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THE DISTRIBUTION OF INTESTINAL HELMINTH INFECTIONS IN A RURAL VILLAGE IN GUATEMALA

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Fecal egg count scores were used to investigate the distribution and abundance of intestinal helminths in the population of a rural village. Prevalences of the major helminths were 41% with Ascaris lumbricoides, *60% with* Trichuris trichiura *and 50% with* Necator americanus. *All three parasites showed a highly aggregated distribution among hosts. Age/prevalence and age/intensity profiles were typical for both* A. lumbricoides *and* T. trichiura *with the highest worm burdens in the 5-10 year old children. For hookworm both prevalence and intensity curves were convex in shape with maximum infection levels in the 30-40 year old age class. Infected females had higher burdens of* T. trichiura *than infected males in all age classes of the population; there were no other effects of host gender. Analysis of associations between parasites within hosts revealed strong correlations between* A. lumbricoides *and* T. trichiura. *Individuals with heavy infections of* A. lumbricoides *and* T. trichiura *showed highly significant aggregation within households. Associations between a variety of household features and heavy infections with* A. lumbricoides *and* T. trichiura *are described.*

Key words: *Ascaris lumbricoides* - *Trichuris trichiura* – hookworm – Guatemala – Epidemiology

Intestinal helminths frequently rank low in the list of priorities in public health programs and as targets for research grants. Cheap and effective drugs for controlling intestinal helminth infections are available, yet worldwide population rates of helminth parasitism have not changed markedly since the turn of the century (Crompton et al., 1989). In Central America prevalences have remained unchanged for the past 50 years (Botero, 1981). Only one country in the world, Japan, has successfully controlled helminthiases using population chemotherapy (Yokogawa, 1985). The lack of interest of public health agencies probably stems from the fact that reinfection rates following chemotherapy are extremely rapid; in 6 months an individual may reacquire precontrol burdens of parasites (Elkins et al., 1986; Thein-Hliang et al., 1987; Forrester 1990). Furthermore morbidity due to helminth infections is extremely difficult to quantify. Unlike diseases such as malaria, cholera or AIDs, the effects of helminth infections on the human population cannot be measured unambiguously in terms of mortality figures. Intestinal helminths characteristically cause low levels of mortality (Gilman et al., 1983; Cook, 1986; Aquilar & Gonzalez Camargo, 1991) and probably excert their major impact on host populations through their interaction with nutrition.

Two developments have given a renewed impetus to research on intestinal helminths in the past decade. A variety of carefully controlled experimental studies involving both laboratory models and human populations have clearly demonstrated that helminth infections have a detrimental effect on human nutrition. It has been unambiguously demonstrated, for example, that anthelminthic treated children

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grow faster than untreated controls (Willet et al., 1979; Stephenson et al., 1980, 1989) and that helminth infections cause lactose intolerance (Taren et al., 1987), reduced serum vitamin A levels (Sivikumar & Reddy, 1975; Mahalanabis et al., 1976) as well as reduced levels of nitrogen, D-Xylose, and fat absorption (Stephenson, 1987). Useful summaries of the current status of research on intestinal helminths and nutrition are given in Stephenson (1987), Taren & Crompton (1989), and Holland (1989).

An additional source of renewed interest has resulted from work on the epidemiology of helminth infections, spearheaded by the mathematical modelling work of Anderson (Anderson & May, 1985; Anderson & Medley, 1985). These authors have emphasized the importance of measuring the intensity of infection rather than simply the prevalence and they have suggested that targeting of treatment against heavily infected individuals or sectors within the population may be the most cost effective method for reducing both morbidity and transmission (Anderson & May, 1985; Anderson & Medley, 1985). The discovery that some individuals appear to be "predisposed" to heavy infections (Schad & Anderson, 1985; Thein-Hliang, 1985; Elkins et al., 1986; Bundy et al., 1987; Forrester et al., 1990) has given a further impetus to this approach to chemotherapy. As a consequence a current focus of helminthologists is to investigate patterns of parasite distribution in communities in order to optimize the targeting of treatment.

In Guatemala prevalence figures for intestinal helminth infection are available for a variety of regions. Aquilar & Gonzalez Camargo (1991) review current prevalence figures deduced from routine stool examinations in hospitals and health centers country wide. Prevalences range from 11% in Retalhuleu to 37% in the Peten. This provides useful background data on relative prevalences but the figures are unlikely to represent random samples of the population. At specific locations prevalences may be much higher: Pratdesaba et al. (1991) report prevalences of *A. lumbricoides* and *T. trichiura* of 88% and 36% in school children from the Department of Solola, while Chavez Escandon et al. (1991) detected 74% infected with *A. lumbricoides* and 88% infected with *T. trichiura* in the Departments of Chimaltenango and Suchitepequez. Little information concerning intensities of infection is available for Guatemala.

In this article we present an analysis of some factors affecting the distribution and abundance of helminth infections in a small Guatemalan village. Data from a cross-sectional survey is used to analyze the effects of host characteristics such as age and sex on levels of parasite infection, as well as levels of parasitism within and between different household units.

MATERIALS AND METHODS

Study site – The study was carried out in Potrerillos, an aldea in a rural region of the Department of Santa Rosa, 60 kms south-east of Guatemala City. The aldea was chosen on the basis of its size and the enthusiasm of the local health workers. The village is situated at 1170 ms altitude, and is two miles from the nearest public transport. At the time of the study (August – November 1989) Potrerillos contained 516 people in 87 households (a household is defined as a group of individuals who eat and sleep in the same compound). The mean (±1 standard deviation) household size was 6.14 ± 2.67 people. The people are predominantly latino, though there is a influx of indians into the region during the coffee harvest (Oct/Nov). The main crop in the area is coffee though staples such as maize and black beans are also grown. Potrerillos has no electricity and poor sanitary facilities. Seventy percent of the households lacked latrine facilities of any kind and defecation generally occurs in the vicinity of the house. Sixty-three percent of fathers and 71% of mothers were literate (Zizza, 1990). Many of the preschool children (1-5 year olds) in this community were malnourished; 35% of weight-for-age Z-scores, 68% of height for age and 4% of weight for height Z-Scores were more than two standard deviations below mean NCHS reference values (Zizza, 1990).

Community survey of intestinal parasites – Helminth ova were counted using a modified Kato-Katz egg counting procedure (Forrester & Scott, 1990). Stool samples were collected in plastic sample cups, which were distributed, with clear instructions, to a responsible member of each household in Potrerillos. Cups were clearly marked with the name of each household member (a color or picture coding system was used in the case of illiterate families) and collected the following day. After thorough mixing, a sample was strained through plastic gauze to remove large particles, and 50 mg was placed on a slide and covered with cellophane presoaked in a 50:50 aqueous solution of Glycerol and Malachite green. The samples were then spread over a known area using a template (380.1 mm2). Duplicate slides were prepared and read from each stool sample. Diarrhoeal stool samples were read but the results were not included in the analysis.

All slides were prepared and read by one of us (T.J.C.A.) on an Olympus BH-2 microscope. Where possible slides were read within 24 hrs to quantify hookworm eggs. For each slide 10 microscope fields were inspected for parasite eggs (*A. lumbricoides, T. trichiura* and hookworm) in a transect across the slide and the number of eggs of each parasite species were recorded. If eggs of one or more species of parasite were not seen then the whole area of the slide was scanned for these species, and the number of eggs in the complete 50 mg sample was recorded. Egg counts were converted to egg per gram (epg) scores using calculated conversion factors. A full explanation of the calculation of conversion factors as well as a rigorous evaluation of the sensitivity and precision of this egg counting technique is given in Forrester & Scott (1990). The presence of *Taenia* and *Hymenolepis* eggs was also recorded but not quantified.

All egg-positive individuals (> 2 years old) were treated with a course of Mebendazole (200 mg twice daily for three days) to expel *A. lumbricoides, T. trichiura* and hookworm infections. Children younger than two years were treated with Pyrantel Pamoate at a dose of 10 mg/kg body weight. Individuals excreting *Taenia* or Hymenolepid eggs were treated with Yomosan and a laxative. Anthelminthic drugs were obtained from INTECFA (12 Avenida, Zona 5, Guatemala City).

Standard of living interviews were conducted by one of us (G. M. L.), a trained anthropologist. The questionnaire collected information on house construction, water supplies, fecal disposal, cooking facilities, material possessions and livestock.

RESULTS

In the following analysis we have investigated patterns of parasite infection at two levels; at the level of the individual, and at the level of the household unit.

A total of 495 fecal samples were collected; 28 samples were subsequently discarded from the analysis since they were too watery for reliable quantification of egg counts. The following analysis is based on 467 individuals from whom we have egg count data for *A. lumbricoides* and *T. trichiura*. For a subset of these individuals (n = 186) we also have data for hookworm (*N. americanus*). A summary of the age and sex of the participants of the study is given in Table I.

TABLE I

Summary Statistics for the population studied.
The figures in parentheses indicate % co-operation

Age class	Males	Females	Total
1-4	36 (100)	35 (100)	71 (100)
5-9	62 (97)	31 (100)	93 (98)
10-19	54 (90)	68 (96)	122 (93)
20-29	23 (69)	36 (92)	59 (81)
30-45	29 (88)	28 (100)	57 (93)
46 +	28 (90)	37 (88)	65 (89)
Totals	232 (90)	235 (95)	467 (93)

Egg counts indicated a high level of aggregation for all three helminth species (Fig. 1); most infected individuals were excreting few eggs while a small proportion were excreting massive numbers of eggs. For each of the three helminth species the most heavily infected 10% of the host population were excreting between 68 and 71% of all the eggs in the community.

The age/prevalence curves for the three helminth species are shown in Fig. 2. *A. lumbricoides* and *T. trichiura* showed typical patterns with peaks in the 5-19 and 10-29 year old age groups respectively. The hookworm prevalence curve rose less steeply than either *A. lumbricoides* or *T. trichiura*, but otherwise was similar in form, reaching a shallow peak in the 10-29 year old age group, and dropping to lower levels in the older age classes.

Age/intensity curves for *A. lumbricoides* and *T. trichiura* were also typical in shape with sharp peaks in egg output in the 5-9 year old age group (Fig. 3a). These graphs show arithmetic means of epg scores for each age class in the population. The non-normal distri-

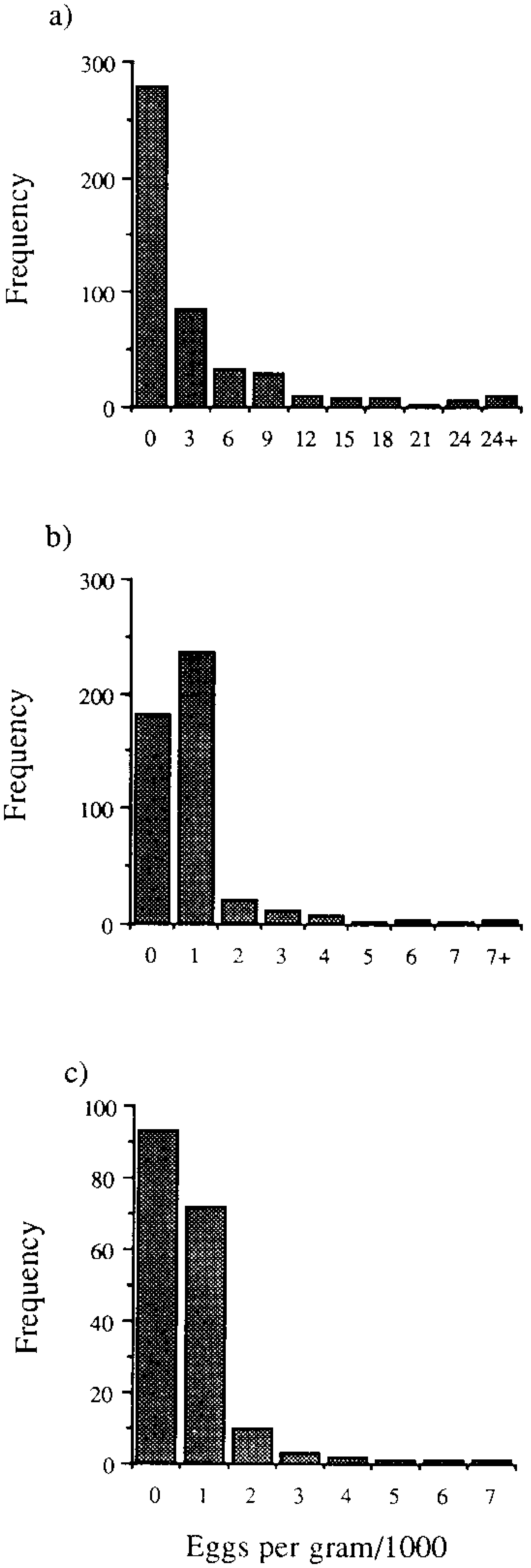


Fig. 1: frequency distributions of eggs per gram (epg) scores for a) *Ascaris lumbricoides* b) *Trichuris trichiura* and c) hookworm.

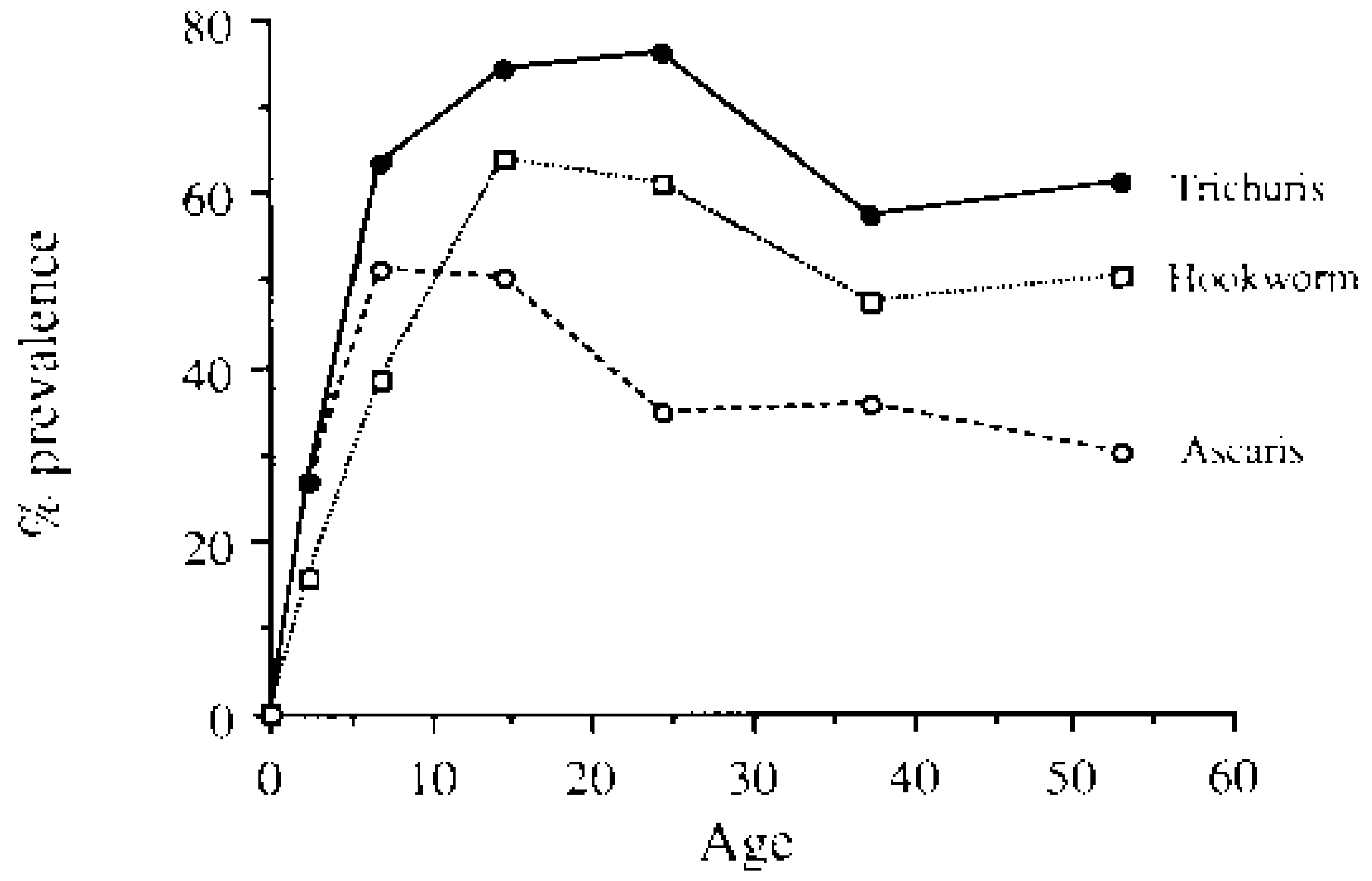


Fig. 2: age/prevalence curves for *Ascaris lumbricoides*, *Trichuris trichiura* and hookworm.

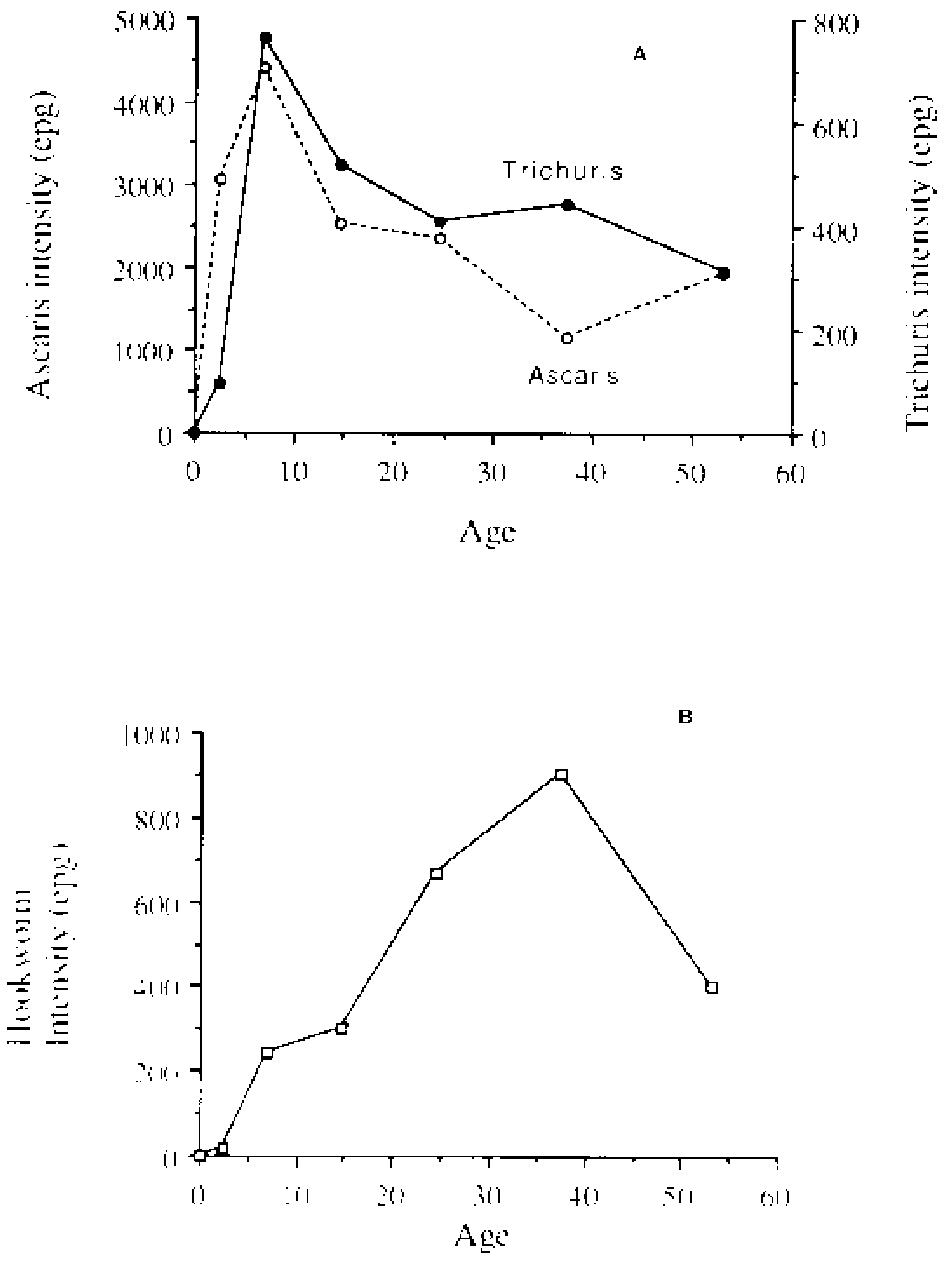


Fig. 3: age/intensity curves for A) *Ascaris lubricoides* and *Trichuris trichiura* and B) hookworm

bution of data precludes parametric analysis of untransformed egg-counts. However non-parametric analysis demonstrated that age had strong effects on infection intensity (Kruskall-Wallis non-parametric ANOVA for *A. lumbricoides*, H = 51, $P < 0.01$; for *T. trichiura*, H = 38.4, $P < 0.001$).

Age/intensity curves for hookworm contrasted strongly with those for *A. lumbricoides* and *T. trichiura*. Intensity levels rose steadily reaching peak levels in the 30-45 year old age group (Fig. 3b). The 46+ age group showed lower mean levels of egg output. However owing to the overdispersed nature of the data and the relatively low sample size we cannot be sure if this phenomena is due to sampling errors; Kruskall-Wallis non-parametric ANOVA revealed age related effects which bordered on significance (H = 10.4, P = 0.06, NS).

Host gender did not influence parasite prevalence for any of the three helminth species and had no effect on the intensity of infection for *A. lumbricoides* or *N. americanus*. However in the case of *T. trichiura* infected females had higher mean epg scores than infected males (Mann-Whitney Pairs test Z = -2.15, P < 0.05) in all age classes. The influence of host gender on *T. trichiura* intensity is shown graphically in Fig. 4.

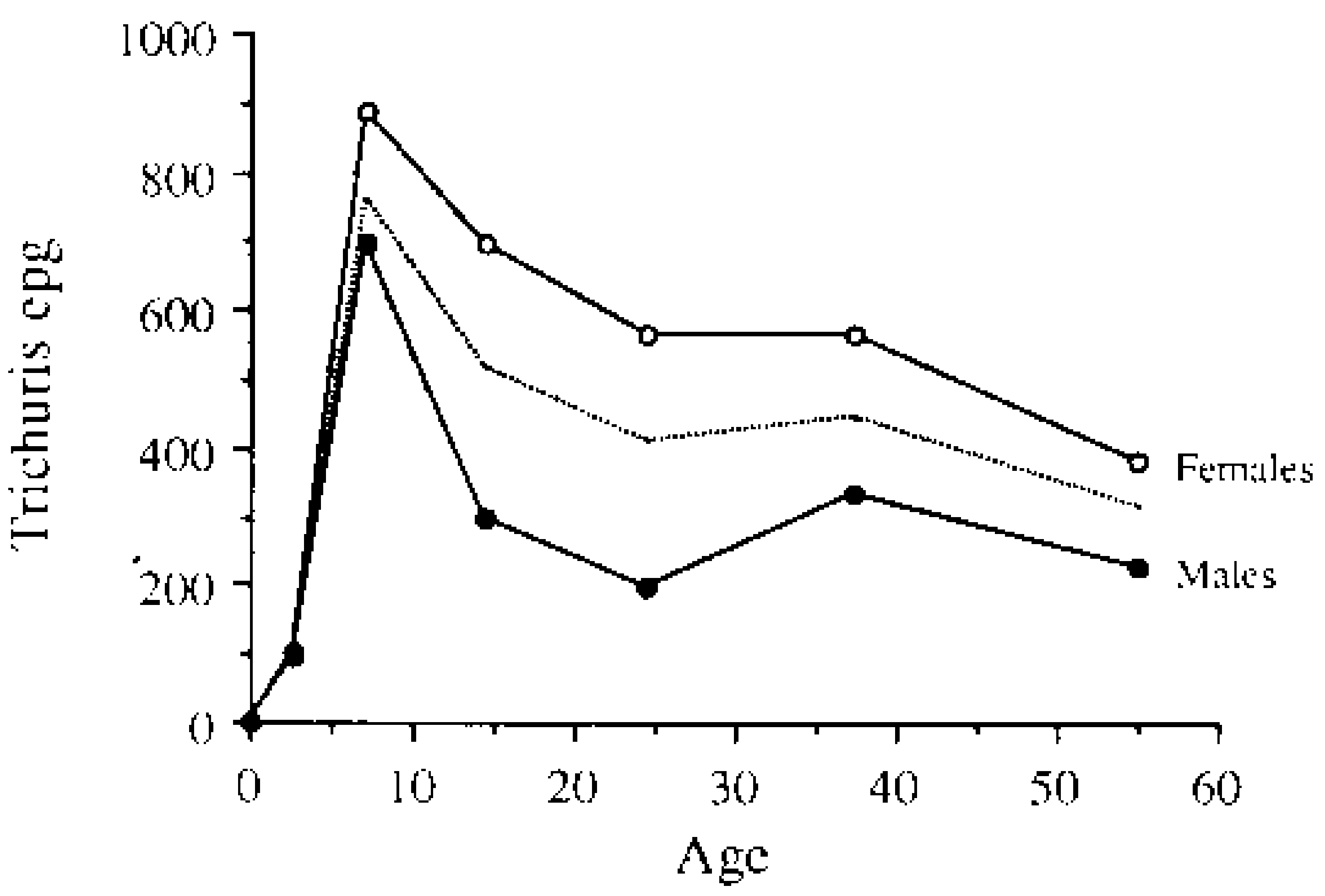


Fig. 4: the effects of host sex on epg scores for *Trichuris trichiura*.

Within Potrerillos many individuals were infected with more than two species of parasite. In order to investigate whether infections of the different parasite species were randomly distributed within the host population we used rank correlations to compare egg count scores of different parasites within the same individuals. A summary of the correlation coefficients between the three species pairs in three different age classes of the population is shown in Table II. Highly significant positive Spearman's rank correlations were found for all three pairwise comparisons between helminth species. *A. lumbricoides* and *T. trichiura* were associated in all age groups while *T. trichiura* and *N. americanus* were associated in the one to nine and in the 26 plus age group, but not in the 10 to 25 year olds. *A. lumbricoides* was only associated with *N. americanus* in the youngest age group.

Since underlying age/intensity relationships tend to lead positive correlations between helminth species, the analysis of interspecific correlations was repeated using data standardized to reduce age effects. The standardization procedure follows Haswell-Elkins et al. (1987). The data was stratified into age classes (1-4, 5-9, 10-19, 20-35, 36+ years) and standardized epg scores were calculated according to the equation: $Y_{ij} = (X_{ij} - X_j)/S_j$, where Y_{ij} is the standardized epg of individual i in age group j, X_{ij} is the unstandardized epg score of that individual, X_j is the mean epg for individuals in age group j and S_j is the standard deviation of epg scores in age group j. This procedure adjusts epg scores so that the mean score within each age group is zero and the standard deviation is one, thereby minimizing age effects across age groups (Haswell-Elkins et al., 1987). Following standardization significant association was still found between *A. lumbricoides* and *T. trichiura*. Age standardized data showed no correlation between *A. lumbricoides* and hookworm or *T. trichiura* and hookworm.

TABLE II

Values of Spearman's rank correlation coefficient between pairs of helminth species. Sample sizes are shown in parentheses. See text for explanation of age-standardization procedure

	Helminth species pairs		
Age group	*Ascaris-Trichuris*	*Ascaris-Necator*	*Trichuris-Necator*
1-9	0.51^b (164)	0.48^b (58)	0.59^b (58)
10-25	0.35^b (157)	0.10 (76)	−0.05 (76)
26 +	0.18^a (146)	0.24 (52)	0.49^b (52)
All ages	0.36^b (467)	0.27^b (186)	0.30^b (186)
All ages (Age-standardized)	0.10^a (467)	0.12 (186)	0.05 (186)

a: $P < 0.05$; *b*: $P < 0.001$.

TABLE III

Analysis of household aggregation of *Ascaris lumbricoides* and *Trichuris trichiura* in Potrerillos. Only families donating 4 or more stool samples were included in the analysis

	No. of families with 0, 1, 2, 3, or 4 heavily infected members in a random sample of 4 individuals									
	A. lumbricoides					*T. trichiura*				
	0	1	2	3	4	0	1	2	3	4
Observed	33	16	10	5	1	33	15	10	4	3
Expected	26.6	26.6	10	1.7	0.1	26.6	26.6	10	1.7	0.1
	(X^2 = 20.26, df = 3, P $<$ 0.001)					(X^2 = 93.81, df = 3, P $<$ 0.001)				

Expected values calculated from the binomial expansion, $(p + q)^4$, where p, the proportion of the population with heavy infections, was set at 0.2 and q = 1-p (see text for details).

A number of other parasites were found in the course of the egg count survey. *Taenia* eggs were found in 12 stool samples (2.6%). We did not determine if these infections were *T. solium* or *T. saginata*. Hymenolepid eggs were found in two samples, both children less than 10 yrs old.

The preceding analysis describes patterns of infection at the level of the individual. In the next section we present an analysis of patterns at the level of the household unit. A casual view of the data suggested that parasites were clumped within families; some families were completely free of parasites while in others most or all individuals were infected. In order to investigate this phenomenon statistically we treated each household as a separate "population" (pages 72-82, Sokal & Rohlf, 1981). From each of the "populations" in the village, samples of four individuals were picked randomly. Households in which less than four members contributed stool samples were excluded from the analysis, leaving a total of 65 households. The frequency of heavily infected individuals in each household was tabulated. Heavily infected individuals were defined as those who ranked within the most heavily infected 20% of the population for their age group (1-4, 5-9, 10-19, 20-29, 30-45, and 45+ yrs olds). The observed frequency of samples containing 0, 1, 2, 3, and 4 heavily infected individuals was then compared with the expected values calculated from the binomial expansion $(p + q)^4$, where p is the proportion of the population with "heavy" infections (p = 0.2), and q is the proportion with "light" infections (q = 0.8). Table III lists the observed and expected values and X^2 values for household aggregation of *A. lumbricoides* and *T. trichiura* infections. For both parasite species the observed distribution showed highly significant differences from expected values, indicating that these two parasites species are aggregated within certain households.

The "standard of living data" were used to investigate associations between household features and levels of parasitism. Only features which varied between households were analyzed. Thus for example none of the houses in Potrerillos had electricity, so this feature was excluded from the analysis. The number of heavily infected individuals living in households with different household features are compared with expected values using χ^2 tests. A summary of the associations between heavy infection with *A. lumbricoides* and *T. trichiura* is presented in Table IV. For *A. lumbricoides,* households with dirt floors had higher levels of parasitism than households with concrete floors, while households possessing a radio or cassette player were less infected than expected. Households with pigs were more likely to be heavily infected while households owning horses were less likely to be heavily infected. For *T. trichiura* infections the following household features were associated with higher than expected infection levels: dirt floors and possession of pigs and goats. Families possessing a radio/cassette player contained fewer heavily infected individuals.

The previous analyses demonstrate that a) parasites are aggregated within individuals and b) that infected individuals tend to be clumped within households. On a larger spatial scale we can ask if infected households are spatially aggregated within the village. The spatial distribution of infected households in Potrerillos,

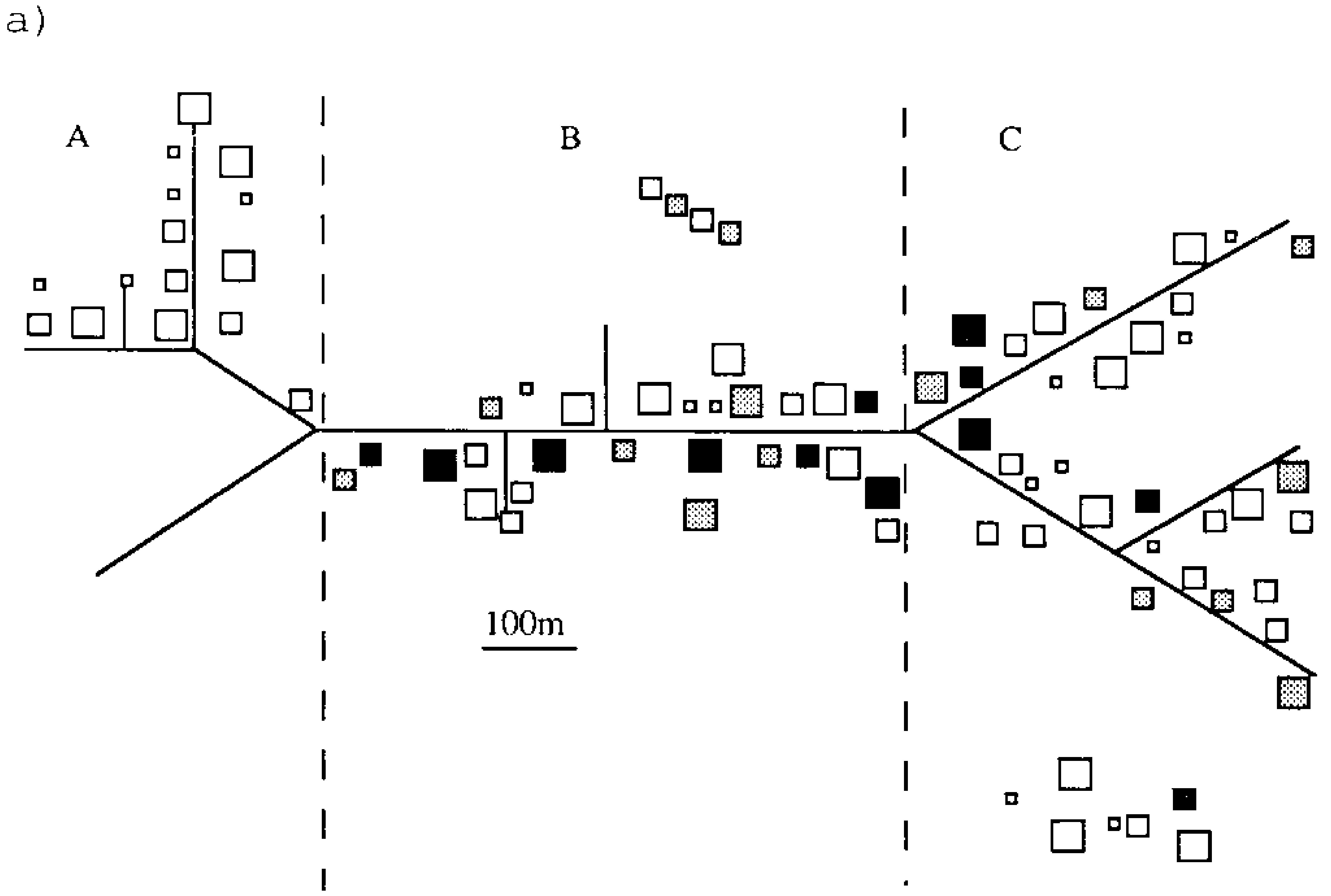
TABLE IV

Standard of Living indices and helminth parasitism. See text for explanation of "high" and "low" intensities of infection

Housing feature	No. of households	No. of samples	*A. lumbricoides*		*T. trichiura*	
			High	Low	High	Low
House ownership						
Rented	10	58	7	51	11	47
Owned	70	402	86	316	81	321
			(X^2 = 2.7, ns)		(X^2 = 0, ns)	
Floor						
Earth	58	318	75	243	74	244
Cement	23	145	18	127	18	127
			(X^2 = 7.7 [a])		(X^2 = 7.4 [a])	
People per household						
2-7	53	228	46	182	46	182
8-12	28	235	47	188	46	189
			(X^2 = 0, ns)		(X^2 = 0, ns)	
No. of rooms						
1-2	36	189	37	152	34	155
3-6	45	274	56	218	58	216
			(X^2 = 0.1, ns)		(X^2 = 0.7, ns)	
People per room						
< 0.5	40	290	60	230	61	229
$\geqslant 0.5$	41	173	33	140	31	142
			(X^2 = 0.2, ns)		(X^2 = 0.6, ns)	
Fecal disposal						
None	59	349	70	279	63	286
Latrine	22	114	23	91	29	85
			(X^2 = 0, ns)		(X^2 = 2.8, ns)	
Water supply						
Spring/river	23	124	25	99	26	98
Piped water	51	289	62	227	55	234
			(X^2 = 0.1, ns)		(X^2 = 0.2, ns)	
Radio or Cassette player						
No	23	106	34	72	32	74
Yes	59	357	59	298	60	297
			(X^2 = 12.3 [b])		(X^2 = 9.1 [b])	
Ownership of pigs						
No	63	347	60	287	53	294
Yes	18	116	33	83	39	77
			(X^2 = 6.7 [a])		(X^2 = 18.2 [b])	
Ownership of goats						
No	60	323	60	260	46	277
Yes	21	140	33	107	46	94
			(X^2 = 1.5, ns)		(X^2 = 21.4 [b])	
Ownership of horses						
No	59	332	77	255	62	270
Yes	22	131	16	115	30	101
			(X^2 = 7.0 [b])		(X^2 = 1.1, ns)	

a: $P < 0.01$; *b*: $P < 0.001$.

with houses shaded to indicate the number of "heavy" infections, is shown in Fig. 5. The village was arbitrarily divided into three sections (see Fig. 5) and the ratio of people with heavy or light infections were compared between sections using G tests for heterogeneity among samples (Sokal & Rohlf, 1981). For *A. lumbricoides* there was significant heterogeneity among village sectors (G_H = 28.334, df = 2, $P < 0.001$): people living in the central section (B) were more heavily infected than those living in sections C, while in sector A no heavily infected individuals were found. The distribution of *T. trichiura* infections also showed highly significant heterogeneity among sectors (G_H = 23.99, df = 2, $P < 0.001$) and closely mirrored the patterns of *A. lumbricoides.*



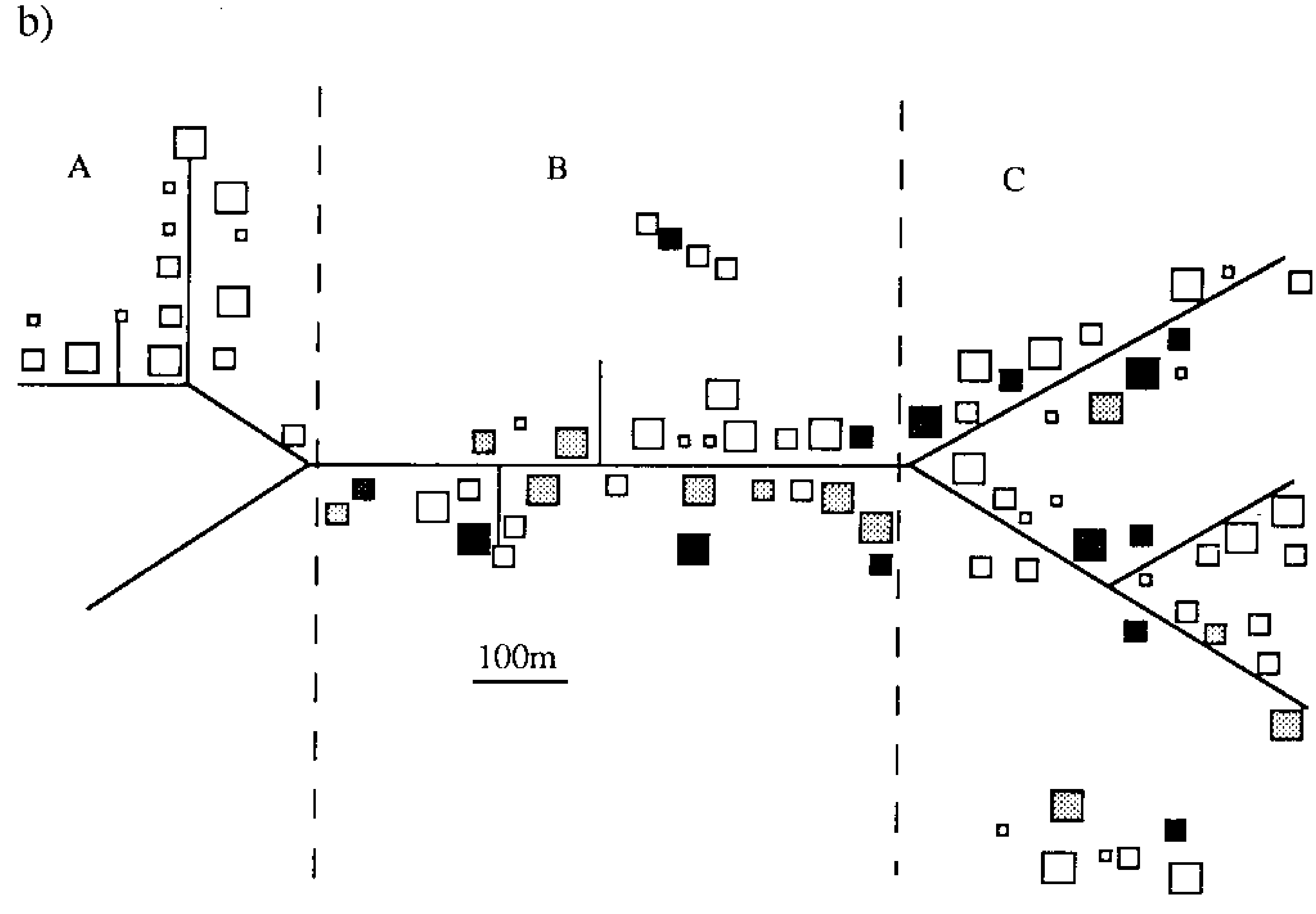


Fig. 5: map of Potrerillos showing the spatial distribution of parasitism with a) *Ascaris lumbricoides* and b) *Trichuris trichiura*. Each square represents a household. Small squares represent households containing <4 individuals, medium sized squares represent households containing 4-7 individuals and large squares represent households containing >7 individuals. The degree of shading indicates the proportion of people in each household with "heavy" infections of *A. lumbricoides* in 1989. Light shading indicates that < 25% are heavily infected, dark shading indicates that > 50% have heavy infections and in black houses > 75% are heavily infected. An individual with a heavy infection ranks in the 20% of his/her age class with respect to parasite egg counts.

DISCUSSION

Distribution of parasites among individuals – T. trichiura (60%) hookworm (*N. americanus*) (50%) and *A. lumbricoides* (41%) were the predominant helminth species found in this community. It is important to note that these figures are probably underestimates of the true prevalences, since egg counting techniques cannot detect infections with immature parasites, non-fecund females or all male infections. Assuming a prevalence of 41% for *A. lumbricoides* we can use the published relationship between prevalence and mean worm burden (Guyatt et al., 1990) to estimate the size of the worm population in Potrerillos. We calculate that the mean worm burden is likely to be close to one and that this village contains a worm population approximately equal to its human population.

For all three major helminth species epg scores showed a highly aggregated distribution, with a few individuals harboring the majority of the helminth population (Anderson & May, 1985). With very few exceptions such patterns are typical of helminth populations. Since the probability of helminth associated pathology is related to the size of the parasite burden (Anderson & May, 1985) it has been suggested that the emphasis of public health programs directed against helminths should be to target treatment against those individuals or age groups in the population which have the heaviest helminth infections (Anderson & Medley, 1985).

Patterns of prevalence and intensity were typical of *A. lumbricoides* and *T. trichiura* (Anderson & May, 1985), with peaks in both prevalence and intensity occurring in the 5-15 year old age group. The relative influence of environmental and genetic influences in determining the observed patterns is beyond the scope of this article, but is discussed at length in Bundy (1988a).

An interesting feature of *T. trichiura* infections in Potrerillos is that mean epg scores in females are higher than those in males. Sexual biases in infection rates have been found in a number of previous field studies from other parts of the world (Bundy, 1988b). Sex biased infection rates are also frequently found in animal systems. There is strong evidence that the heavier worm burdens frequently found in male mice are a result of hormonal influences (Alexander & Stimson, 1988). However this explanation seems unlikely in humans. The fact that the biases are either towards males or females and are not always present strongly suggests that they are environmental in origin. It may be that females spend proportionally more time in regions of transmission (ie the household) than do males. However if this is so it is surprising that sex biases were not found in *A. lumbricoides* in view of the similarity between the lifecycles of *A. lumbricoides* and *T. trichiura*.

Potrerillos is situated at 1170 ms altitude. We were surprised to find such high levels of hookworm in this community. In studies by INCAP (Viteri et al., 1983) communities in the same constellation of aldeas were used as a hookworm-free control group to compare with communities on the coast.

Another interesting feature concerns multispecies patterns of infection. Highly significant Spearmans Rank correlation coefficients were found between all pairwise combinations of parasite species using raw egg counts. After standardization correlations remained only between *A. lumbricoides* and *T. trichiura* illustrating the importance of controlling for age effects. The patterns found in this study are extremely similar to those observed by Haswell-Elkins et al. (1987) in a heavily infected village in South India. In both Guatemala and India consistent correlations were found between *A. lumbricoides* and *T. trichiura.* Haswell-Elkins et al. (1987) argued that there may be a common genetic basis to host susceptibility to intestinal helminth infections. However since the common helminth infections rely on contact with fecal matter for transmission the observed correlations may have a common "socioeconomic basis". A number of studies (Taren et al., 1987; Holland et al., 1988; Forrester et al., 1990) including this article have quantified environmental or "socioeconomic" correlates of helminth infections. This explanation seems especially likely in view of the fact that strongest associations are found between species with similar fecal-oral transmission (*A. lumbricoides* and *T. trichiura*). However it is also possible that initial infection by one helminth species may, in some way facilitate infection by other species. Helminth parasites, including *A. lumbricoides,* are known to produce immuno-inhibitors (Crandall et al., 1978; WHO 1981), while both competitive and synergistic interactions have been observed between different parasite species in animal model systems (Prichard et al., 1984; Algali et al., 1985).

From a public health standpoint these interspecific correlations between helminth species and the observed age/intensity profiles are extremely important. A variety of different targeting strategies have been proposed. By targeting the most heavily infected individuals in a population it should, in theory, be possible to improve the cost effectiveness of control measures while at the same time expelling parasites from the sector of the population suffering the highest levels of morbidity. Suggested treatment strategies include targeting the most heavily infected individuals in the population, the most heavily infected families (Forrester et al., 1988, 1990) or the most heavily infected age groups (Bundy, 1988). Using the data from this study we can predict the effects of targeting treatment against the most heavily infected individuals. If we assume that there is a linear relationship between epg and worm burden then targetting treatment (with a broad spectrum anthelminthic such as mebendazole) against the 10% of the population most heavily infected with *A. lumbricoides*, would remove 70.6% of the *A. lumbricoides* population but only 20.4% of the *T. trichiura* population. Thus in this community, despite the associations between these two species, targeting the sector of the population most heavily infected with *A. lumbricoides* is unlikely to have a major impact on *T. trichiura* transmission. This is due to the fact that the majority of heavy infections with both helminth species are found in children less than 10 years old; in this age group there are no associations between *A. lumbricoides* and *T. trichiura*. Perhaps a more feasible and cost-effective approach is to target chemotherapy against school age children, since this group of the population harbors the highest burdens of both *A. lumbricoides* and *T. trichiura*. In this community treatment of school-children (6-12 year olds), who represent 25.7% of the host population, would reduce *A. lumbricoides* burdens by 34.2% and *T. trichiura* by 43.5%. Inclusion of pre-schoolers (3-5) into the target population improves these figures to 64% and 52% respectively. This level of population treatment is unlikely to have a marked effect on transmission but may well be a cost effective method for reducing morbidity due to helminth infections. The situation in Potrerillos is complicated by endemic hookworm transmission. The older age groups in the host population contain the heaviest burdens of this parasite. Control of hookworm in addition to *A. lumbricoides* and *T. trichiura* can only be achieved within the framework of a mass chemotherapy program or by alternative non-chemotherapeutic means.

For a more rigorous evaluation of treatment strategies in Guatemala further research is needed in a variety of areas. More detailed information is required on the age/intensity and age/prevalence relationships of hookworm. Also information about the rate of reinfection with helminths following chemotherapy would enable public health workers to optimize the length of time between treatments. Useful models for such studies are provided by the work of Thein-Hliang (1985), Elkins et al. (1986, 1988), Haswell-Elkins et al. (1987), and Forrester et al. (1990).

Distribution of parasites among families – A number of authors have suggested that familial features may be important determinants of parasite infection. In this study individuals with "heavy" parasite infections were shown to be aggregated within households for both *A. lumbricoides* and *T. trichiura*. Williams et al. (1974), Chai et al. (1983), and Forrester et al. (1988) have demonstrated familial aggregation of helminth infections, while Forrester et al. (1990) demonstrated that the average parasite burden of families in Mexico pre- and post-treatment were significantly correlated. The work of these authors and the patterns observed in this study suggest that household aggregation or "family clumping" of heavily infected individuals is probably a ubiquitous feature of the epidemiology of human intestinal helminths. It seems likely that such patterns are the result of differences in the "socioeconomic status" of houses as well as being due to focal transmission of parasites within the confines of the household (Forrester et al., 1988), though the possibility of a genetic basis to host susceptibility cannot be ruled out. It is important to note that the method of analysis used makes the assumption that there is no effect of household size on the probability of infection. This assumption is justified, since we found no effects of household size in this study (see below).

Spatial patterns of parasite infection were investigated to look for "hot-spots" of parasite transmission. For both *A. lumbricoides* and *T.*

trichiura it appears that heavily parasitized families are more common in the central zone; it is also evident that sector A is virtually free of both *A. lumbricoides* and *T. trichiura.* Both Cerf et al. (1981) and Haswell-Elkins et al. (1989) found that the most heavily infected families live in the central section. This may be due to socioeconomic factors; it is also possible that transmission is more intense in the center of communities, since houses in this region are surrounded on all sides by potential sources of infection (ie other houses).

A number of household features showed associations with parasite infection. It is important to emphasize that these associations do not indicate causation; for example it is unlikely that possessing a radio of cassette player serves to protect against helminth infection. Furthermore, since multiple statistical tests were done it is possible that spurious associations may have been detected. Nevertheless highly significant associations are likely to be real. Associations between dirt floors and parasite infection have been found previously (Holland et al., 1988; Forrester et al., 1990). Such an association may be due to a direct link between dirt floors and parasite transmission, though it is equally possible that both parasitism and dirt floors are associated independently with low "socioeconomic" status. Regardless of whether these are real or pseudo associations, household features which are reliable predictors of parasite infections may be useful guidelines for directing the energies of control programs. No associations were found between possession of latrines and parasitism in this study, which is unusual, but may be indicative of the fact that these latrines are rarely used. Furthermore, in contrast to other recent work (Haswell-Elkins et al., 1989), no relationship was found between family size or "crowding index" and infection with either *A. lumbricoides* or *T. trichiura.*

The associations between possession of livestock and parasitism are of particular interest. The negative associations between possession of horses and parasites are probably indicative of the relative wealth of horse owners. The relationship between pigs and heavy infections with *A. lumbricoides* and *T. trichiura* is more intriguing. Pigs may be infected with *A. suum* and *T. suis;* however it is not currently clear if these species are distinct from *A. lumbricoides* and *T. trichiura* in humans (Crompton et al., 1989). In Potrerillos 33% (6/19) of pigs inspected were excreting *Ascaris* eggs and 10% (2/19) were excreting *Trichuris* eggs. It is possible that pigs act as zoonotic reservoirs of *Ascaris* and *Trichuris* infection in Central America.

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REFERENCES

ALEXANDER, J. & STIMSON, W. H., 1988. Sex hormones and the course of parasitic infection. *Parasitol. Today, 4:* 189-193.

ALGALI, S. T. O.; HAGEN, P. & ROBINSON, M., 1985. *Hymenolepis citelli* (Cestoda) and *Nematospiroides dubius* (Nematoda): Interspecific interactions in mice. *Exp. Parasitol., 60:* 364-370.

ANDERSON, R. M. & MAY, R. M., 1985. Helminth infections of humans: mathematical models, populations dynamics, and control. *Adv. Parasitol., 24:* 1-101.

ANDERSON, R. M. & MEDLEY, G. F., 1985. Community control of Helminth infections in man by mass chemotherapy. *Parasitology, 90:* 629-660.

AQUILAR, F. J. & GONZALEZ CAMARGO, C. L., 1991. Helmintiasis Intestinales en Guatemala. *Revista De La Asociacion Guatemalteca de Parasitologia y Medicina Tropical., 6:* 30-39.

BOTERO, B., 1981. Persistence of endemic intestinal parasitoses in Latin America. *Bull. Pan Am. Health Organ., 15:* 241-248.

BUNDY, D. A. P., 1988a. Gender dependent patterns of infection and disease. *Parasitol. Today, 4:* 186-189.

BUNDY, D. A. P., 1988b. Population ecology of intestinal helminth infections in human communities. *Philos. Trans. R. Soc. Lond. B, 321:* 405-420.

BUNDY, D. A. P.; COOPER, E. S.; THOMPSON, D. W.; DIDIER, J. M.; ANDERSON, R. M. & SIMMONS, I., 1987. Predisposition to *Trichuris trichiura* infection in humans. *Epidemiol. Infect., 98:* 65-71.

CERF, B. J.; ROHDE, J. E. & SOESANTO, T., 1981. *A. lumbricoides* and Malnutrition in a Balinese village: a conditional relationship. *Trop. Geogr. Med., 3:* 367-373.

CHAI, J. Y.; SEO, B. S.; LEE, S. H. & CHO, S. Y., 1983. Epidemiological studies on *A. lumbricoides* in Rural communities in Korea. II Age specific reinfection rates and familial aggregation of the reinfected cases. *Korean J. Parasitol., 21:* 142-149.

CHAVEZ ESCANDON, M. J.; LUJAN, R. & MORALES, B. E., 1991. Prevalencia de parasitosintestinales en Colonos y Cuadilleros de areas endemicas de Oncocercosis en Guatemala. *Revista De La Asociacion Guatemalteca de Parasitologia y Medicina Tropical., 6:* 1001-101.

COOK, G. C., 1986. The clinical significance of gastrointestinal helminths – a review. *Trans. R. Soc. Trop. Med. Hyg., 80:* 675-685.

CRANDALL, R. B.; CRANDALL, C. A. & JONES, J. F., 1978. Analysis of immunosuppression during early acute infection of mice with *Ascaris suum. Clin. Exp. Immunol., 33:* 30-37.

CROMPTON, D. W. T.; NESHEIM, M. C. & PAWLOWSKI, Z. S., 1989. *Ascariaisis and its Prevention and Control.* Taylor and Francis. London, New York and Philadelphia, 406 p.

ELKINS, D. B.; HASWELL-ELKINS, M. & ANDERSON, R. M., 1986. The Epidemiology and control of intestinal helminths in the Pulicat Lake Region of Southern India. I. Study design and pre- and post-treatment observations on *Ascaris lumbricoides* infection. *Trans. R. Soc. Trop. Med. Hyg., 80:* 774-792.

ELKINS, D. B.; HASWELL-ELKINS, M. & ANDERSON, R. M., 1988. The importance of host age and sex to patterns of reinfection with *A. lumbricoides* following mass anthelminthic treatment in a South Indian Fishing Community. *Parasitology, 96:* 171-184.

FORRESTER, J. E. & SCOTT, M. E., 1990. Measurement of *A. lumbricoides* infection intensity and the dynamics of expulsion following treatment with mebendazole. *Parasitology, 100:* 303-308.

FORRESTER, J. E.; SCOTT, M. E.; BUNDY, D. A. P. & GOLDEN, M. N. H., 1988. Clustering of *Ascaris lumbricoides* and *Trichuris trichiura* infections within households. *Trans. R. Soc. Trop. Med. Hyg., 82:* 282-288.

FORRESTER, J. E.; SCOTT, M. E.; BUNDY, D. A. P. & GOLDEN, M. N. H., 1990. Predisposition of Individuals and families in Mexico to infection with *A. lumbricoides* and *T. trichiura. Trans. R. Soc. Trop. Med. Hyg., 84:* 272-276.

GILMAN, R. H.; CHONG, Y. H.; DAVIS, C.; GREENBERG, B.; VIRIK, H. K. & DIXON, H. B., 1983. The adverse consequences of heavy *Trichuris* infection. *Trans. R. Soc. Trop. Med. Hyg., 77:* 432-438.

GUYATT, H. L.; BUNDY, D. A. P.; MEDLEY, G. F. & GRENFELL, B. T., 1990. The relationship between the frequency distribution of *A. lumbricoides* and the prevalence and intensity of infection in human communities. *Parasitology., 101:* 139-145.

HASWELL-ELKINS, M. R.; ELKINS, D. B. & ANDERSON, R. M., 1987. Evidence for predisposition in humans to infection with *Ascaris*, hookworm, *Enterobius* and *Trichuris* in a South Indian fishing community. *Parasitology, 95:* 323-337.

HASWELL-ELKINS, M. R.; ELKINS, D. B. & ANDERSON, R. M., 1989. The influence of individual, social group and household factors on the distribution of *Ascaris lumbricoides* within a community and implications for control strategies. *Parasitology, 98:* 125-134.

HOLLAND, C. E., 1989. An assessment of the impact of four intestinal namatode infections on human nutrition. *Clin. nutr., 8:* 239-250.

HOLLAND, C. E.; TAREN, D. L.; CROMPTON, D. W. T.; NESHEIM, M. C.; SANJUR, D.; BARBEAU, I.; TUCKER, K.; TIFFANY, J. & RIVERA, G., 1988. Intestinal helminthiases in relation to the socioeconomic environment of Panamanian children. *Soc. Sci. Med., 26:* 209-213.

MAHANALABIS, D.; JALAN, K. N.; MAITRA, T. K. & AGARWAL, S. K., 1976. Vitamin A absorption and ascariasis. *Am. J. Clin. Nutr., 29:* 1372-1375.

PRATDESEBA, R.; TORRES, M. F. & QUEVEDO, J. C., 1991. Prevalencia de parasitos intestinales en algunas poblaciones escolares del Lago de Atitlan por Medio de Diversas Technicas de analisis coproparasitologico. *Revista De La Asociacion Guatemalteca de Parasitologia y Medicina Tropical., 6:* 100-101.

PRITCHARD, D. I.; ALI, N. M. H. & BEHNKE, J. M., 1984. Analysis of the mechanism of immunosuppression following heterologous antigenic stimulation during concurrent infection with *Nematospiroides dubius. Immunology, 51:* 633-642.

SCHAD, G. A. & ANDERSON, R. M., 1985. Predisposition to hookworm infections in humans. *Science, 228:* 1537-1539.

SIVIKUMAR, B. & REDDY, V., 1975. Absorption of vitamin A in children with ascariasis. *J. Trop. Med. Hyg., 78:* 114-115.

SOKAL, R. R. & ROHLF, F. J., 1981. *Biometry.* W. H. Freeman and Company. San Francisco, 859 p.

STEPHENSON, L. S., 1987. *The Impact of Helminth infections on Human Nutrition.* Taylor and Francis. London, New York and Philadelphia, 233 p.

STEPHENSON, L. S.; CROMPTON, D. W. T.; LATHAM, M. C.; SCHULPEN, T. W. J.; NESHEIM, M. C. & JANSEN, A. A. J., 1980. Relationships between *A. lumbricoides* infection and growth of malnourished preschool children in Kenya. *Am. J. Clin. Nutr., 33:* 1165-1172.

STEPHENSON, L. S.; LATHAM, M. C.; KURZ, K. M.; KINOTI, S. K. & BRIGHAM, H., 1989. Treatment with a single dose of Albendazole improves growth of Kenyan school children with hookworm, T. trichiura, and *A. lumbricoides* infections. *Am. J. Trop. Med. Hyg., 41:* 78-87.

TAREN, D. L. & CROMPTON, D. W. T., 1989. Clinical interactions during parasitism. *Clin. Nutr., 8:* 227-238.

TAREN, D. L.; NESHEIM, M. C.; CROMPTON, D. W. T.; HOLLAND, C. E.; BARBEAU, I.; RIVERA, G.; SANJUR, D.; TIFFANY, J. & TUCKER, K., 1987. Contribution of ascariasis to poor nutritional status of children from Chiriqui Province, Republic of Panama. *Parasitology, 95:* 603-613.

THEIN-HLIANG, 1985. *Ascaris lumbricoides* infections in Burna, p. 83-112. In D. W. T. Crompton; M. C. Nesheim & Z. S. Pawlowski (eds), *Ascariasis and its Public Health Significance.* Taylor and Francis, London.

THEIN-HLIANG; SAW, T. & LWIN, M., 1987. Reinfection of people with *Ascaris lumbricoides* following single, 6-month and 12 month interval mass chemotherapy in Okpo village, Rural Burma. *Trans. R. Soc. Trop. Med. Hyg., 81:* 140-146.

VITERI, F. E.; ALVAREZ, E.; PINEDA, O. & TORUN, B., 1983. Prevention of iron deficiency by means of iron fortification of sugar, p. 287-314. In B. A. Underwood, *Nutrition Intervention Strategies in National Development.* New York, Academic Press.

WILLET, W. C.; KILLAMA, W. L. & KIHAMIA, C. M., 1979. Ascariasis and Growth rates: a randomized trial. *Am. J. Public Health, 69:* 987-991.

WILLIAMS, D.; BURKE, G. & HENDLEY, J. O., 1974. Ascariasis: a family disease. *J. Pedriatr., 84:* 853-854.

WHO, 1981. Intestinal Protozoan and helminthic infections. Report of a WHO Scientific Group. WHO Tech. Rep. Ser., No. 666.

YOKOGAWA, M., 1985. JOICFP's experience in the control of ascariasis in an integrated programme, p. 265-278. In D. W. T. Compton; M. C. Neisheim & Z. S. Pawlowski (eds), *Ascariasis and its Public Health Significance.* Taylor and Francis, London.

ZIZZA, C. A., 1990. *Influence of household food strategies on vitamin A intakes of Rural Guatemalan children.* Unpublished M. Sc Thesis. University of Arizona.