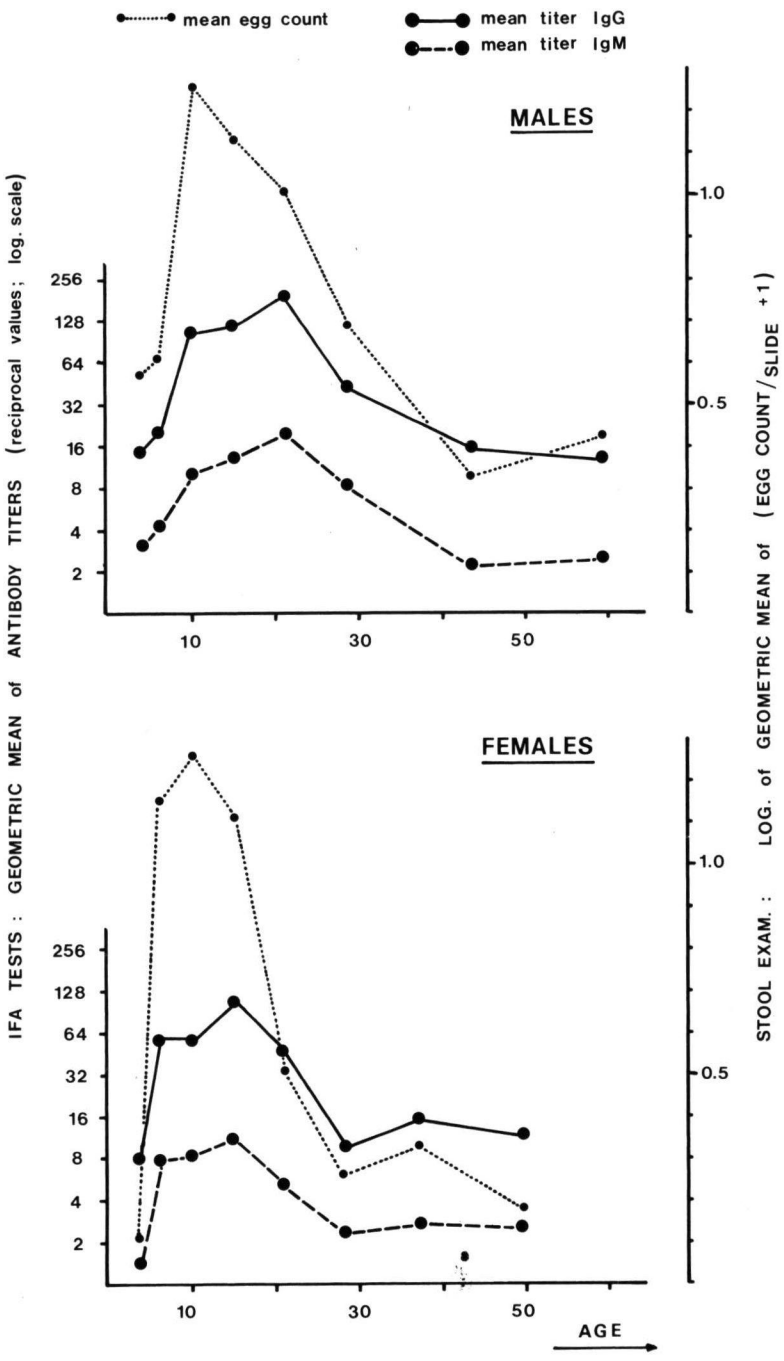


Fig. 6.4. Mean titers for IgG and IgM, and mean egg counts for the same persons

Since low numbers of eggs may easily be missed in parasitological examinations, and since infections with male or female worms only will never be detected by stool examination methods, a high rate of positive serodiagnoses may be expected among 'stool negative' subjects.

From the results presented in table 6.5. it may be concluded that the interpretation of titers of 1/8 remains questionable but that probably the majority of 1/8-titers represent specific antibody responses to past or present infections of *S. mansoni*.

The possibility of false positive reactions due to cross reactions with *S. bovis* has been discussed in par. 3.5.2. There it was explained that these cross reactions will probably not be a factor of great significance in the area of Chiwahit. In Chiwahit some intermediate host snails of *S. bovis* were found but in the neighbourhood of Jenda we never found any *B.'truncatus'*.

High titers (IgG) were most often found among high egg excreters and low titers mainly in subjects among whom no or only few eggs were found. The correlation between the IgG titer and the egg count is given in fig. 6.5. (coëfficient of correlation after logarithmic transformation: 0.55). Since both egg counts and titers show peak levels in the same age classes (fig. 6.3., 6.4.), it is not surprising to find a positive correlation between egg count and IgG-titer. Probably this correlation does not represent a causal relationship between egg count and titer.

The problem of the interpretation of the large numbers of very low titers in older people (that will probably mean: 'in chronic infections') has also been encountered in other studies. In a recent investigation of the epidemiology of fasciolasis in Peruvian children (Stork et al, 1973) I.F.A. tests on a number of sera were performed by Capron. In spite of the well-established procedure of serodiagnosis of fasciolasis (Coudert et al, 1967), a complete lack of correlation between the I.F.A. tests and the stool examinations was found. One explanation for the "somewhat erratic serological results" is - according to the authors - the fact that "we are dealing almost entirely with a chronic fasciolasis problem: a situation which contrasts strongly with human fasciolasis in Europe". (N.B.: only children up to 15 years of age were included in the sample !). In schistosomiasis, too, the stage of the infection (acute or chronic) will probably have its bearing on the sensitivity and specificity of the I.F.A. test. No hard data (except some circumstantial evidence) are available on this subject.

The figures 6.3. and 6.4. show that the age-titer relationship for IgM is quite similar to the age-IgG histogram. However, the titers are lower and the rate of false negatives is higher (even when a titer of 1/2 in considered to be the last specific

Table 6.5. Comparison of the results of coprological and serological tests for those persons in whom one of the tests was negative or only slightly positive

STOOL TEST : POSITIVE ; I.F.A.T. : NEGATIVE OR TITER VERY LOW

MALES				FEMALES			
Age	Egg-count	Titer IgG	Titer IgM	Age	Egg-count	Titer IgG	Titer IgM
3	1	NEG	2	3	9	8	2-4
4	8	8-16	4	4	1	32	2-4
5	6	32	NEG	5	4	8	NEG
6	3	(8)	2-4	9	75	8	2
6	3	16-32	2-4	12	3	NEG	NEG
6	55	32	2-4	16	3	8-16	4-8
7	4	8	8	16	5	NEG	NEG
8	13	16	(2)	20	6	32	NEG
10	5	128	2-4	25	9	NEG	2
16	18	32	(2)	32	30	8	2-4
28	12	8	4-8	50	6	16-32	NEG
40	5	32-64	2-4	60	13	16	NEG
45	4	8	4				
50	5	(8)	NEG				
55	3	(8)	(2)				
60	6	16	2-4				
64	1	(8)	NEG				

STOOL TEST : NEGATIVE

MALES			FEMALES					
Age	Titer IgG	Titer IgM	Age	Titer IgG	Titer IgM	Age (cont.)	Titer IgG	Titer IgM
4	NEG	NEG	3	16	2	30	8-16	NEG
4	NEG	NEG	3	8	NEG	30	16	8
5	NEG	NEG	3	NEG	NEG	30	16	4
6	16	(2)	3	NEG	NEG	30	8	4
7	16-32	(2)	4	16	NEG	32	8	2
7	NEG	NEG	5	(8)	2	32	8	2
27	32	NEG	5	8-16	(2)	34	16	2
33	16	8	6	16	NEG	35	NEG	NEG
34	32	(2)	8	32	2-4	40	16	2
35	NEG	NEG	8	NEG	NEG	40	8	NEG
38	16	NEG	15	16-32	2	40	8	NEG
40	32	4-8	17	16-32	(2)	42	8	2
42	8-16	4	18	NEG	NEG	47	NEG	NEG
49	8-16	NEG	19	64	16	47	16-32	2-4
50	8	2	20	16	2-4	48	16	8
60	8	NEG	20	NEG	NEG	50	8-16	2
63	64	4	24	16	4	50	16-32	NEG
66	NEG	NEG	25	NEG	NEG	52	NEG	NEG
68	8-16	2-4	25	(8)	NEG	70	64	8
70	8	(2)	25	NEG	2	85	NEG	NEG
72	8	(2)	26	16	2	85	8	2
			27	16-32	2-4	35	8	2
			30	32-64	2			

titer, which is too optimistic). In fig. 6.6. the correlation between the IgG and the IgM titers is plotted graphically (coefficient of correlation between log. IgG and log. IgM: 0.81). Analysis of the outliers shows that there is no common characteristic that might explain the comparatively high or low values of those particular individuals.

So, in this type of study in this area, the use of specific anti IgM antiglobulins does not seem to offer any advantages.

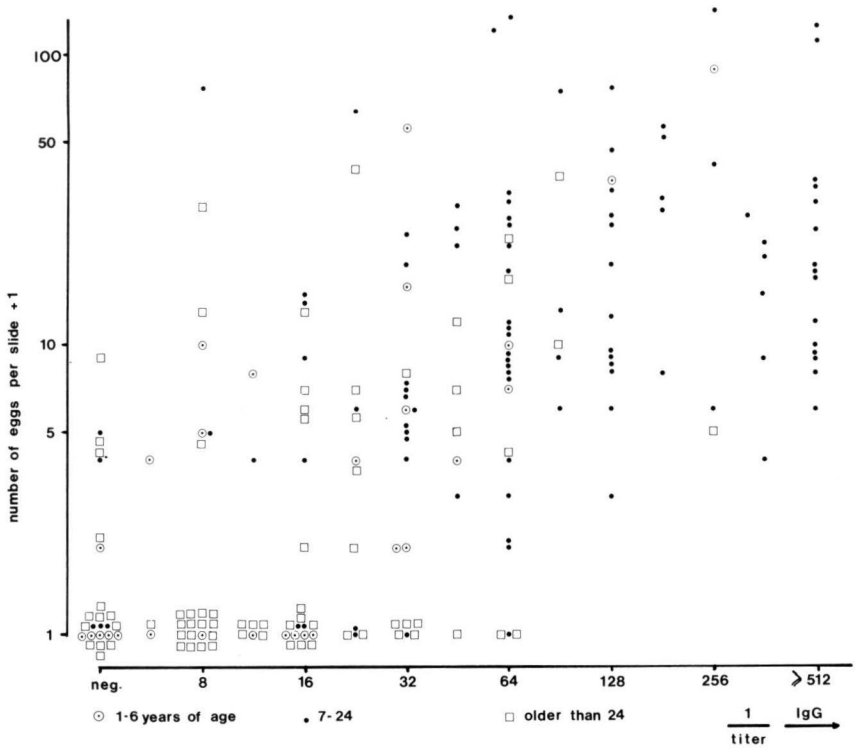


Fig. 6.5. Correlation between IgG titer and egg count/ slide of 195 human sera

According to the experience in the Laboratory of Parasitology in Leiden, the error in the readings of the IgG titers is generally less than ± one titer. Though the experience with IgM titrations is limited, roughly the same will apply to these serological examinations. The errors are likely to be bigger in low titers (around 1/8 for IgG, and around 1/2 for IgM). On each test slide, however, a confirmed negative serum was tested in the critical dilutions of 1/8 for IgG, and 1/2 for IgM. Moreover a known positive serum was tested every time again at the last 'positive dilution' of that specific positive control serum (e.g. 1/128 for IgG, and 1/32 for IgM). In this way the readings of the test sera were fairly well standardized (Besides, it became clear from the readings of the positive control sera that the titer of the controls did not vary more than about one dilution).

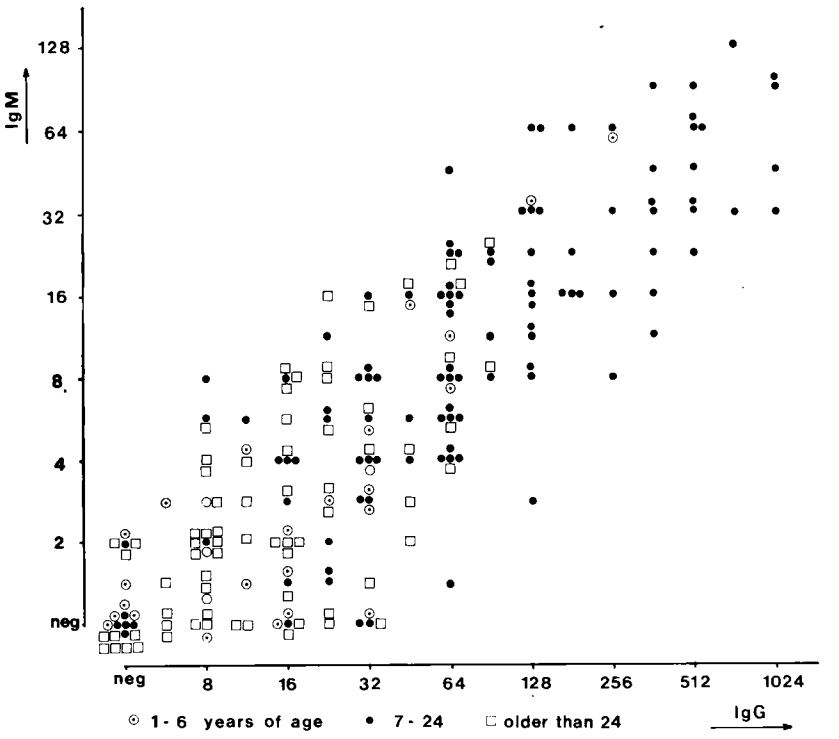


Fig. 6.6. Correlation between IgG and IgM titers

6.6. PHYSICAL EXAMINATIONS: Results and discussion

Though we were aware of the great difficulties that are generally met in the assessment of the public health importance of schistosomiasis, it was attempted to achieve a preliminary impression of the possible rate of complications due to liver involvement in intestinal schistosomiasis. With the kind assistance of Prof. Leithead from Addis Ababa, 152 of the subjects, whose stools were screened for *S. mansoni* eggs previously, were subjected to a physical examination.

Out of the 152 persons the general appearance of 11 was described as 'miserable' (7.2 %). A splenomegaly was noted in 5 cases. Though malaria occurs in the area (mainly during the rains) the blood smears were all negative for these parasites. In 54 subjects a hepatomegaly was noted. The age and sex distributions of these persons are given in table 6.6.

The high rate of hepatomegalies in older males (older than 32) is mainly due to the rate in the very old men (older than 55). All but one of them had an enlarged liver. To a lesser

Table 6.6. Hepatomegaly rates among inhabitants of Jenda

+: liver slightly enlarged (just palpable to one fingerbreadth below the lower costal margin at exhalation).

++: liver enlargement more pronounced (2-4 fingerbreadths).

	MALES				FEMALES			
age	sample size	hepatomegaly +	hepatomegaly ++	% hepato-megaly	sample size	hepatomegaly +	hepatomegaly ++	% hepato-megaly
1- 6	15	1	2	20	16	4	1	31
7-15	9	2	1	33	35	11	7	51
16-32	18	2	4	33	21	2	4	29
> 32	19	6	3	47	17	3	1	24

Table 6.7. Some characteristics of the subjects with splenomegalies and/or gross hepatomegalies

Sex	Age	number of *S. mansoni* eggs	IgG titer	IgM titer	general appearance	splenomegaly	hepatomegaly
M	2	7	-	-	'fair'	no	yes (3 f.b.)
M	6	0	16	Neg.	'miserable'	yes	no
M	18	13	-	-	'good'	yes	yes (4 f.b.)
M	21	3	32	8	'good'	yes	yes (1 f.b.)
M	66	0	Neg.	Neg.	'fair'	no	yes (3 f.b.)
F	12	10	64	32-64	'good'	yes	yes ($3\frac{1}{2}$ f.b.)
F	25	2	-	-	'good'	yes	yes ($3\frac{1}{2}$ f.b.)

Table 6.8. Hepatomegaly rate and the presence of **S. mansoni** *eggs*

numerator: number of hepatomegalies; denominator: number of subjects per group.

		Results of stool examination	
		eggs present	no eggs present
Hepatomegaly rate	Males	11/33	4/16
	Females	21/47	11/34

extent the age group 33-43 contributed to this high hepatomegaly rate. Since considerable amounts of local beer (talla) are consumed by men, this hepatomegaly rate in older men is thought more likely to be due to this rather than due to schistosomiasis (Leithead, pers. comm., 1972).
The high rate of enlarged livers among girls (mainly in the ages 12-15) is remarkable and cannot be ruled out as being possibly caused by schistosomiasis. Some characteristics of the 5 persons in whom the liver came 3 or more fingerbreadths below the lower costal margin and/or in whom a splenomegaly was found, are summarized in table 6.7.

The lack of a clear-cut correlation between the presence of eggs and the hepatomegaly rate (table 6.8.) does not invalidate the notion that the enlarged livers may be caused by schistosome infections since present symptoms may well be the result of past infections. In this report it has been shown that both in Jenda and in Chiwahit almost everybody will have or has had contact with the infection.

In the age-group 4-54 there are too few individuals with a negative I.F.A. test to permit a comparison of the hepatomegaly rates and the I.F.A.T-results.

6.7. THE INTERMEDIATE HOST

From July 1972 until July 1973 regular snail surveys were performed in the Atakelt stream. As in Chiwahit all *B. pfeifferi* were checked for schistosome infections. In addition to large numbers of *B. pfeifferi* some *L. natalensis* and few *G. costulatus* were found. Not a single specimen of *Bulinus* spec. was found. The results of the counts of *B. pfeifferi* are summarized in fig. 6.7.
In this figure the histogram for the monthly precipitation is based on the observations in Chiwahit.

As in Chiwahit there were no clear-cut seasonal changes in the total numbers of snails. The variations in the monthly counts, however, were larger than in Chiwahit. Very many snails were found in the upper part of the stream, but far less or no snails were caught farther downstream (some 1200-1500 m downstream from the first pool that was checked every month). The seasonal fluctuations in the numbers and in the percentages of infected snails were similar to those in Chiwahit: the infection rates were fairly high in the period after the rains (September-December) and much lower otherwise (fig. 6.7.). As in Chiwahit a high infection rate was found in July 1973. This is in agreement with our hypothesis that the high infection rate at this unusual time of the year was caused by the early onset of the rains in 1973.

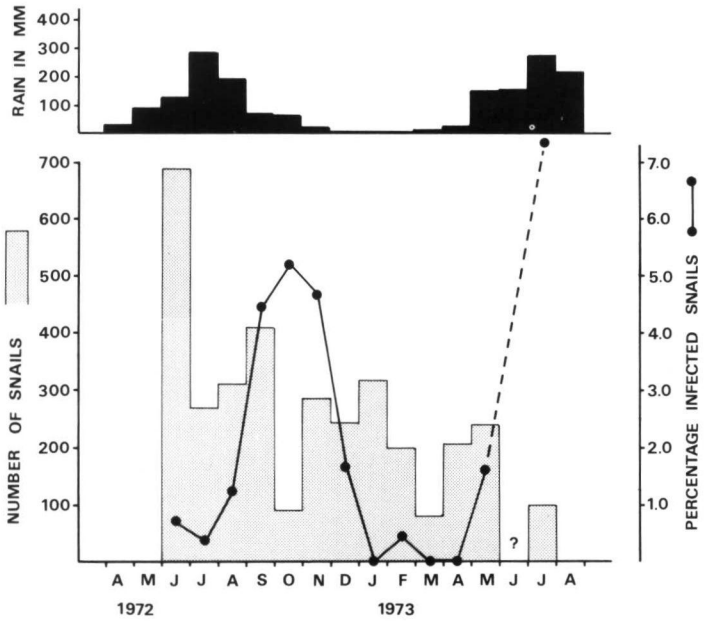


Fig. 6.7. Monthly numbers of snails and percentages of infected snails in Atakelt stream near Jenda

In 16 cases mice were exposed to cercariae from individual snails. *S. mansoni* worms were recovered from 11 mice while the remaining 5 had smooth livers. In three out of the 11 infected mice both male and female worms were recovered. This rate of multiple snail-infections is lower than for Chiwahit. The numbers of mice involved, however, are too small to permit a reliable comparison.

Unfortunately it was not possible to expose mice to the Atakelt regularly. The results of the three exposures that were performed are given in table 6.9. Compared with the results of the mouse exposures to the streams around Chiwahit, the infection rates and the wormloads are low; and the increase of the infection rate in the post rain period is less pronounced.

Table 6.9. Exposures of sentinel mice to Atakelt stream

date	number of mice	number of mice harbouring S. mansoni worms at perfusion.	total number of worms recovered at perfusion.
22/5-26/5	12	3	4
25/8- 1/9	14	3	5
6/11-10/11	10	5	15

6.8. SUMMARY

In this chapter it was attempted to test the results of the parasitological, serological, and malacological studies in Chiwahit, in another community. For this purpose the farmers village of Jenda was chosen.

The prevalence of *S. mansoni* infections was higher in Jenda but this difference could not be explained by religious or professional differences, nor by differences in the infectivity of the water supply in Jenda.

In Jenda more emphasis was put on the serological tests and on the physical examination of the subjects. In older people the geometric mean of the reciprocal antibody titers was much lower than in children (7-15 years of age). This was true both when an anti pooled IgG conjugate and when a specific anti IgM conjugate was used. Specificity and sensitivity of the I.F.A. tests were briefly discussed. Fairly high hepatomegaly rates were found; enlarged livers were most common among girls (7-15 years of age).

In the snail surveys and mouse exposure experiments the seasonal fluctuations in the numbers and percentages of infected snails were shown to be very similar to the seasonal fluctuations described for Chiwahit.

CHAPTER VII GENERAL DISCUSSION AND CONCLUSIONS

AIMS AND SET UP

In the introduction to chapter 3 a central theme of this study was formulated: 'How can we understand that this particular proportion of a certain population is infected ?' In the discussion of the same chapter (p. 78) it was stated that the age-prevalence relationship as presented in figure 3.3. might be explained with either a transmission related explanation or with an immunity related explanation. Both explanations may complement each other. A thorough analysis of the factors that determine the intensity of transmission was thought to be required to decide on the relative role of each.

In chapter 2 some characteristics of the endemic area as a whole were considered. In the chapters 4 and 5 some factors that are likely to determine the observed level of transmission were studied, and in chapter 6 observations were reported on the prevalence of *S. mansoni* in man and on the various factors involved in the transmission for another community (Jenda). Now it will be attempted to discuss some of the observations in the light of the other findings and to draw an overall picture of the transmission of schistosomiasis in Begemder province, and more particularly in Chiwahit and its neighbourhood, including Jenda.

MATHEMATICAL MODELS

Up till now an overall picture including coherent studies of all parts of the life cycle of *S. mansoni* has not been produced. Several mathematical models, however, have been proposed in order to create a framework within which particular investigations may find place. Some of these models attempt to cover the whole life cycle (MacDonald, 1965; Hairston, 1965-a; Goffman and Warren, 1970); others are only directed towards particular stages in the life history of the parasite (Hairston, 1965-b; Sturrock and Webbe, 1971). The limiting factors which govern the applicability of the models and the questions and problems for research that are posed by these models have been a guideline in our studies.

Basically, these models are multiplicative models: the intensity of transmission increases, and the infection rate and worm load increase proportionally when, for instance, the number of infected snails increases, or when the duration of man's exposure increases, while all other variables remain the same. Though this may be true in certain cases, the relationship is only likely to hold true within a certain set of conditions. The use of these models is severely impaired by the fact that we do not exactly know these limitations.

More recently another general theory on the regulation of parasite populations has been proposed (Bradley, 1972). The essence of Bradley's theory is: "to suggest that there are three types of way by which the upper limits of parasite populations are regulated: (1) by transmission; (2) at host population level, by immunological and pathogenic processes; and (3) at the individual host level by premunition and other partial immune responses". This theory does not primarily aim at a mathematical description of all events of the life cycle of the parasite. The implications of the concept of endemicity are discussed, and some remarks are made on the way of control: "the suitable control measures will depend on the type of parasite regulation". "Where regulation at the individual host level predominates, attack on the cycle will require much effort before any returns are gained. Under these circumstances (...) an immunizing approach is more promising...".

In the course of this report a series of observations has been described in which repeatedly the prevalence of infection failed to be related to the apparent intensity of the factors causing transmission. Below some examples will be discussed briefly.

ENDEMICITY AND TRANSMISSION OF *S. MANSONI*

In chapter 2 it was shown that the infection rates among children were zero or very low in 15 communities 1), and high (55-89 %) in 12 communities. In only 5 cases were moderate infection rates found (17, 18, 18, 39, and 46 %). The frequency distribution of the percentage infection

note 1) Very low infection rates are always difficult to interpret: importations from elsewhere can never be excluded in those cases.

rates of all 32 communities that were studied is depicted in fig. 7.1.

Statistically, all of the 12 'highly endemic' communities as well as one of the 'moderately endemic' communities may be considered to be repre-

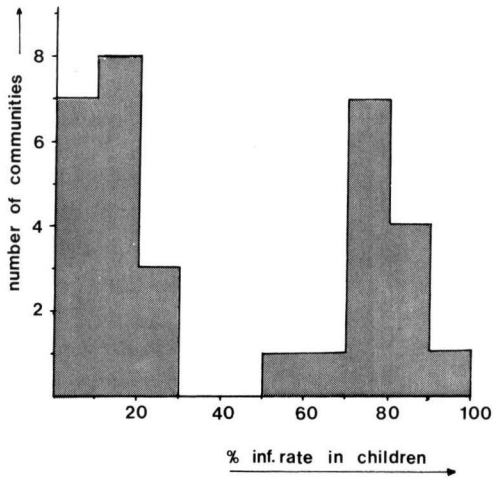


Fig. 7.1. Frequency distribution of the infection rates among children in the communities that were surveyed.

The figure is based on the percentage infection rates after correction for the different Recovery Potentials for both methods used (see chapter 3).

sentatives of one homogeneous population of endemic communities with a mean prevalence of 78 % (according to our methods, and after correction for the Recovery Potential of both methods used) ($p < 0.05$).

A similar non-homogeneous distribution of the infections in even smaller areas has been described for *S. haematobium* in Zanzibar (Forsyth & MacDonald, 1966), and for *S. mansoni* in Surinam (Bruijning, pers. comm.).

Yet, the intensity of transmission was by no means identical in all communities: near Chiwahit, Jenda, Aberdja, Gella Duba, Sakalt, and Chenkela, small streams with abundant snail populations were encountered. In more detailed studies in Chiwahit and Jenda many infected snails were found in that type of stream (chapter 4). Near other communities (e.g. Kolla Duba, Azozo, Addis Alem, Gorgora) snails could only be found during some (short) periods of the year. Infected snails were only found

near Addis Alem. Thus, even great differences in the numbers of snails and in the numbers of infected snails in the various parts of the area are not reflected in differences in the prevalence of *S. mansoni* in children in these communities.

Bradley, in his generalized theory (Bradley, 1972), predicts this type of observation and explains: "Transmission may vary greatly over an area but if all over it infection is maintained at such a level that regulation is at host population or individual level, than a study of infection in these hosts may give a homogeneous picture".

INTENSITY OF TRANSMISSION IN CHIWAHIT

Differences in the intensity of transmission were studied more carefully in Chiwahit, comparing characteristics of various groups of the population. Though a very careful approach and alertness for the risk of cross reactions with animal schistosomes (*S. bovis* !) are required, the I.F.A. tests have supplied us with some additional information with respect to the numbers of infections (either present or of the 'recent' past) that were missed (and partly had to be missed) with our stool examination methods. In paragraph 3.5.2. and fig. 3.8. it has been explained that the I.F.A.T.-results are not necessarily in conflict with the parasitological findings. The high I.F.A.T.-prevalence that was found in our study indicates that in Chiwahit and Jenda almost everybody, whether tailor or tallabrewer, whether he or she is often or almost never going to the streams for collecting water or washing clothes, that almost everybody has been in touch with the parasite.

This observation suggests that the level of transmission is such that even those people who seem to have only a slight chance to contract an infection are within the range of action of the parasite. The exposure of sentinel mice to household water showed that mice (so probably also man) can become infected at home when they are exposed to the infested water that was brought home from the streams. The results of this experiment confirm the occurrence of an intense transmission of *S. mansoni*.

INFECTION RATES AND FREQUENCY OF EXPOSURES

In the analysis of the Charts 1-5 (chapter 3) the age of the individual appeared to be of major importance in the explanation of the overall variation in the infection rates. Differences due to age may in fact be a reflection of differences in behaviour (as far as contact with infested water

is concerned) or of differences in the individual's resistance (acquired immunity) to the infection. In par. 5.3. (summarized in the figures 5.5. and 5.6.) it was shown that even the most intensively exposed group of males has far less contact with infested water than the least exposed women. This was true for moslims and christians; for people washing clothes and for people collecting water. It is true that older women do not go to the streams for fetching water or washing clothes as often as girls and younger women, but this cannot be a satisfactory explanation for the lower prevalence in older women.

So the decline of the infection rates in older age groups is not primarily caused by differences in the people's behaviour (of the present time), but rather by changes in the people's defence system or by factors concerning those exposures which could not be observed (outside Chiwahit and in the past).

IMMUNITY

The concept of "concomittant immunity" (Smithers and Terry, 1967; Smithers, 1972) may be a useful tool in the understanding of this defence mechanism but alternative explanations remain possible (Warren, 1973). In detailed studies of the epidemiology of *S. haematobium* in Tanzania (McCullough & Bradley, 1973; Bradley & McCullough, 1973), evidence was gathered to suggest that something like "concomittant immunity" 1) might in fact be operating in human populations in endemic areas. Though the expression "concomittant immunity" has always been at the back of our mind in the present study, the data do not allow a further discussion of the possible mechanisms of immunity. Our observations on the prevalence and transmission of *S. mansoni* may only permit a discussion of the role of the transmission to explain the regulation of parasite populations as opposed to Bradley's second and third way of regulation (immune response at host population and at individual host level).

note 1) Concomittant immunity: the existence of immunity in the presence of an adult schistosome infection (Smithers & Terry, 1969, as cited by Smithers, 1972).

PATTERNS OF EXPOSURE OUTSIDE CHIWAHIT

In this report much attention has been paid to the role of immigration of persons and their schistosomes into Chiwahit. Since, however, the prevalence of *S. mansoni* in Chiwahit is not lower than in most other communities in the area, and since the transmission of *S. mansoni* seems to be high compared to other communities with comparable high infection rates it is unlikely that the high infection rates among groups of the Chiwahit population that seem to have little contact with infested water are caused by recent infections elsewhere.

PATTERNS OF EXPOSURE IN THE PAST

It is more likely that the infected persons who do not seem to have a great chance to become infected, contracted the infection some or many years ago when the pattern of their exposures was different from the present one. The information we collected on the history of the individual people (dwelling places, exposure patterns) was barely reliable, and the numbers of subjects who could have provided us with adequate information were too small. Therefore, it was not possible to test this possibility thoroughly. Probably, however, the exposure pattern of the individual's past is an important factor in the explanation of the present status of infection among young adults (15-25 years of age). In older adults, on the other hand, the behavioural pattern is less likely to have changes substantially in the last decade or so.

Thus, our inability to explain the pattern of infections from the pattern of exposures may be partly but not entirely due to the role of former patterns of exposure that could not be taken into account in this cross-sectional study.

MARGINAL ENDEMIC SITUATIONS

When the transmission is less intense, e.g. when the numbers of infected snails are very much smaller, or when the frequency of water contacts is very much smaller (babies, old and disabled people) changes in the behavioural or ecological patterns may result in changes in the infection rates. In the Lake side communities of Gorgora and Kunzila the significantly lower prevalence in girls was thought to be due to behavioural and ecological factors: the cercarial density is generally very low in the lake water, and the exposure times to the water are much shorter than among boys who swim in the lake very often (photo 2).

At the foot of the mountain, on the border of the endemic area, we noted the very remarkable difference in the infection rates between Gondar and Addis Alem. This difference could be attributed to the presence of piped water in Gondar, or, perhaps, to the more favourable climatic situation in Addis Alem (alt. ± 2,000 m.) compared with Gondar town (50 - 100 m. higher than the water collection sites of Keha near Addis Alem), or it might be related to the consequences of the entirely Moslim character of Addis Alem. Whichever is the principal causative factor in this case, small behavioural 1), environmental or ecological differences may have a very marked effect.

A MILD DISEASE ?

In other studies in which symptoms of *S. mansoni* infections in man were considered not to be very severe the hepatomegaly rate was still often rather high. Though one has always to be very careful with the interpretation of high hepatomegaly rates (they may or may not be related to schistosomiasis) the absence of enlarged livers is a more convincing finding. When very few enlarged livers are found, it is not very likely that many people suffer from liver disease caused by *S. mansoni*. In our studies, the hepatomegaly rate in Chiwahit was found to be very low, but in Jenda it was rather high. It seems, therefore, that in this area high infection rates of *S. mansoni* do not necessarily cause a great deal of clinical disease. Furthermore, the wormloads were not very high according to the few quantitative egg counts that were performed for us. More data on the eggloads and hepatomegaly rates have been collected by Dr. Hiatt (report in preparation).

The author of this report is aware of the fact that it is impossible - for the time being - to understand why little apparent disease seems to be caused by the abundant schistosome infec-

Note 1) the presence or absence of piped water is considered to result in 'small' behavioural differences since, in Gondar town, many people continue to go to the rivers because it is cheaper and because it is a more pleasant place to dry clothes in the sun after washing.

tions in the area. A few possible factors should be mentioned, however.

In the laboratory is has been shown that the induction of acquired immunity is greatly dependent on the exposure pattern: several light infections are more effective than a single heavy infection (e.g. Olivier & Schneidermann, 1953; Smithers, 1961). The particular pattern of the seasonal variations of the infectivity of the streams around Chiwahit and Jenda might enhance the build up of an efficient level of acquired immunity in the people.

The endemic area we have been studying appeared to be a rather small area that is separated from the outside world by natural borders all around. The altitude of the area is very high (1,840 - ± 2,000 m.), and there are indications that the climatically determined upper limit for the transmission is passed in the highest parts (Aykel, ± 2,200 m., see page 37). Even in the lowest and hottest parts of the endemic area (the area around Chiwahit and Jenda) the air and water temperatures were shown to be fairly low. If there exist racial differences between *S. mansoni* strains from different endemic areas in the world - which is believed by many investigators, and supported by some experimental evidence (e.g. Wright, 1962; Webbe, 1971) - there is certainly reason to believe that the strain of *S. mansoni* from this part of Ethiopia (and probably from Tigrae Province as well) may behave differently from other strains of *S. mansoni*.

FAECAL POLLUTION AND INFECTIONS IN SNAILS

In chapter 4 of this report it has been shown that the snail populations are flourishing around Chiwahit and Jenda: large maximum diameters were attained, the growth rate was rather high while the mortality was not. Almost throughout the year infected snails could be found though there appeared to be periods of high and lower infection rates. These seasonal fluctuations were explained by the importance of the rains in polluting the streams. The observation that some snails got infected during the dry season was attributed to the 'sanitation hazards' (par. 4.3.2.). The observations suggest that a very great difference in the amount of faecal contamination of the streams does not necessarily produce very great differences in the infection rates among snails. The infection rate per infected pool was shown to

be almost the same during the rains and during the dry season. So, even though the infection rates among snails are often low, small amounts of faecal material seem to be capable of 'saturating' a pool's snail population with miracidia. This view is supported by the observation that the mean number of sporocysts per infected snail was thought to be at least 3, and probably even more (page 118).

These considerations make it highly unlikely that even a high degree of improvement of the town's sanitation will be able to reduce transmission of the disease to man effectively. Though a proper use of latrines serves other purposes and is - therefore - urgently needed, it does not seem to be an efficient way of reducing the transmission of *S. mansoni* in Chiwahit.

EGG OUTPUT WORM LOAD AND DISEASE

In fig. 3.3. and 3.8. it has been illustrated that the egg output was small in most persons and very high in a small proportion of the population. This finding has been described in many other and more carefully performed quantitative studies on schistosomes and other parasites as well (e.g. McCullough & Bradley, 1973; Crofton, 1971).

High egg counts, and therefore high worm loads (Cheever, 1968) will be caused by either a failure of the individual's defence system to keep down the numbers of worms effectively, or to an initial exposure to high numbers of cercariae that were able to penetrate and to develop before the host's defence system was build up. For Chiwahit it has been shown that - at certain times of the year, in certain places - the infectivity of the water can become very high. Whatever the role of immunity may be, high worm loads will certainly be caused by prolonged exposures to heavily infested water.

There is increasing evidence (e.g. Jordan, 1972; Cook et al, 1974), that the high worm loads are more likely to cause clinical disease and public health impairment than light infections. In order to reduce the chance to contract high worm loads a reduction of the exposure factor will probably yield some results.
Killing of an appreciable number of snails with molluscicides will probably have the same effect.

CONTROL

It has been discussed already in this chapter that a small reduction of the water contact

frequency or a small reduction of the numbers of snails (and infected snails) will probably not reduce the prevalence of *S. mansoni* in Chiwahit (or Jenda). There appeared to be a stable hyper-endemic situation with a surplus of transmission in these communities. For sociological and economical reasons it will not be possible (for the time being) to cut down (and to keep down over prolonged periods !) the frequency of water contacts of the people or the number of snails to such levels that a manifest fall of the prevalence will be observed 1).

This does not mean, however, that a reduction of the exposure of man and a control of the snails, although imperfect, are useless. Though difficult to register, it is likely that they would reduce the frequency of heavy wormloads in (young) people, and a reduction of the frequency of clinical complications may be expected.

Killing of snails serves no other purposes, and it should be done with some expert's knowledge. Yet,it should be possible to kill the majority of snails in the highly infective post-rain period. The application of molluscicides to some of the most intensively used pools may yield useful results. The quality of the water must not be affected thereby, since we are dealing with the people's only water supply.

THE NEED OF CLEAN WATER

More promising are the efforts to reduce the amount of contact with infested water. The provision of clean water will not eradicate schistosomiasis, and perhaps the prevalence will not even go down very much. Yet, there are plenty of reasons to stress the need of a proper water supply, and concern with the ill effects of schistosomiasis is one of them.

At present the daily amount of water that is used in Chiwahit is less than 5 liter per person (including water for the preparation of beer and for the teahouses and mills). In Holland

Note 1) Yet, at school children should be taught to avoid prolonged contacts with the infested water of the streams. Especially during the months September-December when the water looks very clean and attractive, children should not swim in the streams.

the water use per capita is about 125 liter (excluding industrial consumption). It is to be expected that the water use in Chiwahit will increase with development of the area. The problem of schistosomiasis and the public health impacts of the disease are very likely to increase as a result of the same development.

FINAL CONCLUSION

Since eradication and control are certainly beyond the financial possibilities (for the time being), since the effect of improved sanitation is probably nil in the fight against schistosomiasis, and since the destruction of snails with molluscicides may be useful but requires an expert's hand in order not to contaminate the people's only water supply, the provision of clean water is the only single measure that is attainable. Possibly in combination with a very focal application of molluscicides during the highly infective period, and in combination with chemotherapeutic treatment of the most heavily infected people who happen to present themselves for treatment, the installation and proper maintainance of a number of handpumps is thought to be the most effective measure.

ABSTRACT

- A study of the geographical distribution of *S. mansoni* showed that the parasite is very common in the area between Gondar and Lake Tana. It is not preliminary Lake Tana but rather the numerous small streams in which the intermediate host snail can be found. The situation in the Dembia plains and in the economically important lowlands along the Sudan border (Settit-Humera and Metemma) were discussed.

- The infection rate among children in communities with flourishing snail-populations was not significantly higher compared with communities where few intermediate host snails were found.

- A detailed analysis of the infection rates in various groups of the population in a highly endemic area (the town of Chiwahit) showed that the infection rates are about the same in males and in females (except among schoolchildren). The infection rate in occupational groups with regular exposures to the infested water (tallamakers, housewives) is about the same as that among people with occupations that require no or very little contact with (infested) water (tailors, merchants).

- Observations on man's contact with (infested) water showed that adult men are almost never seen in the neighbourhood of infested water. Yet, their infection rate is about the same as that among women who have a lot of contact with the infested streams. The importance of past patterns of exposure and of the time of immigration into Chiwahit were discussed.

- The populations of intermediate host snails in the study area of Chiwahit were shown to be stable and flourishing: they were little affected by seasonal changes, the growth rate of the snails was high (a field growth curve was constructed), and the mortality rates were fairly low. Conditions appeared to be most favourable for the snail populations in the upper part of the streams; farther downstream less snails were found.

- The infection rates among *B. pfeifferi* were high after the rains of July and August, and much lower during the remaining months. These fluctuations are are related with periods of intensive faecal pollution of the streams during the big rains.

- Regular exposure of sentinel mice to the natural bodies of water showed the same pattern: both infection rate and worm load of the sentinel mice were high between September and December and much lower at other times. In some particular pools, at some particular times of the year, the infectivity of the water was shown to be very high.

- A surprisingly high number of multiple infections was found in individual snails. This observation is difficult to explain.

- Mice that were exposed to household water in the local houses appeared to get infected though the infection rates were low.

- Some central parts of the research as carried out in Chiwahit were repeated in the nearby community of Jenda. The results of the Jenda survey are well in conformity with those of Chiwahit.

- Evidence for the role of acquired immunity and implications for the planning of control measures were discussed.

Het onderzoek, dat werd uitgevoerd in het kader van een NUFFIC ontwikkelings-samenwerkingsprojekt, was gericht op de wormziekte schistosomiasis en had ten doel een beschrijving te geven van de epidemiologie van deze parasitaire aandoening in een plattelandsgebied van de provincie Begemder in Ethiopië.

Om dit doel te bereiken werd eerst een studie gemaakt van de geografische verspreiding van de infectie (hoofdstuk 2).

conclusies:

Schistosoma mansoni *is endemisch in tal van dorpen en plattelandsgebieden in het bestudeerde deel van de provincie. Hoge infectie-indices werden voornamelijk gevonden in het zachtglooiende gebied ten noorden van het Tana meer. Lagere infectie-indices werden geregistreerd in dorpen langs de oevers van het Tana meer (behalve in Gorgora) en in de alluviale laagvlakten rondom dit meer. De situatie tussen Settit-Humera en Metemma, in het grensgebied met Sudan werd potentieel gevaarlijk geacht.*

Vervolgens werden factoren die de intensiteit van transmissie van schistosomiasis bepalen, nader bestudeerd in het dorp Chiwahit dat gelegen is in het centrum van het gebied dat endemisch bleek voor intestinale schistosomiasis. Aan de hand van een vijftal 'charts' (hoofdstuk 3) werd een analyse gemaakt van de correlaties tussen de infectie-indices en de demografische karakteristieken van de verschillende groepen van de bevolking in Chiwahit.

conclusies:

De drie belangrijkste factoren die statistisch significant gecorreleerd bleken te zijn met de infectie-index waren: leeftijd, religie (christen of moslim), en de tijd gedurende welke men in Chiwahit gewoond had. Het uitoefenen van een bepaald 'beroep' dat leidt tot veel dan wel weinig contact met geinfecteerd water bleek niet gecorreleerd met de infectie-index.

De resultaten van een klein aantal immunofluorescentie testen maakten duidelijk dat het aantal mensen dat geinfecteerd was (of recent geinfecteerd geweest was) met *S. mansoni* veel hoger was dan de resultaten van het faecesonderzoek deden vermoeden. De betrouwbaarheid van het faecesonderzoek en de discrepantie tussen de resultaten die verkregen werden met faecesonderzoek en met serologisch onderzoek, werden uitvoerig besproken.

In hoofdstuk 4 werden de resultaten besproken van onderzoek aan populaties van de tussengastheer (de slak *Biomphalaria pfeifferi*). In dit hoofdstuk werd voornamelijk aandacht besteed aan de schistosoma infecties bij deze slak.

conclusies:

De bovenloop van een drietal kleine beken bevatte grote en betrekkelijk stabiele slakkenpopulaties. De slakken bereikten grote diameters en hun overlevingskans was normaal tot groot. Het percentage geinfecteerde slakken was het hoogst gedurende de maanden volgend op het regenseizoen. Dit werd geweten aan het feit dat gedurende de regentijd menselijke faecalien die schistosoma-eieren bevatten naar de slakkenhabitats werden gespoeld.

In hoofdstuk 5 werden experimenten beschreven om de infectiviteit van de stroompjes rondom Chiwahit te bepalen. Ook het water dat in de locale huizen in kruiken opgeslagen wordt, werd op haar infectiviteit getest door laboratorium-muizen aan dat water bloot te stellen.

conclusies:
Muizen die in de maanden september-december in contact werden gebracht met de stroompjes rondom Chiwahit bleken soms zwaar geinfecteerd te raken. Water dat in kruiken was opgeslagen in de locale huizen bleek nog in staat proefmuizen te infecteren; de wormlasten van de op deze wijze verkregen infecties waren echter zeer laag.

In het tweede gedeelte van hoofdstuk 5 werden de waarnemingen besproken aan die aspecten van het menselijk gedrag die leiden kunnen tot infecties met *S. mansoni*.
conclusies:
De hoogste infectie-indices bleken zeker niet voor te komen bij diegenen van de bevolking van Chiwahit die het meeste contact hebben met geinfecteerd water gedurende waterhaal-activiteiten, noch bij die groeperingen die het meest frequent kleren wassen (zie fig. 5.5. en fig. 5.6.). Het belang van watercontacten die zich afspeelden buiten het waarnemingsveld van de onderzoeker (thuis, buiten Chiwahit, of in het verleden) werd besproken.

Een aantal waarnemingen zoals gedaan in Chiwahit werd op kleinere schaal herhaald in Jenda, een dorp op enkele kilometers afstand van Chiwahit. De gegevens betreffende zowel de malacologische als de parasitologische waarnemingen in Jenda werden besproken in hoofdstuk 6.
conclusies:
De seizoensfluctuaties in de aantallen geinfecteerde slakken kwamen overeen met de fluctuaties zoals die werden waargenomen in Chiwahit. De infectie-index van de bevolking in Jenda was hoger dan in Chiwahit. Een analyse van de infectie-indices per categorie van de bevolking was in Jenda minder eenvoudig aangezien de samenstelling van de onderzochte bevolkingsgroep zeer homogeen was.

Op grotere schaal dan bij het onderzoek in Chiwahit werd in Jenda gebruik gemaakt van immunofluorescentie testen ter bepaling van de titers van de anti *S. mansoni* **antilichamen en van de specifieke IgM titers. De specificiteit en sensitiviteit van deze test werden besproken voor gebruik in dit gebied.**

SOME PRACTICAL SUGGESTIONS

- The gradual socio-economic development of the study area is likely to result in a phase of increased transmission intensity of schistosomiasis. In this respect particular attention should be paid to the area between Settit-Humera and Metemma. The ecological situation in the lowlands and the risk of a large scale spread of the disease should be studied as soon as possible.

- A supply of clean water to Chiwahit and other highly endemic communities in the area is badly needed. Such a provision of clean water is likely to reduce the intensity of transmission of schistosomiasis and it serves many other purposes as well.

- Due to several practical reasons a systematic control project including large scale molluscicide programs and mass therapy of the infected subjects does not seem feasible in this area for the time being.

- A more detailed study of the impact of schistosomiasis on the health of the population in this area is required before the priority of an anti-schistosomiasis campaign can be assessed correctly.

- To test the stability of the endemic situation as described in this study, a pilot control project could be executed ("give a push and see what happens"; Bradley, 1972).

- A field study on the process of the infection of snails (relationship between infection rate in snails and faecal pollution , effect of the rains, high rate of multiple infections in snails) is likely to throw light on this neglected aspect of the transmission dynamics. Conditions for such a study are ideal in Chiwahit.

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APPENDIX 1 THE ORGANIZATION OF THE PROJECT

The research program that was described in this report was executed by the author assisted by four untrained technicians. Much baseline information that was thought to be of importance (from the point of view of a foreign aid program) could be collected by this team. The program was planned in such a way that the skills of our technicians could be untilized optimally. They took care of the climatological observations, the greater part of the observations on the human behaviour, they collected the stool specimens, and they performed a great many routine snail surveys. A rigid planning of the work and a training of the technicians together with a continuous supervision of all activities were the main tasks of the principal investigator. Skilled assistance was sometimes available for the microscopical examination of the stool specimens. Later an experienced and dedicated technician was hired for this work.

Laboratory space was made available by the Institute of Pathobiology (H.S.I.U., Addis Ababa) in the first year of the project, and by the Public Health College of the H.S.I.U in Gondar thereafter. A local house in Chiwahit was rented as a field laboratory. In our absence one technician and his family were living in the fieldlaboratory and taking care of it.When we were there they simply moved out.

For transportation the project was dependent on an old jeep, a mule and a donkey. The former means of transport and the regular trips by plane to Addis Ababa appeared to consume a large part of the budget. It was, however, impossible to avoid these high expenses for transport of man and equipment.

Whenever possible the equipment required for the study was purchased or made locally: mouse cages and rain gauges were made from old currogated iron on the market in Addis Ababa; the snail nets were made by a mechanic in a small garage, etc.

Excluding the salary of the principal investigator from Holland and his travel expenses to Ethiopia and back to Holland, the remaining costs can be roughly summarized as follows:

equipment, chemicals, mailing and maintenance of purchased goods, running costs of both laboratories	U.S. $	6,000.--
transportation		5,400.--
salaries of the technicians plus allowances for their overnight stays during field trips		3,700.--
Total (for 2½ yrs)		15,100.--

APPENDIX 2. QUESTIONNAIRE FOR PARASITOLOGICAL SURVEY

№ 0147

name .....
address ..... sex: .....
family composition ..... age: .....
..... born: .....

---

born in: .....

came ..... years ago.
profession: .....
religion: .....
water from ..... ; ..... times a day.
washing clothes in: .....

bathing in ..... ; ..... times a week.
collecting blood: ..... capillary tubes.
inquirer. ..... date .....

Notes

---

time of stool collecting: .....
type of stool: solid / diarrhoeatic / bloody.
way of storing the stool .....
quantity of stored stool: ..... grams.
egg-hatching test: .....
.....

Notes:

Ritchie's concentration-method,

performed by .....

Ascaris .....
S. mansoni .....
Trichuris .....
Strongyloides .....
Hymenolepis .....
Hookworm .....
....
....

Direct smear performed by .....

Micro Fluorescent Antibody Test.

performed by .....

Notes:

APPENDIX 3 RITCHIE'S FORMOL-ETHER CONCENTRATION-TECHNIQUE.

1. Transfer 1 g. of preserved faeces from the stool sample to a conical jar containing about 10 ml. of tap water.
2. Thoroughly comminute the specimen using a wooden applicator.
3. While stirring the suspension, add about 300 ml. of tap water.
4. Filter through a double layer of damp cheesecloth.
5. Keep suspension standing for about 30 minutes. Decant supernatant.
6. Refill jar with about 300 ml of tap water; keep suspension standing for 30 minutes and decant supernatant.
7. Keep the remainder standing for 10 minutes and decant again.
8. Examine the sediment.

3-A. SIMPLE SEDIMENTATION METHOD FOR THE RECOVERY OF *S. MANSONI* EGGS.

1. Transfer 1 g. of preserved faeces from the stool sample to a previously identified vial containing 10 ml. of 7.5% formalin.
2. Thoroughly comminute the specimen using a wooden applicator.
3. Filter through a double layer of damp cheesecloth.
4. Centrifuge for 1 minute at 2,000 rpm. Decant supernatant.
5. Add 7 ml. buffered alcoholic aquous solution [1] and then 2 ml. refrigerated ether. Shake vigourously (30 times).
6. Centrifuge at 2,000 rpm for 2 minutes.
7. Ring round faecal plug with an applicator stick and decant, leaving the sediment with a little supernatant.
8. Examine the whole sediment on two or three microscope slides.

[1] A buffered formalin-alcohol solution (near pH 7) may be prepared as follows: dissolve 17.6 grams of citric acid and 88 grams of sodium phosphate dibasic, in 2,000 ml. of water, dilute to 3,600 ml., and add 400 ml. of formaldehyde solution (37%) and 1,050 ml. of alcohol (95%).

APPENDIX 4 THE IMMUNO FLUORESCENT ANTIBODY TEST (IFAT)

Since only small amounts of serum were available a micro-method was used in this study. Essentially, the test was performed according to Ambroise-Thomas (1969). The conjugate and the counterstain were mixed and applied together.

Antigen: Deepfreeze sections (6-8 µm) of adult male *S. mansoni* worms embedded in abdominal muscles of the guinea pig.
Each slide contained 24 sections, so on each microscope slide 24 tests could be performed.

Antibody: Approximately 10 microliter of human serum, obtained by fingerpricks, and stored in heparinized capillary tubes. The serum is diluted in P.B.S., pH 7.2.

Conjugate: Fluorescent Swine Anti Human globulin (SwAHu/FITC, Nordic, Tilburg, Holland), and Fluorescent Swine Anti Human IgM (SwAHu/IgM/FITC, Nordic, Tilburg, Holland). After reconstitution of the freeze-dried conjugates, the stock dilutions were stored in small aliquots at - 20° C.
Before use the conjugates were diluted in P.B.S., pH 7.2. (dilutions of 1/20 and 1/10 respectively).

Counterstain: Evans Blue (Merck), 1/10,000 (diluted in P.B.S.) for SwAHu/FITC, and 1/5,000 for SwAHu/IgM/FITC.

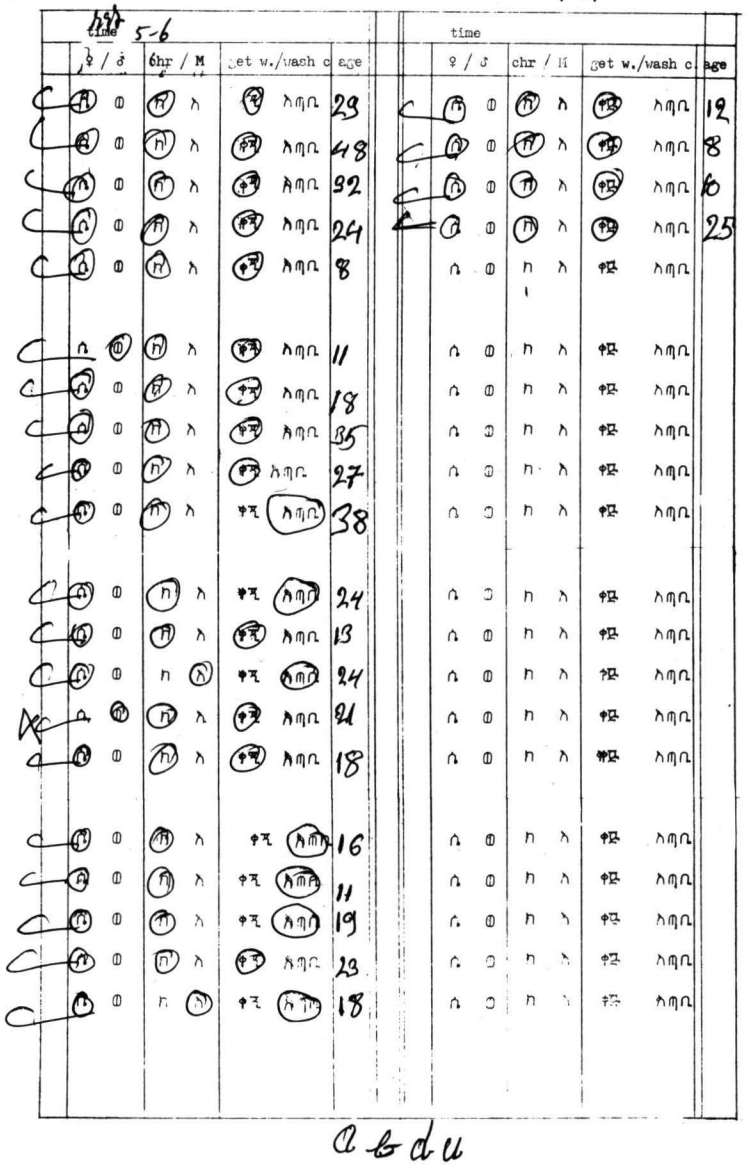
Phosphate Buffered Saline (pH 7.2)
500 ml NaCl 0.29 M (17 g NaCl/l)
200 ml Na_2HPO_4 0.0 M (10.68 g $Na_2HPO_4.H_2O$/l)
300 ml KH_2PO_4 0.01 M (1.36 g KH_2PO_4/l)

The test

-1- Dry slides in the air (in front of a ventilator);
-2- Fixation in aceton p.a. (10 minutes). Dry in the air again;
-3- Draw lines of wax (e.g. "Stopwas", Ceta Bever, Beverwijk, Holland) between the sections in order to avoid mixture of the sera;
-4- Add serum dilutions (in P.B.S.) to the sections (10 microliter/section). Incubate in moist atmosphere (37° C., 30 minutes);
-5- Rinse in P.B.S. (2 times 5 minutes), and dry the slides in the air again;
-6- Add 10 microliter (conjugate + counterstain)-dilution. Incubate in moist atmosphere again (37° C., 30 minutes);
-7- Rinse in P.B.S. 2 times 5 minutes, and dry the slides in the air;
-8- Mount in buffered glycerine (glycerine/buffer: 9/1; pH 7.2);
-9- Examine the slides under the fluorescent microscope.

APPENDIX 5 FORM FOR THE OBSERVATIONS ON WATER CONTACT PATTERNS

river: Ayo time: 5–6 (8) river: Awt. time: 11–12.
date : 16/3/65 date : Saturday 11/12



Abdu

Acknowledgements

The present report is almost entirely based on fieldwork in Chiwahit, Jenda, and other communities in Begemder Province. I am very much indebted to the people in these communities. Every time while collecting stool specimens we had to ask our indelicate questions, and every time again we had to perform fingerpricks for the collection of blood samples. It is honestly hoped that the results of the work may in the end help to ameliorate the health and living standards of the people in these communities.

Litch Gosa Merid and Ato Kebede Belay, the governors of Chiwahit Mikitil Wareda, and the late Dejazmatch Asfau Tesemma, the governor of Gondar Awraja, have constantly stimulated us to execute our research in Chiwahit area. I gratefully acknowledge their influential attitude towards the project and their great help to achieve our goals.

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