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SCHISTOSOMIASIS IN ETHIOPIA

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Abstract—The literature on schistosomiasis in Ethiopia is reviewed with the objective of bringing together in one paper diverse sources which may not be available to those interested in schistosomiasis. Particular attention is given to the influence of altitude and climate, snail ecology and government economic programs on the distribution of schistosomiasis. Out of 365 communities studied between 1961 and 1986 for Schistosomiasis mansoni, cases were reported from 225 (62%), and in 85 (23%) the prevalence ranged from 10 to 92%. Most transmission sites and *S. mansoni* infections are in agricultural communities along streams between 1300 and 2000 m altitude infested with *Biomphalaria pfeifferi*, the major snail intermediate host. *S. mansoni* transmission above 2200 m and below 800 m is precluded in many parts of Ethiopia by low and high water temperatures, respectively. Schistosomiasis haematobium cases have been reported from 30 of the 54 communites studied, 17 of them with infection rates between 14 and 75%. Endemic *S. haematobium* appears to be confined in its distribution to lowlands below 800 m altitude. The highly focal distribution of *S. haematobium* transmission is largely due to the nonsusceptibility of most bulinine snails to the Ethiopian strain of the parasite and low water temperatures in the highlands. Water resources development, resettlement programs, refugee migration and other population movements may result in the spread of endemic *S. mansoni*. Lack of information on snail host/parasite relationships and the ecology of proven and suspected snail hosts does not permit predictions on the spread of endemic *S. haematobium*. Past and present schistosomiasis control programs in Ethiopia are reviewed and recommendations made for the national control program.

Key words—schistosomiasis distribution, snail and parasite ecology, population movements, water resources development, schistosomiasis control, Ethiopia

INTRODUCTION

Both intestinal and urinary schistosomiasis are endemic in Ethiopia. However, the diverse topography and climatic patterns in the country have contributed to the discontinuous, highly focal distribution of both these diseases. Additionally, Ethiopia possesses a unique and varied snail fauna consisting of bulinine species with a wide range of susceptibility to *S. haematobium* infections as well as transmission potentials. Recent government economic programs, including resettlement of drought victims, movement of the rural population into villages, refugee migration and water resources development are causing major changes in both the environment and population distribution which are associated with the distribution of schistosomiasis. Restructuring of health services as part of revised health policy and the development of peasant associations, urban dweller's associations and other mass associations over the past decade have permitted development of infrastructure necessary to support disease control programs, including a national schistosomiasis control program. In order to provide baseline data which are a prerequisite to defining areas of priority action and subsequently to evaluate progress in schistosomiasis control, the Institute of Pathobiology of Addis Ababa University carried out many community surveys between 1965 and 1986.

This paper reviews existing information on schistosomiasis and its physical, biotic and human correlates in Ethiopia. This review is timely due to the appearance of most epidemiological information on schistosomiasis in this country since 1979, when earlier medical geographical studies were carried out [1], and the need for relevant up-to-date information for the development of the national schistosomiasis control program.

During the past two decades studies on schistosomiasis have increasingly been carried out by geographers [1–12]. Reasons for this interest include the extensive data bases available on schistosomiasis occurrence, the strong physical and human behavioral influences in its distribution and the concern over the spread of infection. It is now well established that this three-factor disease complex [13] is not only well established in nearly all African countries and many countries in Asia and Latin America, but is even spreading in many areas. Water resources development, population increase and movements, persisting poverty and lagging control programs have frequently been associated with the spread of schistosomiasis [3]. Nevertheless, although schistosomiasis has been on the increase in many areas, its geographic distribution is far from continuous in most countries where the infection is endemic, due to a number of barriers to transmission and parasite spread. Understanding the nature of these barriers, together with conditions necessary and favorable for transmission is essential for evaluating the public health importance of schistosomiasis and prospects for its control.

Ayad [14], who reviewed the Italian literature on schistosomiasis in Ethiopia for the period 1914–1950, was the first to provide evidence that the two parasites *S. mansoni* and *S. haematobium* were being transmitted in different parts of the country. Since 1961, and especially since 1970, further and more systematic epidemiological studies covering human, snail and environmental aspects, have been carried out by different investigators. So far about 400 communities have been surveyed in all 14 administrative regions of Ethiopia, two thirds of them since 1979, primarily for the prevalence of *S. mansoni* infection; and about 60 communities in 7 administrative regions for *S. haematobium* infection [15–23]. Some of the study results were presented elsewhere [15, 20], but the geographic distribution of schistosomiasis and underlying factors aside from snail genetics and ecology were not analyzed in detail. Owing to the deficiencies in the data base, including scarcity of information on the incidence, intensity and temporal changes in infection, evaluation of the spread of schistosomiasis at the community and regional levels is not possible in this paper [24]. *S. mansoni* and *S. haematobium* are discussed separately due to the different ecology and geographic distribution of these two disease complexes.

METHODOLOGY

All available sources on schistosomiasis in Ethiopia were reviewed at the Institute of Pathobiology and at the Medical School Library of Addis Ababa University. Schistosomiasis maps were prepared from selected prevalence data. Only data from community surveys rather than routine parasitological data gathered by health institutions were used. For communities surveyed more than once, only the most recent and methodologically comparable data were used. Thus consideration was given to the site, age/sex and occupational structure of the study populations and the parasitological techniques used. Volunteers in schools, markets and community meetings were studied in 313 of the 363 communities surveyed for *S. mansoni* and in 33 of the 44 communities surveyed for *S. haematobium*. Randomly and systematically selected households were studied in the remaining communities. A fair degree of standardization in sample selection and parasitological techniques used was achieved since nearly 90% of all communites were studied by the same institutions between 1961 and 1986 (the Institute of Pathobiology). Most stool examination results were obtained with the comparable Ritchie formol/ether concentration, merthiolate-iodine-formaldehyde concentration (MIFC) and Kato techniques and few with the less efficient direct smear method [25]. Intensity of *S. mansoni* infection was studied using the Kato technique. The centrifugal sedimentation technique was used in nearly all communities studied for *S. haematobium*, few recent studies using the nucleopore filter technique. These two urine examination techniques were found to be similarly efficient in different countries [26]. The samples studied and the parasitological techniques used in each community are shown in Appendix 1.

Three hundred and eight of the 365 communities listed in Appendix 1A were mapped in Fig. 2. For the remaining 57 communities, all in heavily studied areas such as Lake Ziway, the upper Awash valley, the Lake Tana basin and the foothills of the eastern highland, rates were presented as mean values due to crowding and associated cartographic difficulties. Only infection rates of 5% and higher were mapped since lower rates are likely to be due to imported cases [15]. This judgment is based on questionnaire results on the origin of infections and on the geographical/altitudinal distribution of *S. mansoni* infection rates (Appendix 1A).

A scatter diagram showing the altitudinal distribution of *S. mansoni* infection was prepared by using data for school children in 278 communities. The advantages of selecting school children for schistosomiasis prevalence and distribution studies include their easy accessibility in rural areas, their fairly wide residential distribution (which overcomes the problem of focal transmission in mapping distribution of infection), the concentration of prevalence and intensity of schistosomiasis in children and the cost effectiveness of studying school children in national surveys [27].

Although the age/sex and occupational structure of the study samples are not strictly comparable, any bias appears to be relatively small and does not invalidate the conclusions drawn. This is indicated by the geographical and altitudinal distribution of infection nationwide and among different population groups in the same communities. Possibly more serious is the selection of most study communities along motorable roads, made necessary by logistic problems, including the inaccessibility of many Ethiopian villages by motor vehicle. This also affected the selection of snail sampling sites, since most of them were in the same communities selected for schistosomiasis studies. Failure of including many isolated areas in the studies resulted in lower geographical coverage than in other countries with less mountainous topography, including Zimbabwe [27].

The snail distribution mapped here is under-reported due to the confinement of most malacological surveys to a single collection site visit. Host snail populations strongly fluctuate seasonally in many Ethiopian streams due to seasonal fluctuations in flow patterns. Most snail samples were taken using a dip net but the rocky substrate of many mountain streams required the use of foreceps instead. Different investigators used different collection techniques and only in the Lake Tana basin, Awash valley and in communities with schistosomiasis control programs could longitudinal and quantitative snail distribution data be gathered. Nevertheless, nearly all snails were collected at human water contact sites around settlements, where schistosomiasis intermediate hosts are usually most common.

S. MANSONI

Human population and schistosomiasis distribution

Ethiopia is one of the least developed countries, with a per capita GNP of $110 in 1984 [28]. The great majority of the rural population lacks safe water supplies and sanitary facilities. According to the first national census carried out in Ethiopia in 1984, there were 42 million people. The national density of 34.4 persons per square kilometer, which is relatively high for East Africa, does not reflect strong regional and altitudinal variations. The highest densities were in the central administrative regions of Shewa (94.7) and Arsi (70.7), but the greatest population pressure on the land exists in the eastern and northern regions of Welo (45.5), Tigray (36.6) and Eritrea (23.0), all of them areas of outmigration and recurrent drought. The lowest densities in 1984 were in the southern region of Bale (8.1). Nearly 89% of the population lived in rural areas and 11.3% in towns of more than 2000 population [29]. The great majority of the rural population were sedentary subsistence farmers living in the highlands. An estimated 10% of the population were nomadic pastoralists, shifting cultivators and hunter/gatherers in the peripheral hot and semiarid to arid lowlands. According to studies of the altitudinal distribution of the Ethiopian population in 1984, 37% lived in areas above 2200 m, 45% between 1500 and 2200 m and 18% below 1500 m [30].

The upper altitudinal boundary of *S. mansoni* distribution in Ethiopia is between 2000 and 2200 m but this parasite is also endemic in many communities below 1500. The population at risk in contracting the infection is therefore probably larger than the 18 million estimated by Ayele [15]. The mean prevalance of *S. mansoni* in 225 communities surveyed between 1979 and 1982 was 14% [15]. On the basis of this prevalence there would be about 2.5–3.0 million infected individuals country-wide. Iarotski and Davis [31] estimated that 31% of the Ethiopian population is at risk of becoming infected with either *S. mansoni* or *S. haematobium*.

It has been suggested that the parasite *S. mansoni* is of some antiquity in Ethiopia [1] in view of its focal distribution in isolated areas such as the Blue Nile gorge [32, 33] and Omo National Park in Gamo Gofa Administrative Region [34]. The shifting cultivators, pastoral nomads and hunter/gatherers inhabiting these areas have little contact with nearby sedentary agriculturalists. Limited social interaction between these groups reduces the possibility of introducing the parasite from outside the isolated communities and, on the other hand, its diffusion from these communities to adjacent areas. Although this view has been supported by the finding that *S. mansoni* circulates in a zoonotic cycle in indigenous monkeys in Omo National Park [34], several other investigators have suggested that this parasite is of recent introduction [14, 35, 36]. Both arguments are probably valid for different communities and localities. Many extensive movements of armies, merchants and ethnic groups have taken place during most of Ethiopia's history [37] and schistosomiasis was probably established in some places many centuries ago. Nevertheless, in new villages, settlement schemes and irrigation farms the presence of schistosomiasis can only be explained by recent introduction, apparently from different parts of the country.

Owing to the extensive movements of people in recent decades from endemic to nonendemic areas and vice versa, *S. mansoni* is now widespread in Ethiopia. In the 365 communities listed in Appendix 1A positive cases were found in 225 (62%), and in 149 (41%) the prevalence was higher than 5%. *S. mansoni* transmission has been verified in 33 of these 149 communities through recovery of infected *Biomphalaria* snails from human water contact sites [15, 20]. Overall, the four northern administrative regions of Eritrea, Tigray, Welo and Gonder are the most affected, with 54 (48%) of the 112 communities studied having prevalence levels higher than 10%, some reaching more than 90% among school children. The southern and western regions of Bale, Sidamo and Ilubabor are the least affected, with only 3 (6%) out of 51 communities with rates above 10%. The remaining seven regions of Shewa, Gojam, Welega, Arsi, Harerge, Gamo Gofa and Kefa had 30 (16%) of 182 communities with rates above 10%. High *S. mansoni* infection rates were clustered in five geographical areas: (1) Lake Tana basin, (2) the far northern highlands, (3) the eastern foothills of the central highlands, (4) the central part of the rift valley above 1300 m altitude (upper Awash valley, Lake Ziway and Lakes Abaya/Chamo areas), and (5) the western lowlands. All 19 communities studied around Lake Ziway had rates betwen 8 and 64%; 12 of the 40 communities in the Lake Tana basin had rates above 50% and in 34 of the 43 communities in the eastern foothills they were 5–77% (Appendix 1A). Prevalence did not decrease in larger towns. Rates between 5 and 59% were reported from 23 towns with more than 10,000 population, including the capitals of the administrative regions of Welo and Kefa (Dese and Jima) and the two rapidly growing industrial centers of Akaki and Bahir Dar (Table 3). *S. mansoni* transmission was confirmed in seven towns above 10,000 population [20, 66]. High *S. mansoni* prevalence in larger towns reflects the generally inadequate water supply and environmental sanitation in towns and perhaps also high rural–urban migration rates. Most Ethiopian towns have been described as oversized villages without adequate social services and urban economic structure [30]. The wide distribution of underdeveloped towns in developing countries indicates that schistosomiasis is not strictly a disease of rural agricultural people, contrary to common beliefs [3].

Differences in prevalence between subsistence farming, migrant laborer and pastoral nomadic populations are mainly due to ecological differences between their areas of residence and population movements. Subsistence farming communities are located mostly at altitudes between 1500 and 3000 m, with most affected communities between 1500 and 2100 m. Peasants from the overpopulated areas of central, eastern and northern Ethiopia have settled or work seasonally in lowland irrigated state farms, particularly in the Awash valley. By desegragating the prevalence data for the same communities or localities in the Awash valley into rates for indigenous pastoralists and migrant farm laborers (together with studies of the snail distribution) it was possible to identify endemic areas and to evaluate the role of labor migrations. Whereas the presence of infection among pastoralists in the upper valley and the absence of infection in the middle valley and lower plains is due to *B. pfeifferi* snail distribution and actual transmission levels in the Awash valley, the high rates among migrant farm laborers in the lower valley were traced to importation of the infection from the highlands [20] (Appendix 1A).

Approximately 90% of the known endemic communities are villages located by small streams at intermediate altitudes, between 1300 and 2200 m. This altitudinal zone supports the majority of the population due to the suitability of the climate and soils for rainfed sedentary agriculture and the absence or near-absence of malaria, trypanosomiasis and other severe vectored diseases of the hot lowlands. Rural populations largely depend on stream water for their daily needs due to the scarcity of piped and well water, or because of traditional customs and preferences. Practically all streams are contaminated with human excreta, resulting from defecation along streams, washing of soiled children's clothes, bathing, swimming and numerous other domestic, economic and recreational activities. This contamination results in the release of miracidia which hatch from eggs and then infect the snail intermediate host. Swimming, crossing of streams, washing, fishing and other exposure type activities result in infection by cercariae produced by the snail host at the same sites assure that the schistosome transmission cycle is maintained [12, 22, 38]. High *S. mansoni* infection rates were also reported from communities around Lake Tana, the freshwater rift valley lakes Ziway and Abaya, from several irrigation schemes in the Awash valley (300–1500 m) and from the western lowlands (500–1000 m) (Figs 1 and 2; Appendix 1A).

The altitudinal distribution of endemic schistosomiasis mansoni shows a distinct pattern when examining prevalence data for school aged children in 278 communities. Particularly strong associations were observed in the rift valley and in the central, eastern and northern highlands. Prevalence generally increased with altitude, reaching around 90% in several villages in the highlands and then sharply declined above 2000 m. None of the communities above 2300 m had infection rates above 7%. In the western lowlands and highlands only a weak association with altitude was noted. Infections were present

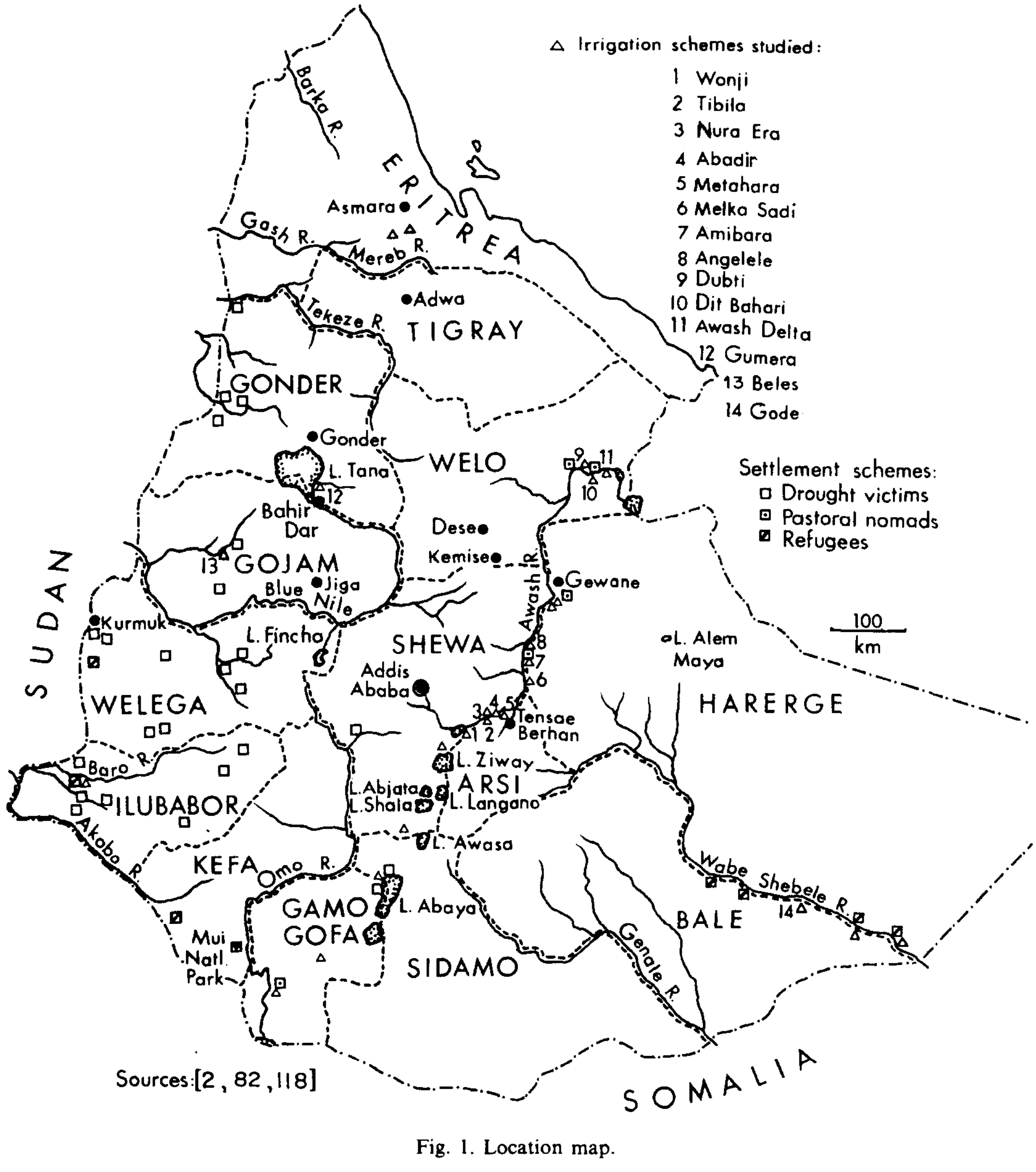

Fig. 1. Location map.

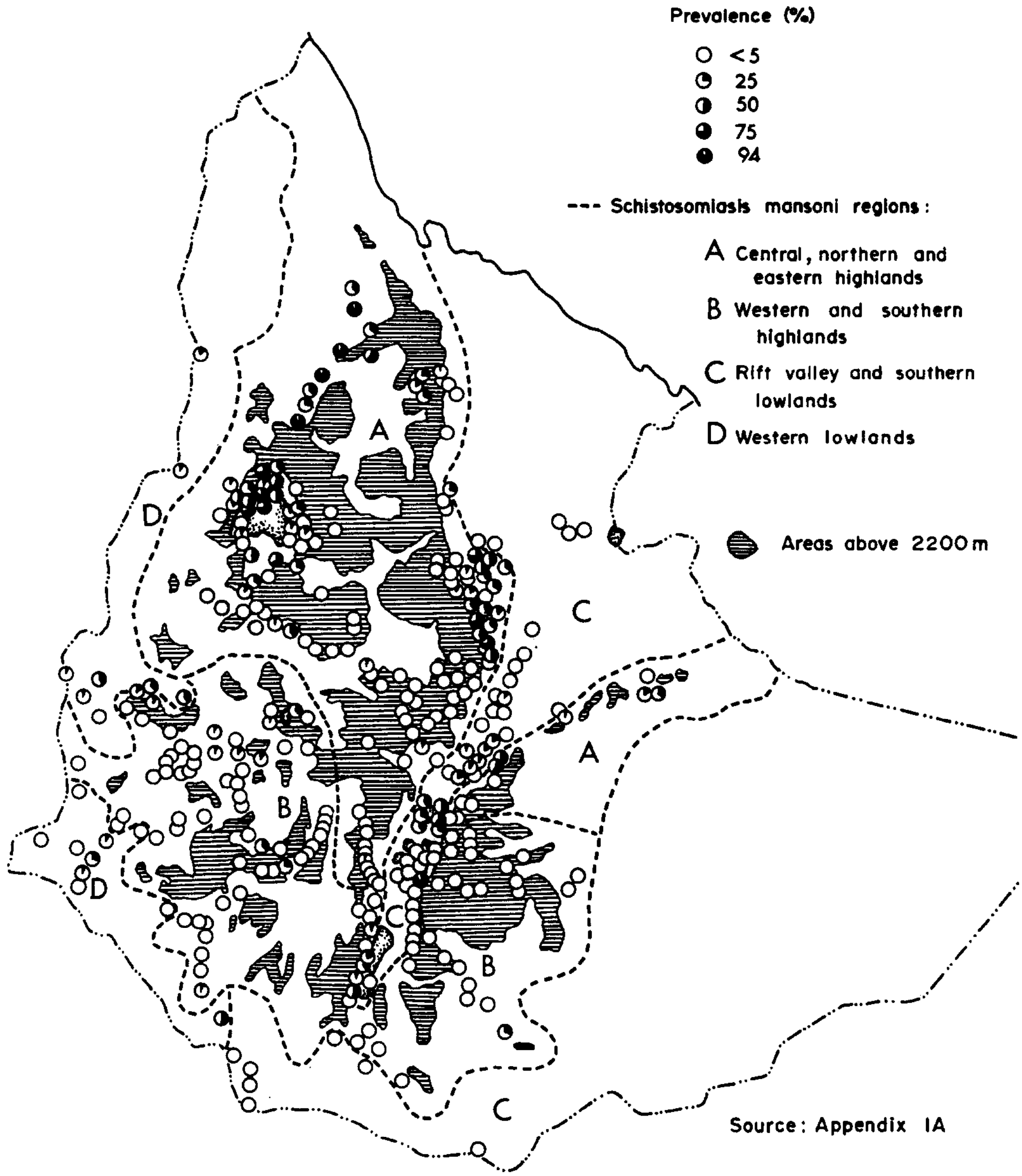

Fig. 2. Schistosomiasis mansoni distribution in 365 communities.

in most western lowland communities (500–1000) but did not increase with altitude (Fig. 4).

Nearly all studies of schistosomiasis in Ethiopia are prevalence studies. Few investigators studied intensity of infection. This situation reflects the emphasis given by the Institute of Pathobiology and the Ministry of Health to determining basic patterns of schistosomiasis distribution in the country but also the absence of a national schistosomiasis control program. Intensity of *S. mansoni* infection, usually expressed quantitatively as the number of eggs excreted per gram of stool, is an essential measure for the evaluation of control programs since it is more sensitive to changes in infection status in individuals and communities than prevalence. In only five communities was intensity of infection studied in some detail, namely the towns of Tensae Berhan, Kemise and Jiga (Fig. 1) and in the two rural villages of Guramba and Twawuzgi in the Lake Tana basin. In Tensae Berhan, egg counts ranged from 21 eggs/g stool in males 36–65 years old to 180 eggs/g in boys 11–15. Egg counts were somewhat lower in females [39], which correlates with observed water contact patterns [38]. In the two villages the highest counts were in males 10–14 (298 eggs/g) and lowest in females 40–49 (40 eggs/g) [40]. In Kemise, where a pilot control study was carried out egg counts were significantly higher in males 5–19 years of age (238 eggs/g) than in females 5–19 (143 eggs/g) prior to mass chemotherapy [17]. In Jiga the highest excreters were the 15–19 age group (368 eggs/g), but the highest index of infection, which considers age-specific population size, prevalence and intensity was in the 10–14 group. According to the index of infection, the age group 5–19 years was responsible for 93% of the contamination in the local streams.

The various intensity studies revealed the characteristic relationship between prevalence and intensity of infection and symptomology. Heavy infections were most commonly associated with abdominal pain and distention as well as bloody diarrhea and light infections with few or no symptoms [39, 40]. Compared to other endemic areas in Africa, the Ethiopian communities had relatively low intensity levels. They were significantly lower than those in the hyperendemic areas of Kenya [42, 43] and lower Egypt [44] but somewhat higher than those in the hypoendemic areas of the Nile delta [45].

Snail and parasite ecology

Of the six African intermediate hosts of *S. mansoni*—*Biomphalaria pfeifferi*, *B. sudanica*, *B. alexandrina*, *B. choanamphala*, *B. angulosa* and *B. camerunensis* [46]—only the former two are endemic in Ethiopia. *B. pfeifferi* is the more important of the two species because of its wide distribution. *B. sudanica* is confined in its distribution to few localities. The distribution of both snails is shown in Fig. 3. *B. pfeifferi* has been found in pools, swamps, lakes, small to medium streams, irrigation canals and seepages associated with these various water bodies. By far the most important habitat is small streams with slow current, moderate turbidity but low silt content, much vegetation at the margin, and a muddy or mixed bottom with gravel or rocks. *B. pfeifferi* occurs at altitudes as low as 650 m (Mui National Park) and as high as 2800 m (in the highlands of central and northern Ethiopia). The highest altitude where *S. mansoni* transmission is known to take place in Ethiopia is in a stream in Dese town in Welo Administrative Region, at 2470 m [15, 17]. The lowest known transmission locality is Omo National Park [34].

The altitudinal distribution of *S. mansoni* in Ethiopia is due primarily to the retarding effect of low water temperatures on both the infectivity of the free swimming cercariae and snail breeding and the deleterious effect of high temperatures on snail survival [1]. The most favorable conditions for snail population growth and *S. mansoni* transmission are in the highlands at intermediate altitudes, between 1000 and 2000 m in most parts of the country, although *B. pfeifferi* is also established in the western lowlands. *B. pfeifferi* has never been found in the Awash valley irrigation schemes, streams and lakes below 800 m, in spite of repeated malacological surveys between 1973 and 1987 by the Institute of Pathobiology [12, 15, 19, 46]. Mean maximum water temperatures at 800 m in the Awash valley were 28°C, reaching 32°C in the lower plains [2]. Surveys in southern Ethiopian lowlands also failed to find *B. pfeifferi* [1]. Similarly, the absence of this snail from the East African coast 10°S and 10°N has been attributed to year round high temperatures [3] and its altitudinal distribution in Southeast Africa is also temperature related [47]. In the laboratory *B. pfeifferi* survived well in water temperatures between 18°C and 25°C, but at higher temperatures it laid few eggs, many eggs failed to hatch and the death rate was higher [48, 49]. Snails die of oxygen starvation due to reduction of dissolved oxygen and increases in the heart beat and oxygen consumption in warm water [50].

At high altitudes it is primarily the cercariae and miracidia that are affected by low temperatures, although breeding and growth of *B. pfeifferi* are also reduced. Three streams in Shewa Administrative Region west of Addis Ababa, at 2200–2750 m and with mean monthly water temperatures of 13–15°C supported *B. pfeifferi* seasonally. Local school children in two villages along these streams were free of *S. mansoni* infection [51, 52]. The 2100–2200 m contours lie between the 16–18°C isotherms in Ethiopia [53]. Laboratory experiments show that cercariae are almost motionless at 10°C and hyperactive and thus highly infective at 40°C. Optimum temperatures for *S. mansoni* cercariae penetration are between 18 and 35°C [48]. Even if miracidia succeed in infecting *Biomphalaria* snails, the incubation period of the parasite in the snail is significantly prolonged in low water temperatures, as shown by Lakew in a stream at 2800 m near Addis Ababa [54]. In the Transvaal in South Africa, cercariae developed from sporocysts in 34 days in outside aquaria with mean monthly temperatures of 24°C but required 132 days in 8°C temperatures [55, 56]. Seasonally low temperatures are associated with the seasonal disruption of transmission in Egypt [57], Zimbabwe and South Africa [55, 58].

In addition to temperature high silt concentration and instability of stream habitats in the hot lowlands are factors in the scarcity and absence of *B. pfeifferi* at lower altitudes in Ethiopia. Silt mechanically injures the respiratory system of aquatic snails and the seasonal drying up of many lowland streams causes high mortality in spite of their ability to survive dessication for several months by estivation [2].

Regional differences in rainfall patterns are another factor in the distribution of *B. pfeifferi* and *S. mansoni*. The low prevalence of infection in the western and southern highlands is associated with the scarcity of *B. pfeifferi*. The western highlands receive more than 2000 mm of annual rainfall in many areas, which are the highest values recorded in Ethiopia. The rainy season in the western and southern highlands is correspondingly longer, resulting in relatively little fluctuations in stream flow patterns. The fast flowing streams in these areas contrast with the generally smaller streams in eastern and northern Ethiopia which are drastically reduced in size during the dry season. Small, slow flowing streams which form pools are the most suitable habitats for *B. pfeifferi* reproduction and growth in this country. Snail and human infections reach their peak during the hot dry season, when human water contact is most intense and snail densities highest. During the subsequent rains strong currents flush *B. pfeifferi* out of its habitat, causing sharply increased mortality. In the central, eastern and northern highlands, the presence of one or two dry seasons therefore facilitates intensive seasonal transmission [39, 46, 59–65]. Macrovegetation appears to contribute to the observed regional distribution pattern of *B. pfeifferi* and *S. mansoni* infection. Brown [62] suggested that the scarcity of *B. pfeifferi* in the humid highlands of western Ethiopia is due largely to the concentration

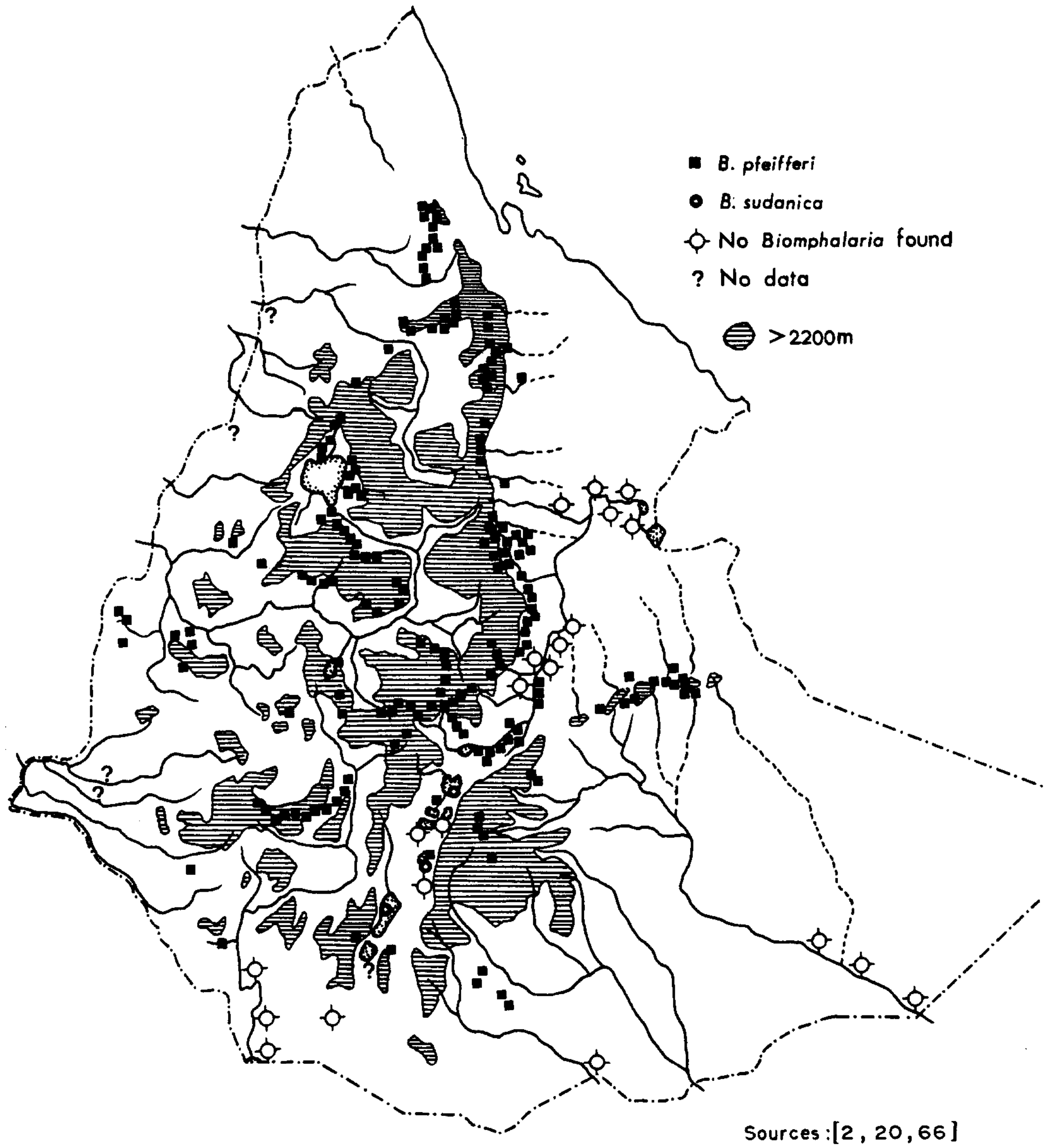

Fig. 3. Distribution of *Biomphalaria pfeifferi* and *B. sudanica.*

of Ethiopia's high forests in this part of the country. This would be in agreement with the scarcity of this snail and human infections in the rainforest zone in Central Africa although low human population density may be an additional factor [3]. Accelerated deforestation and population increase in western Ethiopia due to resettlement may thus possibly result in the spread of endemic *S. mansoni.*

B. pfeifferi is the most common species among the freshwater gastropods of Ethiopia. Combined results from several major snail surveys show that this snail existed in 30–48% of 698 different types of water bodies, followed by *Bulinus* species (20–41%) [20, 66]. Swamps and lakes are less suitable habitats, apparently due to oxygen scarcity in the swamps and wave action in the lakes, as noted elsewhere in Africa [46, 47]. However, *B. pfeifferi* has been found in Lake Tana [59, 60, 68, 69], Lake Alemaya, Lake Awasa [62, 70], the crater lakes Hora and Bishoftu south of Addis Ababa [46] and in Lake Mai Bahir [17], all above 1600 m altitude (Fig. 1). The high incidence rates (4.5–64.5%) during a 4 month period among students and teachers coming from other parts of Ethiopia to 11 communities on Lake Tana indicates that transmission in the lake and in the tributary streams is intense. The higher prevalence in males (33%) than females (10.8%) and Moslems (40.0%) than Christians (26.8%) were associated with more frequent swimming of boys and with ritual washing of Moslem males [71]. In irrigation schemes *B. pfeifferi* is now well established in Wonji, Metahara, Nura Era, Tibila, Abadir, Melka Sadi and Amibara, all in the Awash valley, and in Beles, Gumera and Upper Birr (Table 1, Fig. 1). Snail densities generally decrease between Wonji (1540 m) and Amibara (800 m), further supporting the temperature hypothesis of *B. pfeifferi* distribution in Ethiopia [1, 46].

B. sudanica has been found only in lakes Ziway, Awasa and Abaya in the rift valley, where it is the only transmitter of *S. mansoni,* and in an isolated

Table 1. Water resources development and schistosomiasis in Ethiopia

Water resources development projects	Start of irrigation*	Size (ha)*	Altitude (m)	Intermediate host snails present†	*Schistosoma* infection rates‡	Year of study	Source
IRRIGATION SCHEMES:							
Rift valley and southern lowlands							
Various schemes in the upper Awash valley	1954–1966	23,105	960–1,540	*Bpf*	5–20	various (1972–1980)	[2, 119]
Various schemes in the middle Awash valley:	1953–1983	22,118	620–740	*Bpf*§	0–7	1965–1980	[2, 119]
Dofan/Bolhamo	Under construction	9,000	750	?	?		
Various schemes in the lower Awash valley:	16th century 1974	17,800	340–380	no	0–16	1966, 1973	[2, 119]
Lower Awash I	Under construction	5,000	350	?	?		
Lower Awash II		31,000	350	?	?		
Central rift valley:							
Bilate (Shewa)	1973	1,500	1,450	?	?		
Arba Minch (G. Gofa)	1972	2,000	1,400	?	?		
Alaba Kolito (Shewa)	Under construction	20,000	1,450	?	?		
Southern rift valley:							
Woyto (Gamo Gofa)	Under construction	10,000	600	?	?		
Lower Omo (G. Gofa)	Under construction	10,000	600	no	no		[117]
Southern lowlands:							
Gode South (Harerge)	Under construction	20,000	400	*B*	0–42	1977	[94]
Gelana (Sidamo)	Under construction	8,000	400	?	?		
Western lowlands							
Alawero (Ilubabor)	1986	10,000	500	?	?		
Sedit Humera (Gonder)	Planned	30,000	550	no	0	1972	[59, 60]
Tekeze-Sedit valleys	Planned	30,000	1,200–1,500	?	?		
Highlands							
Rib and Gumera	Under construction	40,000	1,700	*Bpf*	1–34	1981	[15, 20]
Welkite (Shewa)	Planned	4,500	2,200	?	?		
Jiga (Gojam)	Planned	24,000	1,450	?	?		
Butajira (Shewa)	Planned	3,000	1,800	?	?		
Barka (Eritrea)	Planned	130,000	500–1,000	?	?		
Mereb Gash (Eritrea)	Planned	4,000	600–1,200	?	?		
Debena (Welega)	Planned	6,100	1,280	?	?		
Jijiga (Harerge)	Planned	4,000	1,500–1,700	?	?		
Upper Birr (Gojam)	Under construction	23,350	1,700	*Bpf*	4.6	1980	[80]
Lower Birr (Gojam)	1981	6,600	1,500	?	?		
Beles (Gojam)	Under construction	63,000	1,150	*Bpf*	0.7	1980	[80]
Six small schemes in Welo	Under construction	150–1,250 each	1,300–2,000	?	?		
MANMADE LAKES:							
Koka I (Shewa)	1958		1,550	*Bpf*	3.3	1968	[35]
Koka II (Shewa)	1962		1,500	*Bpf*	0	1968	[35]
Fincha (Welega)	1976		2,000	*Bpf*	33.0	1982	[20]
Melka Wakena (Har.)	1986		500	?	?		
Gibe (Kefa)	Planned		1,450	*Bpf*	?	1985	[118]

*Or completion of dam construction; most information is based on Kloos [12] and WRDA [118].
†*Bpf* = *Biomphalaria pfeifferi*; ? = no data; *B* = unidentified *Bulinus*.
‡The rates shown for Gode South are for *S. haematobium*; all other rates are for *S. mansoni*; ? = no data.
§*B. pfeifferi* snails were found only in Amibara and Melka Sadi farms.

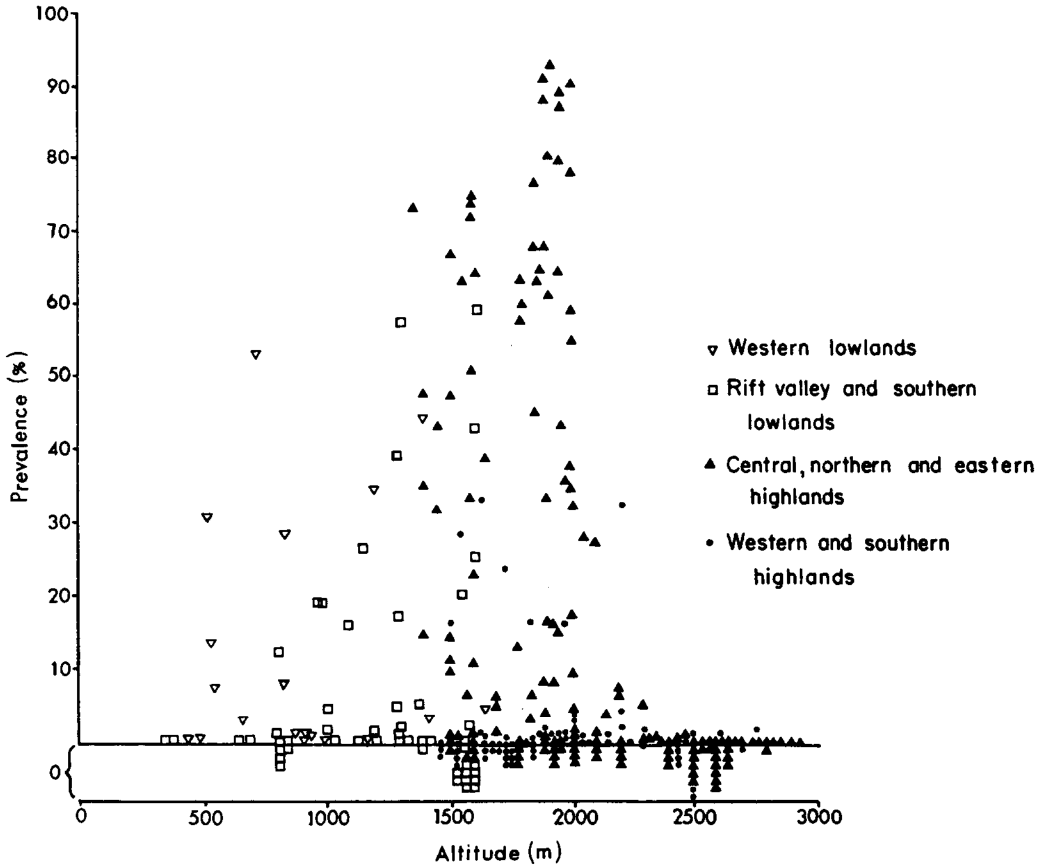

Fig. 4. Altitudinal distribution of schistosomiasis mansoni among school aged children in 278 communities, by schistosomiasis region.

focus in a stream in northern Shewa region (Fig. 4) [60]. This species is usually present in reeds and floating mats of grasses, mostly in shallow waters along the shores of these lakes but is absent from open beaches subject to strong wave action [72]. *S. mansoni* infection rates in 16 villages on Lake Ziway ranged from 8 to 63%, with the highest rates in fishermen [22, 62]. *B. sudanica* is absent from the alkali lakes Abaya, Shala and Langano. Except for these and several other alkali/salt lakes in the rift

Table 2. Intermediate host snail species in Ethiopia and their susceptibility to *S. mansoni* and *S. haematobium*

Snail species	Susceptibility status*	Source
Biomphalaria:		
B. pfeifferi	+ +	Ito *et al.* [113]; Lemma *et al.* [114]
B. sudanica	+ +	Ito *et al.* [113]; Institute of Pathobiology [80]
Bulinus:		
Truncatus/tropicus complex:†		
B. tropicus (*n* = 18)	−	Lo [115]
B. truncatus (*n* = 36)	±	Wu and Burch [112]
B. hexaploidus (*n* = 54)	−	Lo [115]
B. octoploidus (*n* = 72)	±	Lo [115]
Africanus group:		
B. abyssinicus	+ +	Lo [116]
B. africanus	±	Ali *et al.* [16]
B. ugandae	?	
Reticulatus group:		
B. reticulatus	?	
B. scalaris	?	
Forskalii group:		
B. forskalii	?	

*+ + = Highly susceptible. ± = Susceptible to only some Ethiopian or nonEthiopian strains of *S. haematobium*. − = Nonsusceptible. ? = No information available; the susceptibility status of *B. reticulatus* and *B. scalaris* in other African countries is uncertain and *B. ugandae* and *B. forskalii* were experimentally shown to be nonsusceptible [46].

†Shows the haploid chromosome numbers of each species in this group.

valley, water chemistry does not appear to be a limiting factor in snail distribution in Ethiopia. The low ion and cation, particularly calcium concentrations associated with the absence of *B. pfeifferi* in some Central African localities [67] have not been recorded in Ethiopia [2, 17, 19].

The high susceptibility of both *B. pfeifferi* and *B. sudanica* to the Ethiopian strain of *S. mansoni* (Table 2) indicates that endemic *S. mansoni* will probably spread to all localities below 2000 m altitude where these snails already occur but where the transmission cycle is not yet established.

Water resources development, resettlement programs and population movements

The government of socialist Ethiopia has given high priority to the development of irrigated agriculture, the construction of dams for irrigation and hydroelectric power production, and resettlement of the rural population with the objective of reversing the downward economic trend in the 1980s and to provide a long-term solution to the recurrent drought and famine [73, 74]. Four medium and many small-sized manmade lakes were in operation by 1986. Most of them are in the Awash, Blue Nile and Wabe Shebelle river basins. A fifth multipurpose dam is planned on the Gibe branch of the upper Omo river (Fig. 1). According to the Water Resources Development Authority [75], a total of 73,000 ha were irrigated on large state farms in 1986, 63,000 of them in the Awash valley alone. Plans call for the development of another 470,000 ha. More than 50 medium and large irrigation projects have been identified for future development, 18 of them for immediate implementation under the Ten-Year Plan (1985–94). These 18 schemes are in the Blue Nile, Wabe Shebele, Awash, Omo, Mereb/Gash, Genale, Baro/Akobo and Tekeze river valleys. They comprise a total of 243,000 ha. The total irrigable area in Ethiopia has been estimated at 1.8–3.0 million ha [75, 76]. Nearly all existing and planned irrigation schemes are located below 2000 m altitude, where water shortage is most serious and schistosomiasis is endemic (Figs 1 and 2; Table 1). No comprehensive information is available on small-scale, subsistence type irrigation, which is receiving greater attention by peasant associations as a means of boosting food production.

The characteristically rapid spread of both *B. pfeifferi* and *S. mansoni* infection in irrigation systems has been documented in Ethiopia only in Wonji sugar estate. Ten infected laborers were first reported by the farm hospital in 1964, 10 years after commencement of irrigation. They were thought to have imported the infection from their home areas in the highlands [77]. In 1968, 7.5% of the farm population was infected, 9% in 1972, 17% in 1975 and 20% in 1980 [2, 78]. Prevalence continued to increase in spite of snail control and health education programs in the labor camps and local schools [12, 79]. Similar increases were reported from Metahara sugar estate in the 1980s [2, 80]. Temporal changes in schistosomiasis occurrence in the other irrigation schemes are not known due to lack of longitudinal data but migrant laborers from the highlands apparently introduced *S. mansoni* to the Awash valley schemes [81].

Most irrigation schemes in Ethiopia have been located and developed without prior assessment of the risk of schistosomiasis and other water related diseases. Failure to systematically incorporate basic preventive structures and measures into the design of schemes from the beginning, including proper location and construction of canal systems and siting of labor camps in relation to canals, provision of potable domestic water supplies and latrines, and screening of migrant laborers for schistosomiasis must be expected to facilitate transmission and disease spread.

Among the manmade lakes, *S. mansoni* transmission takes place in Lake Fincha, where 33% of the local population is infected. Snail surveys by the Water Resources Development Authority revealed *B. pfeifferi* in most tributary streams of the upper Omo river where the high dam is to be built. The status of *S. mansoni* in the Koka I and Koka II lakes is not known due to incomplete data [2, 35] and no studies have been carried out in the recently (1986) completed Melka Wakena Lake. The full epidemiological impact of water resources development in Ethiopia is not known primarily due to lack of information on the changing ecology and human population of projects.

Resettlement schemes have been developed in Ethiopia for drought victims, pastoralists and refugees since the early 1970s. In response to the 1983/84 drought the government implemented a resettlement program that involved the movement of about 600,000 drought affected people from the central and northern regions of Shewa, Welo, Tigray (and eastern Gojam and Gonder) to the western regions of Kefa, Ilubabor, Welega and Gojam, where conditions for dry farming are more favorable [82, 83]. This massive movement of settlers from the highly endemic areas in eastern and northern Ethiopia to some 50 settlement schemes, in some of which transmission takes place [23, 80, 84] may result in the spread of *S. mansoni* infection. Acceleration of spontaneous down-slope movements in recent years in response to overpopulation and land degradation in the Ethiopian highlands and the control of malaria in some lowland areas [85] may further contribute to parasite spread. A preliminary study designed to evaluate the status of schistosomiasis, malaria and other water related parasitic diseases in the rapidly growing resettlement schemes is being carried out by the Ministry of Health.

Less information is available on the possible impact of the national program of peasant settlement in local villages on *S. mansoni* occurrence. Under this program, which is designed after the Tanzanian Ujamaa model, nearly all the sedentary rural population is to be moved to new villages with 500 households each as a prerequisite for rural development. Before the 1974 revolution less than 5% of the population lived in villages [86]. Although all new villages are to be provided with safe water supplies and sanitary facilities, budgetary and other constraints have not always permitted their installation. The change from dispersed to nucleated settlement, with associated concentration of the rural population at fewer contact sites at streams and lakes may increase the intensity of transmission in endemic areas and potentially endemic areas. In any case, evaluation of the net effect of this village settlement program on schistosomiasis must also consider the planned extension of health services in the new villages. Coverage by the settlement program has been uneven, with about half of the rural population of Harerge and Bale administrative regions resettled but only an estimated 10–20% of the other regions and only few people in Tigray and none in Eritrea. In late 1986, 5.73 million people or 15.4% of the total rural population had been moved into 5180 villages in 308 *weredas* (districts) in 10 administrative regions. With the completion of another 5400 villages in 1987, a total of 9.4 million people or 25% of the rural population will have been relocated [86].

S. HAEMATOBIUM

Human population and schistosomiasis distribution

The human population at risk of contracting *S. haematobium* infection in Ethiopia is difficult to estimate owing to the high mobility of the population in the lowlands, where the parasite is endemic, and lack of comprehensive census data. Pastoral nomads, shifting cultivators, migrant farm laborers and settlers from drought affected areas constitute the majority of the population. All four known *S. haematobium* endemic areas in Ethopia are below 800 m altitude (Fig. 5). Only in the western Ethiopian focus do the two schistosome species overlap in their distribution (Figs 2 and 5). Ayele [15] estimated that 4 million people are in danger of getting infected with *S. haematobium*.

There were sporadic case reports of *S. haematobium* infection by Italian workers in the 1930s, from several communities in Tigray, Gojam, Kefa and Harerge administrative regions. Endemicity, however, was not established [14]. In 1957, the first community survey of *S. haematobium* infection in Ethiopia reported 48% prevalence among Afar pastoralists near Gewane in the Awash valley [87]. Since

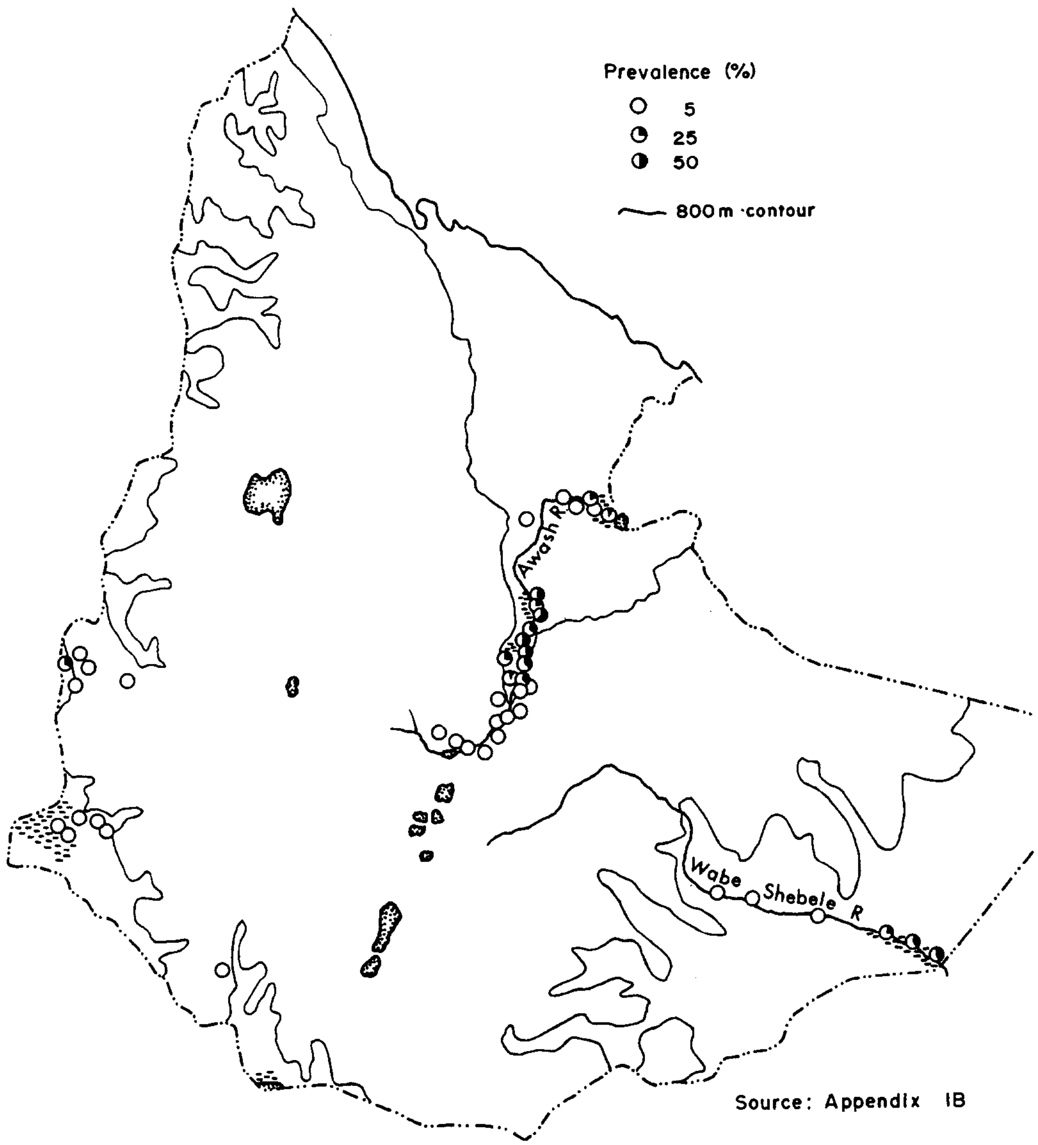

Fig. 5. Schistosomiasis haematobium distribution.

1969 several studies have been made on the distribution of *S. haematobium* and its intermediate snail hosts. The parasite was shown to be endemic in several communities in the middle and lower Awash valley (300–750 m), in the lower Wabe Shebele valley near the Somali border (200–400 m) and in western Welega near the Sudan border (700 m) [15, 20, 66]. These four endemic areas are widely separated from each other (Fig. 5). Although other places studied so far have not been shown to be endemic, imported cases have been reported from several communities in western, central and eastern Ethiopia [2, 14, 88].

Prevalence of infection in the four endemic areas ranged from 5 to 58%. Most infected communities and the highest infection rates were found in the Awash valley (Fig. 5, Appendix 1). Intensity of infection was studied only in the Afar village of Enta-Doyta, where 58% of the population were infected. Mean egg counts were 13.1 eggs/ml of urine. Female children 15–19 years were the most (42.9 eggs/ml) and males 40–44 the least (0.5 eggs/ml) infected [18, 89]. These egg counts are considerably lower than those obtained in hyperendemic areas in The Gambia [90] and Tanzania [91] but higher than in the Nile delta [45]. Whereas infection rates were higher among males in the focus in Kurmuk town in western Welega, they were always higher among females in the Afar society [18, 92]. Division of work is the major factor in the sex differences among the Afar and apparently also in Kurmuk town. Afar males have less contact with infective water than females, who collect several aquatic plants for food and hut construction in the local swamps and freshwater lakes, the only habitat of these plants and of the intermediate snail host in the Awash valley [92].

Snail and parasite ecology

From the epidemiological and ecological points of view it is important that all snail hosts of *S. haematobium* in Africa belong to five species groups, the *africanus*, *truncatus*, *tropicus*, *forskalii* and *reticulatus* groups. Recently Brown [46] placed the *truncatus* and *tropicus* groups into the *truncatus/tropicus* complex. Of particular significance is the discovery of genetically different snails in the *truncatus/tropicus* complex. All snails with the haploid chromosome numbers of 18 ($n = 18$), except for one snail population in South Africa are nonsusceptible to *S. haematobium* infection both in nature and in the laboratory. Other polyploid snail species are tetraploids ($n = 36$), which are generally susceptible to infection, hexaploids ($n = 54$) and octoploids ($n = 72$). Whereas polyploid snails are often difficult to distinguish morphologically, they may be quickly identified genetically through chromosome counting [20, 46].

In Ethiopia 10 species of bulinid snails have been reported, as follows: *B. tropicus* ($n = 18$), *B. truncatus* ($n = 36$), *B. hexaploidus* ($n = 54$), *B. octoploidus* ($n = 72$), all in the *truncatus/tropicus* complex; *B. africanus*, *B. ugandae* and *B. abyssinicus* in the *africanus* group; *B. forskalii* and *B. scalaris* in the *forskalii* group; and *B. reticulatus* in the *reticulatus* group. Only the *africanus* group is implicated in *S. haematobium* transmission in Ethiopia but the *truncatus/tropicus* complex is also of major concern because *B. truncatus* and several other tetraploid members of this complex serve as intermediate hosts of *S. haematobium* in West Africa, the Mediterranean region and the Middle East [20, 46]. Snail/parasite noncombatibility (the resistance of bulinid snails to *S. haematobium* infection), which is genetically determined, accounts for much of the discrepancy between the wide distribution of potential transmitters and the highly localized distribution of *S. haematobium* (Figs 5 and 6; Table 3).

The distribution of snails in the *africanus* group and *truncatus/tropicus* complex is shown in Fig. 6. Both *B. tropicus* and *B. truncatus* are distributed over large areas. The latter has been found in both highlands and lowlands, between 2470 m (Dese town in Welo region) and 300 m (lower Awash valley). *B. hexaploidus* and *B. octoploidus*, however, are restricted in distribution to the highlands between 2000 and 2800 m [20, 46]. *B. reticulatus* was reported only once, near Gonder town. *B. scalaris* occurs in at least 12 communities in Gonder and Kefa regions. *B. forskalii* is locally very common and is often the only bulinid snail present in habitats. Whereas *B. abyssinicus* is limited in its distribution to swamps and some freshwater lakes below 800 m in eastern and possibly southern Ethiopia, *B. africanus* occurs in streams and lakes up to 1800 m [20]. Since *B. africanus* is a highly efficient transmitter of *S. haematobium* in other Sub-Saharan countries [46], the apparent absence of transmission in many Ethiopian communities where this snail occurs may be due to low water temperatures, although this needs to be studied further.

Whereas *B. abyssinicus* appears to be the only transmitter of *S. haematobium* in the Awash valley [92], more research is required to confirm the snail intermediate host in the lower Wabe Shebele valley. The fact that *B. abyssinicus* is the sole transmitter of *S. haematobium* in the Wabe Shebele and all other river systems in Somalia [93] suggests that this snail is also the host in the Wabe Shebele in Ethiopia [94]. In Kurmuk town on the Sudan border people become infected in a small stream which originates in Sudan, rendering any control program extremely difficult. The snail host in Kurmuk is *B. africanus*, suggesting that the parasite may represent a different strain from that found in the Awash and Wabe Shebele valleys [16], since different bulinid snail species tend to vary in their susceptibility to different strains of *S. haematobium* [20, 46].

Water resources development, resettlement programs and population movements

Unlike in intestinal schistosomiasis, the areas of endemic urinary schistosomiasis have probably not increased as a result of population movements and water resources development. Nevertheless, the rapidly changing environment in the lowlands appears to become more suitable for *S. haematobium* transmission and spread. Transmission levels and the epidemiology of *S. haematobium* have been variably affected in at least one endemic area, in the middle Awash valley. The Amibara Irrigation Project illustrates some of the changes that have taken place in irrigation schemes. This project covers 10,000 ha and includes 25 km of main drain and 214 km of primary, secondary and tertiary supply canals [95]. *B. abyss-*

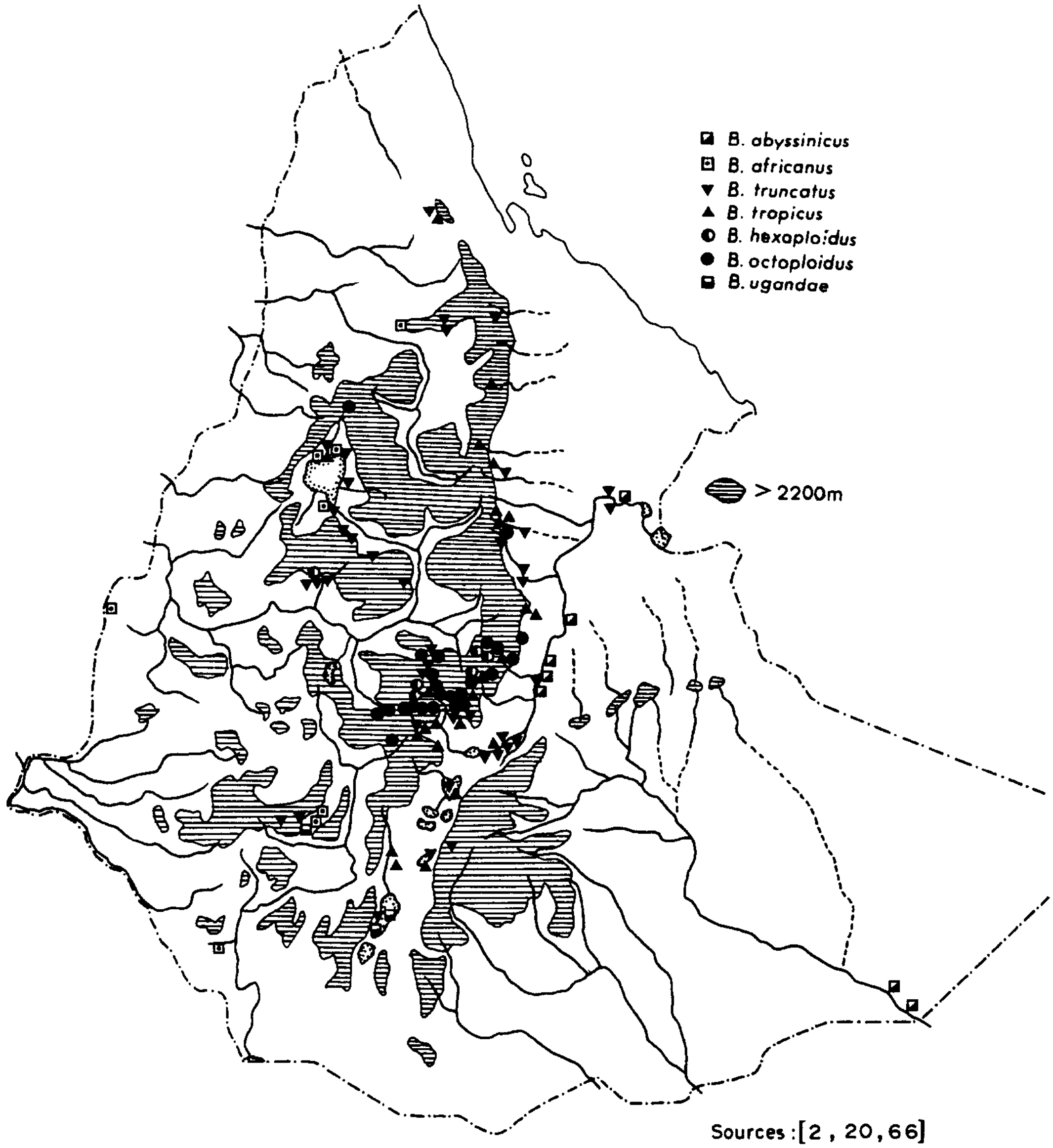

Fig. 6. Distribution of *Bulinus* spp.

inicus has never been found in the canals, although irrigation dates back to the late 1960s. The manmade hydrological changes in this part of the valley have even been associated with increased dessication of the floodplains and disappearance of *B. abyssinicus* supporting swamps. However, while *S. haematobium* infection rates appear to have decreased among the pastoral Afar inhabiting the shrinking swamps, the influx of migrant farm laborers from the highlands has resulted in high infection rates among some of these newcomers [12, 92, 96]. If *B. abyssinicus* becomes established in the canal systems, as in Somalia [94], transmission will certainly increase.

The presence of *B. africanus*, *B. abyssinicus* and high *S. haematobium* infection rates in Sudan, Kenya and Somalia, together with increasing population movements from some of these countries to Ethiopia is a major concern of Ethiopian health officials. Particularly the number of refugees, both Ethiopian nationals and foreigners, across these borders has rapidly increased in recent years. An estimated 700,000 people fled from the Ogaden area of south-eastern Ethiopia to Somali as a result of the 1977 Ethio–Somalia war and the 1975–78 drought. During the 1983/84 drought an additional 140,000 people from southern Ethiopia sought refugee status in Somalia [97]. Nearly 500,000 Ethiopians from Tigray and Eritrea regions fled to Sudan due to continuous civil strife in northern Ethiopia [98]. Increasing numbers of these refugees have been returning in 1985–87 to their home areas due to improvements in the rains and the amnesty the Ethiopian government granted to Ethiopian refugees living in Sudan and Somalia. At least 160,000 Ethiopians returned from Sudan and more than 500,000 from Somalia. In addition, Sudanese refugees are settling in increasing numbers in Ethiopia's western lowlands due to the civil war in southern Sudan. By late 1987 more than 200,000

Table 3. *S. mansoni* prevalence, by schistosomiasis region, prevalence of infection and size of communities

Schistosomiasis region	Prevalence (%) <5		5–50		>50		Total	
	Size of communities							
	<10,000	>10,000	<10,000	>10,000	<10,000	>10,000	<10,000	>10,000
Rift valley and southern lowlands	45	2	37	0	4	0	86	2
Western lowlands	8	0	8	1	1	0	17	1
Western and southern highlands	80	5	6	4	0	0	86	9
Central, northern and eastern highlands	76	2	56	7	21	2	153	11
Total	209	9	107	12	26	2	342	23

Sources: [29] and Appendix 1A.

Sudanese refugees lived in several camps in Ilubabor, Welega and Kefa [99] (Fig. 1). This situation points out the need for studies of the susceptibility of the various Ethiopian bulinid snails in different parts of the country to *S. haematobium* strains circulating in these snails and those endemic in neighboring countries. More immediately, camps and other settlements for international migrants from Sudan and Somalia should be carefully sited, away from streams and swamps where potential intermediate snail hosts occur. Monitoring of infections and mass chemotherapy of migrants would be difficult and incomplete in view of the predominance of spontaneous migrations which characteristically bypass the border entry points.

CONTROL

The schistosomiasis control strategy recommended by the World Health Organization [100] is aimed at reducing the disease and the parasite in heavily infected individuals. This new policy of control is considered to be more realistic and less costly than the conventional control methods involving multiple methods that tried to eradicate the parasite in the environment [42]. Although effective and safe single-dose antischistosomal drugs are increasingly used toward this objective, it is also recognised that benefits may be obtained from the more conventional methods of applying molluscicides, sanitation, water supply and health education. In particular, possibilities and opportunities of applying these and other methods using the primary health care approach in community supported programs are increasingly being considered [101, 102]. Critics however consider it impossible to achieve effective schistosomiasis control using the primary health care approach [103]. Control strategies and tactics are still evolving in the search for economically and technologically feasible, socioculturally acceptable and operationally sustained programs. Since there is no 'typical' schistosomiasis endemic area or community, it is unlikely that a blue print for an effective control protocol applicable to all areas will ever be developed. Requirements, effects and constraints of control strategies were reviewed by Jordan [104]. He noted that major difficulties in the application of the principles of schistosomiasis control include not only lack of ecological information and finances but also lack of motivated health administrators and trained personnel, infrastructure and logistic problems.

In Ethiopia control efforts have been directed primarily toward reducing the snail intermediate hosts through the application of *endod* (*Phytolacca dodecandra*) and synthetic molluscicides with limited case treatment, health education and environmental sanitation [105–109]. In Adwa town, *S. mansoni* prevalence was reduced from 64% to 33% after 5 years (1969–74) of the application of the slurry of *endod* berries. Other measures, including guarding and fencing of hazardous sections of the streams, were not successful. A rate of 44% was reported in 1981 [19] but these data are not strictly comparable due to sampling bias and no information is available on intensity of *S. mansoni* infection in Adwa. High cost and scarcity of *endod* berries were additional constraint of this program [105]. In the Wonji sugar estate the control program consisted of the application of synthetic molluscicides (Frescon and Bayluscide) to the canals, health education in the local schools and treatment of all diagnosed *S. mansoni* infections in farm laborers with Ambilhar and later Praziquantel oral drugs. The evaluation done after 4 years showed that transmission was continuing with subsequent increases in prevalence [79].

In Kemise town, where health education, latrine construction, chemotheraphy and improved water supplies were applied, *S. mansoni* infection rates before and after treatment were 49.5 and 30.6%, respectively, and mean number of eggs/g of feces were 537 and 345. Public awareness of schistosomiasis increased and the number of latrines nearly doubled; moreover, the infected *B. pfeifferi* and the number of cercariae in the streams declined sharply. Nevertheless, the prevalence in the human population rose above pretreatment levels within 1 year after treatment [21].

The current control program in the town of Jiga consists of community supported health education, latrine construction and snail control in addition to mass chemotherapy administered by the Institute of Pathobiology and community piped water supply installed by the Water Resources Development Authority. The Jiga Peasant Association is playing an active role in coordinating health education, latrine construction and clearance of the stream of vegetation prior to molluscicide application. Some households, particularly merchants, shops and gasoline stations, had their own private taps installed by the Peasant Association. These more affluent households then sold water to their neighbors at a price somewhat higher than that charged at the community taps. This development is largely due to the greater accessibility of the private than the community taps. Whereas the private taps are accessible throughout the day, the community taps operate only a few irregular hours. A study of this unexpected but encouraging situation is under way to evaluate people's water needs and preferences and the opportunities, benefits and constraints of village community and private water supply in a socialist society [80].

A control program consisting of mass chemotherapy with Metrifonate oral drug and snail control through closure of Awash defluents maintaining several floodplain swamps and the application of molluscicides was carried out in *S. haematobium* endemic area of the middle Awash valley. The high mobility of the local pastoralists and administration of repeat doses of the oral drug at designated treatment centers resulted in unsatisfactory compliance by patients. Moreover, the application of *endod* and synthetic molluscicides to local swamps was opposed by the Afar, who feared for the health of their livestock drinking the water. In an effort to save their prime grazing areas from dessication and degradation the Afar opened the defluents, thus also maintaining the swamps and *B. abyssinicus* [80, 110, 111].

A strategy consisting of snail control through environmental modification and chemotherapy with Praziquantel has been developed by the National Research Institute of Health of the Ministry of Health in the Afar village of Enta-Doyta on the Awash floodplains near Gewane. All Awash defluents feeding the swamps around the study village were closed in 1985 with technical assistance from the Relief and Rehabilitation Commission (RRC) of the Ethiopian government with the objective of eliminating all *B. abyssinicus* habitats in the vicinity. This was only partly successful due to the inadequacy of the dikes during floods and the opening of some defluents by Afar desparate for pasture land during the 1985 drought. Chemotherapy was administered to all *S. haematobium* infected individuals in Enta-Doyta. One year later 62% of the 126 previously positive cases that had been treated were still egg negative on reexamination and in the remaining 38% of the cases a 92% reduction in egg counts was observed. This large reduction in infection and the relatively low incidence rate (31%) were due in part to the destruction of some snail habitats near the village [18]. The outcome of this control program will depend to a large degree on the success of the RRC program designed to develop irrigated pasture and agriculture for the Afar pastoralist clans on the Gewane floodplain, which would make them independent of the swamps.

The mixed results obtained by these various control programs emphasize the need for more carefully designed human behavioral studies on the needs and perceptions of rural people surrounding water use as well as community participation. In addition, intersectorial collaboration and cooperation, a major objective of the Ethiopian government's Ten-Year Plan, needs to be strengthened together with research capabilities. Progress in these areas can be instrumental in overcoming persisting problems in the selection and application of appropriate and adequate control measures and strategies and in the evaluation of control programs.

A national schistosomiasis control program is presently being developed by the Ministry of Health. Priorities and objectives are to be used on the results of studies of the epidemiology and geographic distribution of the parasites and their intermediate hosts. Pilot control studies are in Jiga town, Metahara irrigation scheme and several rural communities around Lake Ziway, which represent different ecological settings. Outcomes may permit the evaluation of the relative impact of chemotherapy, improved water supplies, environmental sanitation, health education and snail control with the objective of developing effective and appropriate control strategies for different communities. As part of this program some technical personnel of the Ministry of Health are being retrained in fields relevant to schistosomiasis, particularly malacology and parasitology. They will be assigned to work in health centers and health stations throughout the country. This control program may eventually permit the survey of large parts of the country for endemic schistosomiasis and its intermediate hosts, with appropriate follow-up control measures within the context of primary health care.

Because schistosomiasis is clearly a socioeconomic problem that has its roots in rural poverty, ignorance and the persistence of certain customs and habits, it is necessary that broadly based rural development programs involving active community participation be integrated into the national control program. This would include: (1) provision of safe and abundant water supply for domestic purposes, (2) construction and use of latrines, (3) development of relevant and effective health education programs covering all aspects of water use and excreta disposal, (4) extension of primary care services, (5) strengthening of peasant association health committees in rural areas and *kebele* (urban associations) health committees in towns to encourage and coordinate community based control activities; in (6) irrigated areas careful selection of sites and design of schemes, adherence to regulations regarding the operation and maintenance of irrigation and resettlement schemes so as to prevent snail hosts and then transmission cycle from becoming established, and (7) follow-up treatment of newly arriving migrant farm laborers and settlers infected with *Schistosoma*. All control measures and activities, including chemotherapy, should be carried out predominantly, if not entirely, with the use of indigenous material and human resources to assure the economic feasibility of programs [101, 104]. Further intersectorial cooperation between government agencies, including the Ministry of Health, the Ministry of State Farms Development, Ministry of Agriculture, Ministry of Industry, Relief and Rehabilitation Commission, the Water Resources Development Authority, the regional and district offices of the Worker's Party of Ethiopia (WPE) and the university research institutes will be necessary.

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APPENDIX 1A

Results of Schistosomiasis mansoni Surveys in Ethiopia, by Geographical and Administrative Regions

Community, by geographical and administrative regions*	Altitude (m)	Sample†	Number examined	Method‡	Percent infected	Source
WESTERN LOWLANDS						
Sedit Humera (G)	550	S	54	R	13	[60]
Metema (G)	800	S	8	R	25	[60]
Jikawo (I)	350	R	50	K	0	[19]
Itang (I)	500	S	98	K	0	[19]
Abobo (I)	510	R	73	R	4	[23]
Pignido (I)	530	R	83	R	5	[23]
Ukana Kijang (I)	530	R	78	R	30	[23]
Gambela (I)	550	S	98	K	8	[19]
Tepi (I)	1200	S	105	K		[19]
Dedessa (I)	1200	S	51	R	2	[19]
Beles State Farm (Go)	1200	R	135	R	1	[15, 19]
Kurmuk (W)	650	S	101	K	4	[19]
Sirba (W)	700	R	215	R	28	[32]
Dalati (W)	1200	R	130	R	11	[32]
Agalo Meti (W)	1130	S	121	K	36	[19]
Bambesi (W)	1450	S	100	K	1	[19]
Mengi (W)	1450	S	100	K	44	[19]
Mui National Park (K)	700	R	81	R	54	[19]
RIFT VALLEY AND SOUTHERN LOWLANDS						
Awash valley						
Dubti, pastoralist camps (H)	380	SP	51	D	0	[1]
Dubti irrigation scheme	380	SM	151	R	13	[119]
Dit Bahari irrigation scheme (Wo)	350	SM	151	R	15	[119]
Assaita (Wo)	350	SM	43	R	16	[119]
Assaita (Wo)	350	SP, SU	32	R	0	[119]
Chifra (Wo)	1000	R	83	R	2	[19]
Arabati (Wo)	1000	R	47	R	2	[19]
Zobil (Wo)	1300	S	65	R	28	[19]
Galela Dora (H)	620	P	41	R	0	[119]
Galela Dora (H)	620	M	30	R	7	[119]
Ambash irrigation scheme (H)	740	M	100	R	2	[19]
Amibara irrigation scheme (H)	750	M	196	R	1	[19]

continued overleaf

Appendix 1A continued

Community, by geographical and administrative regions*	Altitude (m)	Sample†	Number examined	Method‡	Percent infected	Source
Amibara (H)	750	P	15	R	13	[19]
Melka Worer irrigation scheme	750	M	157	R	3	[119]
Melka Sadi irrigation scheme	750	M	130	R	2	[119]
Miesso (H)	1300	S	44	R	0	[1]
Kessem Kabena irrigation scheme (S)	750	M	78	R	3	[19]
Awara Melka irrigation scheme (S)	760	M	232	R	2	[119]
Awara Melka pastoralist camps	760	P	29	R	0	[119]
Bolhamo irrigation scheme (S)	740	M	90	R	0	[19]
Nura Era irrigation scheme (S)	1100	M	252	R	6	[119]
Nura Era, pastoralist camps	1100	P	88	R	15	[119]
Abadir irrigation scheme (S)	960	M	264	R	8	[119]
Abadir, pastoralist camps	960	P	53	R	15	[119]
Dera (A)	1650	S	100	K	1	[15, 19]
Wollenchiti (S)	1400	S	44	R	6	[1]
Metahara irrigation scheme (A)	960	M	200	K	18	[80]
Metahara, pastoralist camps	960	P	53	R	4	[119]
Golgota irrigation scheme (A)	1100	M	196	R	5	[119]
Wonji irrigation scheme (A)	1540	M	2251	R	20	[58]
Wonji, subsistence farming villages	1540	R	56	R	34	[119]
Eight villages in Sodere area	1500	R	225	R	0–3	[35]
Lake Ziway (S, A):						
Three islands	1625	R	526	R	43–54	[22]
Six villages on the eastern shore	1625	R	465	R	13–64	[22]
Two villages on the western shore	1625	R	914	R	13–16	[22]
Four villages on the northern shore	1625	R	316	R	8–38	[22]
Four villages on the southern shore	1625	R	491	R	17–41	[22]
Lake Awasa area (S, Si):						
Dalati	1550	R	14	R	0	[1]
Loke	1600	R	15	R	0	[1]
Adarie	1600	R	25	R	0	[1]
Melka Doret	1600	R	35	R	0	[1]
Sama	1600	R	40	R	0	[1]
Birbow	1600	R	45	R	0	[1]
Swamp at L. Awasa	1600	S	55	R	90	[80]
Awasa town	1550	U	277	R	1	[80]
Bashilo	1600	R	142	R	38	[80]
Samajersa	1600	R	136	R	0	[80]
Tulo	1600	R	105	R	2	[80]
Lake Langano area (S):						
Bosuma	1600	R	18	R	0	[1]
Kello	1600	R	15	R	0	[1]
Chancho	1600	R	10	R	0	[1]
Ashelamo	1600	R	23	R	0	[1]
Lake Abaya and L. Chamo areas (GG):						
Ugayo	1300	R	174	R	59	[15, 19]
Chano	1280	R	15	R	40	[15, 19]
Lake Abaya	1280	R	22	R	18	[15, 19]
Gedebonke	1280	R	81	R	6	[15, 19]
Sile Woregamo	1300	R	49	R	6	[15, 19]
Arba Minch	1400	SU	197	R	2	[15, 120]
Lante	1300	S	246	R	4	[15, 19]
Bugo	1300	R	54	R	2	[15, 19]
Southern lowlands						
Bume (GG)	650	R	77	R	0	[15, 19]
Kelem (GG)	800	R	74	R	0	[15, 19]
Yandefro (GG)	850	R	22	R	0	[15, 19]
Omorate (GG)	550	R	40	R	0	[15, 19]
Moyale (Si)	900	R	32	D	0	[117]
Shewa Ber (So)	1180	R	57	K	0	[15, 19]
Abela Fericho (Si)	1350	S	102	K	0	[19]
WESTERN AND SOUTHERN HIGHLANDS						
Western highlands						
Didessa State Farm (W)	1440	R	101	K	4	[15, 19]
Dimtu resettlement scheme (W)	1550	R	200	K	8	[15, 19]
Assosa resettlement scheme (W)	1750	S	101	K	0	[15, 19]
Begi (W)	1640	S	100	K	0	[15, 19]
Judbo (W)	1650	S	105	K	1	[15, 19]
Assosa town (W)	1750	S	100	K	5	[15, 19]
Guliso (W)	1740	S	101	K	0	[15, 19]
Nejo (W)	1800	S	103	K	0	[15, 19]
Anjilo (W)	1740	S	100	K	0	[15, 19]
Dembi Dolo (W)	1850	SU, S	200	K	0	[15, 19]
Aegu Agamsa (W)	1840	S	100	K	18	[15, 19]
Ghimbi (W)	1890	SU, S	103	K	0	[15, 19]
Tsigemariam (W)	1940	S	107	K	1	[15, 19]

Appendix 1A continued

Community, by geographical and administrative regions*	Altitude (m)	Sample†	Number examined	Method‡	Percent infected	Source
Nole Kaba (W)	1940	S	98	K	0	[15, 19]
Mendi (W)	1900	S	100	K	1	[15, 19]
Gengi (W)	1940	S	100	K	1	[15, 19]
Dabo Hana (W)	2000	S	100	K	1	[15, 19]
Sibu Sire (W)	2000	S	99	K	1	[15, 19]
Gute (W)	2000	S	101	K	0	[15, 19]
Nekemte (W)	2000	SU	100	K	10	[15, 19]
Njango (W)	2040	S	102	K	0	[15, 19]
Gidame (W)	2100	R	105	K	0	[15, 19]
Guie (W)	2100	S	98	K	0	[15, 19]
Fincha (at L. Fincha)	2150	S	103	K	33	[15, 19]
Meka Bila (W)	2150	S	100	K	0	[15, 19]
Hareto (W)	2200	S	100	K	0	[15, 19]
Shambu (W)	2500	S	100	K	0	[15, 19]
Kombolcha (W)	2500	S	100	K	0	[15, 19]
Arjo (W)	2600	S	100	K	0	[15, 19]
Mekonen (W)	2650	S	100	K	0	[15, 19]
Getema (W)	2700	S	102	K	3	[15, 19]
Yembero (I)	1700	S	99	K	0	[15, 19]
Nopa (I)	1750	S	100	K	0	[15, 19]
Chora (I)	1800	S	100	K	0	[15, 19]
Yaya (I)	1800	S	100	K	0	[15, 19]
Bure (I)	1800	S	95	K	1	[15, 19]
Metu (I)	1850	SU, S	100	K	0	[15, 19]
Dembi (I)	1900	S	97	K	1	[15, 19]
Masha (I)	2000	S	100	K	0	[15, 19]
Bedele (I)	2090	S	100	K	0	[15, 19]
Gore (I)	2100	S	100	K	1	[15, 19]
Debeka State Farm (K)	1300	S	100	K	0	[15, 19]
Gojeb (K)	1400	R	154	K	1	[15, 19]
Mizan Teferi (K)	1600	R	100	R	0	[15, 19]
Agaro (K)	1600	S	215	R	34	[15, 19]
Abelti (K)	1750	S	41	R	0	[15, 19]
Deneba (K)	1750	S	99	R	2	[15, 19]
Serbo (K)	1800	S	100	R	3	[15, 19]
Shebe (K)	1850	R	100	R	0	[15, 19]
Bonga (K)	1800	S	394	R	1	[15, 19]
Jimma (K)	1800	U, SU	450	R	18	[15, 19]
Asendabo (K)	1820	S	99	R	1	[15, 19]
Sekoru (K)	1980	R	50	R	0	[15, 19]
Saja (K)	1990	S	50	R	2	[15, 19]
Kumbi (K)	1990	S	48	R	0	[15, 19]
Limucosa (K)	2000	S	95	R	1	[15, 19]
Dedo (K)	2000	S	100	K	4	[15, 19]
Natri (K)	2030	S	50	R	0	[15, 19]
Shewa Gimira (K)	2060	S	162	R	0	[15, 19]
Buchana (K)	2150	S	121	K	3	[15, 19]
Chena (K)	2230	S	98	K	0	[15, 19]
Chayit (K)	2300	S	92	K	2	[15, 19]
Maji (K)	2350	U, SU	245	K	6	[15, 19]
Southern highlands						
Dera (Si)	1420	R	50	K	0	[15, 19]
Negele Borana (Si)	1450	S	104	K	29	[15, 19]
Chew Bet (Si)	1500	R	106	K	0	[15, 19]
Chicha (Si)	1540	R	85	K	0	[15, 19]
Dila (Si)	1650	S, SU	93	K	0	[15, 19]
Shakiso (Si)	1680	S	100	K	0	[15, 19]
Wadera (Si)	1750	S	100	K	2	[15, 19]
Megera (Si)	1750	R	92	K	0	[15, 19]
Awado (Si)	1750	R	128	K	0	[15, 19]
Gesu (Si)	1850	R	124	K	0	[15, 19]
Dumarso (Si)	1900	R	112	K	0	[15, 19]
Kebre Mengist (Si)	2000	S, SU	100	K	0	[15, 19]
Agere Mariam (Si)	2000	R	106	K	0	[15, 19]
Yirba Muda (Si)	2500	S	100	K	0	[15, 19]
Hagere Selam (Si)	2700	S	100	K	0	[15, 19]
Huruta (A)	1960	S	105	K	0	[15, 19]
Deneba (A)	2000	S	96	K	1	[15, 19]
Arate (A)	2300	S	153	K	1	[15, 19]
Asela (A)	2400	SU	150	K	0	[15, 19]
Sagure (A)	2440	S	100	K	0	[15, 19]
Kofele (A)	2600	S	100	K	0	[15, 19]
Benkoji (A)	2850	S	73	K	0	[15, 19]
Asasa (A)	2850	S	95	K	0	[15, 19]

continued overleaf

Appendix 1A continued

Community, by geographical and administrative regions*	Altitude (m)	Sample†	Number examined	Method‡	Percent infected	Source
Goro (B)	1700	S	95	K	0	[15, 19]
Ginir (B)	1800	S	96	K	0	[15, 19]
Gasera (B)	2200	S	99	K	0	[15, 19]
Agarfa (B)	2300	S	102	K	0	[15, 19]
Robe (B)	2400	S	131	K	0	[15, 19]
Adaba (B)	2480	S	100	K	0	[15, 19]
Dodola (B)	2600	S	100	K	1	[15, 19]
Meraro (A)	2900	S	102	K	0	[15, 19]
CENTRAL, NORTHERN AND EASTERN HIGHLANDS						
Central highlands						
Boditi (Si)	1800	S	97	K	0	[19]
Shone (S)	1800	S	59	R	0	[1]
Durame (S)	2000	S	44	R	0	[1]
Butajira (S)	2100	SU	13	R	0	[1]
Angecha (S)	2300	S	50	R	6	[1]
Hosanna (S)	2300	SU	87	R	0	[1]
Shurmo (S)	2350	S	46	R	2	[1]
Asawde Yefeterke (S)	2400	S	20	R	0	[1]
Serera (S)	2700	S	26	R	0	[1]
Bako (S)	1900	S	100	K	0	[15, 19]
Debre Zeyit (S)	1900	U	312	K	0	[15, 19]
Filkilik (S)	1900	S	35	MIFC	9	[52]
Wollenchomi (S)	2200	S	115	R	0	[51]
Akaki (S)	2250	U, SU	120	R	6	[36, 80]
Addis Ababa (S)	2500	SU	468	R	0	[114]
Sendafa (S)	2550	S	34	MIFC	0	[52]
Weberi (S)	2575	S	35	MIFC	0	[52]
Lege Tafo (S)	2550	S	34	MIFC	0	[52]
Debre Tsegi (S)	2600	S	25	R	0	[1]
Gorfu (S)	2600	S	37	MIFC	0	[52]
Chancho (S)	2600	S	35	MIFC	0	[52]
Muke Turi (S)	2600	S	35	MIFC	0	[52]
Inewari (S)	2650	S	34	MIFC	0	[52]
Aliltu (S)	2650	S	42	R	0	[1]
Jihar (S)	2650	S	34	MIFC	0	[52]
Debre Sina (S)	2650	S	37	MIFC	0	(52]
Chacha (S)	2750	S	35	MIFC	0	[52]
Debre Berhan (S)	2750	S, SU	71	R	0	[1]
Fiche (S)	2800	SU, S	69	R	0	[1]
Sheno (S)	2825	S	35	MIFC	0	[52]
Sela Dingay (S)	2850	S	39	MIFC	0	[52]
Mendita (S)	2800	S	35	MIFC	0	[52]
Ankober (S)	2900	S	35	MIFC	3	[52]
Kombolcha (Wo)	1900	R, U	48	MIFC	2	[52]
Tossa Falana (Wo)	2400	R	68	K	4	[15, 19]
Mai Bahir (Wo)	2450	R	86	K	0	[15, 19]
Tita (Wo)	2500	R	81	K	0	[15, 19]
Alasha (Wo)	2600	R	82	K	0	[15, 19]
Dese (Wo)	2500	SU, S	300	K	8	[15, 17, 19]
Kutaber (Wo)	2680	R	101	K	0	[15, 17, 19]
Segno Gebaya (Wo)	2500	S	81	K	1	[15, 17, 19]
Birr State Farm (Go)	1500	R	307	R	5	[15, 19]
Chagni (Go)	1600	R	171	R	1	[15, 19]
Finote Selam (Go)	1900	S, SU	40	MIFC	5	[52]
Jiga (Go)	1900	R	913	K	41	[19, 41]
Mankusa (Go)	2000	S	42	MIFC	0	[52]
Bure (Go)	2100	S	41	MIFC	2	[52]
Dembecha (Go)	2100	S	35	MIFC	0	[52]
Yetman (Go)	2400	S	33	MIFC	0	[52]
Amanuel (G0)	2400	S	35	MIFC	0	[52]
Mota (Go)	2470	S	383	R	1	[15, 19]
Lumane (Go)	2500	S	35	MIFC	0	[52]
Wegel (Go)	2500	S	35	MIFC	0	[52]
Debre Work (Go)	2600	S	252	R	0	[15, 19]
Bichena (Go)	2600	SU, S	233	R	0	[15, 19]
Eastern foothills of central highlands						
Shewa Robi (S)	1400	R, U	93	R	3	[15, 19]
Gerbi (S)	1500	R	83	R	28	[19]
Harawa (S)	1500	R	102	R	67	[19]
Senbete (S)	1500	S	74	R	74	[15, 19]
Ataye (S)	1500	S	112	R	36	[19]
Chefa Robi (S)	1540	S	103	K	12	[15, 19]
Aliyu Amba (S)	1700	R	71	R	0	[15, 19]
Karakore (S)	1850	S	100	K	3	[15, 19]

Appendix 1A continued

Community, by geographical and administrative regions*	Altitude (m)	Sample†	Number examined	Method‡	Percent infected	Source
Chifra (Wo)	1000	R	83	R	2	[15, 19]
Arabati (Wo)	1000	S	47	R	6	[15, 19]
Zobil (Wo)	1500	S	65	R	28	[15, 19]
Burka (Wo)	1400	R	19	R	16	[15, 19]
Chekorti (Wo)	1400	R	76	R	37	[15, 19]
Salmene (Wo)	1500	R	72	R	49	[15, 19]
Kemise (Wo)	1500	R	1392	K	44	[15, 19]
Harbu (Wo)	1500	S	107	K	15	[15, 19]
Chefa State Farm (Wo)	1580	S	101	K	7	[17, 19]
Hara (Wo)	1550	S	58	R	0	[15, 19]
Imam (Wo)	1580	R	65	K	32	[15, 19]
Genda Moti (Wo)	1550	R	38	K	5	[15, 19]
Endigaw (Wo)	1580	R	64	K	13	[15, 19]
Sitir (Wo)	1580	S	83	K	34	[15, 19]
Gadula (Wo)	1580	R	51	K	77	[15, 19]
Chemero (Wo)	1580	R	60	K	12	[15, 19]
Fura (Wo)	1560	R	11	K	9	[15, 19]
Gende Habure (Wo)	1560	R	41	K	10	[15, 19]
Fecha (Wo)	1600	S	86	R	7	[15, 19]
Bati (Wo)	1580	R, U	186	R	47	[15]
Bati (Wo)	1580	R, U	1371	K	51	[15, 19]
Gogam (Wo)	1600	R	33	K	3	[15, 19]
Birra (Wo)	1600	R	73	K	73	[15, 19]
Dure (Wo)	1600	R	34	K	12	[15, 19]
Arabo (Wo)	1650	R	78	K	8	[15, 19]
Gerba (Wo)	1600	R	133	K	8	[15, 19]
Miawa (Wo)	1650	R	100	K	21	[15, 19]
Kolobo (Wo)	1680	R	31	K	36	[15, 19]
Tapisa (Wo)	1670	R	37	K	76	[15, 19]
Kuni (Wo)	1660	R	85	K	34	[15, 19]
Dero Giber (Wo)	1800	S	35	K	3	[15, 19]
Erensa (Wo)	1700	S	101	K	7	[15, 19]
Chefa (Wo)	1700	S	47	K	2	[15, 19]
Waraba (Wo)	1700	R	100	K	6	[15, 19]
Degan Abicho (Wo)	1850	R	131	K	2	[15, 19]
Northern highlands: Lake Tana basin						
Tadda (G)	1800	SU, S	35	S	59	[60]
Gorgora (G)	1800	S	57	R	77	[60]
Woreta (G)	1800	S	62	K	10	[15, 19]
Engore and Wangatara (G)	1800	R	146	K	6	[15, 19]
Twawazgi (G)	1850	R	326	K	43	[40]
Delghi (G)	1850	R	28	R	28	[60]
ShinaTsion (G)	1860	R	101	K	1	[15, 19]
Dengel Ber (G)	1850	R	30	S	0	[60]
Achera Mariam (G)	1850	R	25	R	8	[60]
Bahir Dar (Go)	1850	U, R	677	K	15	[19, 69]
Bahir Dar (Go)	1850	SU	205	K	69	[19, 69]
Kunzila (Go)	1850	S	24	MIFC	46	[52]
Alefa (G)	1800	R	24	R	0	[60]
Gigna (G)	1900	S	105	K	1	[19]
Shina (G)	1900	R	163	K	0	[19]
Chiwahit (G)	1900	R	64	R	80	[60]
Yifag (G)	1900	S	101	K	18	[15, 19]
Emfraz (G)	1900	R	98	R	63	[60]
Shaga (G)	1900	R	97	R	0	[15, 19]
Bambiko (G)	1900	S	100	K	0	[15, 19]
Misir Midir (G)	1900	R	155	K	0	[15, 19]
Ehud Gebeya (G)	1900	S	136	K	1	[15, 19]
Nabaga (G)	1900	R	132	K	2	[15, 19]
Kokit (G)	1900	R	76	K	0	[15, 19]
Wetet Abay (Go)	1950	S	42	MIFC	0	[52]
Meshenti (Go)	1950	S	42	MIFC	0	[52]
Merawi (Go)	2000	S	45	MIFC	33	[52]
Chewa Dubba (G)	1950	R	23	R	17	[60]
Gonder (G)	1950	SU	128	S + R	43	[60]
Chenker (G)	1950	R	26	R	65	[15, 19]
Chenkela Abo Yessus (G)	1960	R	35	R	66	[15, 19]
Jenda (G)	1980	R	44	R	89	[60]
Azezo (G)	1930	S	39	S	64	[60]
Aykel (G)	2000	S	32	R	8	[60]
Sakalt (G)	2000	R	36	R	39	[60]
Gella Dubba (G)	2000	S	30	R	60	[60]
Kolla Dubba (G)	2000	S	56	R	55	[60]

continued overleaf

Appendix 1A continued

Community, by geographical and administrative regions*	Altitude (m)	Sample†	Number examined	Method‡	Percent infected	Source
Addis Alem (G)	2000	S	63	S	79	[60]
Addis Zemen (G)	2000	S, SU	223	K	34	[15, 19]
Quara (G)	2000	R	24	R	0	[60]
Dangla (Go)	2150	S	42	MIFC	12	[52]
Northern highlands other than Lake Tana basin						
Zerima (G)	1300	S	34	MIFC	94	[52]
May Tseberi (May Tsemre)	1500	S	48	D	40	[52]
Adi Arkay (G)	1600	S, SU	25	D	24	[52]
Deguma (G)	2100	S	32	D	0	[121]
Ibnat (G)	2150	S	43	D	0	[121]
Debre Tabor (G)	2450	SU, S	111	K	4	[19]
Chercher (T)	1700	S	84	R	1	[15, 19]
Adwa (T) prior to control (1969)	1800	U, R	1080	R	64	[105]
Adwa (T) post-control (1974)	1800	U, R	544	R	33	[105]
Adwa (T) in 1981	1800	U, R	818	R	44	[15, 19]
Inda Baguna (T)	1900	S	29	MIFC	90	[52]
Seleklaka (T)	1950	S	29	MIFC	90	[52]
Inticho (T)	2000	S	34	R	35	[105]
Shihet (T)	2000	S	49	R	2	[15, 19]
Enda Sellasie (T)	2000	S	67	R	5	[15, 19]
Mukufito (T)	2000	R	31	MIFC	0	[52]
Wikro (T)	2050	S, SU	48	MIFC + R	28	[19, 52]
Mekele (T)	2200	SU	149	MIFC + R	11	[19, 52]
Kwiha (T)	2100	S	54	R	28	[15, 19]
Adi Kwala (E)	2000	S	35	MIFC	83	[52]
Eastern highlands						
Tensae Berhan (A)	1600	R	1485	R	34	[39]
Dolchia (A)	1800	R	190	R	30	[122]
Guna (A)	2200	R	35	R	0	[122]
Asbe Teferi (H)	1750	S, SU	24	R	4	[1]
Harer (H)	1950	SU	158	R	30	[123]
Alemaya (H)	2050	S	53	R	19	[70]
Gandaberi (H)	2100	R	186	R	4	[80]

*Administrative regions: A = Arsi, B = Bale, E = Eritrea, G = Gonder, Go = Gojam, H = Harerge, I = Ilubabor, K = Kefa, S = Shewa, Si = Sidamo, T = Tigray, W = Welega, Wo = Welo.

†R = Mostly locally born farming populations, all ages. S = School aged children of farming populations. P = Semi-nomadic pastoralists. SP = School aged children of semi-nomadic pastoralists. M = Migrant labor populations, all ages. SM = School aged children of migrant laborers. U = Predominantly urban populations, all ages. SU = School aged children of urban populations.

‡R = Ritchie formol/ether concentration. S = Simple sedimentation. D = Direct smear. MIFC = Merthiolate iodine formaline concentration.

APPENDIX 1B

Results of Schistosomiasis haematobium Surveys in Ethiopia, by Communities, Geographical and Administrative Regions

Communities, by geographical and administrative regions*	Altitude (m)	Sample†	Number examined	Method‡	Percent infected	Source
AWASH VALLEY						
Awash delta, agropastoralist communities (Wo)	340	P	248	S	2	[92]
Assaita (Wo)	350	SP, SU	79	S	5	[119]
Barga (Wo)	350	M	118	S	0	[119]
Dit Bahari (Wo)	380	M	194	S	0	[119]
Dubti (Wo)	380	M	290	S	0	[119]
Gewani area (H):						
Galela Dora	620	P	67	S	27	[92]
Galela Dora	620	M	35	S	20	[119]
Enta-Doyta	620	P	515	N	54	[18]
Bahdu plain, pastoralist camps	620	P	132	S	14	[92]
Lake Hertale (H)	640	P	22	S	32	[92]
Kortume (H)	650	P	50	S	52	[92]
Halidebi (H)	650	P, M	285	S	37	[111]
Deli (H)	680	P, M	34	S	41	[111]
Adengele (H)	680	P, M	63	S	46	[111]
Daknamo (H)	700	P, M	33	S	49	[111]
Dahitele (H)	710	P, M	361	S	31	[111]
Hasoba (H)	720	P, M	447	S	5	[111]
Sublele (H)	730	P, M	400	S	1	[111]
Ambash irrigation scheme (H)	740	P, M	1232	S	1	[111]
Amibara irrigation scheme (H)	750	P, M	1595	S	1	[111]
Melka Worer irrigation scheme (H)	750	P, M	2409	S	0	[111]
Melka Sadi irrigation scheme (H)	750	M	260	S	1	[119]
Melka Sadi irrigation scheme (H)	750	P	83	S	4	[119]
Lake Lyadu pastoralist camps	750	P	39	S	23	[92]

Appendix 1B continued

Community, by geographical and administrative regions*	Altitude (m)	Sample†	Number examined	Method‡	Percent infected	Source
Bolhamo, pastoralist camps	750	P	33	S	6	[92]
Bolhamo irrigation scheme (S)	750	M	41	S	0	[119]
Kassem Kabena irrigation scheme	750	M	69	S	0	[119]
Awash Station (S)	850	U	188	S	0	[35]
Metahara, pastoralist camps	960	P	72	S	0	[119]
Metahara irrigation scheme (A)	960	M	225	S	0	[119]
Abadir irrigation scheme (S)	960	P	61	S	0	[119]
Golgota irrigation scheme (A)	1100	M	118	S	1	[119]
Sodere area, 6 villages (S)	1500	R	254	S	0	[35]
Wonji irrigation scheme (S)	1540	M	320	S	0	[35]
Koka (S)	1560	R	30	S	0	[35]
Melka Konture (S)	1800	R	47	S	0	[35]
LOWER WABE SHEBELE VALLEY						
Burakur (H)	200	P	70	S	50	[94]
Mustahil (H)	210	P	31	S	32	[94]
Mustahil (H)	210	R	28	S	75	[94]
Kellafo (H)	230	R	136	S	24	[94]
Gode irrigation scheme (H)	280	R	261	S	1	[94]
Kugno (H)	350	P, R	100	S	1	[94]
Imi (H)	400	P, R	100	S	0	[94]
WESTERN LOWLANDS						
Kurmuk (W)	650	R	374	S	30	[16]
Famatheri (W)	800	R	177	S	0	[15]
Bashir (W)	800	R	99	S	0	[15]
Dalati (W)	1200	R	71	S	0	[15]
Assosa (W)	1750	R	200	S	0	[15]
Jikowa (I)	350	R	127	S	0	[15]
Telut (I)	380	R	149	S	0	[15]
Pol (I)	400	S	114	S	0	[15]
Itang (I)	500	S	96	S	0	[15]
Gambela (I)	550	S	53	S	0	[15]

*See Appendix 1A for identification of administrative regions.
†See Appendix 1A for identification of samples.
‡S = centrifugal sedimentation technique. N = nucleopore filtration technique.