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"When I was a little girl, we left sickness behind us when we moved." !Kung Bushman Woman (Marshall 1982)

Introduction

Ascariasis, the infection produced by the round worm, *Ascaris lumbricoides,* continues to be a major health hazard throughout the world. *Ascaris* can cause a number of serious, and sometimes fatal, complications, such as: intestinal blockage, bile duct blockage, liver damage, and rupture of the appendix. It has been estimated to infect about one fourth of the world's population (Peters and Gilles 1977). In 1979 the annual global mortality from ascariasis was estimated to be 20,000 persons a year and the morbidity rate to be one billion cases a year (Walsh and Warren 1979). A comparison of levels of *A. lumbricoides* infestation in two groups of Indians in the Northwest Amazon of Brazil revealed unusually high as well as low levels of infestation within a single geographic sample. These findings suggest that worm loads are related to such factors as sedentarism and social contact. Furthermore, the specimens revealed the highest percentage of unidentifiable helminth eggs in any study to date.

Ascaris lumbricoides, the common roundworm, is the largest of the intestinal nematodes and the most common of all helminths parasitizing the human intestine. *Ascaris* eggs enter the human host by ingestion. Once within the host the second stage larvae penetrate the intestinal wall and enter the circulation where they migrate first to the liver and later to the lungs. From there they enter the upper respiratory tract to the throat and return to the alimentary tract. There an adult female lays an estimated 240,000 eggs per day over a period of approximately one year. The eggs are eliminated in the feces. Since *Ascaris* eggs are discharged in the feces of affected individuals, the endemicity of this parasite depends upon habitual or continual re-contamination of the soil. The degree of infestation among a population is therefore expected to be directly related to exposure and re-exposure to the eggs via their contact with the contaminated soil. This contact is, in turn, related to settlement patterns and associated practices of hygiene (defecation). According to this theory, the more time spent by a population in a single location, the greater the incidence of a given soil-borne parasite. Two characteristics of *Ascaris* make it a particularly sensitive indicator of ground contact contamination: the short life span of the sexually mature worm in the human host (one year); and 2) the necessary role which soil plays in the life cycle of the helminth.

Evidence suggests that *Ascaris* was introduced into the New World by Europeans. Ova of *Ascaris* have been identified in at least eight European prehistoric sites; however, while helminth ova of other species have been found in Pre-Columbian remains, there is no evidence of *Ascaris* in the Pre-Columbian New World (Cockburn 1977:111). The archeological data are supported by observations among relatively unacculturated New World hunter-gatherers. For example, the lowest infection rate for *Ascaris* reported from a New World population not knowing sanitation comes from a study conducted by Baruzzi and others among the newly-contacted, nomadic, hunting and gathering Kren-Akorore Indians of the Brazilian Xingú (Baruzzi et al. 1977). These researchers report an *Ascaris* infection rate of only 15.1%. In this paper, we argue that sedentarism plays a major role in the distribution of the *Ascaris* parasite. Furthermore, based on this finding, we suggest that other parasites not endemic to the New World were also spread through the sedentarism that often accompanies acculturation.

Study Populations

Two distinct indigenous populations occupy the Uaupés river basin in northwestern Brazil near the border with Colombia—the sedentary fishing and farming Tukano and the hunting and gathering Maku (see Figures 1,2). The estimated 10,000 Tukano Indians of the Uaupés inhabit permanent settlements situated at distances of .5 to 35 kms from one another along the river edge. A village consists of sturdy mud and daub houses with thatch roofs and dirt floors situated around a common clearing or plaza and is typically occupied for several generations. The Tukano subsist largely on root-crop cultivation and fishing, with a single nuclear family clearing up to 380 hectares of land for cultivation. Since maintaining this land requires a significant amount of labor, Tukano attempt to draw Maku hunting groups to assist in cultivation (Chernela 1983).

The settlement patterns of the 1,700 Makuan Indians estimated by Reid to inhabit the forested Uaupés interfluve (1979:14; see also Silverwood-Cope 1972) contrast markedly with those of the Tukano. As opposed to the large, sedentary villages of the riverine Tukano, the population density of the interfluve Maku is scant, with campsites situated at great distances from one another. Local populations are small and group composition is flexible. Groups migrate between base settlements and three to six hunting camps (Reid 1979:63). Camp sites are occupied for 3–5 days before the group moves on to a new hunting location. Maku base camp houses are rebuilt annually from palm leaves or tree bark. Houses open in the direction of the forest and, unlike the Tukano, share no common plaza. The Maku subsist on a broad spectrum of foods including arboreal and terrestrial animals, insects, forest fruits and other non-domestic plants and, to a lesser extent, seasonal fishing and horticulture. When Maku do maintain gardens these are small and relatively unproductive.

Figure 1. Location of research area.

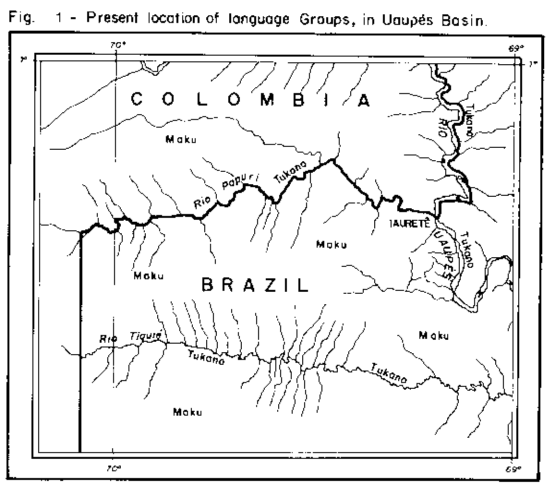

Figure 2. Present location of language groups in Uaupés Basin.

Traditionally, Maku bands and Tukano villages were paired in a mutualistic trade relationship with Maku trading agricultural labor or meat for Tukano garden products or fish. These contractual relationships, though flexible, persisted over many generations. Today, Maku-Tukano exchange relationships range from no or minimal contact to ongoing contact. In the former, contact is limited to short-term exchanges of river and forest resources, such as game for fish. In the latter, Maku set up base camps near Tukano villages, trading their labor in Tukano gardening and food preparation for processed agricultural products.

Maku and Tukano populations differ little with respect to defecation patterns. In both Maku and Tukano villages, food preparation is carried out on the house floor in the vicinity of other activities. Adults defecate in underbrush near the village. Small children occasionally defecate inside the house, and although this is immediately swept away the cleaning may be partial. While the Tukano plaza is cleaned regularly, it is impossible to keep it free of dog feces. Both Tukano and Maku obtain drinking water from nearby streams where bathing also occurs.

Materials and Methods

Population Studies

Three sub-groups of this population were selected for study: 1) Tukano fisher-agriculturalists who inhabit permanent riverine villages; 2) Maku hunter-horticulturalists who live in close contact with these fishing villages, providing residents with meat and agricultural labor in an on-going exchange relationship; and 3) Makuan hunter-horticulturalists who inhabit the forest interior and have little contact with permanent river settlements. Fecal samples were collected from 498 individuals in the region of the Tiquié and Uaupés Rivers in the northwestern portion of the Brazilian Amazon (see Figure 1). Of the 498 individuals in the study, 220 were Tukano, 135 Maku in contact with Tukano, and 143 Maku with little or no contact with Tukano. This sample comprises all of the individuals of 12 villages, ranging in age from new-born to approximately 70 years. Data on demography, settlement pattern, and diet were collected through interviews and observation. These data constitute part of an ongoing study, initiated in 1978, of the indigenous populations of the Uaupés basin (Chernela 1983, 1985, 1989).

Field and Laboratory Tests

Field and laboratory tests to identify parasite infestations were performed on every member of the study population. Instructions were explained to a headman who communicated them to other villagers. Villagers were encouraged to visit the temporary laboratory and to participate in the survey. Each individual was provided with a small plastic bag marked in waterproof ink with a collection number and the donor's name. Stool specimens were collected within twelve hours of distribution (bags were distributed in the evening and collected the following morning). A fresh specimen was examined at the site and a fixed specimen prepared and sent to Manaus for laboratory examination. In addition, sputum samples were collected from nine individuals.

Fresh material was prepared at the site by using microflotation. A large drop of saturated sugar solution was placed on a microscope slide and a 50-100 mg fecal sample was transferred onto it with a spatula. The sample was mixed with the sugar water and triturated vigorously with two toothpicks for 30 seconds. Hard objects such as seeds and large fibers were removed with a forceps. A 22 × 22 mm coverglass was placed over the drop and the preparation left standing for 10 minutes. The preparation was examined at 100 × magnification while focusing the microscope at the level of the bottom of the coverglass. Helminth ova were counted. We have found that this method is better at clearing detritus than methods using glycerine (cf., Kato and Miura technique as described in Martin and Beaver 1968) and is less damaging to hookworm eggs.

Permanent fecal samples were also prepared and sent by air to Manaus for laboratory analysis. The thimble-sized samples were preserved in a fixative solution consisting of 85 parts alcohol, 10 parts of commercial formalin and 5 parts of glacial acetic acid (AFA). A marble-sized fecal specimen is placed in a 15 ml wide-mouthed vial and covered with 5–10 ml of AFA. Although AFA penetrates and fixes fecal material rapidly, approximately one week is required for the alcohol to dissolve the mucous matter in the sample. Feces fixed in this way have been stored for as long as four years without noticeable alterations in helminth ova and protozoan trophozoites and cysts.

Thimble-sized samples, preserved in AFA fixative solution, were examined by centrifugal concentrations of 100 mg samples. Each specimen was re-hydrated and stirred thoroughly in a centrifuge tube. The mixture was then poured through a double layer of gauze into another tube and centrifuged at low speed for 30 seconds. After decanting the water, the material that remained in the tip of the tube was removed with a thin pipette and placed on a microscope slide for examination. This method was found to be faster and more accurate than concentration by flotation or by formalin-ether sedimentation as it does not collapse hookworm eggs. This method permits detection of infection loads as low as 10 EPG.

Temporary fecal specimens were also prepared for immediate examination. AFA-fixed feces normally have a 20–30% water content. Most of this was removed by decanting the AFA and replacing it with 95% alcohol. A 50mg sub-sample was removed and transferred to a large drop of phenol-fuchsin stain on a microscope slide where the feces and the solution were mixed thoroughly with two toothpicks. Hard objects and large fibers were removed with a fine forceps. A coverglass was placed over the material and in 10–15 minutes the preparation ready to be examined and helminth ova counted. To prepare the phenol-fuchsin stain used in the above method, the pure phenol should be liquified at room temperature using a small amount of 95% ethanol. A few crystals of acid fuchsin stain should be mixed with the liquid phenol to produce a pink colored stain. An excess of fuchsin will cause a dark red or wine-colored solution which should be avoided. If permanent mounts are needed, the excess phenol-fuchsin should be withdrawn with filter paper after the hard objects and fibers have been removed, as described above. Balsam mounting medium can then be dropped over the material and a coverglass applied.

A miniaturization of the Harada-Mori filter paper technique was used to prepare microcultures for transport to Manaus where the living hookworm larvae were studied. After smearing 200–300 mg of feces on a 15 × 50 mm strip of filter paper, the paper was placed in an upright position in a 20 ml screw-capped bottle containing about 5 ml of water. After 6 to 10 days the living larvae were collected from the water by centrifugal concentration.

Table 1.
Infestation Rate of Amazonian Amerindians with 13 Intestinal Parasites. 498 Subjects from 12 Villages Near Río Negro, Brazil. Percent of Subjects Having Each Parasite in Stool Sample.

Entamoeba coli	63%
Entamoeba histolytica	6.6
Endolimax nana	5
Iodamoeba bütschlii	12
Enteromonas hominis	3
Chilomastix mesnili	30
Giardia lamblia	5
Balantidium coli	6
Necator americanus	96
Ascaris lumbricoides	75
Trichuris trichura	77
Enterobius vermicularis	6
Strongyloides stercoralis	3.5

Findings

Helminth Parasite Survey

Table 1 shows the results of stool examinations for parasite ova and cysts in 498 individuals. All three negatives found were infants under six months of age. A total of 19 parasitic helminth and protozoan species were recorded, of which five were not specifically identified. The maximum number of different species found in one individual was seven, with an average of four species per person. Three common parasite species were notably prevalent: the hookworm *Necator americanus* (96%); the whipworm *Trichuris trichura* (77%); and the roundworm *Ascaris lumbricoides* (75%). The protozoan species *Entamoeba coli* (63%) and *Chilomastix mesnili* (30%) were found to be moderately prevalent. In addition, eight other intestinal parasites occurred with frequencies of less than 15%: *Entamoeba histolytica* (6.6%); *Endolimax nana* (5%); *Iodamoeba butschlii* (12%); *Enteromonas hominis* (3%); *Giardia lamblia* (5%); *Balantidium coli* (6%); *Enterobius vermicularis* (6%); *Strongyloides stercoralis* (3.5%).

Of nine sputum samples examined, one each contained eggs of *Enterobius*, *Trichuris*, and *Necator*.

Unusual Eggs

Rare, unspecified nematode eggs were seen in fecal samples from 60 of 390 persons (15%) residing in 10 Amazonian Amerindian villages. A total of 79 eggs were found, studied, and measured. Morphological and size differences suggest that three nematode species are involved. The largest eggs measured 118–142 × 50–90 micra and therefore are within the size range and general form of eggs that are known from *Nematodirus spp. Nematodirus* is a nematode genus with several species found in domestic and wild herbivorous mammals. Species of this genus have a world-wide distribution but apparently have never been reported in humans. Smaller, unknown nematode eggs measuring 75–88 × 35–50 micra could well be from a species of *Trichostrongylus.* Somewhat larger eggs measuring 93–110 × 35–60 micra were also found. These ova were smaller and more elongate than those of *Nematodirus.* Their size is greater than that usually found in species of *Trichostrongylus,* suggesting that these eggs represent a different genus of Trichostrongylidae. It has not yet been possible to identify the source of the eggs, but the worms producing them probably occur as natural parasites of some wild herbivorous or omnivorous mammals.

In Maku villages, *Nematodirus*-like eggs occurred in 10 to 16% of the population, while among the Tukano villages the same type of eggs were found in 0 to 8% of the inhabitants. Since the Maku are more dedicated to hunting and have more contact with the forest, these figures suggest a wild mammal source for such eggs. *Trichostrongylus*-like eggs, in contrast, were more than twice as prevalent among Tukano villages (3–12%, mean 7.4%) than Maku villages (0–6%, mean 3.4%). These observations suggest a domestic animal source for these eggs since the Tukano have attempted to keep pigs and some other domestic mammals from time to time.

In addition to three nematode artifacts, objects closely resembling eggs of the trematode *Paragonimus* were found in 6 individuals of one interfluvial hunting village. Nine such eggs were seen and studied. They measured 63–77 × 33–50 microns and appeared to be operculate. Although *Paragonimus* infection in humans has never been verified in Brazil, many cases are known in Equador. Also, *P. rudis* (Diesing 1960) is known to be present in wild mammals of Brazil. If the trematode eggs actually represent infections of the human lung fluke *Paragonimus spp.*, they would reflect Makuan dietary habits since transmission may be through the consumption of freshwater crabs. A second type of trematode egg measuring 100–102 × 65 microns was seen in another sample from the same group of hunters. The egg is relatively thick-shelled and bears an operculum on its upper, narrow extreme. These eggs also fall within the size range for *Paragonimus* but morphologically resemble eggs of *Echinostoma.*

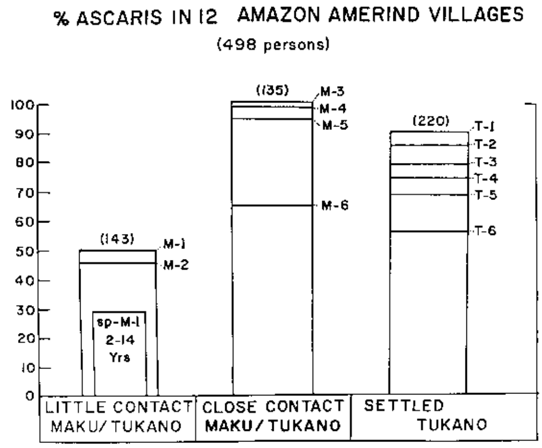

Figure 3. Percent Ascaris in 12 Amazonian Amerindian villages. 498 persons.

Population Distribution

As shown in Figure 3, between 46% and 100% of the inhabitants of each village were infected with *Ascaris.* Tukano villages consistently reported the highest rates of *Ascaris* infection with percentages ranging from 56% to 89% and with a mean rate of 75%. The lowest rates were found among the Maku groups who inhabited the forest and maintained little or no contact with Tukano. (In one isolated Maku settlement, children 2–14 yrs showed an *Ascaris* infection rate as low as 34%.) The pattern of *Ascaris* infection reported among Maku living in sedentary villages associated with Tukano settlements was similar to that of their Tukano neighbors, ranging from 65% to 100%. In some cases the Maku groups having a long-term association with Tukano riverine groups reported a higher rate of infection than the Tukano group with which they were associated.

These figures indicate that the isolated and semi-nomadic Maku were in much better health, in terms of intestinal parasitism, than the sedentary Tukano. In the village designated M-1, 70% of the children and 50% of adults had no *Ascaris* at all (Figure 3). Although most members of the group had *Entamoeba coli,* this protozoan has never been implicated as a cause of any human disease. Most of these people also had *Necator americanus*, but at a very low intensity (10–30 EPG). Egg counts in this range indicate the presence of but three to five adult worms; this light infection is unlikely to cause any inconvenience or symptoms of clinical disease.

On the other hand, the sedentary Tukano and the Maku in close contact have a heavy intestinal worm burden. From 55 to 100% of the people in these villages had heavy infections of *Ascaris lumbricoides*. Most also had *Necator americanus* and *Trichuris trichura*. Eggs of these three nematodes were too numerous to count accurately in most of the samples, but they were estimated as light, moderate or heavy. Worm burdens for each of these species ranged from 50 to 300 worms in each individual. All three are known to be highly pathogenic, with *Necator* and *Trichuris* being responsible for primary anemia from blood loss.

The protozoans, ciliophoran and unidentified nematodes in this population are probably of minimal importance in terms of health. Among the protozoans, only *Entamoeba histolytica* and *Giardia lamblia* are known pathogens and they were demonstrated in relatively few people. The high prevalence of *Entamoeba coli*, especially in the most isolated group, suggests that this may have been the native species of amoeba and that perhaps *E. histolytica* has been introduced from the outside. The presence of the ciliophoran *Balantidium coli* in some villages could indicate an association with the domestic pig, since the species passes directly from pig to man; however, we have recently found a high prevalence of this parasite in peccaries and other wild mammals. These infections no doubt produce severe diarrhea, but are probably transitory. As for the unidentified nematode eggs, they indicated only light infections (10–30 EPG) and we have no evidence that they produced any disease symptoms.

Proximity to western medical facilities produced no apparent effect. Two mission centers with clinics are located within the study area in easy access of Tukano settlements. Despite this, parasite burdens found among the Tukano of the study population were consistently high. Moreover, T-1, the Tukano village which showed the highest prevalence of ascariasis, was located closest to the mission center and clinic.

Discussion

The prevalence of *Ascaris* infection in these populations are among the highest and lowest ever recorded for populations without sanitation facilities. These figures may be compared to those reported by Lawrence and Neel (1980) for three Amazonian Indian villages. In that study, infection rates were found to be relatively light in newly contacted Yanomama villages and high in acculturating villages. The authors attributed their observations to several factors, including the reduction in shifting of village site which accompanies acculturation (1980:536). The findings reported here from our study in Brazil support the findings of Lawrence and Neel and show even lower infection rates for populations with shifting settlement patterns.

The lowest infection rate for *Ascaris* reported from a population not utilizing sanitation facilities comes from a study conducted by Baruzzi et al. (1977) among the newly-contacted, nomadic, hunting and gathering Kren-Akorore Indians of the Brazilian Xingú. These researchers report an infection rate of only 15.1%. The semi-nomadic Maku, with little association and no co-residence with Tukano, show a higher level of infection than the Kren-Akorore, but lower than the Tukano. This is explained by a history of intermittent contact, but a relatively semi-nomadic settlement pattern. High parasite rates were found both in sedentary Tukano populations and in their associated Maku settlements. Proximity to medical centers did not lower incidence of ascariasis. These figures represent a gradation from minimal to maximal infection which can best be explained by environmental contamination associated with increased sedentarism.

The relationship between sedentarism and *Ascaris* infection changes when even minimal sanitation is introduced. Faust's (1958) study of a poor, urban population with latrines in Cali, Colombia, shows an *Ascaris* infection rate of 48.3%. Data from our study and the Baruzzi study reveal that nomadic groups with little contact with whites and no sanitary facilities have lower rates of *Ascaris* infection than an urban population with inadequate sanitary devices. Therefore, it appears that a nomadic subsistence pattern decreases the incidence of ascariasis more than rudimentary sanitation or medical facilities.

Conclusion

A number of variables including population density, the presence of intermediate hosts, humidity, temperature, the physical conditions of the soil, and the life cycle of the helminth govern whether or not a pathogen can persist within a population. Parasites with short life spans require constant reinfestation, while those with longer life spans may persist in a population without reinfestation. Consequently, although the semi-nomadic Maku have a high incidence of the long-lived (15 years) hookworm *Necator americanus,* their semi-nomadic subsistence pattern prevents them from having the ongoing contact with contaminated ground that appears to be required for *Ascaris* infestation. In Maku that have settled in villages, parasite intensity for all species soon rises to that of the neighboring Tukano. Since *Ascaris* lives only up to one year, in contrast with the longer life spans of such other helminths as the whipworm and hookworm, it is a particularly sensitive gauge of environmental contamination. The sedentary life of Indian groups such as the Tukano makes them subject to this contamination, as is evidenced by the higher incidence and heavier parasite loads experienced among the sedentary Tukano villages. On the other hand, a semi-nomadic band such as a hunting group having only intermittent contact with permanent villagers, tends to leave *Ascaris* behind as it moves to a new location.

NOTES

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