Original article

Transmission dynamics of *Schistosoma mansoni* in an irrigation setting in Ethiopia

Fekadu Abebe[1], Shibru Tedla[1], Hailu Birrie[1], Girmay Medhin[1],

Summary: The transmission dynamics of *S. mansoni* was studied in the Metehara Sugar Estate for 12 months. The prevalence of human infection ranged from 7.4% to 71.3% for 6 villages in the Estate. The infection rate was highest in the 10-14 years of age while the intensity reached peak in the 5-9 years. There were significant variations in the focality and seasonality of transmission. *Biomphalaria pfeifferi* which was persistent year round, was most abundant during the dry season. Absence of potable water supply and sanitary facilities, proximity to irrigation canals, and overcrowding are some of the most important factors influencing transmission of schistosomiasis in Metehara Sugar Estate. Mass chemotherapy and mollusciciding should be launched in Awash and Chore farm villages to control transmission, while treatment of children under 15 years is believed to control morbidity in other villages. [*Ethiop. J. Health Dev.* 199-;0(0): 0-00]

Introduction

Although the majority of the schistosomiasis endemic localities in Ethiopia are villages located near small streams at intermediate elevations (1500-2000m) (1,2) agricultural and/or hydroelectric power sites are already endemic for schistosomiasis. The Awash River basin is the most important in terms of irrigated land (over 60,000 ha.) (3). Schistosomiasis mansoni is increasing in both prevalence and intensity in the Awash Valley. For instance, in Wonji-Shoa Sugar Estate which is located in the upper portion of the valley, *S. mansoni* prevalence in farm labour population increased from 0.5% in 1964 to 19.4% in 1984 (4). Moreover, schistosomiasis which was a rare disease in the 1960s in Metehara Sugar Estate has, now emerged as a serious public health problem. In the 1960s the plantation's medical service in 1966 and Aklilu

Lemma (5) recorded only 1.4% positive cases while, the Institute of Pathobiology found an overall prevalence of 20.0%, after about 25 years (6).

The present study was aimed at obtaining information on the transmission dynamic of *S. mansoni* and investigate factors that may influence the transmission of the parasite in selected farm villages. Information generated by this study would also enable formulate cost effective control strategies in Metehara Sugar Estate and similar irrigation schemes in Ethiopia.

From the [1] Department of Biology and Institute of Pathobiology, Addis Ababa University, P.O.Box 1176, Addis Ababa, Ethiopia

Methods

Study Area: Metehara Sugar Estate Which lies within the Upper Valley of Awash River basin is about 200 km. east of Addis Ababa on Assab road at an altitude of about 950 meters above sea level. The present scheme which used to be known as the Metehara Sugar Estate and Abadir farm were established in 1966 for the development of irrigation-based sugar cane plantation and for growing vegetables by private owners, respectively. The two irrigation schemes were then annexed immediately after nationalisation by the government in 1975 and the area has since been under rapid development.

The water for irrigation is taken from the Awash river at two intakes, one at Merti and another at Abadir. It is then led into the field through earthen canals by gravity feed. The irrigation network consists of 248.4 km of irrigation canals and 27.08 km of open main drains. The irrigation canals and drains in turn end-up in numerous field (feeder) ditches and small drains. In addition to these, there are 18 reservoirs with a total volume of 4.8 ha.

Including the headquarters (factory village), there are 11 villages in the sugar plantation with a total population of 30, 341. The sugar factory, offices, modest living quarters and clubs, stores, garages, a sugar research laboratory, a highschool and a polyclinic are found in the headquarters (factory village), located at a distance of 2-15 kms from other farm villages. There are only 4 satellite clinics in the heavily populated farm villages (Awash, Chore, Kikan and Abadir). Otherwise, by and large, health services are rendered by the polyclinic staffed with 3 medical doctors and 116 other health personnel.

Parasitological methods.

Before conducting parasitological examination, information on population size and the number of households of each camp was obtained from the health administration at the polyclinic. In order to have a general picture on the prevalence of schistosomiasis, the hospital record for 7 consecutive years (1986/1991) was also analyzed. In order to have a general picture of the disease in different irrigation villages and their relative importance in disease transmission, stool samples were examined for 5-10% of the residents in six selected camps (Awash, Chore, Kikan, Guenet, Bertukan and North Camp). The sample population for the study was selected by systematic random sampling taking a household as a unit, and every member of the selected household was examined. Stool specimens were collected in pieces of plastic sheets which were distributed to the residents. Stool specimens were processed for microscopic examination using the modified kato technique (7). A double slide was processed for each faecal specimen and egg counts were made. The average of the two slides was used to calculate geometric mean of egg counts. The name, sex, age, occupation, religion and duration of stay of each individual in the study were also recorded.

In order to determine fluctuation in *Biomphalaria pfeifferi* population density and *S. mansoni* infection rates, three sites (one each from Awash, Chore and kikan farm villages) were selected for monthly monitoring. The sites were selected based on intensity of human water contact. All the selected water bodies were drainage canals which were heavily used by the residents. Each sampling site was 10m. stretch of a canal, and snails were collected from each site by scooping 20 times with a scoop made of wire mesh. The collected *Biomphalaria pfeifferi* were measured using Vernier Caliper, counted and examined for patent *S. mansoni* infection by allowing the snails to shed cercariae by placing them individually in vials containing 2mm adged water. The snails were exposed to natural light for two hours and the emergence of cercariae was observed under a dissecting microscope.

In order to determine cercarial infestation of the waterbody, a batch of five swiss albino mice (Mus musculus) was exposed to canal water at each site for two hours between 10:00 and 12:00 hr. in floating cages. The cages were kept in a fixed position during exposure. The mice were sacrificed and worms perfused after six to eight weeks post-exposure using automatic perfusion apparatus modified by DuVall and Dewitt (8).

Results

Parasitological findings. Analysis of hospital record for 1985/86 - 1991/92 indicate that infection by *S. mansoni* was progressively increasing at a considerable rate. Although there was a similar trend for all farm villages, this was particularly true for Awash, Chore, and Kikan. For instance, in 1985/86, 1.8% infection rates were recorded from Awash and Chore, while in 1990/91, 6.5% and 9.4% infection rates were recorded from the two farm villages, respectively (Fig. 1).

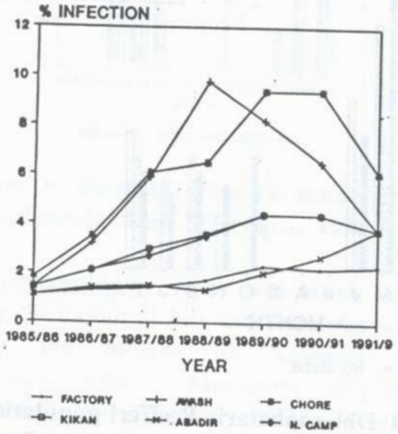


Figure 1: **Schistosoma mansoni infection among diagnosesd cases at metehara polyclinic, 1985/86 - 1991/92**

Point prevalence: Results of stool examination of sample population ranging in age from 1-54 years in six farm villages (Awash, Chore, Kikan, Guenet, Bertukan, North Camp) in 1992 indicate that infection rates of *S. mansoni* were 71.3%, 36,6%, 22.3%, 34.3% 17.5% and 7.4%, respectively. Mean age of the sample population was 21.1, 18.3, 16.7, 11.9, 13.5, and 41.9 years for Awash, Chore, Kikan, Guenet, Bertukan and North Camp, respectively. In four of the six camps (Awash, Chore, Guenet, Bertukan) infection rates were the highest in age group 10-14 years while peak infection was seen in the age group 15-19 years in Kikan. In North Camp, peak infection rate was seen in the age group 5-9 years. In all instances, there was a sharp decrease in infection rates beyond the age of 20 years, except for Awash village where infection rates remain high even in older age groups. For instance, age group 40-44 years had 83.3% infection rates, (Fig. 2).

Intensity of infection. Overall intensity of infeciton with *S.mansoni* (expressed as eggs per gram of stool, epg), was the highest in Awash (453.6 epg), followed by Chore (207.7 epg) and Kikan (201.5 epg). The least intensity of infection was recorded in North Camp (57.8 epg), followed by Bertukan Sefer (85.1 epg). Peak intensity of infection was observed in the age group 5-9 years in Awash (272.7 epg); Chore (343.1 epg); Bertukan (123.3 epg) and North Camp (66.8 epg), while it was the highest in age group 10-14 years in Kikan (629.8 epg) and Guenet (142.9 epg) farm villages (Fig. 3).

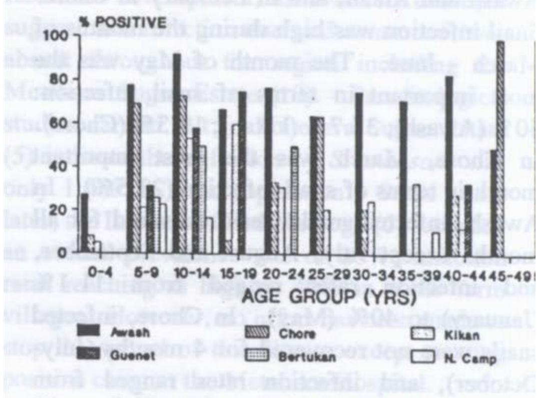


Figure 2: **Prevalence of schistosoma mansoni in sample population in study farm villages, Metehara, 1992/93**

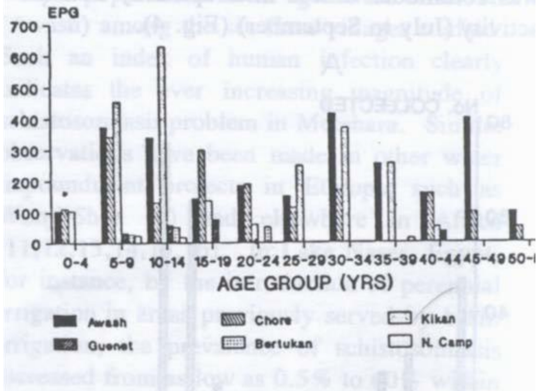
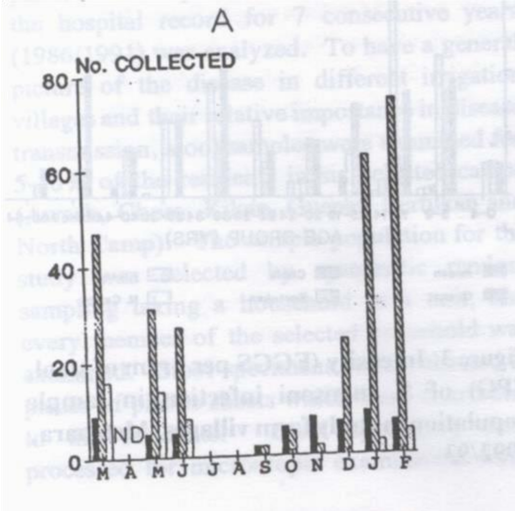


Figure 3: **Intensity (EGGS per gram of stool, EPG) of S. mansoni infection in sample population in study farm villages, Metehara, 1992/93**

Malacological findings: Results of monthly snail survey are as follows: A total of 401 *Biomphalaria pfeifferi* were collected from all study sites, [58 (Awash), 297 (Chore) and 46 (Kikan) drainage canals] during the entire study period of March 1992 to April, 1993. There were site and seasonal variations in both snail abundance and infection. Snails were most abundant at Chore (297) drainage canal than in any one of the three sites studied, followed by Awash (58) and Kikan (46). Snails were most abundant during the months of January through May; however, peak population density was observed in March in Awash and Kikan, and in February in Chore. Snail infection was high during the months of March - June. The month of May was the most important in terms of snail infection: 40% (Awash); 35.7% (kikan); 19.3% (Chore). In Chore, March was the most important month in terms of snail infection (23.5%). In Awash, infected snails were recovered for all months except July, August and September, and infection rates ranged from 11.1% (January) to 40% (May). In Chore, infected snails were not recovered for 4 months (July-October), and infection rates ranged from 8.0% to 23,5%. In Kikan, infected snails were recovered for 3 months (March, May and June). Except for April (1992), which was not studied, snails were present and transmission was continuous unless interrupted by human activity (July to September) (Fig. 4).



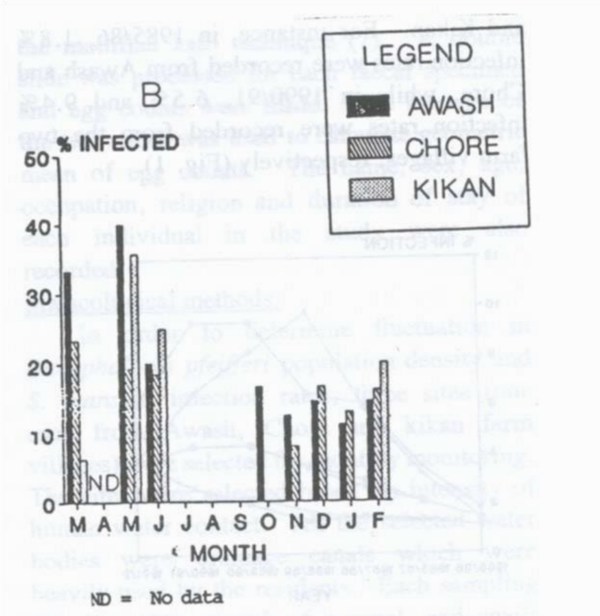


Figure 4: **Dbiomphalaria Peefferi population density (A) and schistosoma infection (B) in study sites, Metehara, 1992/93**

Cercarial Infestation Measurements. The results of mouse immersion indicate that there was infection from May 1992 to January 1993 at least in one of the 3 sites. Infection rate in mice was the highest in May 1992 (50%, 66.7% and 33.3% for Awash, Chore and Kikan, respectively). Hundred percent infection rate was obtained for Chore in January and 40% in Awash, the same month. In Kikan mice were infected for the months of May and June 1992. In infected mice, average worm load per mouse ranged from 3 to 12. Snail population density reaches peak in January and February, and a decline afterwards. Snail infection reaches a peak in March and the same holds true with mice infection, and continues to be high till interrupted by vegetation clearance and diversion of canal water (fig 5).

Meteorology. There was heavy rainfall during the month of July and there was no rain during the months of November and December, 1992. Maximum temperature ranged from 30°C (January) to 36.9°C (June), and minimum temperature ranged from 20°C (November) to 28°C (May). The maximum water temperature was recorded for the month of May and June (28°C), and the minimum was obtained for the month of October (20°C) (Fig.6).

PH ranged from 5.3 to 6.5 (Awash), 5.5. to 6.5 (Chore); 5.7 to 6.3 (Kikan). By and large, the pH values recorded did not show a marked difference and are within the tolerable range for snails.

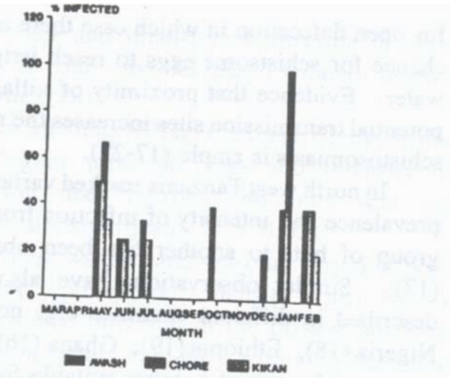


Figure: 5: Results of mouse immersion at selected study sites, Metehara, 1992/93

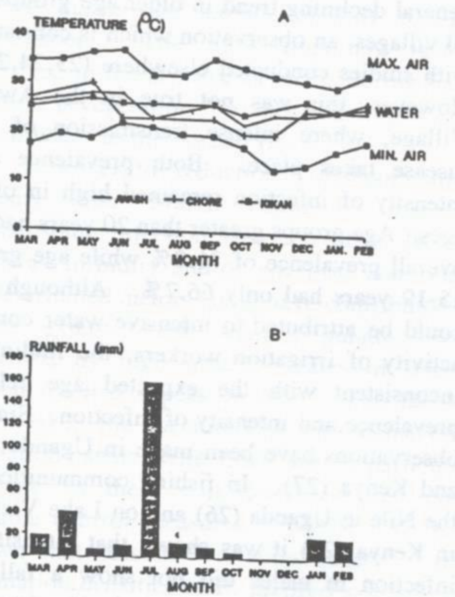


Figure 6: Monthly temperature (maximin and water) and rainfall measurements in Metehara, 1992/93

PH ranged from 5.3 to 6.5 (Awash), 5.5. to 6.5 (Chore); 5.7 to 6.3 (Kikan). By and large, the pH values recorded did not show a marked difference and are within the tolerable range for snails.

Discussion

Epidemiological studies carried our prior to the impoundment of the Awash river indicate that only *Schistosoma haematobium* had been endemic in swamps and lakes in the middle Awash valley for a long time (9). Although no study of schistosomiasis mansoni was carried out in the Awash valley prior to water resources development, all available evidence suggest that infection due to *S. mansoni* was absent throughout the region including the Metehara Sugar Estate (10). Parasitological studies carried out in Metehara Sugar Estate (5) indicate that infection by *S. mansoni* was only 1.4% in farm population. Some years later, the Institute of Pathobiology (6) recorded an overall prevalence rate of 20%, infection rates reaching as high as 40% in some farm villages. However, no effort has been made to stop the spread of this disease except treating positive cases at the Metehara Hospital.

In the present study which was aimed at determining transmission dynamics of *S. mansoni* in Metehara Sugar Estate, very high prevalence rates, reaching as high as 71% in sample populations of all ages were observed (Awash) among the six farm villages studied. Such an index of human infection clearly indicates the ever increasing magnitude of schistosomiasis problem in Metehara. Similar observations have been made in other water impoundment projects in Ethiopia such as Wonji-Shoa (4) and elsewhere in Africa (11,12,13,14,15,16). In Lake Naser, Egypt, for instance, by the introduction of perennial irrigation in areas previously served by basin irrigation, the prevalence of schistosomiasis increased from as low as 0.5% to 60% within less than five years (13). In Ghana, schistosomiasis prevalence has increased 5 to 10% (in children of age 10-14 years) within one year of the construction of the Akosomba Dam, lake Volta (16). In Wonji-Shoa sugar plantation, Ethiopia, *S. mansoni* prevalence in farm population increased from 0.5% in 1964 to 19.4% in 1984 (4).

By the finding of infected snails and identification of human water contact points active transmission has been proven in all the six camps where stool was examined.

The present study also indicates that transmission of *S. mansoni* is highly variable from one village to the other as evidenced by prevalence and intensity of infection, snail population density and their schistosomal infection, and sentinel mouse. Human infection rates among the six villages ranged from 7.4% (North Camp) to 71.3% (Awash). Intensity of infection (stool examined) ranged from 57.8 epg (North Camp) to 453.6 epg (Awash) among the sample population of the six farm villages. Absence of sanitary facilities and potable water supply, proximity of the dwellings to slow flowing irrigation canals and overcrowding are some of the most important factors influencing transmission of *S. mansoni* in the study villages. For instance, the two most affected villages, Awash and Chore, located very near (less than 100m) to drainage canals, together with Kikan, are the most overcrowded with population size greater than 3000 each, among the six villages. Moreover potable water supply and sanitary facilities are absent. The relatively low indices of human infection in Kikan compared to Awash and Chore could be attributed partly to the presence of a primary canal which is nearer to the village than the drainage canal. Since snails are absent from this canal, it seems to be a good source of water for domestic consumption. Another important reason is the less favourable environment in the drainage canal in Kikan for snail hosts as compared to Awash and Chore. The least affected villages (North Camp and Bertukan Sefer), although lacking potable water supply and sanitary facilities, have less population size, 1000 (North Camp) and 400 (Bertuken Sefer). They are located away from slow flowing irrigation waters and use the bush for open defecation in which case there is little chance for schistsome eggs to reach irrigation water. Evidence that proximity of villages to potential transmission sites increases the risk of schistosomiasis is ample (17-22).

In north west Tanzania marked variation in prevalence and intensity of infection from one group of huts to another has been observed (17). Similar observations have been described in different countries e.g. northern Nigeria (18), Ethiopia (19), Ghana (16). The presence/absence of habitats suitable for snail intermediate hosts and the proximity of these habitats has been attributed to this patchy distribution of schistosomiasis (16,20,21). Sturrock et al (20) found out children living close to a river which provides the main habitats for intermediate hosts had higher chance of infection than children living far from the river in Machakos District, Kenya. Berhanu Erko (22) observed a strong correlation between geographical proximity to potential transmission sites and infection rates of *S. mansoni* in Bahr Dar, Ethiopia.

Obviously, peak prevalence was in the second decade of life which is followed by a general declining trend in older age groups in all villages, an observation which is consistent with studies conducted elsewhere (23,24,25). However, this was not true in the Awash Village, where intense transmission of the disease takes place. Both prevalence and intensity of infection remained high in older ages. Age groups greater than 20 years had an overall prevalence of 71.8% while age group 15-19 years had only 66.7%. Although this could be attributed to intensive water contact activity of irrigation workers, the finding is inconsistent with the expected age related prevalence and intensity of infection. Similar observations have been made in Uganda (26) and Kenya (27). In fishing communities on the Nile in Uganda (26) and on Lake Victoria in Kenya (27) it was shown that intensity of infection in males did not show a fall but remained stable or tended to increase throughout adult life. This observation strongly supports the view that the decline in prevalence and intensity of infection in older ages is due to decreased water contact activities (28).

In all study villages, except Chore, males had higher infection rates and intensity of infection than females, but this was not statistically significant ($P > 0.5$).

There was site and seasonal variation in *B. pfeifferi* population density and their schistosomal infection in the present study in irrigation canals studied. Although the three farm villages studied are very adjacent to one another, snails were most abundant in Chore drainage canal, followed by Awash drainage canal. The least number was collected from a drainage canal at Kikan. Factors influencing snail population density in the three drainage canals may vary. In Kikan, scarcity of vegetation, gravel and sand substrate, periodic drying of the canal are some of the reasons for low density of *B. pfeifferi* population. In Awash increased pollution as a result of canal water stagnation and accumulation of silt load are some of the factors that cause decrease in snail density. Snails were most abundant during the months of January to May and were absent during the months of July through September. The most important factors involved in the absence of snails during these months is vegetation clearance and diversion of canal water to the Awash river.

However, the reduction in snail population density after March could be due to schistosome infection although other factors such as turbidity and/or silt load and other undetermined factors could have contributed to some extent. Peak snail population was followed by high infection rates in snails, which reached a peak in May. The factors involved in the variations of snail density in irrigation canals, with time, are of particular interest, as these will determine the most suitable control measures. Webbe (30) has shown that seasonal variation occurs in the population densities of *B. pfeifferi* colonies in lakes and streams in Tanganyika. These fluctuations were attributed to a number of factors such as variation in water temperature, silt load and flood water. Sodeman (32) reviewed studies of monthly changes in schistosome vectors in several West African countries (Ghana, Nigeria, Gambia, Sierra Leone) and found expansion of Snail population size during the dry season and contraction during the remaining season. The present study agrees with this pattern, although the effect of flooding has not been observed. Dennis et al (33) in Bong County, Liberia, attributed a decline in *B. pfeifferi* population density to drying and heat stress (February and March). Analysis of various factors (vegetation cover, water temperature, water volume, pH and rainfall) indicates that environment plays a role in influencing *B pfeifferi* population density in the different farm villages. For instance, water volume seems to be the most important factor influencing *B* *pfeifferi* population density in Awash (r = 0.8) and kikan (r = 0.53), whereas vegetation cover was the most important in Chore (r = 0.73) and Kikan (r = 0.7). Water temperature was a common denominator correlated with snail abundance in the three villages, Awash (r = 0.5); Chore (r 0.7) and Kikan (r = 0.5). In Wonji-Shoa Sugar Estate, Ethiopia, *B. pfeifferi* population fluctuated seasonally which was attributed to changes in temperature (34). Babiker et al. (35) by studying a small village, Tayeba El Sheikh Goirashi, in the Gezira irrigated area of Central Sudan found in 1981 that March-June were months of peak *B pfeifferi* population, coinciding with high temperature, slow or stagnant water at the end of the irrigation season, zero silt load content and increasing vegetation, whereas in 1982, canal closure caused desiccation of snails in May and June. There was a similar pattern to the transmission of *S. haematobium* by *B. truncatus* in the northern Gezira, Sudan (36). The population of *B. truncatus* increased during the period February - May, which coincided with decrease in water velocity in the canals as demand for irrigation increased, decrease in turbidity, increase in vegetation and temperature (36).

In the present study, there was a strong correlation between infection rates in snails and that of sentinel mice indicating that peak transmission of *S mansoni* is during the months of March - May. Schistosomiasis transmission in Metehara sugar estates, as observed in the present study, starts in October and continues through to June, a marked reduction during the wet season (July to September), but persistent during the rest of the year.

Conclusion and recommendations

The present study clearly indicates that schistosomiasis mansoni is a serious public health problem in Metehara calling for timely and appropriate control measures. The prevalence and intensity of infection observed in Awash village are the highest so far reported from Ethiopia. The observed differences in intensity of transmission between different farm villages in Metehara show the importance of geographical location in disease transmission, which in turn helps to design cost-effective control measures. Differences in infection rates of *S mansoni* between sexes and ages also indicate which section of the population should be given priority in chemotherapy. In Metehara Sugar Estates absence of potable water supply and sanitary facilities, proximity to irrigation waters, and overcrowding are some of the most important factors influencing transmission of schistosomiasis. In this study snail population density reached a peak during the mid-dry months of January and February, followed by a decline in density during peak transmission of schistosomiasis (March to May) as evidenced by snail infection rates and infection rates in sentinel mouse. Infection with schistosome seems to be the most important factor causing a decline in *B. pfeifferi* population density during peak transmission while vegetation abundance, increase in water temperature and water volume are believed to be important factors for the peak in snail density during the mid-dry season. Transmission and snails seem to persist all year round unless disturbed by human activity, (season of irrigation) in Metehara. The peak snail population density and transmission during the mid dry season indicate the most propitious time for intervention masures aimed at transmission control. From the present study it believed that mass chemotherapy and focal molluscididing should be launched in Awash and Chore farm villages, while treatment of children under 15 years is recommended for other farm villages to control morbidity.

References

1. Kloos H., Lemma A. and DeSole G. Schistosomiasis mansoni distribution in Ethiopia: A study in medical Geography, Ann. Trop. Med. Parasitol. 1978;72:462-470.
2. Institute of Pathobiology (IPB) 1986. Expanded programme of Applied Research and Training. Towards the control of Schistosomiasis in Ethiopia (Proj. ETH/MPD)003 and ETH/POP/001), Prog. Report 4.
3. Tedla S, Kloos H. and Tilahun G. Schistosomiasis in Ethiopia, a monograph, Addis Ababa University press, 1989;146 pp.
4. Tedla S. and Yimam M. Schistosomiasis at the Wonji-Shoa Sugar Estate during two decades (1964-1985). Afr. J. Sci. Tech. 1986;1:1-18.
5. Lemma A. Studies on bilharziasis in Wonji-Shoa and Metehara Sugar plantation with recommendation for possible control measures to be taken by the HVA company. Institute of Pathobiology, Addis Ababa University (internal publication), 1968;30pp.
6. Birrie H., Ayele T., Tedla S. and Abebe F. Transmission of Schistosoma mansoni in three ecological settings in Ethiopia. I Epidemiological aspects. Ethiop. J. Health Dev. 1993;7:63-69.
7. Peters P.A, El Almay M., Warren K.S. and Mahmoud A.A.F. Quick Kato smear for field quantification of S. mansoni eggs. Am. J. Trop. Med. Hyg. 1980;29:217-219.
8. DuVall R.H. and DeWitt W.H. An improved technique for removing adult schistosomes from laboratory animals. Am. J. Trop. Med. Hyg. 1967;16:483-486.
9. Kloos H. and Lemma A. Schistosomiasis in irrigation schemes in the Awash Valley, Ethiopia. Am. J. Trop. Med. Hyg. 1977;26:899-908.
10. Kloos H. The ecology of schistosomiasis in agricultural development schemes in the Awash Valley, Ethiopia. In: The Ecology of Health and Diseases in Ethiopia, Ministry of Health, Addis Ababa 1988.
11. WHO. The control of schistosomiasis. Tech.Report Series 1985;728:112 pp.
12. Gorden-Smith, E.E. Changing patterns of disease in the tropics. In: Man Made Lakes and Human Health, 1975;345-362 (eds) Stanley, N.F. and Algers, M.P. Academic press, London, New York, San Francisco, Torento.
13. Farid M.A. The Aswan High Dam Development Project. In: Man Made Lakes and Human Health: 1975;89-102 (eds), stanley N.F. and Algers M.P., Academic press, London, New York, San Francisco, Toronto.
14. Dazo B.C. and Biles J.E. The schistosomiasis situation in the Lake Naser area. Arab Republic of Egypt. WHO, Schisto. 1971;72:23.
15. Deschiens R. Influence of the creation of artificial lakes by lake African dams for parasitic endemics. Comparative study of the Akosombo Lake in the Black Volta (Ghana) and Naser Lake on the Nile (Egypt, Sudan). Bull Soc pathol Exot Filiales 1972;65:240-263.
16. Scott Di., Senker K. and England E.C. Epidemiology of Human Schistosoma haematobium infection around Volta Lake, Ghana, 1973-1975. Bull. WHO. 1982;60:89-100.
17. Forsyth D.M. and Bradley D.J. The consequences of bilharziasis: medical and public health importance in north west Tanzania. Bull. WHO. 1966;34:715-735.

18. Pugh R.N.H. and Gilles H.M. Malumfashi endemic diseases research project. III. Urinary schistosomiasis, a

longitudinal study. Ann Trop. Med. parasit. 1978;72:471-482.
19. Polderman A.M. Transmission dynamics of endemic schistosomiasis. Trop. Geogr. Med. 1979;31:465-475.
20. Sturrock R.F., Kimani R.R., Cotrell B.J., Butterworth, A.E., Seitz H.M., Siongok T.K. and Houba V. Observations on possible immunity to reinfection among Kenyan chool children after treatment for Schistosoma mansoni Trans. R. Soc. Trop. Med. Hyg. 1983;77:363-371.
21. Goll P.H. and Wilkens R.H. Field studies on Bulinus Senegalensis Muller and the transmission of Schistosoma haematobium 1984.
22. Erko B. Epidemiology of schistosomiasis in Bahr Dar, M.Sc. Thesis Addis Ababa University 1988;65pp.
23. Sturrock R.F. Field studies on the transmission of Schistosoma mansoni and on the dynamics of its intermediate host Biomphalaria pfeifferi in St. Lucia, West Indies. Int. J. Parasit. 1973;3:175-194.
24. Jordan P., Christie J.D. and Unrau G.O. Schsitosomiasis transmission with particular reference to possible ecological and biological methods of control. Acta Tropica. 1980;37:95-135.
25. Jordan P. and Webbe G. Schistosomiasis Epidemiology treatment and control 1st ed., William Heinman Medical Books Ltd., London 1982.
26. Ongom V.L. and Bradley D.J. The epidemiology and consequences of Schistosoma mansoni infection in West Nile, Uganda. I. Field studies of a community at Panyagoro. Trans. R. Soc. Trop. Med. Hyg. 1972;66:835-851.
27. Smith D.H., Warren K.S. and Mahmoud A.A.F. Morbidity in schistosomiasis mansoni in relation to intensity of infection: a study of a community in Kisumi, Kenya. Am. J. Trop. Med. Hyg. 1979;28:220-229.
28. Sturrock R.F. Field studies on the transmission of Schistosoma mansoni and on the bionomics of its intermediate host, Biomphalaria glabrata in St. Lucia, West Indies, Int. J. Parasit. 1973;3:175-194.
29. Webbe G. Observation on the seasonal fluctuation of snail population densities in the northern province of Tanganyika. Ann. Trop. Med. Parasit. 1960;54:54.
30. Webbe G. The transmission of S. haematobium in an area of Lake province, Tanganyika Bull. WHO. 1962;29:5985.
31. Sodeman JR. W.A. A longitudinal study of schistosoma vector snail population in Liberia. Am. J. Trop. Med. Hyg. 1979;28:531-538.
32. Dennis E., Yorkpor P., Holzer B., Manson A., Saladin B., Saladin K. and Degremont A. Studies on the epidemiology of schistosomiasis in Liberia: The prevalence and intensity of schistosomal infection in Bong country and the bionomics of the snail intermediate hosts. Acta Tropica. 1983;40:205-229.
33. Redda T. and Goll P.H. Investigation into the control of schistosomiasis at the HVA Wonji Shoa Sugar Estate in Ethiopia 2. Interim evaluation of the project Ethiop. Med. J. 1978;16:115-127.
34. Babiker S.M., Blankespoor H.D., Wassila M., Fonwick, A. and Daffala A.A. Transmission of Schistosoma haematobium in North Gezira, Sudan. J. Trop. Med. Hyg. 1985a;88:65-73
35. Babiker S.M., Fenwick A., Daffala A.A. and Amin M.A. Focality and seasonality of Schistosoma mansoni transmission in the Gezira irrigated area, Sudan. J Trop. Med. Hyg. 1985b;88:57-63.