Zeitschrift: Acta Tropica

Herausgeber: Schweizerisches Tropeninstitut (Basel)

Band: 40 (1983)

Heft: 3

Artikel: Studies on the epidemiology of schistosomiasis in Liberia : the prevalence and intensity of schistosomal infections in Bong County and the bionomics of the snail intermediate hosts

Autor: Dennis, E. / Vorkpor, P. / Holzer, B.

DOI: https://doi.org/10.5169/seals-313132

Acta Tropica *40*, 205–229 (1983)

[1] The Liberian Institute for Biomedical Research, P.O. Box 31, Robertsfield, Liberia, West Africa
[2] Swiss Tropical Institute, Socinstrasse 57, CH-4051 Basel, Switzerland
[3] Bureau of Biological Research, Rutgers University, Piscataway, N.J. 08854, USA

Studies on the epidemiology of schistosomiasis in Liberia: the prevalence and intensity of schistosomal infections in Bong County and the bionomics of the snail intermediate hosts[4]

E. DENNIS[1,3], P. VORKPOR[1], B. HOLZER[1,2], A. HANSON[1], B. SALADIN[1,2], K. SALADIN[1,2], A. DEGRÉMONT[2]

Summary

Urine samples from 3548 individuals residing in six of the eight districts which comprise Bong County, Liberia, the project area of the Bong County Agricultural Development Project (BCADP), and fecal specimens from 3408 of these individuals were examined for schistosome ova. A total of 164 water sites, including rice paddies, were surveyed for schistosome vector snails and monthly changes in snail population density and infection rate were determined in selected water sites. *Bulinus globosus* was more widely distributed than *Biomphalaria pfeifferi* but the latter species showed a higher infection prevalence (12.3%) than the former one (10.3%). Snail population density and infection rate fluctuated with season, being higher in the dry season and lower during periods of heavy rainfall. Dessication and/or heat stress may have contributed to the contraction of snail population size at the end of the dry season. More water sites contained infected snails during December through February than at any other time of the year. In selected water sites examined at monthly intervals, mean snail density was higher in rice paddies than in other water contact sites but the latter showed a higher prevalence of infected snails than the former. The overall prevalence of *Schistosoma mansoni* (24.8%) was significantly higher than that of *S. haematobium* (22.7%) but the difference in prevalence rates of the two species in school children was not statistically significant. The intensity of *S. haematobium* infection (13.2 $\bar{x}$G) was significantly higher than

[4] This work was supported jointly by a grant from the Liberian Government, the United States Aid for International Development and the World Bank

Correspondence: Dr. E. Dennis, Bureau of Biological Research, Rutgers University, Nelson Biological Laboratories, Busch Campus, Piscataway, N.J. 08854, USA

that of *S. mansoni* (6.3 $\bar{x}$G). Mixed infections in school children did not have a significant effect on egg output. The prevalence and intensity of *S. haematobium* showed a dramatic decline between the age groups 0–15 and 20–50+ years old; the differences between these age groups in *S. mansoni* infection were unremarkable. In Zota, Jorquelle and Kokoya Districts, prevalence rates of *S. haematobium* were higher than those of *S. mansoni;* the reverse was observed in Suakoko and Panta-Kpai Districts but relative prevalence rates varied according to specific locality in each district. A south to north stratification of schistosomal infection prevalence was observed similar to the west to east gradient reported by Saladin et al. (1980). New rice paddies developed during the three year operational period of the BCADP contained little or no vector snails and schistosomal infections in farm families of these paddies reflected the characteristic of the disease in corresponding localities. Older paddies, pre-dating the operations of the BCADP, contained infected vector snails and farm families of some of these paddies showed higher prevalence rates of schistosomiasis than corresponding school children. The implications of these findings are discussed.

Key words: epidemiology; schistosomiasis; vector snails; Liberia.

Introduction

Previous reports have shown that *Schistosoma mansoni* and *S. haematobium* are endemic in Liberia and are transmitted by the intermediate hosts, *Biomphalaria pfeifferi* and *Bulinus globosus*, respectively (Maas, 1927; Maas and Vogel, 1930; Strong and Shattuck, 1930; Vogel, 1932, 1958; Harley, 1933; Veatch, 1946; Poindexter, 1949; Miller, 1957; Walter, 1959; Levine, 1960; Sodeman, 1973, 1979; Saladin et al., 1980). Based on the previous residence of *S. haematobium* infected workers at a rubber plantation located in coastal Harbel, Montserrado County, Miller (1957) concluded that transmission foci of the parasite appeared to be concentrated around Gbarnga in central Liberia. The author deduced that coastal areas were probably free of transmission. Recently, Saladin et al. (1980) examined urine and fecal samples of school children and water sites along the 170 mile road from Harbel to Gbarnga and reported three geographical zones for the distribution of schistosome vector snails. Zone I, nearer the coast, harbored no vector snails; only *B. globosus* were found in the next or Middle Zone II inland, but both *B. globosus* and *B. pfeifferi* occurred further inland in Zone III. The prevalence of *S. haematobium* and *S. mansoni* in school children increased from Zone I to Zone III in accordance with the occurrence of corresponding snail hosts.

The 120 mile highway between Monrovia, the coastal capital of Liberia, and Gbarnga is the principal transportation route between the capital and most of interior Liberia. This highway provides access to Bong County, and from

Gbarnga through comparatively less suitable roads, access to Lofa, Nimba and Gedeh Counties. Probably, because of the relative ease of getting to and from Gbarnga, most previous epidemiological studies on schistosomiasis in Liberia have focused on water sites and school children in the Suakoko-Gbarnga area where prevalence rates as high as 82% for *S. haematobium* (Vogel, 1958) and 79% for *S. mansoni* (Saladin et al., 1980) infections have been reported. Both *B. globosus* and *B. pfeifferi* occur in the area and show seasonal fluctuations in population density and infection rates (Walter, 1959; Sodeman, 1979; Saladin et al., 1980).

The present study was carried out from mid 1978 to mid 1981 with the purpose of determining probable distributional patterns in the occurrence and infection rates of snail intermediate hosts of human schistosomes and the prevalence and intensity of schistosomiasis in selected populations in the project area of the Bong County Agricultural Development Project as a prerequisite for further epidemiological studies designed for testing control measures.

Background and Description of the Study Area

Liberia is divided into nine counties, the major political subunits of the country. Each county is subdivided further into succeedingly smaller administrative units consisting of districts, clans and towns or villages, respectively. Five of Liberia's nine counties (Cape Mount, Montserrado, Bassa, Sinoe, Maryland) are situated diagonally from northwest to southeast, respectively along the Atlantic Sea coast of West Africa and four countries (Lofa, Bong, Nimba, Gedeh) are adjacent interior counties (see Fig. 1). From sea level of the coastal areas, the interior counties show a topographical rise to a plateau of varying elevations above sea level.

The climate of Liberia is characteristic of the West African rainforest belt and consists of a rain season from April to November and a dry season from November to April. A mid-dry season generally occurs between June and August but annual and local variations in the extent of each season are usual. During the present study period, the annual rainfall averaged 75.4 inches in Suakoko, Bong County and the annual mean temperature was 26.3° C. Monthly mean temperatures varied from minima of 17.0° C in January and 23.5° C in August to maxima of 28.2° C in September and 33.2° C in March. The low temperature reading in January was a consequence of the harmatten winds which usually blow off the Sahara Desert in December and January resulting in comparatively cooler nights and mornings during that time of the year.

The study area was identical to the project area of the Bong County Agricultural Development Project (BCADP), a cooperative venture of the Liberian Government, the United States Aid for International Development and the World Bank, geared toward extensive cultivation of swamp rice, cocoa and coffee, and the construction of town to market roads. The BCADP began operations in 1978 and its project area included six (Sanoyea, Zota, Suakoko, Jorquelle, Kokoya, Panta-Kpai) of the nine districts which constitute Bong County, an area, as it turned out, almost identical to the transmission zone of human schistosomes in the county. Two other western districts (Fuama and Salala) were excluded from the BCADP and study area (Fig. 1).

Bong County occupies about 10% of the 37,160 square miles of Liberia's territorial land area and contains about 13% of its 1.5 million population resulting in a county population density of 51.3 persons per square mile (Hasselman, 1979). Approximately 70% of the population of Bong County resides in the study area. The Bong and Validi Mountain ranges occupy most of the northwestern region of Bong County and the rest of the county consists of gradually rolling hills and valleys with Gbarnga being about 3,000 feet above sea level. Water resources in the county are provided primarily by tributaries of two main rivers: the St. Paul's River which separates most of Bong County from

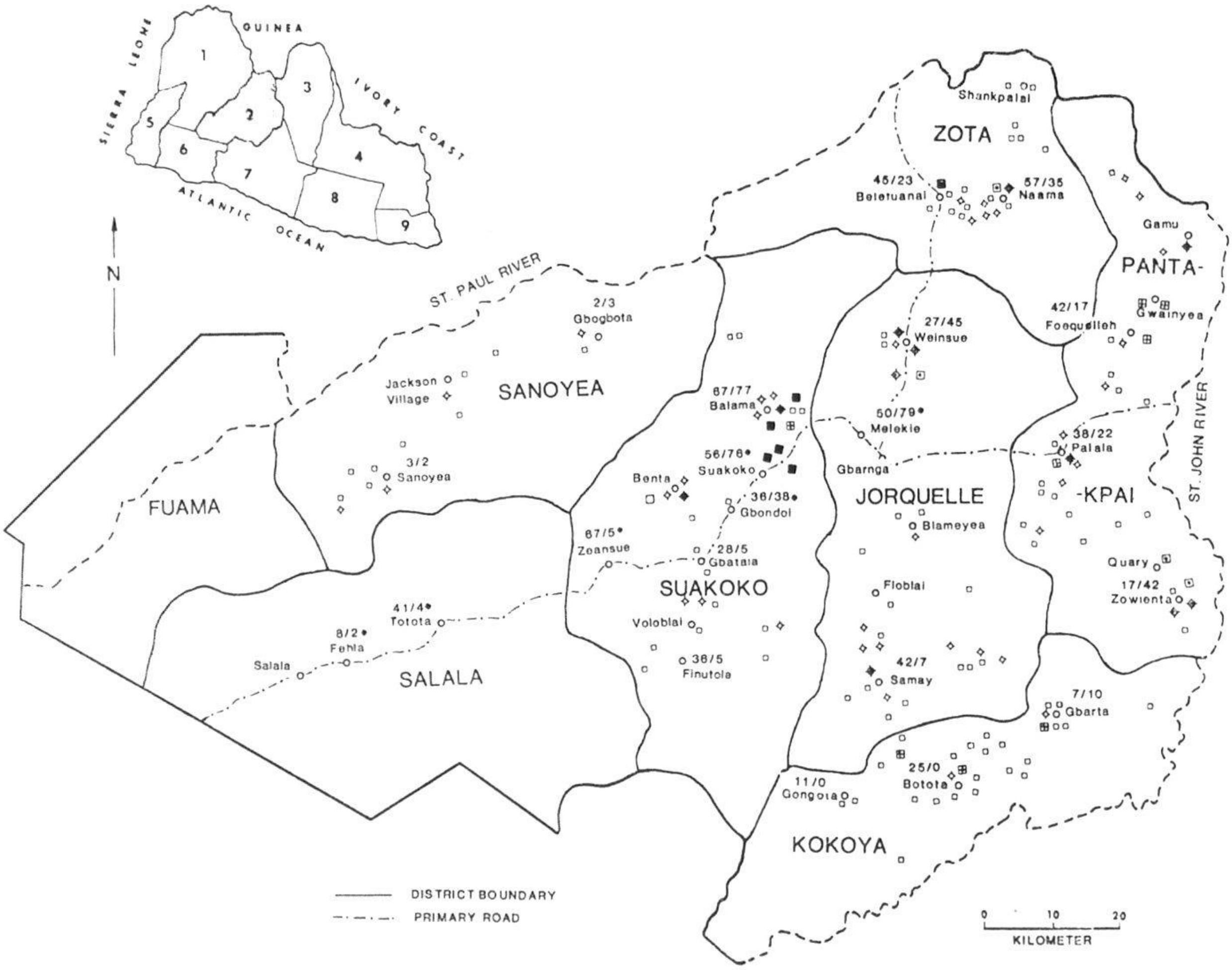

Fig. 1. Distribution of schistosomal infection prevalence (numerator = *S. haematobium;* denominator = *S. mansoni*) in children <20 years old, and schistosome vector snails in Bong County, Liberia.

□ Rice paddies
⊞ With *B. globusus*
⊡ With *B. pfeifferi*
■ With *B. globosus* and *B. pfeifferi*

-◇- Other water contact sites
-◇- With *B. globosus*
-◇- With *B. pfeifferi*
-◆- With *B. globosus* and *B. pfeifferi*

1 Lofa County
2 Bong County
3 Nimba County
4 Gedeh County
5 Cape Mount County
6 Montserrado County
7 Bassa County
8 Sinoe County
9 Maryland County

Lofa County to the north and the St. John's River which serves as a boundary between Bong and Nimba Counties to the east and parts of Bong and Bassa Counties to the south. Both rivers empty into the Atlantic Ocean running diagonally from a northeast to a southwest direction. Vegetation in Bong County consists mainly of secondary forests and cultivated land of rubber plantations, rice, coffee, cocoa, fruits and vegetables. Subsistence farming, fishing and hunting are the major occupations of rural village populations. Prior to the BCADP, upland rice farming was the predominant mode of rice cultivation although scattered rice paddies were not unusual.

In most rural and portions of urban areas, water related activities such as bathing, washing dishes and clothing, swimming, fishing, etc. occurred in permanent expanded portions of river tributaries adjacent to individual towns. These sites were practically in constant use during the day in relatively large towns of about 75 or more houses but less frequently used in smaller towns. The smaller the town, the less populated it was during the day as families tended to spend the entire day and carried out water related activities at individual small farms up to two hours walk from the town of residence of the farm family. Seepage water from rocky hills, shallow wells and streams served as the main source of drinking water for rural village populations.

As part of its operations, the BCADP established a schistosomiasis surveillance unit under the investigative supervision of the Liberian Institute for Biomedical Research for the purpose of: determining the prevalence and intensity of schistosomiasis in swamp rice farmers enrolled in the project and in other selected populations in the project area; assessing the distribution and infection rates of schistosome snail intermediate hosts and administering treatment to infected farmers. Chemotherapy was carried out under the supervision of Phebe Hospital located near Suakoko where a field station for the surveillance unit was constructed.

Materials and Methods

Malacologic survey

The distribution and infection rates of schistosome snail hosts in the study area were determined by collection surveys of selected community water contact sites and swamp rice paddies. Water contact site in this report refers to sites of water related activities other than rice paddies. These contact sites were selected and examined when they were judged, from interviews and/or observations, to be primary foci at which water related activities were carried out by the residential communities of the human populations surveyed for parasitic infections. New or existing rice paddies were examined within two to six months after the farmers were enrolled in the BCADP but within the first rice growing period of the new paddies. Initial examination of all water sites involved a thorough search of the entire area by three to five individuals using 8.5″ × 8.5″ wire mesh scoops. Snails collected were returned to the laboratory in containers lined with moistened cloth and covered with perforated tops. Snails were isolated individually under exposure to fluorescent light and examined for human schistosome cercariae at hourly intervals for at least four hours after isolation. Results were recorded as the number of each species collected per site and the number and percent of each species infected. Schistosome species were confirmed by cercarial passage in laboratory rodents.

Based on geographical location and the occurrence of one or both species of vector snails at a water site, four rice paddies in Balama (Suakoko District), Palala, Quary and Zowienta (Panta-Kpai District), and four water contact sites in Weinsue (Jorquelle District), Balama, Palala and Zowienta were selected for monthly surveys to determine possible changes in snail population density and infection prevalence. These water sites were examined at regular monthly intervals between July 1979 and June 1981 but each site was surveyed for at least a consecutive 12 month period. During each visit, three persons surveyed each site for 20 minutes. Snails collected were taken to the laboratory, examined and results recorded as described above. All snails were returned to their original habitats the same or following day. Density is expressed as the number of snails collected per minute per man (SMM). Temperature and rainfall data were obtained from the Agricultural Experimental Station near Suakoko.

During the same period of monthly surveys, five other rice paddies in Gbatala (Suakoko District), Balama, Weinsue, Palala and Zowienta, in which no vector snails were found during the initial survey, were monitored by bi-monthly examinations. Three additional rice paddies in each district, initially negative for vector snails were also monitored by semi-annual surveys.

Parasitologic survey

The prevalence and intensity of schistosomiasis in the study area were determined by collecting and examining urine and fecal samples from selected school children, village populations and swamp rice farm families. Each individual was classified in only one of the latter categories. Preliminary visits were made to each area prior to the day of the survey. The nature of the disease and the purpose of the survey were explained to officials or head of households of each population to be examined. Eleven schools were randomly selected to reflect different geographical regions so that each district within the study area was represented by at least one school. The five village populations surveyed were chosen to demonstrate either age and sex specific prevalence and intensity of schistosomiasis where both schistosome species were known to be transmitted (Balama) or to confirm little or no transmission of one (Samay and Gbarta) or both schistosome species (Gbogbota and Jackson's Village). A census of each population was taken on the day specimens were collected and information regarding age, sex, relationship, occupation, etc. recorded whether an individual was present or absent. Excreta from farm families were collected from each person of a family present at a rice paddy on the day of survey. Specimens were collected within two to six months after the head farmer was enrolled in the BCADP. Results from farm families were recorded according to the town of residence of each family.

Urine samples were collected between 10:00 a.m. and 2:00 p.m. in large urine collection cups and processed by the filter paper method of Olivier (1973). For school children, 10 ml aliquot of each sample was filtered fresh and the filter paper examined microscopically in the field for schistosome eggs. The same aliquot of urine from each individual of village populations and farm families was transferred to small specimen jars containing 10 ml of 10% formol-saline and transported to the laboratory. The entire 20 ml preparation was then filtered and examined as indicated above. Results were recorded as the number of eggs per 10 ml of urine.

Fecal samples were processed by the modified Ritchie formol-ether concentration method (Knight et al., 1976). Small portions of each fecal sample was added to specimen jars containing 9 ml of 10% formol-saline until the fluid reached the 10 ml mark. The preparations were then mixed with individual applicator sticks, stoppered and transported to the laboratory for further processing and microscopic examination. Results were recorded as the number of schistosome eggs per gram of feces. Prevalence is expressed as the percent of individuals infected and intensity as the geometric mean ($\bar{x}G$) of egg count per 10 ml urine or per gram feces.

Statistical analysis

The chi-squared (χ^2) test was used to determine the level of significance in the differences of infection prevalence rates and the Student t-test was used for differences in infection intensity rates and the means of snail population density.

Results

Malacologic findings

The only snail intermediate hosts of *Schistosoma haematobium* and *S. mansoni* found in the study area were *Bulinus globosus* and *Biomphalaria pfeifferi*, respectively. *Bulinus forskalii* occurred in a few water sites but this species was negative for schistosome larvae. *Lymnaea natalensis* was most commonly found in the habitats of the schistosome vector snails.

Water sites surveyed in the study area are shown in Fig. 1. In Table 1, results of the snail survey are listed according to districts and the towns in or near which water sites were examined. The total numbers of snail shown for each town, district and the study area include collections from population density studies at selected sites. Water contact sites were, in general, road side expansions of streams or similar bodies of water where the population of a town washed clothes and dishes, swam, fished, etc. Rice paddies were generally

Table 1 Distribution & Infection Rates of Schistosome Snail Intermediate Hosts in Bong County

District Water Site Town	#Sites Exam.	Ha.*	Bulinus globosus #Coll.	#Pos.	%Pos.	Biomphalaria pfeifferi #Coll.	#Pos.	%Pos.
Sanoyea	13		0	-	-	0	-	-
Rice Paddies	9	7.1	0	-	-	0	-	-
Kpotoloma	1	0.5	0	-	-	0	-	-
Sawmill	1	2.1	0	-	-	0	-	-
Sanoyea	3	2.5	0	-	-	0	-	-
Jackson V.	1	0.9	0	-	-	0	-	-
Ngornukai	1	0.2	0	-	-	0	-	-
Gbarmokollieta	1	0.4	0	-	-	0	-	-
Gbogbota	1	0.5	0	-	-	0	-	-
Water Contact Sites	4		0	-	-	0	-	-
Kpotoloma	1		0	-	-	0	-	-
Sanoyea	1		0	-	-	0	-	-
Jackson V.	1		0	-	-	0	-	-
Gbogbota	1		0	-	-	0	-	-
Zota	22		5	0	-	65	3	1.5
Rice Paddies	16	9.0	1	0	-	57	3	5.3
Belefuanai	3	1.4	1	0	-	13	3	23.1
Kollieta	4	2.4	0	-	-	0	-	-
Naama	3	2.6	0	-	-	44	0	-
Pelelei	3	1.0	0	-	-	0	-	-
Shankpalai	2	1.0	0	-	-	0	-	-
Kpo	1	0.6	0	-	-	0	-	-
Water Contact Sites	6		4	0	-	8	0	-
Kollieta	2		0	-	-	0	-	-
Naama	4		4	0	-	8	0	-
Suakoko	29		1245	78	6.3	292	24	8.2
Rice Paddies	19	24.5	1094	61	5.6	260	16	6.2
Balama	2	3.8	957	61	6.4	119	14	11.8
Suakoko	3	5.3	135	0	-	141	0	-
Gbondoi	1	1.0	0	-	-	0	-	-
Pegnyan	1	0.7	0	-	-	0	-	-
Kandakiata	1	1.2	0	-	-	0	-	-
Gbatala	2	2.6	0	-	-	0	-	-
Taylorta	1	3.2	0	-	-	0	-	-
Dulemu	1	0.4	0	-	-	0	-	-
Sinyea	3	1.8	2	0	-	0	-	-
Benta	1	0.5	0	-	-	0	-	-
Doloquenta	1	1.5	0	-	-	0	-	-
Bukomma	1	1.5	0	-	-	0	-	-
Voloblai	1	1.0	0	-	-	0	-	-

Table 1 (continued)

District Water Site Town	#Sites Exam.	Ha.	Bulinus globosus #Coll.	 #Pos.	 %Pos.	Biomphalaria pfeifferi #Coll.	 #Pos.	 %Pos.
Suakoko								
Water Contact Sites	10		151	17	11.3	32	8	25.0
Balama	4		147	14	9.5	26	7	26.9
Benta	3		4	3	75.0	6	1	16.7
Taylorta	2		0	-	-	0	-	-
Doloquenta	1		0	-	-	0	-	-
Jorquelle	35		244	80	32.8	444	107	24.1
Rice Paddies	20	12.9	0	-	-	22	0	-
Kayata	2	1.0	0	-	-	0	-	-
Weinsue	2	1.8	0	-	-	0	-	-
Tucker V.	1	1.6	0	-	-	22	0	-
Gbangbata	1	0.8	0	-	-	0	-	-
Jangheata	1	0.5	0	-	-	0	-	-
Floblai	1	1.6	0	-	-	0	-	-
Blameyea	2	1.0	0	-	-	0	-	-
Tamita	1	0.8	0	-	-	0	-	-
Samay	1	0.5	0	-	-	0	-	-
Duata	1	0.6	0	-	-	0	-	-
Gorgota	2	0.9	0	-	-	0	-	-
Sheansue	1	0.4	0	-	-	0	-	-
Tolomah	1	0.5	0	-	-	0	-	-
Yorkollieta	3	1.0	0	-	-	0	-	-
Water Contact Sites	15		244	80	32.8	422	107	25.4
Weinsue	3		201	75	37.3	405	107	26.4
Tucker V.	1		0	-	-	17	0	-
Blameyea	1		0	-	-	0	-	-
Tamita	3		0	-	-	0	-	-
Samay	2		43	5	11.6	0	-	-
Gorgota	1		0	-	-	0	-	-
Sheansue	2		0	-	-	0	-	-
Tolomah	2		0	-	-	0	-	-
Kokoya	28		28	0	-	0	-	-
Rice Paddies	26	18.2	28	0	-	0	-	-
Botota	10	5.5	18	0	-	0	-	-
Gbarta	5	4.0	5	0	-	0	-	-
Gbalkpalla	7	4.2	5	0	-	0	-	-
Gongota	2	3.5	0	-	-	0	-	-
Dayweah	1	0.5	0	-	-	0	-	-
Welta	1	0.5	0	-	-	0	-	-

Table 1 (end)

District Water Site Town	#Sites Exam.	Ha.	Bulinus globosus #Coll.	#Pos.	%Pos.	Biomphalaria pfeifferi #Coll.	#Pos.	%Pos.
Kokoya								
Water Contact Sites	2		0	-	-	0	-	-
Gbarta	1		0	-	-	0	-	-
Gotota	1		0	-	-	0	-	-
Panta-Kpai	37		974	100	10.3	925	79	8.5
Rice Paddies	24	20.2	571	91	15.9	882	58	6.6
Shiaquelleh	1	1.5	0	-	-	0	-	-
Gwainyea	2	1.8	28	0	-	0	-	-
Foequelle	2	4.1	5	0	-	0	-	-
Sawolo	2	1.0	0	-	-	0	-	-
Baila	1	0.5	0	-	-	0	-	-
Palala	2	1.6	536	91	17.0	0	-	-
Duta	3	1.8	0	-	-	0	-	-
Gatayea	2	1.6	0	-	-	0	-	-
Melinta	1	0.5	0	-	-	0	-	-
Quaipa	2	1.0	0	-	-	0	-	-
Jonkai	1	0.5	0	-	-	0	-	-
Yopea	1	0.8	0	-	-	0	-	-
Quary	1	0.8	0	-	-	619	26	7.4
Zowienta	2	2.6	0	-	-	263	12	4.6
Yillata	1	0.5	0	-	-	0	-	-
Water Contact Sites	13		403	9	2.2	43	21	48.8
Shiaquelleh	1		0	-	-	0	-	-
Palaquelleh	1		0	-	-	0	-	-
Belimu	1		0	-	-	0	-	-
Garmu	1		1	0	-	0	-	-
Foequelle	1		0	-	-	0	-	-
Sawolo	1		0	-	-	0	-	-
Palala	3		303	5	1.7	1	0	-
Duta	1		0	-	-	0	-	-
Gatayea	1		0	-	-	0	-	-
Zowienta	2		99	4	4.0	42	21	50.0
Totals	164		2496	258	10.3	1726	213	12.3
Rice Paddies	114	91.9	1694	152	9.0	1221	77	6.3
Water Contact Sites	50		802	106	13.2	505	136	26.9

*Hectare

located in valleys or on water laden flat land up to 1.5 hours walk from the residential village of the farmers. A small hut was usually built at the rice paddy site and farmers spent most of the day at the site. Any part of the irrigation canal served for water related activities but mainly the canal nearest the hut. The size of rice paddies ranged from 0.4 to 3.5 (average 0.79) hectares.

B. globosus and/or *B. pfeifferi* were collected from all districts of the study area except Sanoyea District where examination of 13 water sites showed no schistosome snail host. *B. globosus* was collected from every other district in the study area and showed a wider, particularly southern distribution than *B. pfeifferi.* The latter species was not found and probably does not occur in the southern most parts of Suakoko, Jorquelle and Kokoya Districts. The over-all infection prevalence of *B. globosus* was 10.3% while that of *B. pfeifferi* was 12.3%. Snail infection rates in rice paddies were lower than those in water contact sites where *B. pfeifferi* showed a significantly higher prevalence of infection (26.9%) than *B. globosus* (13.2%) (Tables 1 and 2).

Table 2 shows that 14.6% of a total of 164 water sites examined in the study area contained *B. globosus* while 11.0% harbored *B. pfeifferi.* However, fewer numbers of these sites contained only *B. globosus* (5.6%) or only *B. pfeifferi* (3.1%). Both species of snails were found together in 7.8% of the water sites examined. Infected *B. globosus* and *B. pfeifferi* were found in 6.2% and 5.5% of the total number of water sites examined, respectively, while only 3.7% of these sites contained infected snails of both species. Consequently, infected *B. globosus* and *B. pfeifferi* occurred in 47.6% and 47.1% of the sites harboring these species of snails, respectively. More water sites in Suakoko District contained schistosome snail hosts than in any other district but infection rates in snails were highest in Jorquelle District (Table 2).

Significantly higher percentages (χ^2-test $p<0.01$) of the water contact sites examined in the study area contained uninfected as well as infected *B. globosus* and *B. pfeifferi* than rice paddies (Table 2). Except in Sanoyea District, all rice paddies found negative for the occurrence of schistosome vector snails were new paddies constructed since 1978 during the project period of the BCADP. These new paddies constituted over 90% of the rice paddies in the study area. None of the rice paddies which were initially negative for the occurrence of schistosome vector snails and examined at bi-monthly and annual intervals showed the presence of these snails up to the end of our study period. Rice paddies harboring *B. globosus* and *B. pfeifferi* were older paddies in operations prior to the establishment of the BCADP.

Four rice paddies, one each near Balama (Suakoko District), Palala, Quary and Zowienta (Panta-Kpai District) and four water contact sites, one each near Weinsue (Jorquelle District), Balama, Palala and Zowienta were surveyed at monthly intervals to determine possible seasonal changes in snail population density and infection rate. All paddies had the same basic structural design: three longitudinal canals connected by several transverse canals dividing the

Table 2 Comparison Between Rice Paddies & Other Water Contact Sites as Habitats for Schistosome Snail Intermediate Hosts

District	#Sites	B. globosus	B. pfeifferi	#/% Sites With					
Water Site	Exam.	#Coll./%Pos.	#Coll./%Pos.	B.g.	B.p.	Both	S.h.	S.m.	Both
Sanoyea	13	0	0	0	0	0	0	0	0
RP	9	0	0	0	0	0	0	0	0
WCS	4	0	0	0	0	0	0	0	0
Zota	22	5/0	65/4.5	2/9.9	3/13.6	2/9.1	0	1/4.6	0
RP	16	1/0	57/5.3	1/6.3	2/12.5	1/6.3	0	1/6.5	0
WCS	6	4/0	8/0	1/16.7	1/16.7	0	0	0	0
Suakoko	29	1245/6.3	292/8.2	8/27.6	7/24.1	7/24.1	3/10.3	4/13.8	3/10.2
RP	19	1094/5.6	260/6.2	6/31.6	5/26.3	5/26.3	1/5.3	2/10.5	1/5.3
WCS	10	151/11.3	32/25.0	2/20.0	2/20.0	2/20.0	2/20.0	2/20.0	2/20.0
Jorquelle	35	244/32.8	444/24.1	3/8.6	3/8.6	1/2.9	3/8.6	1/2.9	1/2.9
RP	20	0	22/0	0	1/5.0	0	0	0	0
WCS	15	244/32.8	422/25.4	3/20.0	2/13.3	1/6.7	3/20.0	1/6.7	1/6.7
Kokoya	28	28/0	0	3/10.7	0	0	0	0	0
RP	26	28/0	0	3/11,5	0	0	0	0	0
WCS	2	0	0	0	0	0	0	0	0
Panta-Kpai	37	974/10.3	925/8.5	9/24.3	5/13.5	3/8.1	4/10.8	3/8.1	2/5.4
RP	24	571/15.9	882/6.6	4/16.7	2/8.3	0	1/4.2	2/8.3	0
WCS	13	403/2.2	43/48.8	5/38.5	3/23.1	3/23.1	3/23.1	1/7.8	2/15.4
Totals	164	2496/10.3	1726/12.3	24/14.6	18/11.0	13/7.8	10/6.2	9/5.5	6/3.7
RP	114	1694/9.0	1221/6.3	12/10.5	10/8.8	6/5.3	2/1.8	5/4.4	1/0.9
WCS	50	802/13.2	505/26.9	12/24.0	8/16.0	7/14.0	8/16.0	4/8.0	5/10.4

Abbreviations: RP=Rice Paddies; WCS=Other Water Contact Sites; B.g.=*Bulinus globosus*; B.p.=*Biomphalaria pfeifferi*; S.h.=*Schistosoma haematobium*; S.m.=*Schistosoma mansoni* paddies into rectangular plots. The central canal was usually larger than the two lateral canals, averaging about five feet in width by three to four feet in depth. Water source and control were at the beginning and end of the central canal with water flow approximating a small stream during the raining season and a pond during the dry season. Vegetation lined the canals; plants which interferred with water flow were cleared. The bottom was usually muddy and contained decaying vegetation. During periods of peak snail population size, snails were found in the plots as well as in the trenches, but mainly in the trenches when population size decreased or plots were comparatively dessicated. Snail collection for density studies were restricted to the canals. The water contact sites surveyed at monthly intervals were road expansions of streams or swampy areas which bissected the road through a small bridge or culverts. The water contact sites were located at either end of a town. Water related activities occurred nearer the road where the bottom was less muddy and more rocky or sandy but wading deeper into the water was usual. Water flow was slower at the expanded portions of these sites than at origins and exits.

The rice paddy near Balama and the water contact sites near Balama, Weinsue and Zowienta harbored both *B. globosus* and *B. pfeifferi.* Both the rice paddy and water contact site near Palala contained only *B. globosus* while the paddies near Quary and Zowienta showed the presence of only *B. pfeifferi* (Table 3). In these water sites, *B. globosus* showed· a higher mean population density per site per month (0.22 SMM) than *B. pfeifferi* (0.16 SMM) but a lower infection rate (10.4%) than the latter species (13.0%). However, these differences were not statistically significant (t-test and χ^2-test $p>0.05$). The mean monthly population density of *B. globosus* was significantly higher (t-test $p<0.01$) in the rice paddies (0.40 SMM) than in the water contact sites (0.11 SMM) examined but similar difference for *B. pfeifferi* in these water sites was not statistically significant (t-test $p>0.05$) (Table 3). Infection prevalence of *B. globosus* in rice paddies (10.5%) and water contacts sites (10.0%) did not differ significantly but *B. pfeifferi* showed a much higher infection rate in water contact sites (29.5%) than in the rice paddies (7.4%).

Monthly changes in the means of snail population size were similar for *B. globosus* and *B. pfeifferi* (Fig. 2). The general tendency observed as a decline in population size during the period of heavy rainfall between late August and early October. As the quantity of rainfall declined, snail population size increased and remained relatively high from late October through most of the dry season particularly from December through February. Another contraction in snail population size was observed during or shortly after the period of least rainfall and relatively higher temperatures between late February and early April. Snail population density then expanded, with oscillations, during the initial months of the raining season through the mid-dry season (late April to early August). Peak population size during the latter period was usually lower than that observed during the dry season. Variations within this general tendenle 3 Monthly Changes in Snail Population Density and Infection Rate

.l Species :e	January	February	March	April	May	June	July	August	September	October	November	December	x̄/Month/ Site
;lobosus	0.28/5.8*	0.39/20.2	0.19/9.8	0.19/5.8	0.11/10.0	0.28/3.9	0.21/11.1	0.21/7.1	0.02/0	0.20/3.9	0.20/21.5	0.39/3.7	0.22/10.4
:e Paddies	0.66/3.0	0.84/20.5	0.43/9.2	0.27/3.3	0.26/7.4	0.43/1.1	0.13/12.3	0.18/7.3	0.03/0	0.52/2.3	0.39/29.9	0.70/3.4	0.40/10.5
ılama	1.00/3.6	1.13/4.1	1.09/7.0	0.27/7.0	0.26/19.0	0.34/0	0.13/11.8	0.19/8.3	0.03/0	0.11/3.7	0.32/9.7	0.68/4.9	0.44/5.6
ılala	0.24/0	0.58/51.4	0.20/13.2	0.27/0	0.28/0	0.50/1.6	0.15/12.9	0.09/0	0/0	0.98/1.7	0.41/39.4	0.69/0	0.36/17.6
:er Contact :es	0.11/13.0	0.08/18.2	0.06/11.5	0.10/12.1	0.05/15.4	0.19/8.3	0.30/10.4	0.24/7.2	0.01/0	0.05/11.8	0.09/0	0.10/6.5	0.11/10.0
ılama	0.08/20.0	0.08/0	0.06/28.6	0.07/11.1	0.02/25.0	0.05/0	0.32/21.4	0.04/0	0/0	0.11/0	0.21/0	0.71/0	0.11/10.2
:insue	0.07/20.0	0.09/72.7	0.07/11.1	0.14/28.6	0.06/66.7	0.11/40.0	0.12/46.7	0.15/35.4	0/0	0.08/20.0	0.07/0	0.05/16.7	0.07/33.7
ılala	0.11/8.7	0.12/0	0.02/0	0.16/0	0.14/5.3	0.40/0	0.48/0	0.88/0	0.04/0	0.02/0	0.07/0	0.06/20.0	0.17/1.7
owienta	0.26/8.7	0.07/0	0.09/0	0.09/25.0	0/0	0.50/7.0	0.15/0	0.01/0	0/0	0/0	0/0	0/0	0.07/5.1
ofeifferi	0.24/19.5	0.27/19.3	0.11/4.9	0.15/20.9	0.07/64.5	0.10/16.0	0.13/12.8	0.20/1.8	0.13/5.1	0.21/4.6	0.13/0	0.13/15.6	0.16/13.0
:e Paddies	0.29/19.5	0.36/12.0	0.06/0	0.09/0	0.02/0	0.09/0	0.14/8.9	0.22/1.0	0.19/5.1	0.26/2.6	0.13/0	0.13/4.1	0.17/7.4
ılama	0.11/30.8	0.15/18.5	0.14/0	0.03/0	0.09/0	0.02/0	0.02/0	0.05/20.0	0/0	0.04/0	0.07/0	0.04/12.5	0.06/1.2
ıary	0.56/23.5	0.84/13.9	0.01/0	0.33/0	0/0	0.21/0	0.37/0	0.18/0	1.18/7.5	0.48/0	0.26/0	0.37/2.6	0.34/7.9
owienta	0.16/3.1	0.22/0	0.08/0	0/0	0/0	0.04/0	0.13/28.1	0.40/0	0.10/0	0.58/5.7	0.06/0	0.02/0	0.13/4.8
:er Contact :es	0.19/20.8	0.12/58.6	0.19/7.5	0.28/33.3	0.15/80.0	0.11/30.8	0.10/29.2	0.09/9.1	0/0	0.14/9.7	0.08/0	0.13/53.5	0.13/29.4
ılama	0/0	0/0	0.01/80.0	0.22/15.0	0/0	0/0	0/0	0/0	0/0	0/0	0.01/0	0/0	0.03/26.9
:insue	0.21/20.8	0.33/58.6	0.26/0	0.37/50	0.49/80.0	0.20/30.8	0.15/29.2	0.10/9.1	0/0	0.20/9.7	0.15/0	0.15/53.3	0.18/29.6

ıil per minute per man/percent positive

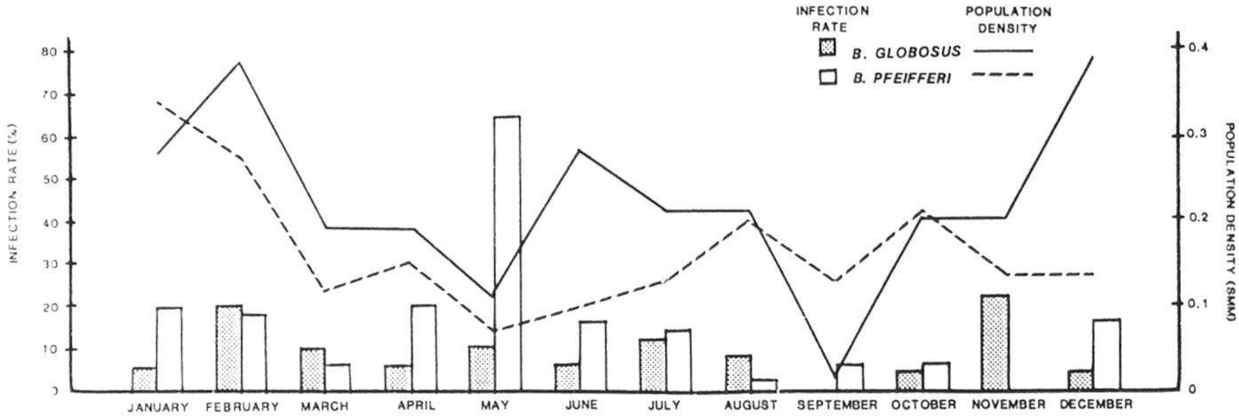

Fig. 2. Monthly changes in the means of snail population density and infection rate summarized from seven water sites in Bong County (SMM = snail per minute per man).

cy was the rule. *B. globosus* was found in the Balama rice paddy and Palala water contact site during every month of the year (Table 3). These snails were not found in the other water sites during the period of heaviest rainfall (September). Except for the water contact site in Zowienta which appeared to contain an unstable population of *B. globosus*, seasonal fluctuations in the population density of the latter snail in all water sites examined were similar. A relatively large population of *B. pfeifferi* was found in the Zowienta and Quary rice paddies in September when no other water site showed the presence of these snails.

Monthly changes in snail infection rate appeared to follow similar trends described for population density; relatively high infection rates during the dry season and low rates during the raining season with variations according to site. Except for the rice paddy in Quary where infected *B. pfeifferi* was found in September, infected snails were not found in any other water site during this month. Chances of finding infected snails were greatest in January when five of the six sites (83%) with *B. globosus* and four of the five sites (80%) with *B. pfeifferi* showed infected snails. For *B. globosus*, the number of sites with infected snails varied between two and four from February to August and between two and three from October to December. Three of the five sites with *B. pfeifferi* showed infected snails in February and December. This number varied between one and two sites from March to October. Infected *B. pfeifferi* was not found in November.

Parasitologic findings

Urine samples from a total of 3548 individuals residing in six districts of Bong County and fecal specimens from 3408 of these individuals were examined for the presence of *S. haematobium* and *S. mansoni* ova. Table 4 shows total prevalence rates of 22.7% for *S. haematobium* and 24.8% for *S. mansoni* infections in the population surveyed. The intensity of infection was 13.2 (*S. haematobium*) and 6.3 (*S. mansoni*) geometric mean egg count ($\bar{x}G$) per ten

Table 4 Age & Sex Specific Prevalence & Intensity of Schistosomiasis in Bong County

	Age Group	Male # Exam.	Male # Pos.	Male % Pos.	Male $\bar{x}G$*	Female # Exam.	Female # Pos.	Female % Pos.	Female $\bar{x}G$	Both Sexes # Exam.	Both Sexes # Pos.	Both Sexes % Pos.	Both Sexes $\bar{x}G$
Schistosoma haematobium	0-9	465	116	25.0	18.7	433	103	23.8	12.5	898	219	24.4	15.4
	10-19	1072	323	30.1	15.2	572	176	30.8	12.1	1644	499	30.4	14.0
	20-29	187	17	9.1	7.5	177	18	10.2	8.6	364	35	9.6	8.1
	30-39	83	2	2.4	1.4	177	23	13.0	6.7	260	25	9.6	5.9
	40-49	72	3	4.2	4.4	102	14	13.7	6.2	174	17	9.8	5.8
	50+	126	5	4.0	6.6	82	6	7.3	2.6	208	11	5.3	4.0
	Total	2005	466	23.2	15.2	1543	340	22.1	10.9	3548	806	22.7	13.2
Schistosoma mansoni	0-9	455	115	23.3	5.8	430	108	25.1	8.5	885	223	25.2	7.0
	10-19	1038	269	25.9	6.2	530	170	32.1	7.0	1568	438	28.0	6.5
	20-29	182	37	20.3	4.6	175	38	21.7	4.8	357	75	21.0	4.7
	30-39	73	6	8.2	4.5	163	39	23.9	7.2	236	45	19.1	6.8
	40-49	65	8	12.3	6.9	99	25	25.3	6.3	164	33	20.1	6.4
	50+	119	14	11.8	3.0	79	16	20.3	5.3	198	30	15.2	4.1
	Total	1932	449	23.2	5.8	1476	396	26.8	7.0	3408	845	24.8	6.3

*Geometric mean egg count/10 ml urine/gram feces

Table 5 Age Specific Prevalence & Intensity of Schistosomiasis in Balama Town, Bong County

Age Group	Schistosoma haematobium				Schistosoma mansoni			
	#Exam.	#Pos.	%Pos.	$\bar{x}$G*	#Exam.	#Pos.	%Pos.	$\bar{x}$G
0-9	197	73	37.1	13.6	193	119	61.7	7.6
10-19	130	71	54.6	16.3	125	98	78.4	7.2
20-29	44	9	20.5	7.2	44	35	79.5	6.4
30-39	58	13	22.4	6.3	55	33	60.0	7.2
40-49	37	10	27.0	4.0	36	23	63.9	6.8
50+	45	6	13.3	3.7	43	22	51.2	4.5
Total	511	182	35.6	12.1	496	330	66.5	7.1

*Geometric mean egg count/10 ml urine/gram feces

milliliters of urine and per gram of feces, respectively. The prevalence of *S. mansoni* was significantly higher than that of *S. haematobium* (χ^2-test $p<0.05$) while the egg output with the latter species was higher than with the former. Individual egg counts ranged from 1–6002/10 ml urine and 1–213/g feces.

Although the prevalence and intensity of *S. haematobium* were higher in males than in females (Table 4), the differences were not statistically significant (χ^2-test and t-test $p>0.05$). However, in females 20 years and older, the prevalence of *S. haematobium* (11.8%) was significantly higher than in males (5.8%) of the same age group (χ^2-test $p<0.01$). Similarly, the prevalence, but not the intensity, of *S. mansoni* was significantly higher (χ^2-test $p<0.05$) in females (26.8%) than in males (23.2%).

The age specific prevalence and intensity of schistosomiasis in the study population (Table 4; Fig. 3) was characteristic of the disease in endemic areas: higher infection rates were observed in children than in adults. In the age group <20 years old, the prevalence of *S. haematobium* (28.2%) did not differ significantly from that of *S. mansoni* (27.0%), but in this age group, the intensity of infection with the former species (14.4 $\bar{x}$G) was significantly higher (t-test $p<0.01$) than with the latter species (6.7 $\bar{x}$G). Conversely, in the age group >20 years old, the prevalence of *S. mansoni* (19.2%) was significantly higher (χ^2-test $p<0.01$) and showed a less dramatic decline with increasing age (Fig. 3) than that observed for *S. haematobium* (8.3%). However, the intensity of *S. mansoni* and *S. haematobium* infections did not differ significantly in the age group >20 years old (Table 4).

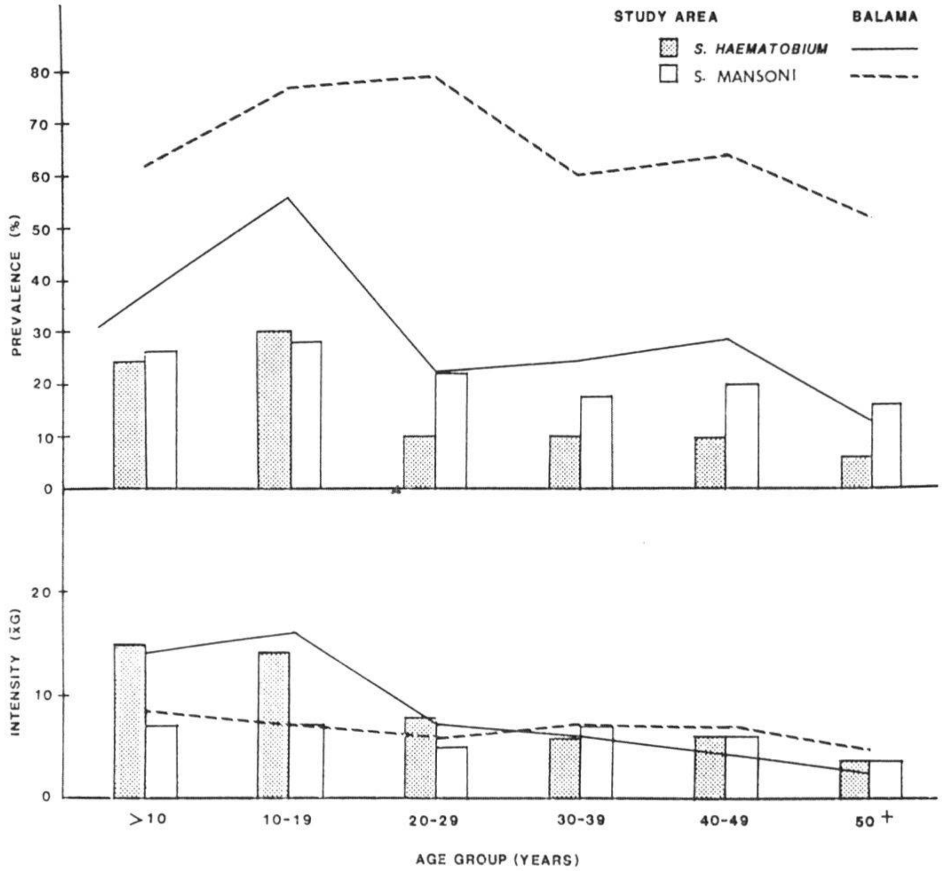

Fig. 3. Age specific prevalence and intensity of schistosomiasis in Balama town and in six districts of Bong County ($\bar{x}G$ = geometric mean egg count).

Table 5 shows the age specific prevalence and intensity of schistosomiasis in one village population, Balama (Suakoko District), where evidence of transmission of both schistosome species was observed (see above). Fig. 3 compares the age frequency distribution of schistosomal infection in Balama with that of the entire study population, the latter including subpopulations with varying degrees of exposure to infection. In Balama, the prevalence, but not the intensity of schistosomiasis was significantly higher than in the combined study population (χ^2-test $p<0.01$). Similar to the study population, Balama also showed a significantly higher prevalence (χ^2-test $p<0.01$) of *S. mansoni* (66.5%) than *S. haematobium* (35.6%).

The locality specific prevalence and intensity of schistosomal infections in the study area are presented in Table 6 according to districts. The population tested in each district is further separated into subpopulations of school children, village populations and swamp rice farm families, and listed according to their towns of residence. Our study population consisted of 49.9% school children ($\bar{x}$ age = 14), 21.1% farm families ($\bar{x}$ age = 24.4) and 23.0% village populations ($\bar{x}$ age = 23). The composition of farm families was 53.8% males and 47.2% females with 53% less than 20 years old.

The prevalence and intensity of *S. haematobium* in school children (32.2%; 18.0 $\bar{x}G$) were significantly higher than in the five village populations (15.3%;

Table 6 Locality & Population Specific Prevalence & Intensity of Schistosomiasis in Bong County

District	Schistosoma haematobium				Schistosoma mansoni			
Population Town	# Exam.	# Pos.	% Pos.	$\bar{x}$G*	# Exam.	# Pos.	% Pos.	$\bar{x}$G
Sanoyea	478	6	1.3	7.9	448	12	2.7	3.9
Sanoyea School	123	3	2.4	17.3	115	0	-	-
Villages	334	3	0.9	3.6	312	11	3.5	3.2
Jackson V.	93	0	-	-	93	6	6.5	3.3
Gbogbota	241	3	1.2	3.6	219	5	2.3	3.1
Farmers	21	0	-	-	21	1	4.8	1.0
Kpotoloma	9	0	-	-	9	0	-	-
Ngornukai	3	0	-	-	4	1	25.0	1.0**
Gbarmokollieta	0	-	-	-	1	0	-	-
Bendata	9	0	-	-	7	0	-	-
Zota	390	144	36.9	27.1	352	87	24.7	4.5
Schools	249	126	50.6	33.8	218	62	28.4	5.9
Belefuanai	128	57	44.5	34.0	122	28	23.0	5.4
Naama	121	69	57.0	33.3	96	34	35.4	6.2
Farmers	141	18	12.8	5.8	134	25	18.7	2.4
Belefuanai	17	1	5.9	2.0	17	5	29.4	4.0
Kollieta	50	50	20.0	5.6	47	4	8.5	3.9
Naama	29	3	10.3	1.8	27	8	29.6	1.3
Pelelei	12	0	-	-	11	4	36.4	3.0
Shankpalai	33	4	12.1	7.8	32	4	12.5	2.1
Suakoko	675	230	34.1	11.9	657	338	51.4	7.0
Schools	110	62	56.4	29.4	105	53	50.5	9.3
Balama	71	48	67.6	26.4	66	51	77.3	9.5
Finutole	39	14	35.9	42.8	39	2	5.1	4.2
Balama Village	403	135	33.5	8.2	396	252	63.6	5.9
Farmers	162	33	20.4	9.9	156	33	21.2	15.3
Balama	37	4	10.8	13.1	34	27	79.4	21.8
Suakoko	27	5	18.5	10.9	27	3	11.1	4.4
Gbondoi	38	15	39.5	10.7	37	1	2.7	2.0
Pegnyan	12	2	16.2	2.2	14	1	7.1	1.0
Kandakaita	13	0	-	-	12	1	8.3	2.0
Gbatala	13	5	38.5	12.2	12	0	-	-
Taylorta	20	2	10.0	6.2	18	0	-	-
Dulemu	2	0	-	-	2	0	-	-

Table 6 (continued)

District Population Town	Schistosoma haematobium # Exam.	# Pos.	% Pos.	$\bar{x}$G	Schistosoma mansoni # Exam.	# Pos.	% Pos.	$\bar{x}$G
Jorquelle	752	173	23.0	11.6	747	156	20.9	10.0
Schools	390	120	30.8	14.5	387	135	34.9	11.9
Weinsue	289	77	26.6	17.2	285	128	44.9	12.3
Samay	101	43	42.6	10.6	102	7	6.9	5.8
Samay Village	254	35	13.8	6.2	263	16	6.1	2.8
Farmers	108	18	16.7	9.0	97	5	5.2	6.6
Floblai	7	0	-	-	7	2	28.6	11.2
Samay	101	18	17.8	9.0	90	3	3.3	4.6
Kokoya	403	41	10.2	11.7	388	18	4.6	3.0
Bototа School	64	16	25.0	37.7	62	0	-	-
Gbarta Village	184	7	3.8	5.5	178	18	10.1	3.0
Farmers	155	18	11.6	5.5	148	0	-	-
Bototа	9	2	22.2	11.2	9	0	-	-
Gbarta	13	0	-	-	11	0	-	-
Gbalkpalla	69	15	21.7	5.4	68	0	-	-
Gongota	20	1	5.0	2.0	19	0	-	-
Wleta	37	0	-	-	34	0	-	-
Yolota	7	0	-	-	7	0	-	-
Panta-Kpai	850	212	24.9	10.4	816	234	28.7	5.0
Schools	691	196	28.4	11.0	671	208	31.0	5.1
Foequelle	118	49	41.5	26.4	117	21	17.0	5.4
Palala	240	92	38.3	10.9	231	51	22.1	4.3
Zowienta	333	55	16.5	5.2	323	136	42.1	5.4
Farmers	159	16	10.1	5.2	145	26	17.9	4.5
Gwainyea	3	0	-	-	3	0	-	-
Foequelle	11	0	-	-	10	2	20.0	4.6
Sawolo	49	3	6.1	2.0	43	10	23.3	3.3
Palala	7	3	42.9	15.7	7	0	-	-
Duta	15	1	6.7	13.0	15	0	-	-
Melinta	15	4	26.7	2.6	13	0	-	-
Quaipa	29	1	3.4	6.0	29	0	-	-
Yopea	5	2	40.0	5.2	5	0	-	-
Zowienta	28	2	7.1	9.6	23	14	60.9	5.5
Totals	3548	806	22.7	13.2	3408	845	24.8	6.3
Schools	1627	523	32.2	18.0	1558	458	29.4	7.1
Villages	1175	180	15.3	7.6	1149	297	25.9	5.4
Farmers	746	103	13.8	7.2	701	90	12.8	7.7

*Geometric mean egg count/10ml urine/gm feces
**Actual egg count where only one individual positive

7.6 x̄G) and the farm families (13.8%; 7.2 x̄G) surveyed (χ^2-test and t-test $p<0.05$). The differences in prevalence and intensity rates of *S. haematobium* between the village populations and were not statistically significant. However, differences in prevalence rates of *S. mansoni* among three categories of populations surveyed (Table 6) were statistically significant (χ^2-test $p<0.05$). The intensity of *S. mansoni* was similar in school children (7.1 x̄G) and farmers (7.7 x̄G) but significantly higher (t-test $p<0.05$) in the latter groups than in the villages (5.4 x̄G).

Although farm families as a group showed the lowest prevalence rate of schistosomiasis, focal variations were noted. In Belefaunai (Zota District), Balama and Zowienta, prevalence rates of *S. mansoni* among farmers were significantly higher (χ^2-test $p<0.05$) than in corresponding village populations and/or school children, a situation similar to the prevalence of *S. haematobium* in Palala (Table 6).

Among school children, selected randomly from each district of the study area, the prevalence of *S. haematobium* ranged from 2.4% in Sanoyea School to 67.6% in Balama School (Suakoko District) and the intensity of infection from 5.2 x̄G (Zowienta School; Panta-Kpai District) to 42.8 x̄G (Finutole School; Suakoko District). The range in the prevalence and intensity of *S. mansoni* infection was zero (Sanoyea School) to 77.3% (Balama School) and 12.3 x̄G (Weinsue School; Jorquelle District), respectively (Table 6; Fig. 4). The prevalence and intensity of *S. haematobium* among school children was higher (32.2%; 18.0 x̄G) than those of *S. mansoni* (29.4%; 7.1 x̄G) but only the difference in intensity of infection between the two schistosome species was statistically significant (t-test $p<0.01$). Fourteen percent of the school children tested harbored mixed infections without an apparent significant difference in egg count between the group with mixed infections (*S. haematobium* – 16.9 x̄G; *S. mansoni* – 7.1 x̄G) and the group showing single infections (*S. haematobium* – 18.5 x̄G; *S. mansoni* – 7.5 x̄G). School children in Sanoyea and Kokoya Districts were negative for *S. mansoni* infection (Table 6; Fig. 4); farm families were also practically negative and the village populations showed relative light infections. School children in all six districts comprising the study area showed *S. haematobium* infection but the infection prevalence in Sanoyea District (2.4%) was comparatively insignificant. In each district, the intensity of *S. haematobium* infection was higher than that of *S. mansoni*, but prevalence rates between the two species varied according to district (Table 6; Fig. 4).

The map in Fig. 1 also shows prevalence rates of *S. haematobium* (numerator) and *S. mansoni* (denominator) among school children in Bong County placed near towns where surveys were made and includes some figures from Saladin et al. (1980). In our study, a south to north stratification of infection rates was observed to be similar to the west to east schistosomal gradient reported by Saladin et al. (1980). In the southern portions of Suakoko, Kokoya and Jorquelle Districts (Finutole, Samay and Botota schools), the prevalence of

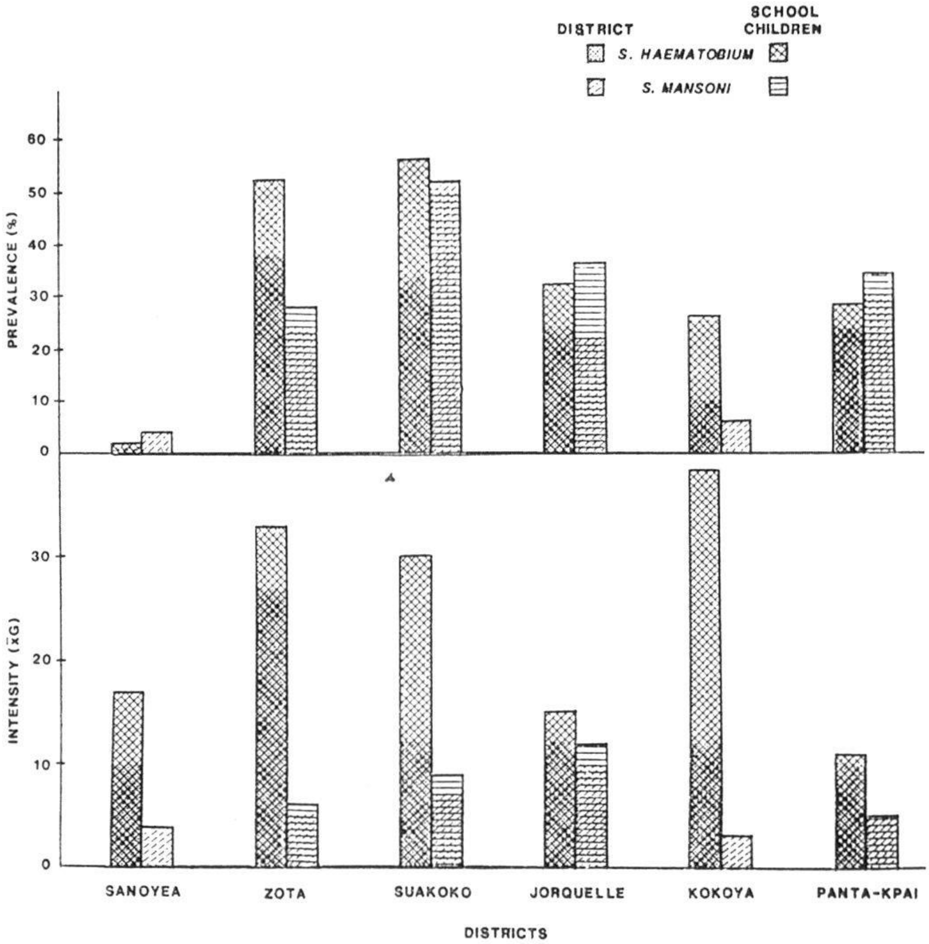

Fig. 4. Prevalence and intensity of schistosomiasis in selected populations from six of the eight districts comprising Bong County ($\bar{x}$G = geometric mean egg count).

S. mansoni was 5% or less. In Suakoko and Jorquelle Districts, prevalence rates of *S. mansoni* increased in a northerly direction becoming higher than *S. haematobium* infection rates in the central and northern parts of the districts. Further north in Zota District, prevalence rates of *S. haematobium* was again significantly higher than those of *S. mansoni.* Similarly, infection prevalence of *S. mansoni* was 0% in Botota school children (Kokoya District); became higher than that of *S. haematobium* in Gbarta Village (Table 6), northeastern Kokoya District, and among Zowienta school children in southern Panta-Kpai District, but lower than the latter species in northern Panta-Kpai District (Palala and Foequelle school children).

Discussion

Miller's (1957) deduction that coastal areas of Liberia were probably free of transmission of human schistosomes was in part confirmed by Saladin et al. (1980) who found no vector snails from Fehla in central Salala District (Bong County), along the principal Monrovia-Gbarnga highway, to the coast. The range of *S. haematobium* transmission foci was shown to commence from the vicinity of Totota, east of Fehla in Salala District; that of *S. mansoni*, from Gbondoi (Suakoko District), east of Totota, and extend eastward (Saladin et al., 1980). Until the present study, systematic investigations of schistosomiasis in Bong County did not extend beyond the Gbarnga-Weinsue area of Jorquelle District.

In Bong County, *Bulinus globosus* was more widely distributed than *Biomphalaria pfeifferi*. Although surveys have not been done in Fuama District, it may be deduced from the present and previous studies that transmission of human schistosomes probably does not occur in the latter District. Results from testing farm families and water sites (Table 6) in Gbatala (Suakoko District), confirm the western limit in the distribution of *S. mansoni* transmission foci in the county. The absence of vector snails in 13 water sites surveyed in Sanoyea District and the relatively low prevalence rates of schistosomiasis in this district (Table 6) indicate little or no transmission in the areas of the district surveyed. Consequently, with the probable exception of Sanoyea, Fuama and the western third of Salala District, *S. haematobium* appears to be transmitted throughout Bong County. Conversely, the occurrence of *B. pfeifferi* was, apparently, restricted to the northeastern half of Bong County. The relatively low prevalence rates of *S. mansoni* in Finutole (5.1%), Samay (6.9%) and Botota (0%) in southern Suakoko, Jorquelle and Kokoya Districts, respectively, and our failure to locate *B. pfeifferi* in these areas, indicate little or no transmission of *S. mansoni* and a southern limit in the occurrence of the vector similar to its western limits in Bong County.

A more restricted distribution of *B. pfeifferi* was observed in Lofa County where the latter species was found only in the northeastern and northwestern corners of the county; *B. globosus* was widely distributed (Dennis et al., in preparation). However, *B. pfeifferi* may be more widely distributed in Nimba County than in Bong and Lofa Counties (Annual Report, The Liberian Institute for Biomedical Research, 1981). Systematic surveys of schistosomiasis in other counties in Liberia have not been carried out. The absence of schistosome vector snails from coastal areas and/or the more restricted distribution of *S. mansoni* vectors than vectors of *S. haematobium* have also been shown to occur in neighboring Sierra Leone (Gordon et al., 1934; Onabamiro, 1971), Gambia (McCullough and Duke, 1954; Smithers, 1956), Guinea, Ivory Coast and some other West African countries (Wright, 1973).

Although *B. globosus* was more widely distributed in Bong County than *B. pfeifferi*, the prevalence of *S. mansoni* in the entire study population was significantly higher than that of *S. haematobium* but the difference in infection rates of the two schistosome species in school children was not statistically significant. The higher prevalence of *S. mansoni* in the combined study population was no doubt a reflection of the characteristic greater retention of *S. mansoni* than *S. haematobium* infection in the age group >20 years old. This probably also contributed to the higher infection rate observed in *B. pfeifferi* (12.3%) than in *B. globosus* (10.3%). Sodeman (1979) reported similar infection rates in *B. pfeifferi* (10%) and *B. globosus* (2%) in the Suakoko-Gbarnga area where he found the former species to be more prevalent. The viability of *S. mansoni* ova excreted by individuals >20 years old and their role in the transmission of the latter species in the study area require assessment. However, the intensity of *S. mansoni* infection (6.3 $\bar{x}$G) was significantly lower than that of *S. haematobium* (13.2 $\bar{x}$G). Unlike intensity rates of *S. haematobium*, the difference in intensity rates of *S. mansoni* between the younger and older age groups was unremarkable. Mixed infections had little effect on egg output or prevalence rates.

Relative prevalence of *S. haematobium* and *S. mansoni* in Bong County varied according to geographic location and reflected the west to east and south to north gradient in the distribution of their vector snails. In Zota, Kokoya and Jorquelle Districts, prevalence rates of *S. haematobium* were higher than those of *S. mansoni;* the reverse was true in Suakoko and Panta-Kpai Districts. Although more sites surveyed in the study area contained *B. globosus* than *B. pfeifferi*, the occurrence of each snail species in specific water sites in each district, snail population size and infection rates were a focal phenomenon. Within their range of occurrence, *B. globosus* and *B. pfeifferi* inhabited independent water sites (Palala, Quary) or occurred concurrently in the same water sites (Weinsue, Balama, Zowienta).

Sodeman (1979) reviewed studies of monthly changes in schistosome vector snail populations in several West African countries (Ghana, Nigeria, Gambia, Sierra Leone) and found the pattern in Liberia to be similar; expansion of snail population size during the dry season and contraction during the raining season. The present study agrees essentially with this pattern, also shown by Saladin et al. (1980). However, water habitats protected from excessive drying and overflooding tended to show a more stable snail population most of the year. Such control of water levels in rice paddies during the present study was probably responsible for the higher mean density of snails in these sites than in other water contact sites (Table 3).

Another characteristic of snail populations in Bong County was a decrease in population size toward the end of the dry season and the beginning of the raining season between late March and early May. A similar decline in snail population density was shown in a figure by Saladin et al. (1980). Sodeman (1979) correlated decline in snail population density with increase in the quantity of rainfall and expansion of snail population size with decrease in the quantity of rainfall. Following the decline in population size toward the end of the dry season in our study, snail population size increased during the early raining season and into the mid dry season and contracted during the period of heavy rains. The deline in population size observed toward the end of the dry season was probably a consequence of drying and heat stress in February and March.

Changes in infection rates in vector snails also varied according to season but appeared to be influenced by the stability of snail populations in specific water sites and the degree of water contact activities at each site. More water sites contained infected snails from December through February (dry season) than at any other time of the year but peak infection rate varied according to site.

With few exceptions, the prevalence of schistosomiasis among swamp rice farm families reflected the characteristic of the disease in corresponding localities. Majority of the rice paddies were less than three years old and were as yet uninhabited by schistosome vectors. Consequently, other water contact sites were the primary foci of active transmission. However, rice paddies which predated the operations of the Bong County Agricultural Development Project (Zowienta, Balama) contained infected snails and farm families of these sites showed a higher prevalence of *S. mansoni* infection than corresponding school children. As rice paddies were developed, the trenches became additional foci of water related activities such as washing and bathing. These activities increased to fishing and basket setting as small aquatic animals invaded the canals. Within the distributional range of schistosome vector snails, it seems a matter of time before *B. globosus* and *B. pfeifferi* invade these habitats imposing a definite threat to the spread of schistosomiasis in Bong County. The distribution of schistosome vector snails in Liberia provides ample opportunity for water related agricultural project such as swamp rice cultivation outside of the range of distribution of the snails.

Acknowledgments

The authors wish to thank and are grateful to the Ministries of Health and Agriculture, Liberia, for their priority support of the study; the technicians and clerical members of the team, Jeremiah Valhmu, Albert Vandi, Robert Carmo, Michael Raynes, Peter Collins, James Jallah, Mary Sumo, Samual White, Momo Saar, Sekou Sesay and Anthony Gofoe for their dedicated assistance; the Project Management Unit of the Bong County Agricultural Development Project for administrative management of the local team; Dr. Walter Gweinegale of Phebe Hospital for technical assistance; Mrs. Marie Nassau and Miss Bernadette Kahn of LIBR for untiring logistical and clerical assistance. The Bureau of Biological Research, Rutgers University provided funds for manuscript preparation.

Annual Report, The Liberian Institute for Biomedical Research, Robertsfield, Liberia, p. 67–76 (1981).

Dennis E., Horace M., Hanson A., Saladin B., Saladin K., Degrémont A.: The epidemiology of schistosomiasis in Liberia. The prevalence and intensity of schistosomal infections in Lofa County and the distribution and infection rates of vector snails (in preparation).

Gordon R. M., Davey J. H., Peaston H.: The transmission of human bilharziasis in Sierra Leone, with an account of the life cycle of the schistosomes concerned, *S. mansoni* and *S. haematobium*. Ann. trop. Med. Parasit. *28*, 323–418 (1934).

Harley G. W.: Ganta dispensary patients. A statistical study of 6291 consecutive outpatients in northeastern Liberia. Amer. J. trop. Med. *13*, 67–96 (1933).

Knight W. B., Hiatt R. A., Cline B. L., Ritchie L. S.: A modification of the formol-ether concentration technique for increased sensitivity in detecting *Schistosoma mansoni* eggs. Amer. J. trop. Med. Hyg. *25*, 818–823 (1976).

Levine D. M.: Research projects concerning schistosomiasis. Annual Report on the Research Activities of the Liberian Institute of The American Foundation for Tropical Medicine, p. 105–106 (1960).

Maas E.: Zur Pathologie des liberianischen Hinterlandes. Abhandl. Gebiet Auslandskunde *26*, 268–273 (1927).

Maas E., Vogel H.: Beobachtungen über *Schistosoma mansoni* in Französisch-Guinea und Liberia. Arch. Schiffs- u. Tropenhyg. *34*, 564–566 (1930).

McCullough F. S., Duke B. O. L.: Schistosomiasis in the Gambia. I. Observation on the potential snail vectors of *Schistosoma haematobium* and *S. mansoni*. Ann. trop. Med. Parasit. *48*, 277–286 (1954).

Miller M. J.: A survey of *S. haematobium* infections in man in Liberia. Amer. J. trop. Med. Hyg. *6*, 712–714 (1957).

Olivier L. J.: Techniques, statistical methods and recording form. A. Techniques. In: Epidemiology and control of schistosomiasis (bilharziasis), ed. by N. Ansari, p. 620–704. S. Karger, Basel/München/Paris/London/New York/Sydney 1973.

Onabamiro S. D.: Studies on schistosomiasis in Sierra Leone-I. Ann. trop. Med. Parasit. *65*, 497–504 (1971).

Poindexter H. A.: A laboratory epidemiological study of certain infectious diseases in Liberia. Amer. J. trop. Med. Hyg. *29*, 435–442 (1949).

Saladin B., Saladin K., Dennis E., Degrémont A.: Preliminary epidemiological survey of schistosomiasis in central and southern Liberia. Acta trop. (Basel) *37*, 53–62 (1980).

Smithers S. R.: On the ecology of schistosome vectors in the Gambia, with evidence of their role in transmission. Trans roy. Soc. trop. Med. Hyg. *50*, 354–365 (1956).

Sodeman W. A.: The distribution of schistosome vector snails in central Liberia. Ann. trop. Med. Parasit. *67*, 357–360 (1973).

Sodeman W. A.: A longitudinal study of schistosome vector snail populations in Liberia. Amer. J. trop. Med. Hyg. *28*, 531–538 (1979).

Strong R. P., Shattuck G. C.: The African Republic of Liberian and the Belgian Congo, p. 198–512. Harvard University Press, Cambridge 1930.

Veatch E. P.: Schistosomiasis in Liberia. Amer. J. trop. Med. *26*, Suppl. 5, 53–56 (1946).

Vogel H.: Beiträge zur Epidemiologie der Schistosomiasis in Liberia und Französisch-Guinea. Arch. Schiffs- u. Tropenhyg. *36*, 108–135 (1932).

Vogel H.: Bilharziasis survey in the central province. Annual Report on the Research Activities of the Liberian Institute of the American Foundation for Tropical Medicine, p. 40–47 (1958).

Walter H. J.: Field studies on the ecology and bionomics of snail vectors of schistosomiasis. Annual Report on the Research Activities of the Liberian Institute of the American Foundation for Tropical Medicine, p. 43–50 (1959).

Wright W. H.: Geographical distribution of schistosomes and their intermediate hosts. In: Epidemiology and control of schistosomiasis (bilharziasis), ed. by N. Ansari, p. 32–249. University Park Press, Baltimore/London/Tokyo 1973.