THE NEXUS OF YANOMAMÖ GROWTH, HEALTH, AND DEMOGRAPHY

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Introduction

Our goal in this volume is to provide a synthetic overview of studies on Yanomamö health from an ecological perspective with a special emphasis on emerging medical problems that are primarily a consequence of recent contact by non-Yanomamö. As we shall document, throughout most of their recent history the Yanomamö can be characterized as a high mortality and high fertility population who have been subjected to a variety of infectious and parasitic diseases common to other Amazonian populations. Ecologically these illnesses appear to be the primary factors limiting Yanomamö population growth. Our goal is to begin an assessment of the degree to which diet and disease affect Yanomamö growth and development and morbidity and mortality rates. Just as importantly we hope to document the consequences of the introduction of novel diseases on an already highly parasitized people and the steps the governments of Brazil and Venezuela are taking to regulate contact with outsiders and how they are responding to introduced diseases.

We begin with a description of Yanomamö anthropometrics and diet. The Yanomamö are one of the smallest people in all of Amazonia. The cause of their short stature as well as some interesting variation among Yanomamö populations is unknown. In the 1970s a number of anthropologists (e.g., Gross 1975 and Harris 1977) suggested that the Yanomamö were suffering from an inadequate protein intake and this may account for their short stature. Research by Lizot (1977) and Chagnon and Hames (1979) demonstrated that protein intake was more than adequate and Lizot (1977) documented overall caloric and micronutrient sufficiency. Nevertheless, the causes of short stature are unclear and dietary insufficiency in the form of caloric insufficiency may play a role in some areas.

We next turn to an examination of the traditional infectious and parasitic diseases that afflict the Yanomamö. Throughout human history such diseases have had an enormous impact on human population structure and the Yanomamö are no exception. As we shall demonstrate, the Yanomamö are afflicted by a wide variety of diseases but their degree of affliction is probably no greater than other native peoples who live in an equatorial environment, the most disease ridden of all human habitats (see Low 1990 and references therein; Mackintosh 2001). We distinguish between traditional and introduced diseases. By traditional diseases we mean those diseases that appear to predate regular contact with non-Indian populations. Most importantly they include a variety of intestinal parasites and malaria. Introduced diseases are those that seem not to have afflicted the Yanomamö until they came in contact with whites. Some of these diseases such as measles and influenza seem to sweep rapidly through the population and disappear only to reappear through continued contact with outsiders. Others introduced diseases such as tuberculosis and hepatitis are chronic illnesses that slowly spread from village to village causing widespread illness, debilitation and death. Unlike measles and influenza, these chronic infectious diseases persist in villages indefinitely unless public health officials mount well-designed campaigns for their eradication.

Finally, there are two richly detailed demographic investigations of the Yanomamö (Melancon 1982; Early and Peters 2000) that have the ability to inform us about mortality and survivorship, two fundamental dimensions of life correlated with health. These studies indicate that infectious disease is the main health problem and it appears to have a major effect in early years of life.

Throughout we consider the responses of anthropologists, missionaries, NGO's, and state bureaucracies in treating diseases over the short and long term and in controlling Yanomamö contact with outsiders who habitually introduce diseases. Regulation of outside contact and effective monitoring and treatment are critical dimensions for enhancing Yanomamö health.

Yanomamö growth

By Amazonian and world standards the Yanomamö are of small stature. The general literature on growth has consistently demonstrated a negative correlation between SES and adult stature and weight (Huss-Ashmore and Johnston 1985; Bogin 1999). The implication is that poverty leads to either reduced dietary quality or an increase in disease, or both (Garn 1980). It is particularly difficult to untangle the role of nutritional intake and disease and their synergistic relationship. One attempt to document this synergistic relationship [Matorell et al. (1980), cited in Huss-Ashmore and Johnston 1985: 486] reports that common illnesses were associated with a reduction of 20% in food intake. Jenkins' study of Belize children (1981) demonstrates the negative growth effects of chronic diarrhea as do Hodge and Dufour (1991) for Shipibo Indians.

There are several studies of Yanomamö growth. A consistent finding in all is that the Yanomamö are small even by tropical forest standards. Comparative research on this topic was undertaken by Holmes (1995). Figure 1 (men) and Figure 2 (women) contains the ethnic groups Holmes compared to her two Yanomamö groups (Parima and Coyowe-teri). To this we have added additional Yanomamö studies (Coco 1973;Crews and Mancilha-Carvalho 1991; Hames, field data 1987; Spielman et al. 1972;). The figures clearly indicate that of the 16 tropical and sub-tropical Native South Americans surveyed, Yanomamö men and women are the second smallest. Figures 3 (men) and 4 (women) also show they are among the lightest in weight (as above, derived from Holmes with additions). It should also be noted that both the villages surveyed by Holmes contain lightest and shortest Yanomamö ever documented. We will return to this finding below.

Dietary insufficiency is an obvious hypothesis for small stature. Basing her assessment on weight for height curves and arm and fatfold measures, Holmes (1985) notes that children from ages 1-12 are moderately to severely malnourished while older children "…are relatively heavy indicating stocky body proportions.". She also notes that young children and older adults do not manifest good nutritional status. In an earlier report based on the same survey published in 1985 she makes the following assessment (Holmes 1984: 387):

> Few clinical signs of malnutrition were present in the population. It was not uncommon to find very small children (that is, short or light for their age) who would be classified anthropometrical as malnourished, traveling through the forest for several hours carrying heavy loads without signs of physical exhaustion.

Recent research by Hagen et al. (2001) on fatfold thickness in the lowland village of Cejal undergoing short-term food scarcity may provide a context for interpreting Holmes' results. The lowland village of Cejal, located near the mouth of the Casiquiare Canal on the Orinoco, suffered a shortage of horticultural crops as a consequence of garden flooding brought on by the 1998 El Niño weather phenomenon. Children (ages 4-16 years) had triceps skinfolds in the range of 3-8 mm (boys) and 3-16 mm (girls). A figure from Holmes (1985: 252, her Figure 6) on triceps measurements from highland groups show a similar range (this assessment is interpolated from the figure as no tabular or summary measures are presented). Data collected earlier in two non-food stressed lowland villages by one of us (Hames) indicates that boys in these villages had significantly greater skinfolds ($p<0.001$) than the food-stressed village of Cejal (Hagen et al. 2001: 514). The difference between the girls in the two villages was not statistically significant ($p=0.59$) although they were greater in the non-stressed village and they appear to be greater than measurements in Holmes' highland villages. These comparative findings show that the skinfolds of children in the food stressed village of Cejal are similar to those found by Holmes in her highland groups, and the skinfolds of children in non-food stressed lowland villages are greater than either. This suggests that food may be scarcer in highland villages and is reflected in the skinfold measures of children.

Interestingly Holmes (1984: 388, her Figure 3) documents an apparent lack of a relationship between an individual's parasite load and nutritional status. To explain this unlikely relationship Holmes speculates that low nutritional status may protect against parasitic infection. This mirrors an argument made by Kent and Weinberg (1989) in regard to low iron levels in Third World women as a mechanism to protect against bacterial infections. We will return to this hypothesis below.

In a comparative examination of growth and nutrition in more than a dozen Amazonian groups Dufour observes for the Yanomamö: "Indeed, they are the shortest people in Amazonia." (Dufour 1994: 156). In reference to the small stature of Yanomamö adults, Tierney (2000: 60) quotes Dufour as generalizing that this is evidence of "…long term nutritional inadequacy or generally poor environmental conditions, especially ones in which chronic or repeated infections are prevalent". The quote is accurate but misleading since Dufour is speaking of height for age which is a measure of stunting in children and not indicative of "poor environmental conditions" for adults. Indeed, height for age measurements are never made for adults as indicators of relative health. The proper measure for adults is weight-for-height (i.e., BMI). The body-mass indices shown in Figure 5 (men) and Figure 6 (women) show that the Yanomamö are in the healthy range (18.5-24.9) according to the CDC (http://www.cdc.gov/nccdphp/dnpa/bmi/bmi-adult.htm).

How do we account for this result in light of the fact that most biomedical researchers (e.g., Neel et al. 1977; Neel 1979) report that the Yanomamö are well nourished and healthy and the major dietary study we have (Lizot 1977) suggests that the Yanomamö diet meets or exceeds international dietary standards? Research on two exceptionally small populations, the Pygmies and the Mountain Ok of New Guinea, (summarized in Bogin 1999) has implicated genetic variation in the production of a growth hormone (IGF-1) or sensitivity to its effects. At this point there is nothing to suggest that hormonal variation plays a role among the Yanomamö for no such studies have been done. The three smallest Yanomamö villages with smallest statures come from highland areas (Parima and Coyowe-teri in Venezuela and Surucucu in Brazil both at about 1,000 meters) while the villages with the tallest statures (Kedi-Washawa and Ocamo) are in the Mavaca lowlands (Figures 1-2). The men in lowland villages are 7-10 centimeters taller than Holmes' Parima population[1]. This implies an negative altitude gradient which may be correlated with dietary and disease patterns. There is suggestive evidence that lowland villages (Chagnon 1997) may have better access to food resources. Other than onchocerciasis which seems more prevalent at high altitudes, our review below of epidemiological investigations suggests that there is no discernible relationship between altitude and disease pressure.

Rebecca Holmes is the only anthropologist who has attempted to deal with the issue of small stature among the Yanomamö. In her most recent assessment of Yanomamö stature, weight, and growth she argues that the Yanomamö may be "small and adaptive" (Holmes 1995:140). In part, her argument parallels the "small but healthy" position taken by Stini *(1972)* and Seckler *(1982)*: small body size is an adaptation to chronic undernutrition and disease. This hypothesis states that populations under food and disease stress facultatively adjust their growth to adapt to these problems. As Holmes herself notes, this perspective has generated considerable criticism (e.g., Martorell 1989). Holmes also believes that there may be a genetic component to Yanomamö stature as well (Holmes 1995: 132, 138).

In an attempt to explain small stature among native South Americans Salzano and Callegari-Jacques (1988: 116, their Table 6.1) demonstrate that of 43 native ethnic groups they surveyed, there are only three shorter than the Yanomamö. They note there is a statistically significant north-south geographic patterning such that northern groups such as the Yanomamö are significantly smaller than southern groups (Salzano and Callegari-Jacques 1988; their Figure 6.1). The meaning of this pattern is unclear. The authors do not correlate this geographic pattern with genetic markers, linguistic grouping, or ecological factors. The only interpretation at this point is that the small stature of the Yanomamö is consistent with their geographic position in South America. Consequently, it is uncertain what roles disease, nutrition, and genetics play separately or jointly in determining Yanomamö stature in comparison to other Amazonian peoples or within the Yanomamö. Nevertheless, it is an important finding that may help us identify the ecological or genetic factors that underlie this relationship.

Disease patterns

The most important threat to Yanomamö health and quality of life is the presence of infectious disease. The most threatening are those introduced of European and African origin. Some of these have spread to the Yanomamö through recent direct contact, while others may have been introduced prior to actual contact through trade with neighboring Amerindian groups. The most important of these are the mycobacterial infection tuberculosis, the hepatitis viruses (both B and delta), other viral infections such as measles, and parasitic infections such as onchocerciasis and a variety of intestinal helminths. Finally, although malaria has been present in the Amazon for hundreds of years, contact with non-Indians appears to lead to the introduction of new strains that have a devastating effect on the Yanomamö.

The presence of infectious agents among the Yanomamö, although often not life threatening, is a perpetual drain on the body's nutritional and defensive resources. Whether this drain is marginal or detrimental is a complex interplay dependent on the severity of the symptoms of each species, possible interaction between infectious agents, the number of species infecting each individual, and the severity of each infection. It must also be noted that many infections that would not be fatal to those infected had they access to proper medical care, can cause severe problems and even be life threatening in the absence of that care.

Knowing the diseases that affect the Yanomamö and the overall prevalence of these diseases in each village is only the first stage in developing adequate health care programs for the Yanomamö. One must be able to predict the changes that are likely to occur in the patterns of disease and pathogen dispersion among the Yanomamö as they become more sedentary, and have greater exposure to western diet and lifestyle. For this purpose, acculturated native Amerindian peoples of the same region may provide a model for the effects on health of the acculturation process; indeed, some Yanomamö groups that have begun this transition, such as those near mission stations, may also serve for comparison to those groups that still have limited exposure to westerners. We will attempt to synthesize some of the data currently available on each of these groups, in order to make a preliminary comparison of this nature.

Hepatitis

Of grave concern among the Yanomamö are the hepatitis viruses. Both hepatitis B (HBV) and hepatitis delta (HDV) have been identified among the Yanomamö. Most cases of HBV (94% of adult infections, 70% of infections among children; see http://www.cdc.gov/ncidod/diseases/hepatitis/b/fact.htm) are overcome after about 6 months, after which the carrier becomes immune and is no longer infectious. For infants infected at birth, however, about 90% become chronically infected. In 15% to 25% of all cases that remain chronic, liver damage can be a life-threatening concern. This danger is even greater for those infected with HDV, which is more severe. HDV requires the presence of HBV to replicate, and seems to reduce the likelihood that concomitant HBV infection will become chronic. However, it also causes a more acute infection. Of cases of individuals who are chronic for both HBV and HDV, 70% to 80% develop liver damage, rather than the 15% to 25% of HBV carriers alone. Given the fact that the Yanomamö generally do not have immediate access to the type of emergency care necessary for those suffering from severe liver damage, they are undoubtedly more susceptible to mortality associated with the disease than those living elsewhere.

In Ocamo and Mavaca villages, HBV was first introduced in 1968 by an American missionary who had reused needles in administering multivitamin complexes to himself and to the Yanomamö in the village (Torres and Mondolfi 1991). It is unlikely that the viruses were present prior to this time. By the time of a 1986 study in these villages (Torres and Mondolfi 1991), only 16% of 80 Yanomamö who were randomly tested had not been infected. A full 30% of the samples showed active infection, meaning that they were either chronically or newly infected. Over half (54%) of the samples from the two villages were from persons who had been infected and already developed immunity at the time of the study. One can see (Figure 7) that the number of active infections (either chronic or new) does not decrease appreciably with age, which one would expect in a population where the virus is endemic. Furthermore, in the same study, 40% of those infected with HBV also tested positive for HDV. As noted above, those with HBV infection who otherwise showed no symptoms can develop liver damage associated with HDV.

In addition to this, Torres and Mondolfi (1991) studied serum samples that had been collected in 1975 and preserved. In this case, samples had been collected only from individuals with liver damage, thus the prevalence of hepatitis infections in this group is likely to be higher than among the general population. Of these, 97% of the individuals sampled had been exposed to HBV, and 53% had active infection at the time the samples were collected. Of six samples tested for the presence of anti-delta antigens, they were present in all six; this prior even to its description in the medical literature in 1977.

The risks posed by the presence of HBV and HDV among the Yanomamö are serious. The damage associated with chronic HBV is severe, and that with HDV even more so. Because the viruses are spread through contact with saliva, blood and sexual fluids, the intimate nature of interactions among the Yanomamö makes it likely that the disease will spread more quickly than in groups where this contact is not as common. Intimate contact among the Yanomamö includes the universality of breast feeding, premastication of food for infants, body paint mixed with saliva, early onset of sexual activity, and the sharing of chewing tobacco and instruments used to pierce the body.

Tuberculosis

Tuberculosis, like the hepatitis viruses, was very unlikely to have existed among the Yanomamö prior to contact, and is currently a major threat to their health. Although tuberculosis affects primarily the lungs, it can also spread to the gastrointestinal, genitourinary, nervous and lymphatic systems, as well as to the bones and skin. This range makes it a particular threat. Tubercles, which form when macrophages attempt to engulf the *Mycobacterium tuberculosis* bacilli, may heal through fibrosis and calcification, and in this state, the infection can remain arrested until reinfection or other exacerbation of the disease, when a chronic and progressive form may develop.

Drug therapies for tuberculosis are very often successful, and, though less effective than treatment, inoculation with Calmette-Guérin bacillus(BCG) vaccine can prevent infection. However, some drug resistant strains of the bacterium have developed. These are often associated with improper use of drug therapies, but the formation of resistant strains is preventable if proper care is taken with the administration of treatment.

For some groups of Yanomamö, particularly those in Brazil, the disease is likely being contracted through contacts with Brazilians although some suspect that tuberculosis was first introduced among the Yanomamö through contacts with other Yanomamö from the Apiau and Ajarani region (Peters 1980), who had likely first contracted the disease from contacts with whites or with other native groups.

However it was first introduced, directly or indirectly through non-Yanomamö, prevalence of the disease is high. Sousa et al. (1997) found an average prevalence of 6.4% (40 cases out of 625 people) in a study of five Yanomamö villages in Brazil, which is 100 times higher than the average for Amazonas State, Brazil. Peters (1980) found that among 280 Yanomamö, 3.6% had critical tuberculosis infection. In addition, he notes there were"…40-50 [of 280 Yanomamö examined] suspect cases, either of the pulmonary or intestinal variety" (Peters, 1980:276) or about 16% of the population. Apparently these diagnoses were made by "A doctor from the National Division of Tuberculosis." (Peters, 1998: 246).

The study by Sousa et al. (1997) was conducted in an area where BCG vaccine had been administered three years earlier to nearly the entire population. Individuals who had received the vaccine were identified by visible scars. Of the estimated 40 cases of tuberculosis, 28 were bacteriologically confirmed, and 82% of these were in individuals who had received the BCG vaccine.

Comparison of the efficacy of the BCG vaccine among the Yanomamö with that among other groups is difficult, as no study was conducted on the occurrence of tuberculosis in members of the control group (in this case, Brazilian army recruits) who had received the vaccine. The proportion of people whom the vaccine did not protect from infection seems unusually high. Sousa and colleagues suspect that this is related to a seemingly reduced Th1, and related elevated Th2, responsiveness among this population. Th1 response refers to an immune response with high levels of cytotoxic T-cell activity, while Th2 response refers to an immune response with high levels of antibody activity. In addition to low reactivity to the vaccine, the Yanomamö exhibited elevated levels of IgM and IgG in comparison with the control, these being associated with Th2 response..

Given these findings, care should be taken in relying upon vaccination to protect the Yanomamö from infection with tuberculosis. While inoculation should still be provided, as it may protect some, it should not be used as a justification for not investing in proper treatment for Yanomamö who are suffering from infection. Medical care programs should concentrate on providing adequate treatment for infected individuals, and ensuring that treatment regimes are rigorously followed by providing for consistent access to health care professionals by all Yanomamö.

Measles

Measles, and other introduced viral infections, can be a severe health risk to the Yanomamö. The historical record clearly shows that New World peoples experienced massive population reductions when infected by many Old World diseases. This is certainly due to the fact that, unlike the Europeans, they did not have prior experience with the infections. Whether this is due to a genetic immunity present in the Europeans an absent in the Amerindians (see Black 1982) or a consequence of lack of acquired immunity in the community (Neel et al. 1977) is still debated. According to Neel (1979) the high rates of mortality found in Amerindians is mostly likely a consequence of their inexperience with the illness which causes nearly all in the village to become ill. This leads to a break-down in the economic and health care systems of the villages: there is scarcely anyone available to provide food and water to enable the afflicted to fight the illness. It should be understood that tropical forest horticulturalists such as the Yanomamö have a fundamentally different economic system compared to temperate land agriculturalists. In temperate environments food is stored in the home for most of the year. Consequently, if an epidemic strikes, the ill can easily procure food from stores within their dwellings. In contrast, tropical forest horticulturalists rely on root crops and plantains which cannot be processed to store for any length of time. In a sense, food is stored in the garden. To acquire food adults must travel to gardens, harvest, transport the food home, and prepare it. In addition, on a daily basis they tend to spend even more time hunting, gathering, and fishing than they do gardening (Hames, 1989). The successful acquisition of these foraged resources is beyond the abilities of someone who is ill. In this sort of economic system village-wide illness are much more likely to prevent the ill from “curing” themselves through adequate caloric consumption and hydration. In experienced populations, however, large numbers of adults have gained some measure of immunity through previous contact with the illness and they are able to care for those who lack such immunity. Also in modern populations, easy accessibility of water, food, and medications mitigate the symptoms of disease and associated complications.

In a specific instance described in Neel et al. (1970), it was predicted that the Yanomamö were unlikely to have been exposed to measles in the past. Lack of previous infection was confirmed in 1966 and 1967 with serological evidence: in only two villages of 18 did a significant number of individuals test positive for measles antibodies. One of these was located near a mission and had been known to have experienced a measles epidemic; in the other, none of the positive responders was younger than 28 years, suggesting that this village had sustained an epidemic of measles prior to direct contact with non-Indians.

Alarmed by this evidence Neel obtained measles vaccine so he could vaccinate the Yanomamö in 1968. However, measles was introduced to some of these villages by a Brazilian missionary prior to the expedition. Thus they began a vaccination campaign in the midst of a measles epidemic.

Throughout this epidemic, most villages were visited by a government team or by missionaries, and antibiotics were supplied to help prevent secondary infections. For some, especially distant, villages, these were provided late in the infection, however. Neel et al. (1970) estimated that of about 170 cases, 29, or 17.7%, proved fatal. Most of these were due to secondary pulmonary infection. This toll would certainly have been far worse had the team not been able to vaccinate so many, and provide antibiotics to those infected. It also shows what a devastating effect such an outbreak could potentially have in the future if health care workers do not maintain constant vigilance.

Onchocerciasis

Onchocerciasis was probably introduced to the Yanomamö in the early 1970s (Salzano and Callegari-Jacques 1988: 97) and is now very common in highland communities where infection in some villages is 80% (Grillet et al. 2001). It has been present in the Americas since the introduction of immigrants and slaves from Africa where it is endemic in certain regions. Caused by the filarial parasite *Onchocerca volvulus*, it is rarely fatal. However, it can be disfiguring and debilitating, and at its worst can lead to blindness and to disorders of the lymphatic system.

Some of the most adverse consequences of this infection are related to the immune response to the microfilariae by the host. The symptoms of this are often similar to mild to severe allergic reaction, such as itching, cracking and thickening of the skin, related bacterial infection, and eventual fibrosis. Hanging groin can also result from inflammation of lymph nodes associated with the infection.

Blindness results when nodules form in the cornea or retina of the host. Because symptoms develop over time, however, uninvasive diagnosis of infection can be difficult. Palpable nodules may not be found in all infected individuals; Rassi et al. (1976), for example, found only 17 Yanomamö with palpable nodules out of 75 Yanomamö subjects who had tested positive for microfilariae in skin biopsies.

Species of black fly of the genus *Simulium* serve as the vector for the parasite, including *S. guianense*, *S. oyapockense*, and *S. incrustatum*, although the role of the latter as a vector is undetermined. The prevalence of onchocerciasis seems to be greater at higher altitudes. In a study of biting rates of these three species of black fly, the biting rates of both *S. guianense* and *S. incrustatum* increased with altitude (Grillet et al. 2001). This may be related to the fact that the larval stage of the fly requires fast-flowing, highly oxygenated water, which is more likely to be found at higher altitudes.

Prevalence of this disease can vary greatly from one village to another. Rassi et al. (1976) found that onchocerciasis had not yet appeared in several villages inhabited by the Yanomamö. In Toototobi, however, prevalence of the disease, as determined by palpation, vision tests, skin biopsy, and reactivity to Hetrazan[2], was 61%. In Auaris, prevalence was 25%, and in Surucucu, it was 24%.

Onchocerciasis may be on the rise, however. Grillet et al. (2001) measured the prevalence of the disease in several villages as well. Although these were not the same villages examined by Rassi et al. (1976), the average prevalence found was much higher. While they did find an extremely low rate of infection (2.4%) in lowland village of Ocamo, they found the rate of infection in highland villages ranging from 24% to an alarming 80%.

Treatment of onchocerciasis is relatively straightforward; Ivermectin can rid an individual of infection. However, the real likelihood of reinfection makes vigilance and repeated treatment necessary to prevent long-term physical damage from onchocerciasis.

For this to occur, health care workers must be available to administer medications and to ensure that they are used effectively.

Malaria

Malaria is one of the most serious threats to Yanomamö health. In several studies conducted among the Yanomamö *P. falciparum* has proven to be the most common (Perez Mato 1998; Torres et al. 1988, 2000). This species accounted for 68.6% of all infections in one study (Torres et al. 2000), and 57.1% in another (Perez Mato 1998). Torres et al. (1988) found that the titers of antibody to *P. falciparum* were higher than those to *P. vivax* in all but two cases out of 59 studied.

This contrasts with the species distribution common elsewhere, even in Venezuela itself: the average Venezuelan distribution of infections in 1992 was 76% *P. vivax* and only 24% *P. falciparum.* This is significant to the Yanomamö because, although *P. vivax,* unlike *P. falciparum,* can remain dormant in the liver and thus relapse, the infection caused by *P. falciparum* is often much more acute, sometimes fatally so.

Among some Yanomamö groups, virtually everyone has been infected with malaria at some point. Torres et al. (1988; see also Torres et al. 1997 for additional details) found that of 59 serum samples taken from individuals in Ocamo and Mavaca, all 59 had antibodies to both *P. falciparum* and *P. vivax*. The presence of active infection with any of the *Plasmodium* species, however, was found in only 3 out of 110 samples, suggesting a high level of immunity among adults in this area.

Indeed, Perez Mato (1998) found higher levels of *P. falciparum* and *P. vivax* in younger age groups than in adults in Ocamo and Mavaca in 1992 (Figure 8). Out of 35 individuals aged 6 months to less than 10 years, 17.1% had active *P. falciparum* parasitemia and 14.3% had active *P. vivax* parasitemia. Of 12 individuals aged 10 years to less than 15 years, none were infected with either species. Of those over 15 years of age, 3.6 percent had *P. falciparum* parasitemia and only 1.8 percent had *P. vivax* parasitemia. This suggests that some of those in the older age groups have acquired immunity to active malaria infection.

This immunity may have some benefits for the village as a whole. If adults do not become ill, they can care better for ill children. Basic economic functions continue to be fulfilled, such as procurement of food and water. On the other hand, the prolonged or repeated infection required to acquire immunity takes a heavy toll on those living in hyperendemic areas such as Ocamo and Mavaca.

In contrast, areas that are not hyperendemic, while spared from high prevalence of infection much of the time, may experience severe periodic outbreaks of the disease. In a study comparing malaria outbreaks in Coyowe-teri and Matoweteri, Laserson et al. (1999) found that the prevalence of active malaria was very low in August and September of 1993, and again in May and July of 1994. During these two sampling periods, a total of 14 cases of active *P. falciparum* infections were found in 320 (4.4%) samples from both villages. After severe outbreaks in October and November of 1994, however, Coyoweteri had a prevalence of active *falciparum* malaria of 45.2% (out of 62 individuals) and Matoweteri of 45.7% (out of 70 individuals). With this proportion of the population of a village ill, severe economic hardship is a likely result. Ill parents, particularly nursing mothers, cannot provide as well for ill children. Procurement of food and water becomes problematic. Those who are well may flee the village, rather than staying on to care for the sick and risking infection themselves.

The most immediately life-threatening complication of malaria is the often extreme febrile state reached by those suffering current infection and associated dehydration. Many other complications are common, however, including splenomegaly, acute hemolytic anemia, and hepatomegaly, which can lead in turn to portal hypertension and even cirrhosis of the liver. Torres et al. (1988) found that 44% of individuals in the villages of Ocamo and Mavaca suffered some degree of splenomegaly. An estimated 23% of all malaria cases resulted in hyper-reactive malarial splenomegaly. This syndrome was associated with hemolysis in the same villages (Torres et al. 2000). Prior to the study, in just one year, 38 of the 550 inhabitants of Ocamo and Mavaca had required evacuation for emergency transfusion, due to severe hemolytic anemia.

Perez Mato (1998) found that anemia was ubiquitous in Mavaca in 1992. Of the total population of 103 individuals, 91% suffered from anemia. Adults, particularly women, were more likely to suffer from anemia than children. On the other hand, children aged 6 months to less than 10 years were more likely, at 94% of 33 individuals in the age range, to suffer from splenomegaly than were adults, at 68% of 38 individuals. The presence of splenomegaly in this population was strikingly high, at 77%, and 45% suffered from moderate to severe splenomegaly (see Figure 8). This is most likely due to repeated infection with *Plasmodium* parasites.

Other parasites

One of the most ubiquitous and persistent health problems facing the Yanomamö is the presence of a vast range of parasitic infections. Some of these, such as *Entamoeba coli*, are non-pathogenic, and common to the intestinal flora. Others reach an equilibrium within their hosts; while they do sap nutrients and can cause some serious health problems, they are generally not life-threatening. These include many species of intestinal helminth, such as *Ancylostoma duodenale* and *Ascaris lumbricoides*, as well as a variety of roundworms, flatworms, tapeworms, and filarial worms and protozoans.

Many of these parasites are contracted primarily through oral-fecal contact; often this involves soil in which eggs or larvae in the case of worms, or cysts in the case of protozoan infections, have been deposited. Many of these are equipped to enter the new host through the skin, particularly that of bare feet, but can also infect hands and subsequently be ingested. The other primary mode of transmission is through infected water. Because of this, sanitation practices are of great import in determining the severity and prevalence of infection. The Yanomamö, being swidden agriculturalists, have been prone to move periodically, thus evading areas in which infective agents have built up in the soil for several years. As they become more sedentary, unless concomitant measures are taken to ensure proper sanitation such as pit latrines, these infections are likely to increase.

Macroparasites

Ancylostoma duodenale

The genus *Ancylostoma* includes the hookworms, of which *A. duodenale* is one of the most common. Hookworm is contracted through the skin, from fecal material deposited in the soil. Once resident in the intestine, it attaches itself to the mucous membrane and consumes the blood of its host. The most severe effect of hookworm infection is loss of blood, which can result in iron-deficiency anemia, and in very severe cases, malnutrition. In the case of a mild infection, the side effects may be minimal.

Holmes (1984) found that in two Yanomamö Venezuelan villages the rates of infection were respectively 39% and 67%, somewhat lower than the rates of 76% and 80% found by Lawrence et al. (1980) in Mavaca and Patanowa-teri.

Ascaris lumbricoides

Ascaris lumbricoides is the most common roundworm worldwide, currently infecting nearly one and a half billion people. It is also the most common to the Yanomamö. It is passed through feces, and it requires a two-week incubation period in the soil, after which, if ingested, the eggs are infective. They hatch in the intestinal tract, the larvae enter the venous circulation, and pass to the lungs, from which they migrate up the subject's upper respiratory passages and are swallowed. It can cause pneumonia during this stage in its life cycle. Another complication is intestinal obstruction. Most cases, however, are asymptomatic. (http://www.nematode.net/Species.Summaries/Ascaris.lumbricoides/).

This infection is quite common among the Yanomamö; prevalence rates ranged from 73% to 99% in four villages (Lawrence et al. 1980; Holmes 1984). Only Confalonieri et al. (1989; cited in Confalonieri et al. 1991) found a range of 6.6% to 14.3%, for which the specific villages were not named.

Strongyloides stercoralis

This parasite, like the hookworm, is contracted through the skin. The filariform larvae travel to the lungs, from whence they may be swallowed, to take up residence in the intestine and there mature. It may be symptomatic during the pulmonary stage of infection, but is frequently asymptomatic. Unlike some other helminth species, *S. stercoralis* does not require an incubation period in the soil – auto-infection is possible, and in some individuals, particularly those who are immunosuppressed, fever and abdominal pain may occur.

Holmes (1984) found from 0% to 1% in two villages, while Lawrence et al. (1980) observed from 3% to 11% in two others. Confalonieri et al. (1989; cited in Confalonieri et al. 1991) observed a rate of 0% to 3.3% in several unidentified villages.

Capillaria

Three species of roundworm of the genus *Capillaria* can infect humans, one of which, *C. phillipinensis*, is most common, and two of which, *C. hepatica* and *C. aerophila*, are rare. *C. hepatica* causes hepatic capillariasis, which may result in hepatitis and eosinophilia, and *C. aerophila* causes pulmonary capillariasis, which may result in asthma and pneumonia. Both of these may be fatal.

According to the CDC (http:/ / www.dpd.cdc.gov/ dpdx/ HTML/ Capillariasis.htm), the geographic distribution of *Capillaria* species is primarily limited to the Philippines and Thailand, with rare cases reported in the Middle East and Colombia. Confalonieri et al. (1989; cited in Confalonieri et al. 1991) report a prevalence of unspecified *Capillaria* species of 2.8% to 6.6% among the Yanomamö. This illustrates the extent to which even very remote peoples may be exposed to diseases and parasites thought to be locally specific to distant areas.

Hymenolepis nana

Hymenolepis nana, a tapeworm that completes its life cycle within its host, is common worldwide. It is most often asymptomatic, although in the case of heavy infection, it can cause abdominal pain and diarrhea, and possibly sap nutrients from its host. Of three villages studied (Hurtado et al. 1997), it was found only in the Venezuelan village of Coyoweteri, with an overall prevalence of 5.3%.

Mansonella ozzardi

Mansonella ozzardi, a filarial nematode similar to *Onchocerca volvulus*, is transmitted by black flies and midges. Symptoms of this infection can include hepatomegaly and adenopathy. Torres et al. (1988) found a low prevalence, 1.8% in 110 individuals, of this parasite in the Venezuelan villages of Ocamo and Mavaca.

Trichuris trichiura

Trichuris trichiura is a frequently asymptomatic nemathelminth, although in some cases and especially small children it may cause pain, diarrhea, or rectal prolapse. There seems to be considerable variation in the prevalence of this parasite. Holmes (1984) found 9.5% only in Parima B, but Orinoquito had a prevalence of 53.3%. Lawrence et al. (1980) found a prevalence ranging from 68% to 92%.

Microparasites

Entamoeba histolytica

This is the only member of the genus *Entamoeba* that is pathogenic, and is the parasite responsible for amebic dysentery and tropical liver abscess. It seems to be common among the Yanomamö, but this varies in degree. Lawrence et al. (1980), for example, found rates as low as 28% in one village and as high as 77% in another. Confalonieri et al. (1991) found rates ranging from 28.5% to 40%.

Giardia lamblia

Giardia lamblia infection can cause severe symptoms, such as diarrhea, vomiting and weight loss that generally lasts for one to three weeks, but may last longer. In two Yanomamö villages it was present respectively in 4% and 5% (Lawrence et al. 1980), but Holmes (1984) found a prevalence of 20% in both Parima B and Orinoquito.

Toxoplasma gondii

Toxoplasma gondii is a fairly common infection worldwide, most often asymptomatic in adults. However, it may produce blindness in severe cases. If contracted by a pregnant woman, it can cause congenital damage to the heart, brain, or lungs of the fetus. Only one study (Sousa et al. 1997) tested for the presence of *Toxoplasma gondii* among the Yanomamö, and found it in 39% of 202 individuals examined.

Non-pathogenic parasites

Several studies have also tested for the presence of parasites that are non-pathogenic, normal denizens of the human intestine. The effects of these infection on the general health of the host are minimal, except in those with the most severely compromised immune systems. However, while specific symptoms may not appear, chronic or severe infection may result in the draining of energy resources from the host. Of these, *Entamoeba hartmanni* had a prevalence of 0% in one Yanomamö village and of 19% in the other. *Chilomastix mesnili* was prevalent in about 10% of one village, but was found in more than half of another (Lawrence et al. 1980). *Endolimax nana* infected a quarter to a third of the Yanomamö tested for it (Lawrence et al. 1980). *Balantidium coli* was not found among the Yanomamö (Lawrence et al. 1980). These authors found *Entamoeba coli* to be nearly ubiquitous in the Yanomamö villages, with 91% and 100% prevalence. Holmes (1984), however, found somewhat lower rates (70%-84%).

The effects of acculturation

It is clear that virtually all Yanomamö studied bear a heavy parasite burden. Figures 9 and 10 display the variety of diseases carried by individuals of this tribe. Figure 9, compiled from Torres et al. (1988), Torres and Mondolfi (1991), Perez-Mato (1998), and Torres et al. (2000), shows the incidence of debilitating and life threatening parasitic and viral diseases at the mission villages of Mavaca and Ocamo in Venezuela. As is indicated there, everyone sampled had contracted both types of malaria even though only five to ten percent had active cases. The consequences of malaria such as anemia (90%) and hyper-reactive malarial splenomegaly (42%) were common. In addition to malaria and associated conditions, about half had had hepatitis and about 40% had HDV active cases. The load of intestinal parasites can also be quite high. Figure 10, derived from Holmes (1984), shows that members of the highland mission villages of Parima B and Orinoquito carry from 1 to 10 intestinal parasites with a median range of 4 to 6. At this point, we are not suggesting that illness rates are affected one way or the other by the presence of missions. The detailed comparative studies we present in Figures 9 and 10 were based on research done at missions as a probable consequence of the researchers being able to easily enter the area for research purposes because of airstrips and the presence of useful infrastructure (e.g., communications and refrigeration). Below we will attempt to deal with the effects of mission contact on health patterns.

The consequences of these parasite loads on the overall health of the Yanomamö is probably best reflected in mortality patterns that we discuss below. Many of the species, as described above, are life threatening when infection is severe, but may not pose a significant threat if infection is light. Except for the studies represented in Figures 9 and 10, few investigations have examined the intensity as well as the prevalence of infections. Such studies would be useful in the creation of a framework for prioritizing treatment strategies. In any case, for most of the intestinal parasitic infections, treatment consists of a relatively simple vermicide, such as Ivermectin. The difficulty with this is that reinfection is often likely, and treatment would need to be repeatedly available over the long term. The more effective solution, although it is far more difficult to implement, is to impose a certain standard of sanitation that would prevent these parasites from building up in the soil or in the water supply.

Comparative health data on the Yanomamö at missions and in villages some distance from missions as well as health data on acculturated native people who are neighbors to the Yanomamö in Venezuela may allow us to detect changes in health profiles as the Yanomamö become more acculturated. Many of the parasites afflicting the Yanomamö require an incubation period in the soil, and are spread through oral-fecal contact or through contact between bare skin and fecal material. As villages undergo acculturation and their inhabitants become more sedentary, it is possible that parasites build up in the soil and water sources and rates of infection may increase. Add to this the fact that population density around missions tend to be much higher than in non-mission areas. For example, one of us (Hames) noted that the Yanomamö population around Mavaca in the mid 1970s was no more than 150 people. By 1986 there were more than 525 scattered in small settlements around the mission (see also Chagnon 1997: 228-229). At the same time, acculturation may lead to the development of sanitation facilities (e.g., latrines) and the availability of vermicides and other medications from missions or governmental health outposts that may moderate any increase in infection as a consequence of a more sedentary life. Yet, it is undoubtedly the case that sedentization and higher population density increase the potential for the spread of infectious and parasitic diseases. How missions or governmental health workers mitigate these effects is key to Yanomamö well being.

Lawrence et al. (1980) were able to compare parasite infection in two Yanomamö villages to those in three non-Yanomamö (but native) acculturated villages in the same region of the Upper Orinoco Basin of Venezuela. The results are somewhat mixed (Lawrence et al. 1980: 534, their Figure 2). For example, they found that hookworm infection (not identified by species) was very common in both Yanomamö villages, with infection rates of about 76% in one and about 80% in the other. It was even more common in the acculturating villages, however, suggesting that Yanomamö groups may incur an increase in the already high rates of hookworm infection. They also found *Trichuris trichiura* to be more common in acculturating villages than in Yanomamö villages, although, again, even in the Yanomamö villages rates were fairly high, at 68% to 70% in one village and 90% to 92% in another. *Dientamoeba fragilis*, believed to cause vomiting and diarrhea, was found in acculturating villages, but not at all among the Yanomamö. *Giardia lamblia* was also less common in Yanomamö villages than in acculturating villages, in which about a quarter of the people were infected. However, in this case, other studies have found rates among Yanomamö comparable to those of the acculturating villages (see Holmes 1984).

On the other hand, *Entamoeba histolytica*, responsible for amebic dysentery and tropical liver abscess, had a much higher prevalence among the Yanomamö, from 28% in one village to 78% in another, than it did in the acculturating villages. While *Ascaris lumbricoides* was common in both Yanomamö and non-Yanomamö villages, in the Yanomamö villages, with prevalence of 90% and 100%, infection rates did not diminish in adulthood. In the acculturating villages, infection rates of 100% were found in children but declined to less than 10% in adults. Little difference was found between rates of infection with *Strongyloides stercoralis* in the acculturating villages and in the Yanomamö villages.

These results are difficult to interpret. No straightforward generalization can be made about whether the acculturation process leads to a heavier or lighter parasite burden. There was no apparent pattern dependent on the mechanism by which parasites are spread, such as those that build up in the soil versus those that are auto-infective.

It is also difficult to interpret differences in overall parasite load and age-related changes in parasite load. In the Yanomamö villages, a higher average number of species were found per adult person, ranging from 4.2 to 6.8 compared to 3.0 to 4.5 in the acculturated non-Yanomamö communities. This range is nearly identical to what Holmes (1984) found in highland Yanomamö populations (Figure 10). In one Yanomamö village, the average decreased in adults, while in the other the average was fairly constant across age groups. In acculturating communities, the average number of species per person was lower, from 1.3 to 6.0, with no real trend across age groups. Finally, in acculturating villages, 14 different species of intestinal parasites were found, while only 12 species were found in Yanomamö villages.

There is another study that allows us to compare the Yanomamö to Venezuelan nationals who live in the same area. In this case the Yanomamö are compared to poor Venezuelan nationals who are more or less fully integrated into the state economy and social system but who live in the same area. Holmes (1984: 389, her Table II) was able to compare helminth (*Ascaris lubricoides*, *Trichuris trichiura*, *Ancylostoma duodenale*, *Strongyloides stercoralis* and protozoans (*Entamoeba coli* and *Giardia lamblia)* infection rates in two highland Parima Yanomamö groups to the Spanish speaking residents of San Carlos de Rio Negro. San Carlos has been settled for decades and they have access to medical care, schools, and residents purchase most of the food they consume. The comparison is useful because both groups occupy the same general area of the Upper Orinoco, although the Yanomamö are at a significantly higher altitude. Except for the fact that the Yanomamö have a larger fraction of the population infected by *Ancylostoma duodenale* and both kinds of *Entamoeba* there are not striking differences. However, the number of parasites per person is much greater among the Yanomamö than it is for the residents of San Carlos. For example, in San Carlos only 5 percent of the population is infected by 4 or more parasites while the corresponding figure for the Parima villages is that more than 50% of the population is infected by 4 or more parasites (Holmes 1984: 389, her Table I).

It may also be useful to compare Yanomamö villages at different stages in the acculturation process. One of us (Hames), based on research visits to nearly all of the villages surveyed, has rated the villages studied by Lawrence et al. (1980), Holmes (1984), and others summarized in Hurtado et al. (1997) from most to least acculturated. This rating informs our discussion below.

The results of such a comparison are inconclusive (see Figure 11 which compares the least acculturated village to one of the most acculturated villages). The least acculturated village, Patanowä-teri (Lawrence et al. 1980), was an exercise in extremes. For almost every species tested, Patanowä-teri had either the highest prevalence (*Ancylostoma* sp., *A. lumbricoides*, *T. trichiura*, *E. coli* and *E. hystolitica*) or the lowest (*G. lamblia*, and nearly the lowest rate of *Strongyloides* sp.). In the case of *Ancylostoma* sp. and *E. coli*, the margin by which they exceeded their neighbors is insignificant; 1.5% and 4.5%, respectively. The prevalence of *A. lumbricoides* was higher by 8% in the less acculturated village. The prevalence of *T. trichiura*, however, was higher by 11%. The prevalence of *E. histolytica* was higher by a margin of 17.5%. Coyowe-teri, the intermediate village, exhibited no such trend (Hurtado et al. 1997), nor did the more acculturated villages of Parima B, Ocamo and Mavaca.

The results of these comparisons are not revealing, but one may still draw certain conclusions. For example, in both comparisons, rates of *G. lamblia* were lower in the less acculturating groups, suggesting that it (as well other infections contracted through the water supply) may be a health risk of greater concern for the Yanomamö in the future. For parasites that travel through the soil, results are not at all certain. This may be due to differences in sanitation between more acculturated villages, or perhaps the build-up of parasites in the soil is mitigated by having greater and timelier access to vermicidal medications. The differences may also be due to differences in sampling technique from one study to another. Perhaps a more controlled study of a similar nature could provide a more accurate comparison, and thus prescriptive value for treatment programs among the Yanomamö.

Our comparisons of traditional and acculturated (mission) Yanomamö villages on one hand and heavily acculturated non-Yanomamö Amerindian and Venezuelan peasants living in the Upper Orinoco show few clear patterns. Nevertheless, it seems that the variety of parasites and the mean number of parasites per person may be slightly greater in traditional and acculturated Yanomamö villages than in Venezuelan peasant villages. Over the short term it seems that increased settlement around missions will have little effect on Yanomamö health even though the potential for infection may be greater.

Yanomamö demography

Mortality statistics provide us with critical information on the role that diseases play in a population. In tribal populations, as in most, age specific mortality rates commonly present themselves in a U-shaped or J-shaped distribution in relation to age: rates start high in the early years, decline steadily to the teen years and then begin a slow but accelerating climb thereafter. There are two excellent demographic studies of the Yanomamö (Melancon 1982; Early and Peters 2000) that provide important information on mortality rates, life expectancy at various ages, and causes of death among the Yanomamö.

Understanding the causes of death will enable government health authorities, missionaries, and anthropologists to be in a better position to monitor health problems, design preventive programs, and treat the ill. Both of the demographic studies mentioned above tabulate causes of death but there are some obvious problems common to most ethnographic and retrospective investigations in establishing actual causes even within broad categories. The ethnographers had to rely on a informant recollections of causes of death and then translate these causes to a western typology. Infectious diseases such as malaria, influenza, and measles are probably reliably diagnosed by the Yanomamö since they are quite familiar with the symptoms. However, an illness that began as influenza could have led to pneumonia which was the actual cause of death. Even more problematic is when the cause of death is unknown and this seriously distorts rates of reliably identified causes of death. For Melancon (1982: 42, his Table 3.1) the number is only 6% (Figure 12), while for Early and Peters (2000: 201) unknown causes compose anywhere from 18% to 50% (Figure 13) of all deaths depending on the era studied. The difference largely reflects the recent four year time span of Melancon's, investigation compared to the 66 year period covered by Early and Peters.

Aside from a large difference in unknown causes of death comparing both studies is problematic for two other reasons. Melancon does not list infanticide as a cause of death; not because it was absent in his area of study but because he decided not to classify such births as live births. This is not unreasonable, since the decision to commit infanticide is almost always made before an infant is born (unless the infant is born with a congenital anomaly) and therefore one can regard it as a kind of post-partum abortion. In contrast, Early and Peters count infanticide as a cause of death and it comprises anywhere from 5% to 20% of all deaths. Second, while both use the category "infectious disease" Melancon has a category called “degenerative disease” while Early and Peters have a corresponding “non-infectious disease” category. Nevertheless, there is probably considerable overlap between these two categories. With these caveats in mind we compare the two studies immediately below.

Both studies indicate that infectious disease is the major course of death among the Yanomamö (although it is much higher for the Mavaca Yanomamö) and the rates of death from non-infectious and degenerative diseases are about the same. For the Mavaca Yanomamö deaths from infectious diseases are 60% to 70% higher for children than adults (Melancon 1982: 47, his Table 3.2). The higher rates of infectious disease for the Mavaca Yanomamö (70% compared to 50%) to some extent is an artifact of Early and Peters classifying infanticide as a cause of death. If infanticide is removed as a cause of death, infectious disease as a cause of death for the Xiliana increases to 56%. And if the large number of unknown causes were known, death to infectious diseases would be very similar for both populations.

Early and Peters’ study spans a 66 year period and their investigation is divided into a time series based on degree and kind of contact with outsiders. Consequently, it, more than any other demographic study of which we are aware, allows us to understand how contact affects patterns of mortality and disease patterns in a uncontacted tribal population. They divide the demographic history of the Xiliana into precontact, contact, linkage, and Brazil stages, which measures the degree to which interaction with Brazilians has increased through time. Causes of mortality through these periods is displayed in Figure 14. Bearing in mind that “unknown” as a cause of death looms large in every period (especially precontact), the immediately recognizable trend is that death from infectious diseases increases dramatically from precontact to contact and changes little thereafter. During the contact period and thereafter Early and Peters (2000) note that malaria and tuberculosis introduced by miners where the main causes for the increased force of infectious diseases as a source of Yanomamö mortality.

There seems to be little difference in survivorship between the two populations. Life expectancy at birth ranges between 29 and 46 years depending on contact period among the Xiliana (Early and Peters 2000: 199, their Table 19.5) and 37 years for the Mavaca Yanomamö (Melancon 1982: 65, his Table 3.6)[3]. Significantly, the lowest life expectancy for the Xiliana is at first contact, reaches the high point immediately after contact (“linkage” phase), and sadly declines to 35 years during the “Brazilian” stage of sustained contact.

Crude birth and mortality rates and their relationship are fundamental measures of how well a population is adapted to the environment. If a population increases through time then by definition they are able to overcome various sources of environmental resistance (disease and resource insufficiency) and have not reached carrying capacity (when fertility equals mortality and the population ceases to grow). Crude death rates for the Xiliana Yanomamö (Early and Peters 2000: 194, their Table 19.2a) range from 17 to 56 and for Melancon’s study (1982: 89) 46 which places them in the moderate to high range (Early and Peters 2000: 96) by world standards. Crude birth rates range from 28 to 52 for the Xiliana (Early and Peters 2000: 194, their Table 19.2a) and 59 for the Mavaca (Melancon 1982: 89). The natural rate of increase for the Mavaca Yanomamö is estimated to be 1.25% and 1.12% for the Xiliana (derived from Early and Peters 2000: their Table 19.2c for all periods). These figures accord well with early estimates by Neel and Weiss (1975: 38). It is important to realize that these demonstrations of Yanomamö population increase are probably not characteristic of growth patterns elsewhere among the Yanomamö tribal distribution, as we will show immediately below.

Where the Yanomamö come into chronic contact with outsiders and where medical intervention is absent or ineffective there is evidence of population decline. In Brazil, military take over of the Surucucu area through the *Calha Norte* initiative and the construction of the BR 210 road provide dramatic examples of this process. In 1987 the Brazilian military took control of the Surucucu and Paapiú regions as part of the infamous *Calha Norte* project. They then permitted tens of thousands of gold miners to enter the area and expelled missionaries, health officials, and researchers. In 1989 it was estimated that "…23 percent of the Yanomami had been killed by malaria or by *garimpeiro* bullets." (Ramos 1995:277). Ramos also presents data on infectious disease in the area that show astounding increases (400% and more) in malaria, malaria-related illnesses (e.g., anemia), respiratory infections, tuberculosis, and malnutrition (Ramos 1995: 278, her Figure 11.1). There is no indication of how many individuals or villages these figure applies to.

Earlier, the construction of the road BR 210, a spur of the Transamazon Highway, in Brazil in 1974 had a devastating impact on the Yanomamö living near the road. Ramos and Taylor (1979) report that medical treatments by local Catholic missionaries (Consolata Order) for viral diseases and their complications, diarrhea, skin diseases, and malaria, increased from 2,485 three years prior to the road to 12,529 three years after the road was completed. A detailed investigation on the mortal consequences of road construction on three populations living adjacent to several days walk from it revealed the following, as a consequence of a measles epidemic which occurred from February to March of 1977: Iropitheri, 35 of 69 died; Uxiutheri, 15 or 32 died; Maxikopiutheri 10 of 33 died (Saffirio and Hames, 1983).

In Venezuela and Brazil Colchester (1985: 29) claims that while some Yanomamö populations are holding steady or increasing in numbers other groups are losing population. Citing *Migliazza (1982)* Colchester (1985: 64-65) suggests that the Ninam (a small ethnolinguistic division of the Yanomamö) in Venezuela and Brazil lost about 25% of their population (from a base of 125) as a consequence of introduced diseases from 1963 to 1978. This same group was struck by a measles epidemic in 1981 (Colchester 1985: 65) that caused the death of 41 persons.

Finally Chagnon (1997) describes mortality rates (actually, percent of people who died from 1987-1991) in three types of villages and draws the conclusion that health practices of the Mavaca Salesian mission are responsible for a dramatic spike mortality rates in villages that have intermediate contact. Chagnon classified 17 villages into three categories: mission villages who had "maximum" contact with missionaries, "intermediate" villages who had irregular contact with missions, and "minimum" or distant villages who had little or no contact with missions. Over that period Chagnon shows that mission villages and distant villages suffered death rates of 5% and 6.5%, respectively but the intermediate villages suffered a rate of 20%. In addition, he compares age distribution data in distant and intermediate villages showing a severe constriction in the 1-10 year age cohort among the intermediate villages. This elevated rate for intermediate villages is attributed to an active campaign by Salesian missionaries to draw Yanomamö villages nearer to the mission and inadequate health monitoring and treatment by missionaries in the context of an unnamed epidemic (or epidemics, Chagnon 1997: 249) that swept through the area. Although this demonstration is superficially persuasive it has several problems. There is no statistical tests of significance to demonstrate that the death rate differences are other than random. As mentioned, the epidemic is not named or even characterized and its source is unknown and what fraction such deaths contributed to the differences between death rates is not mentioned. Finally, the locations of the villages are not specified, nor is the factor of degree of contact clearly operationalized.

Independently of these problems, the study demonstrates, at least in microcosm, the devastating effects that epidemics caused by direct or indirect contact by outsiders has had and is consistent with findings elsewhere on the Yanomamö such as Neel et al.'s (1970) account of the 1968 measles epidemic. It also demonstrates the inherent dangers in attracting native peoples to the outposts of civilization even if it is believed to be in their best interests (Cowell 1973).

Conclusion

The Yanomamö suffer from extraordinary high disease loads as demonstrated by high mortality rates and short stature. This leads us to suspect that there is a synergetic relationship between high parasite loads (e.g., malaria) and chronic infections (e.g., hepatitis) that slows growth and ultimately reduces stature in adults. Short adults produce short children who are unable to mount adequate immune responses without compromising growth. It is also possible that chronic illness reduces adult economic productivity leading to lowered nutritional intake which increases mortality and slows growth.

There seems to be sufficient variation among Yanomamö in regards to stature and weight differences to attempt to untangle the relationship between disease, diet, and growth through new research. For example, lowland groups are approximately 8 centimeters taller than highland groups. If we were to compare the tallest Yanomamö lowland groups to other Amazonian ethnic groups in Figures 1 and 2 we find that they are of average height for Amazonian peoples. Our review of the literature on parasite load and disease incidence between highland and lowland groups does not indicate any clear differences. Even if such differences were detected they might not be revealing without additional data on intensity of infection, age and sex distributions, and season in which the measures were made. We would also need to know the degree to which a diseases is likely to reduce growth and how diseases interact in this process.

Dietary differences between highland and lowland groups may also be implicated as indicated by anthropometric and economic research. As discussed above, research by Hagen et al. (2001) that showed that skinfolds of children in a lowland group at the village of Cejal were similar to those found by Holmes in her highland research; and they were less than skinfold measurement taken in other lowland villages. The lowland village of Cejal had just suffered food shortages as a consequence of an El Niño weather condition. The other lowland villages where skinfold measurements were made operated under normal economic and dietary conditions. A reasonable interpretation of these findings suggests that highland groups are food stressed. Comparative ecological and economic research on highland and lowland groups elaborates on this possible dietary connection. Hames (1993) summarizes important contrasts between highland and lowland groups. Highland groups rely much more heavily on cultivated crops while lowland groups rely more heavily on food resources foraged through hunting, gathering, and fishing. In fact, lowland groups expend twice as much labor time in foraging activities as they do in horticulture. Plantains and manioc, staples of the Yanomamö diet, are notoriously deficient in protein and micronutrients (Gross, 1975), even though they are very productive calorie sources. It may be the case that lowland groups have a superior diet, especially protein intake and fatty acid intake, and this may account for their greater stature. There are at least two ways in which dietary factors may affect growth. On one hand, it may simply be that a better diet leads directly to enhanced growth or, more complexly, it may be that a better diet may counteract the stunting effects of chronic illness.

Regardless of the role that dietary differences may play in Yanomamö growth we believe we have amply documented that disease is a major problem that affects all Yanomamö. Many of the most mortal and debilitating illnesses are spread as a consequence of contact by non-Yanomamö. Some diseases such as measles and influenza periodically quickly sweep through the Yanomamö and then disappear. Clearly, regulation of outside contact and health monitoring can deter these diseases. But extremely serious diseases such as hepatitis, tuberculosis, and malaria are now embedded in the Yanomamö. Their persistence as a chronic feature of Yanomamö life no longer depends on reintroduction from outside sources.

It is clear that the governments of Brazil and Venezuela along with NGO's have a daunting task ahead of them. Many of the parasitic illness can be treated simply through Ivermectin but without environmental sanitation practices reinfection is guaranteed. Although there is a vaccine for HBV there is no cure and treatment to reduce its effects is expensive. At the same time, embedded cultural practices such a long-term breastfeeding, premastication of food, and the sharing of body piercing objects enhance its spread. The widely used BCG vaccine for tuberculosis, for unknown reasons, appears to have limited efficacy for the Yanomamö. For these reasons and many others any attempt to develop appropriate campaigns to reduce disease among the Yanomamö must be accompanied by scientific biomedical and anthropological research to provide health care workers with the most effective treatments and interventions possible.

Notes

[1]In this comparison we ignore Spielman et al. (1972) 18 village study because it contains a mixture of highland and lowland groups. Nevertheless, his mean stature measures are greater than any of the highland groups.

[2]Hetrazan is a medication that kills the microfilariae infecting the host. As it does so, however, the allergic response elicited by the dead parasites can be extreme; many may experience extreme itching and discomfort. In a few cases, anaphylaxis can result.

[3]Melancon (1982) using a stable population model arrives at a life expectancy at birth of 20.5 years for males and 22.9 years for females. We use his empirical life expectancy at birth to make it consistent with Early and Peters (2000) who do not use stable population models.

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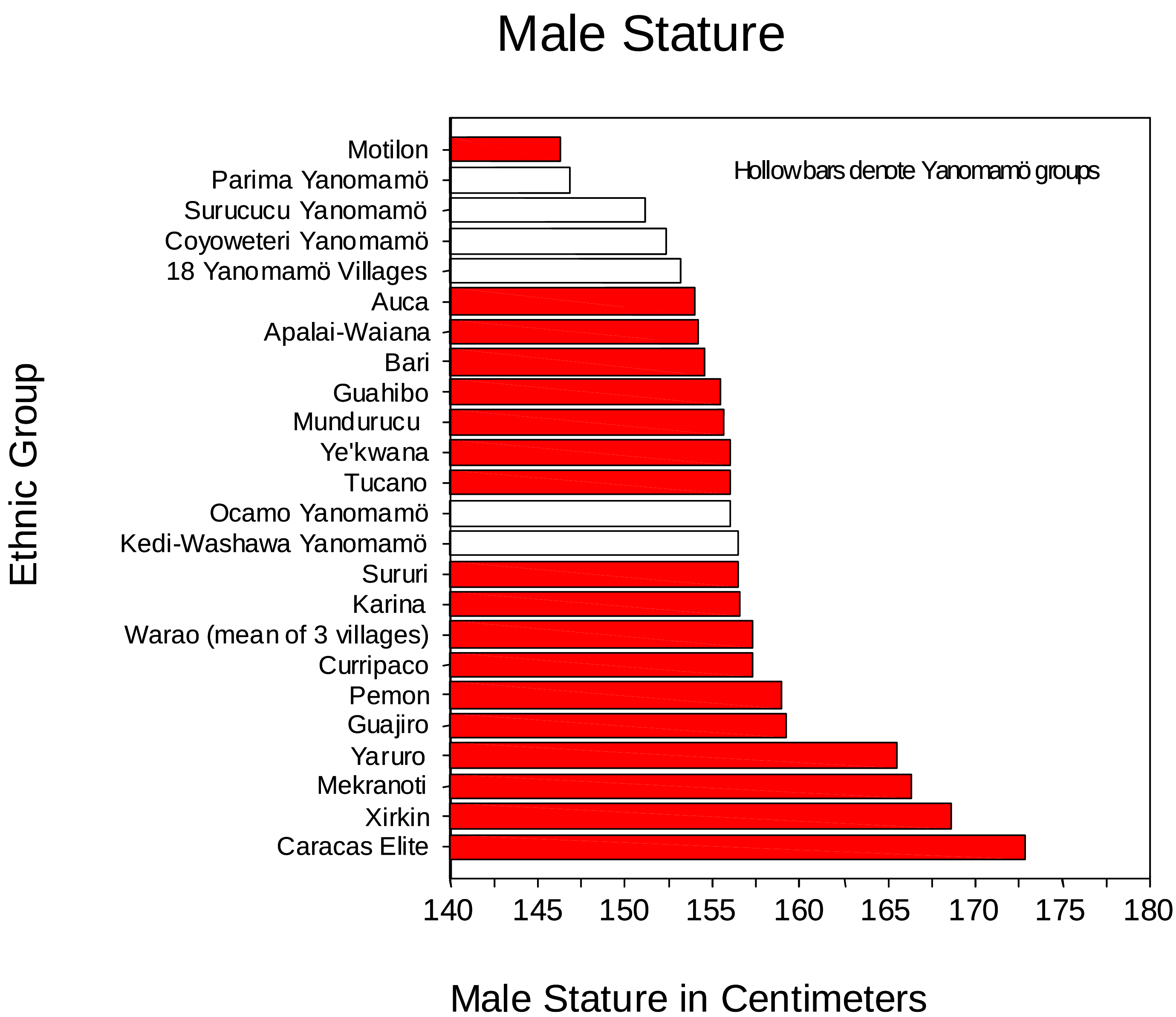

Male Stature
Hollow bars denote Yanomamö groups
Ethnic Group
Motilon
Parima Yanomamö
Surucucu Yanomamö
Coyoweteri Yanomamö
18 Yanomamö Villages
Auca
Apalai-Waiana
Bari
Guahibo
Mundurucu
Ye'kwana
Tucano
Ocamo Yanomamö
Kedi-Washawa Yanomamö
Sururi
Karina
Warao (mean of 3 villages)
Curripaco
Pemon
Guajiro
Yaruro
Mekranoti
Xirkin
Caracas Elite
140
145
150
155
160
165
170
175
180
Male Stature in Centimeters

Fig. 1

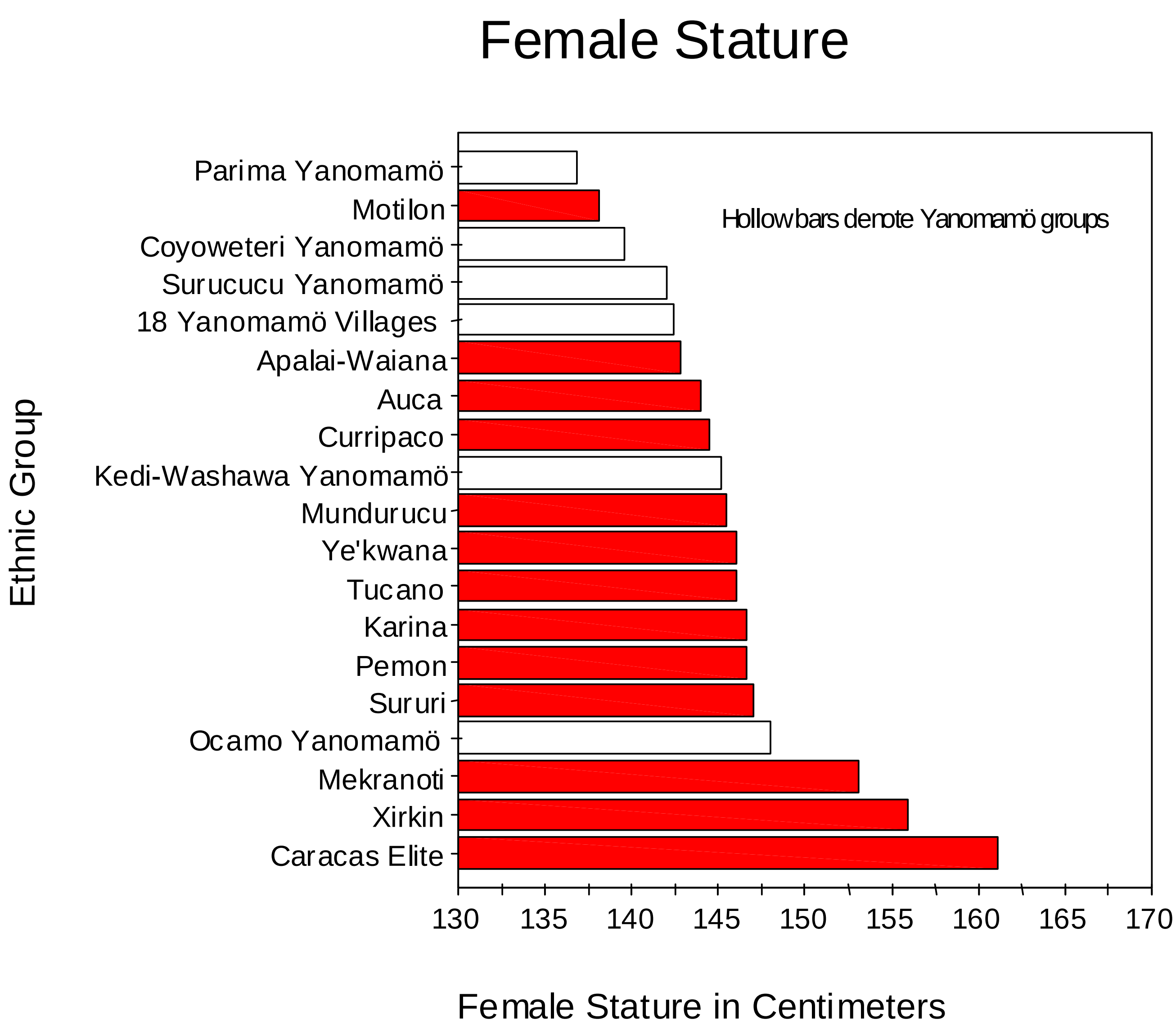

Female Stature
Hollow bars denote Yanomamö groups
Ethnic Group
Parima Yanomamö
Motilon
Coyoweteri Yanomamö
Surucucu Yanomamö
18 Yanomamö Villages
Apalai-Waiana
Auca
Curripaco
Kedi-Washawa Yanomamö
Mundurucu
Ye'kwana
Tucano
Karina
Pemon
Sururi
Ocamo Yanomamö
Mekranoti
Xirkin
Caracas Elite
130
135
140
145
150
155
160
165
170
Female Stature in Centimeters

Fig.2

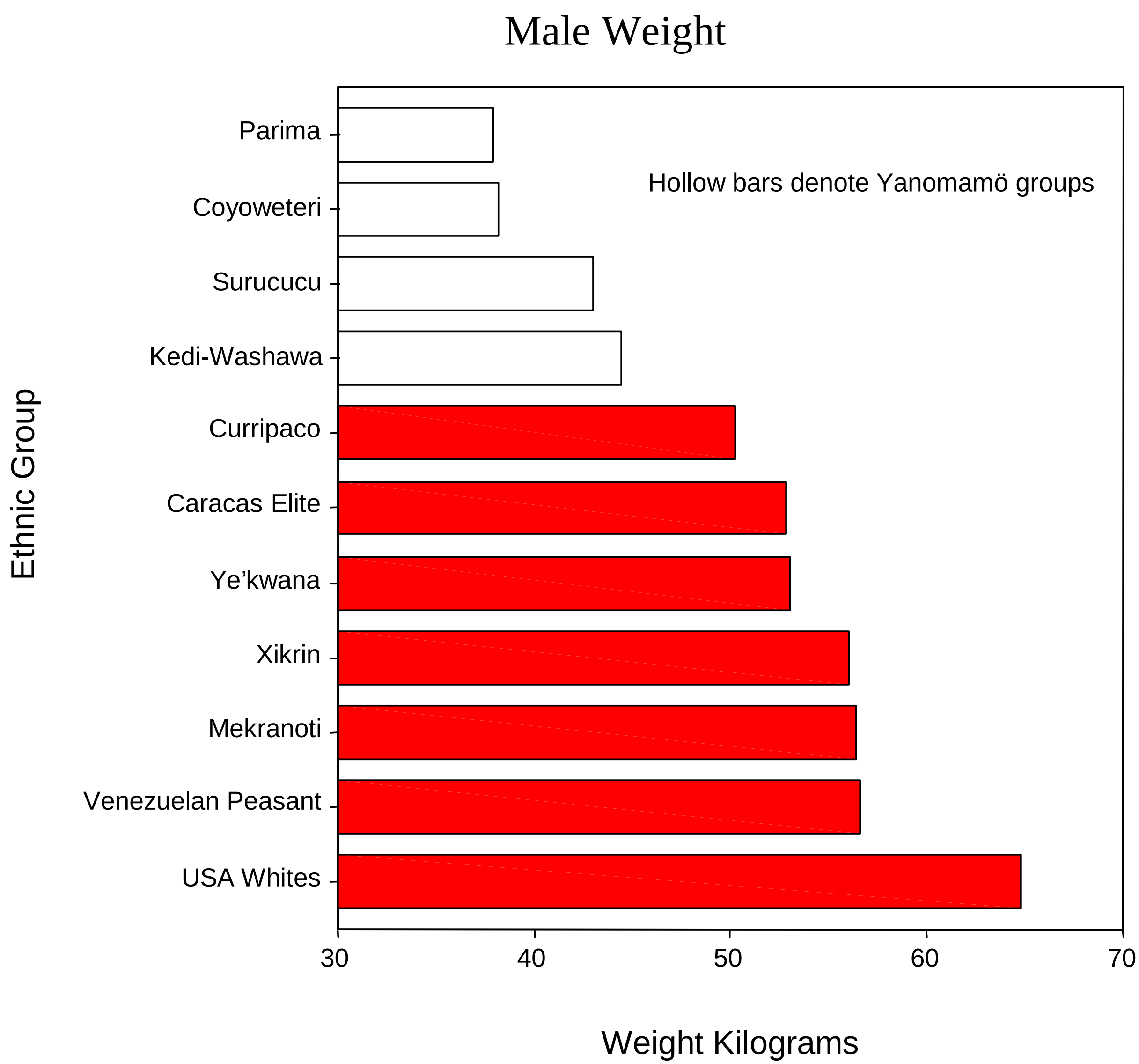

Male Weight
Hollow bars denote Yanomamö groups
Parima
Coyoweteri
Surucucu
Kedi-Washawa
Curripaco
Caracas Elite
Ye'kwana
Xikrin
Mekranoti
Venezuelan Peasant
USA Whites
Ethnic Group
30
40
50
60
70
Weight Kilograms

Fig. 3

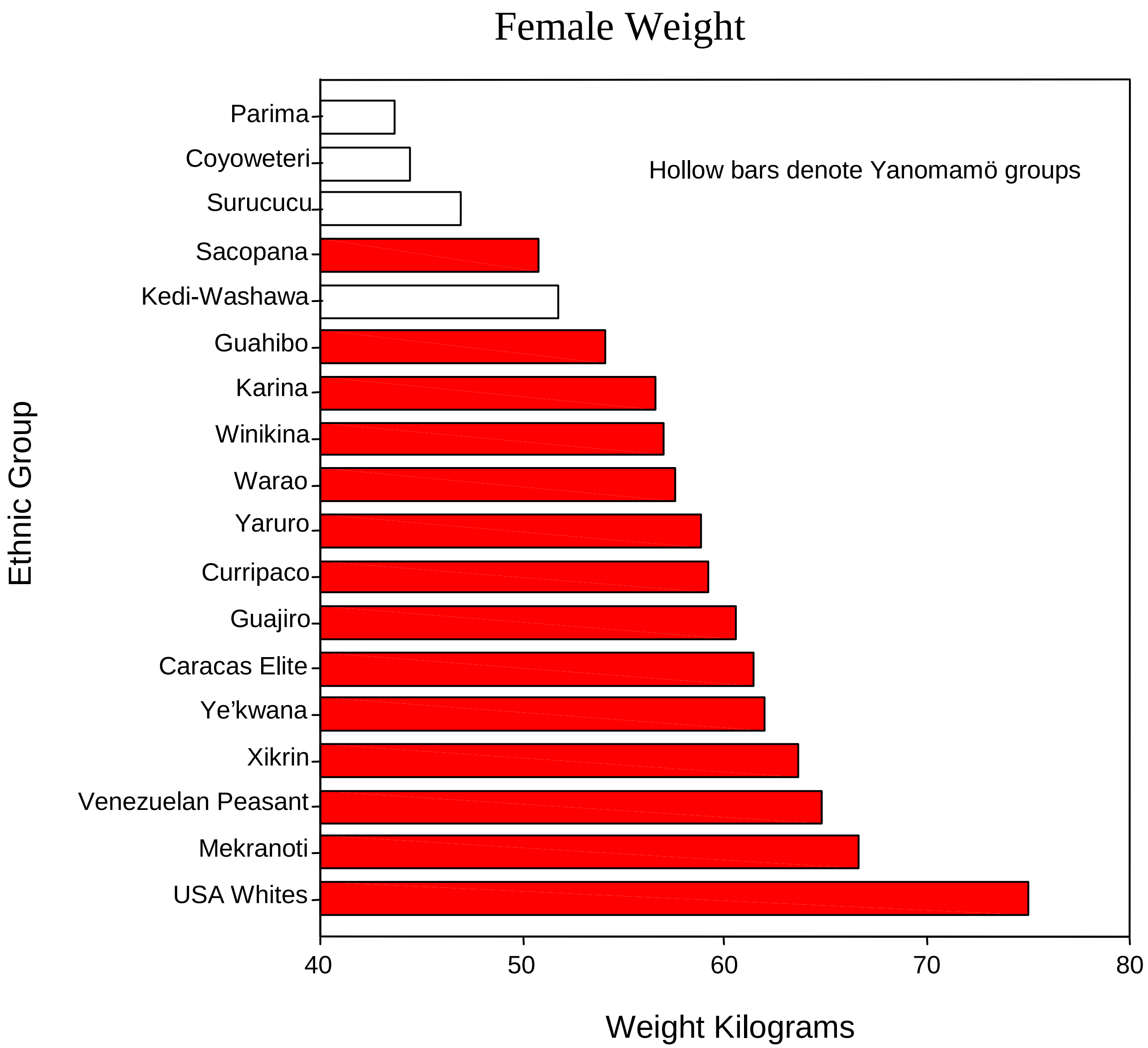

Female Weight
Hollow bars denote Yanomamö groups
Ethnic Group
Parima
Coyoweteri
Surucucu
Sacopana
Kedi-Washawa
Guahibo
Karina
Winikina
Warao
Yaruro
Curripaco
Guajiro
Caracas Elite
Ye'kwana
Xikrin
Venezuelan Peasant
Mekranoti
USA Whites
40
50
60
70
80
Weight Kilograms

Fig. 4

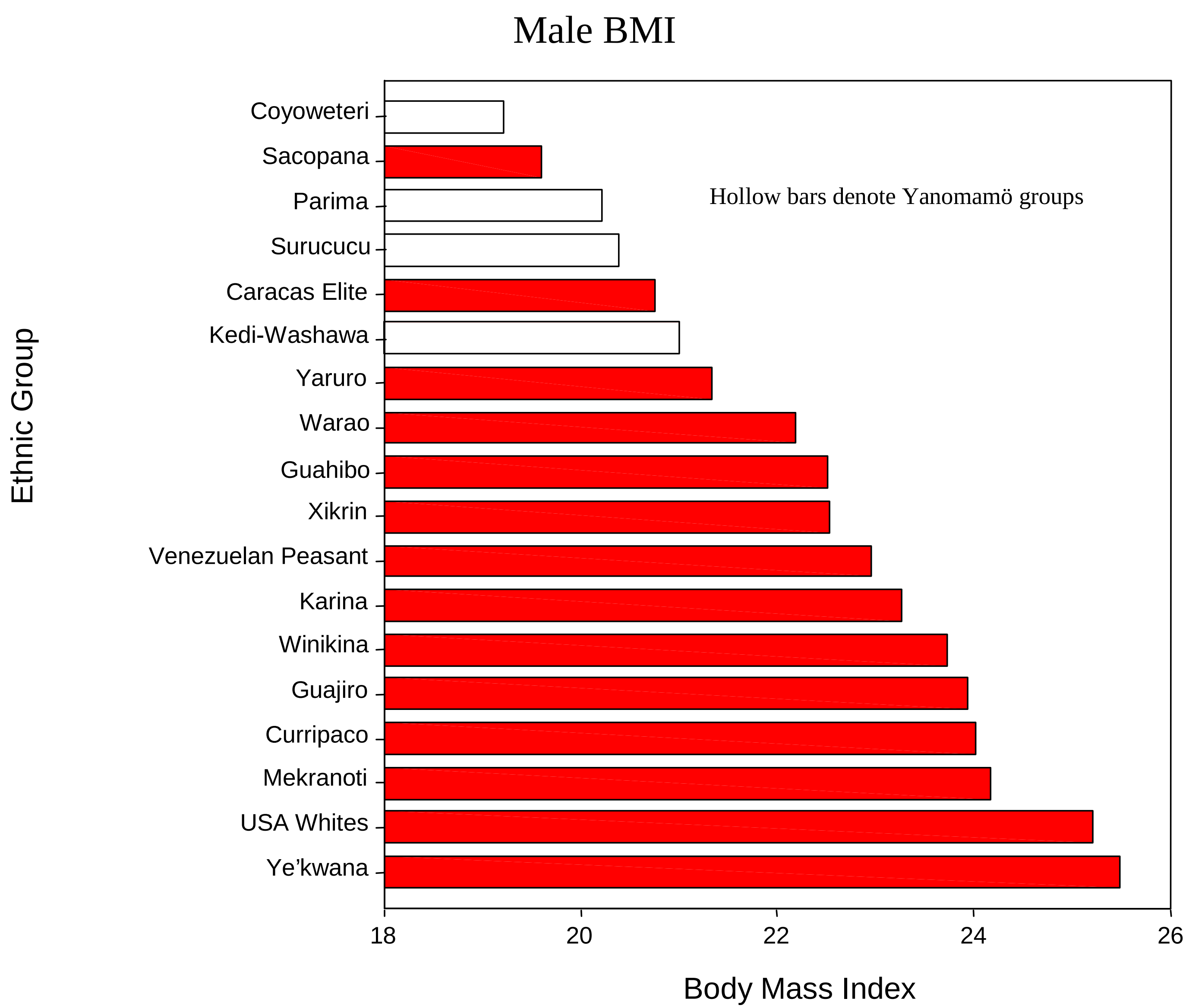
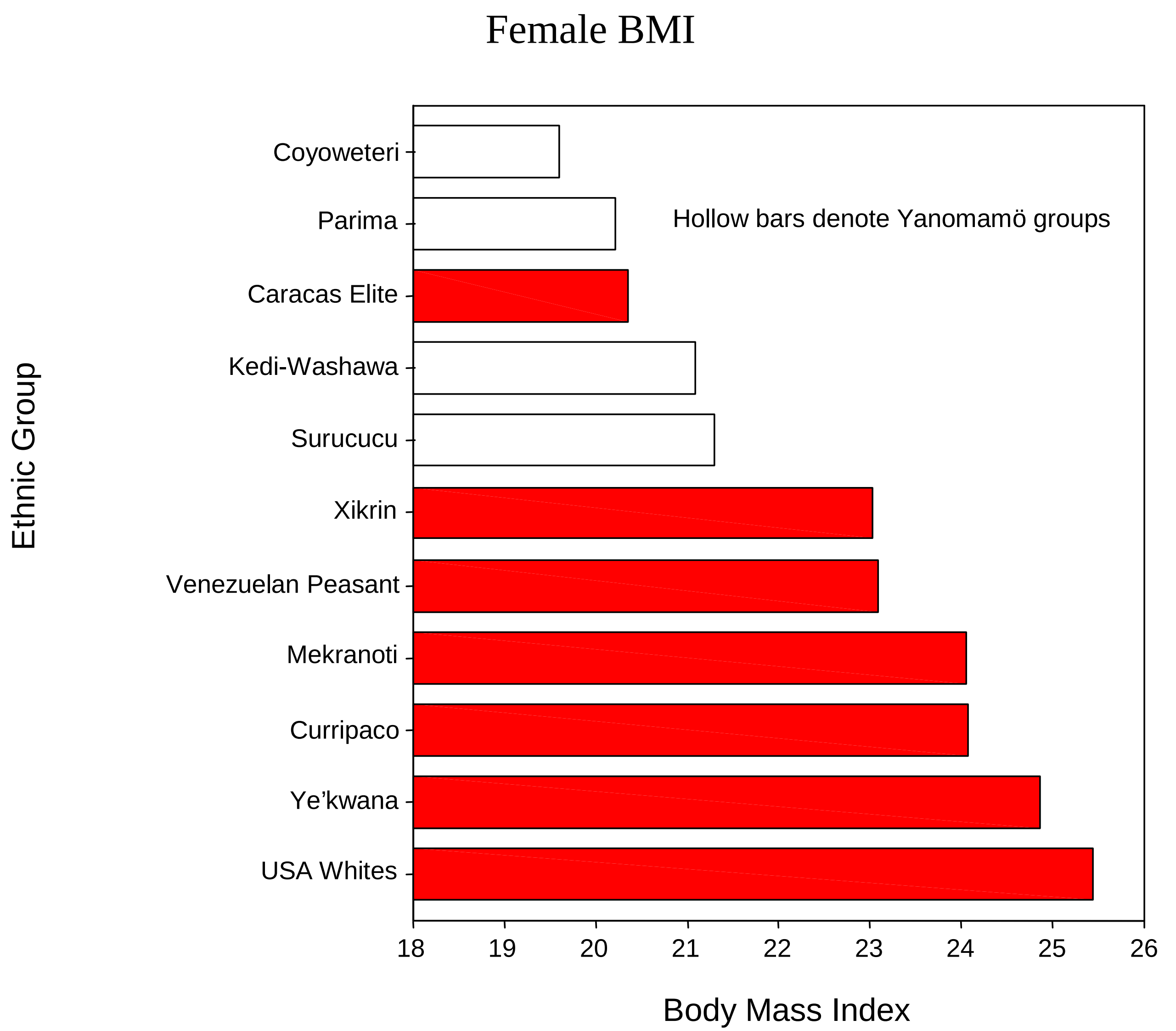

Male BMI
Hollow bars denote Yanomamö groups
Ethnic Group
Coyoweteri
Sacopana
Parima
Surucucu
Caracas Elite
Kedi-Washawa
Yaruro
Warao
Guahibo
Xikrin
Venezuelan Peasant
Karina
Winikina
Guajiro
Curripaco
Mekranoti
USA Whites
Ye’kwana
18
20
22
24
26
Body Mass Index

Fig. 5


Female BMI
Coyoweteri
Parima
Caracas Elite
Kedi-Washawa
Surucucu
Xikrin
Venezuelan Peasant
Mekranoti
Curripaco
Ye'kwana
USA Whites
Hollow bars denote Yanomamö groups
Ethnic Group
18
19
20
21
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23
24
25
26
Body Mass Index

Fig. 6

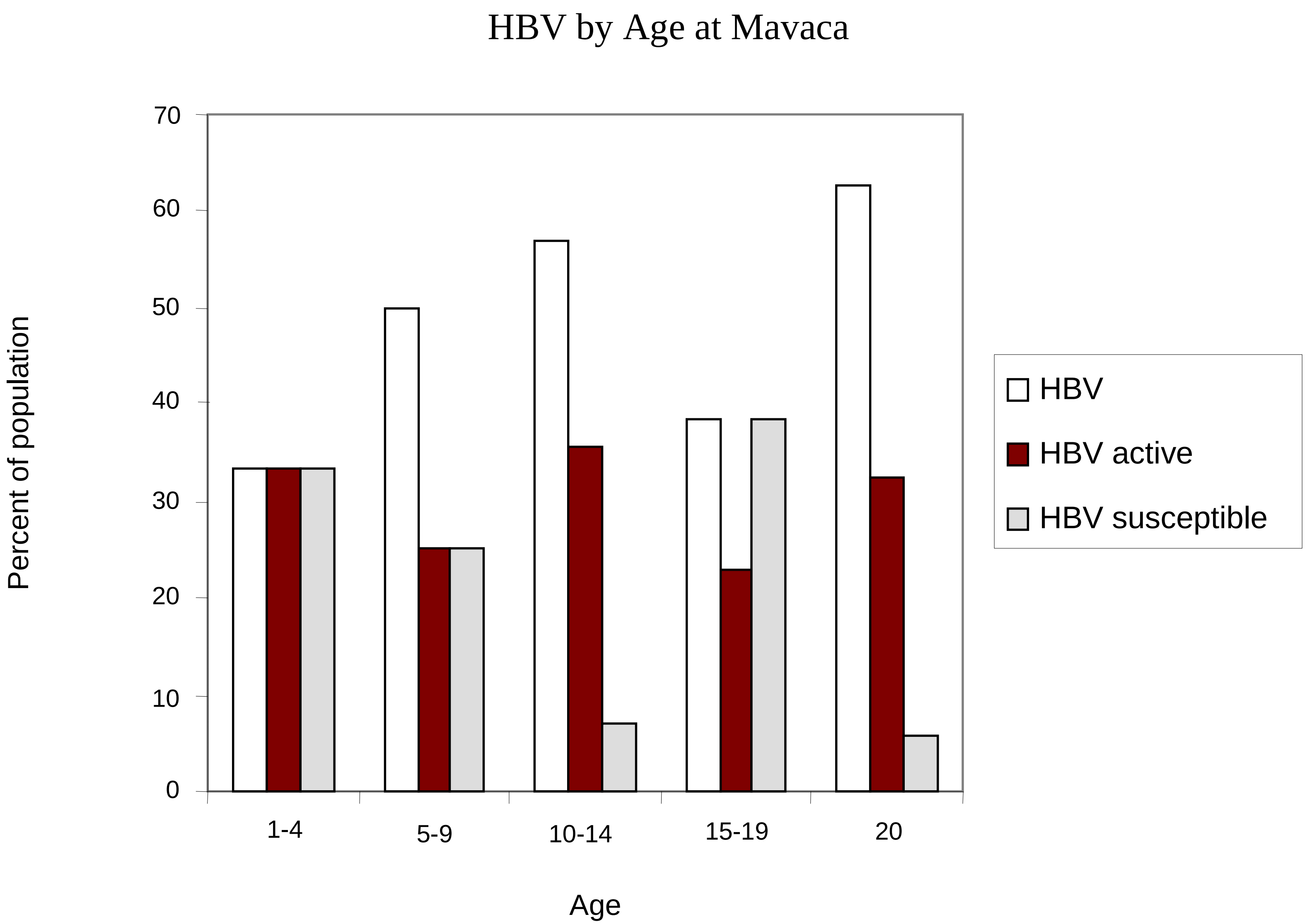

HBV by Age at Mavaca
70
60
50
40
30
20
10
0
Percent of population
1-4
5-9
10-14
15-19
20
Age
HBV
HBV active
HBV susceptible

Fig. 7

Malaria and Malaria Related Morbidity by Age at Mavaca

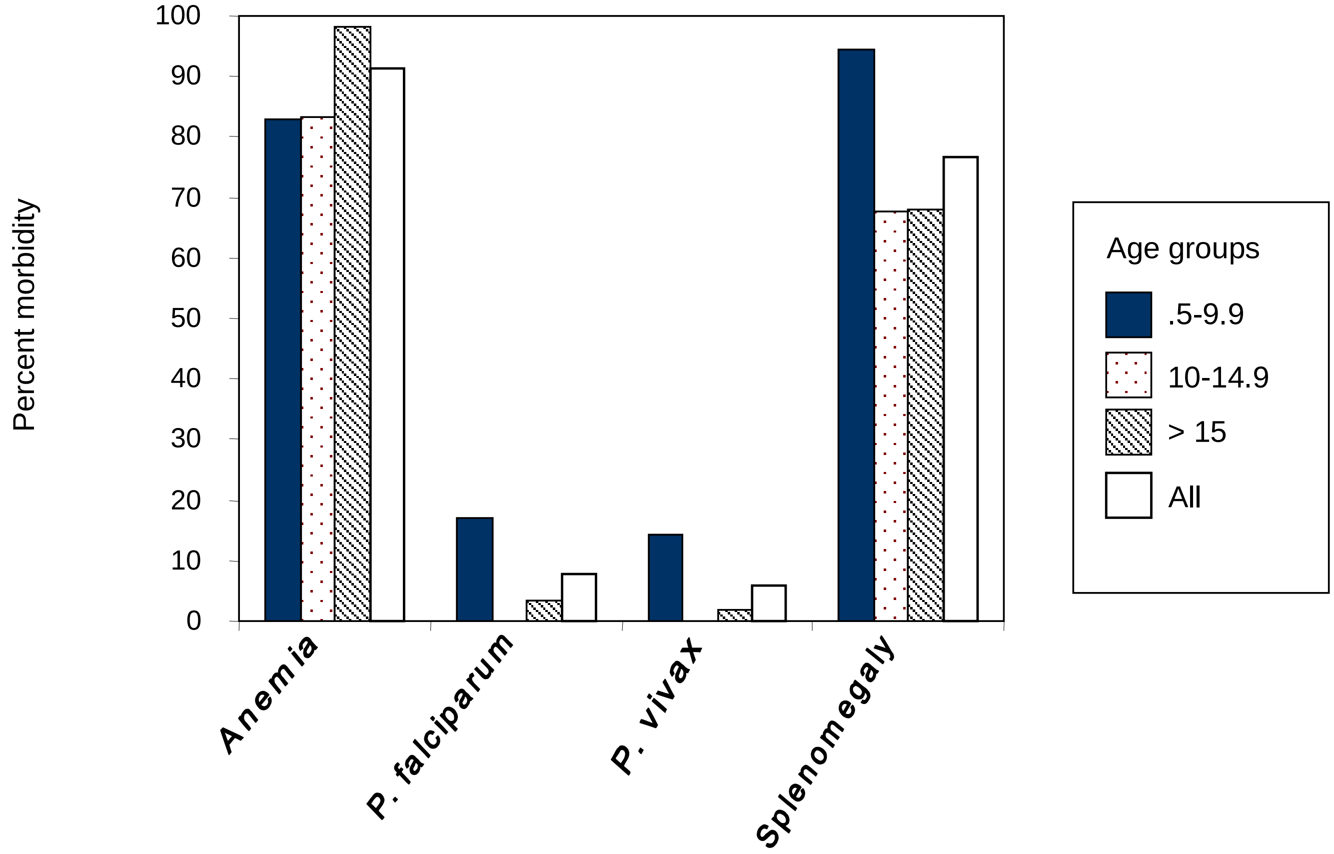
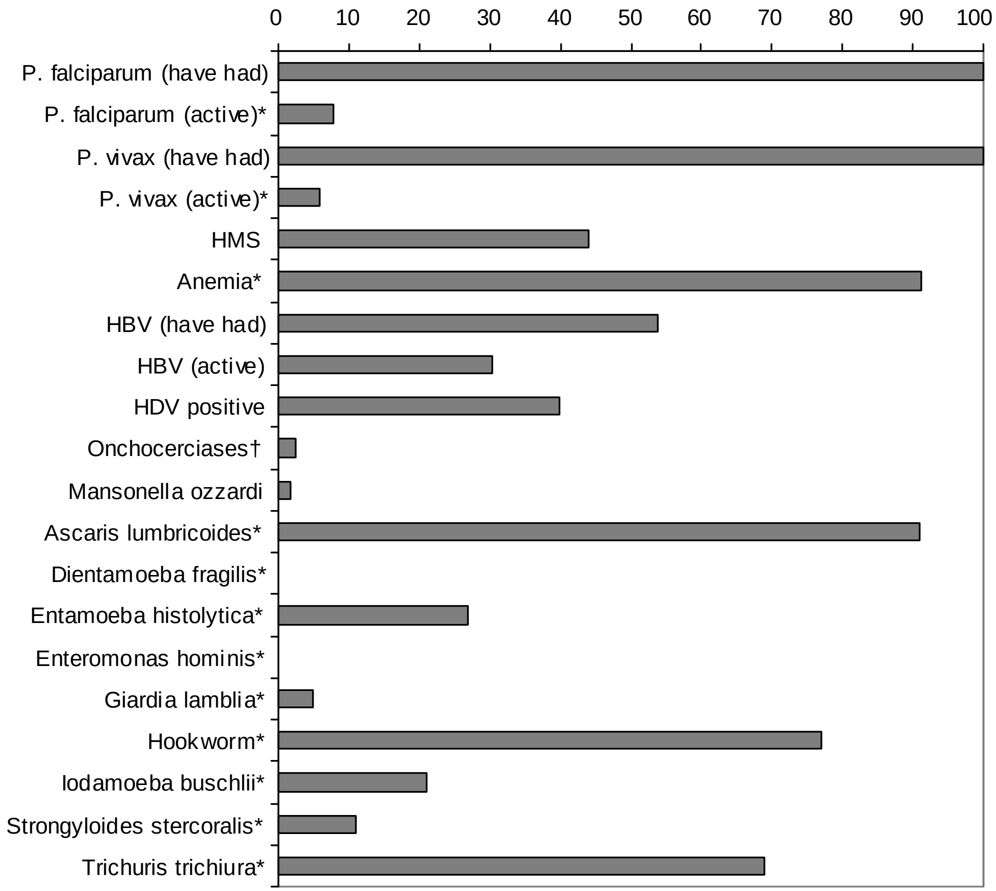


Fig. 8

Disease Profile, Mavaca* and Ocamo† Villages



Note: diseases without * or † indicate combined mean incidence for Mavaca and Ocamo.

Fig. 9

Distribution of parasite per person

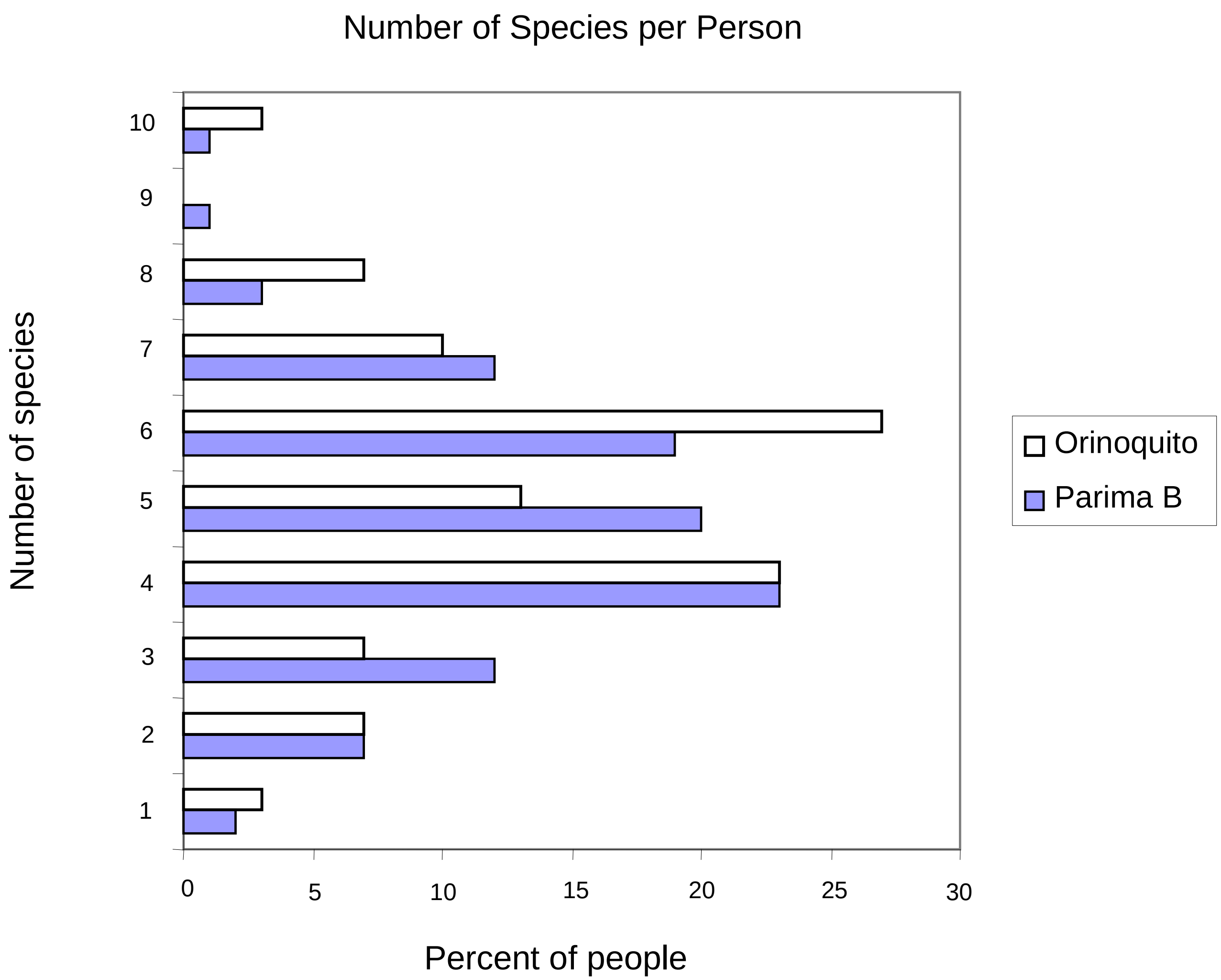


Fig. 10

Parasite loads of mission and lightly contacted villages

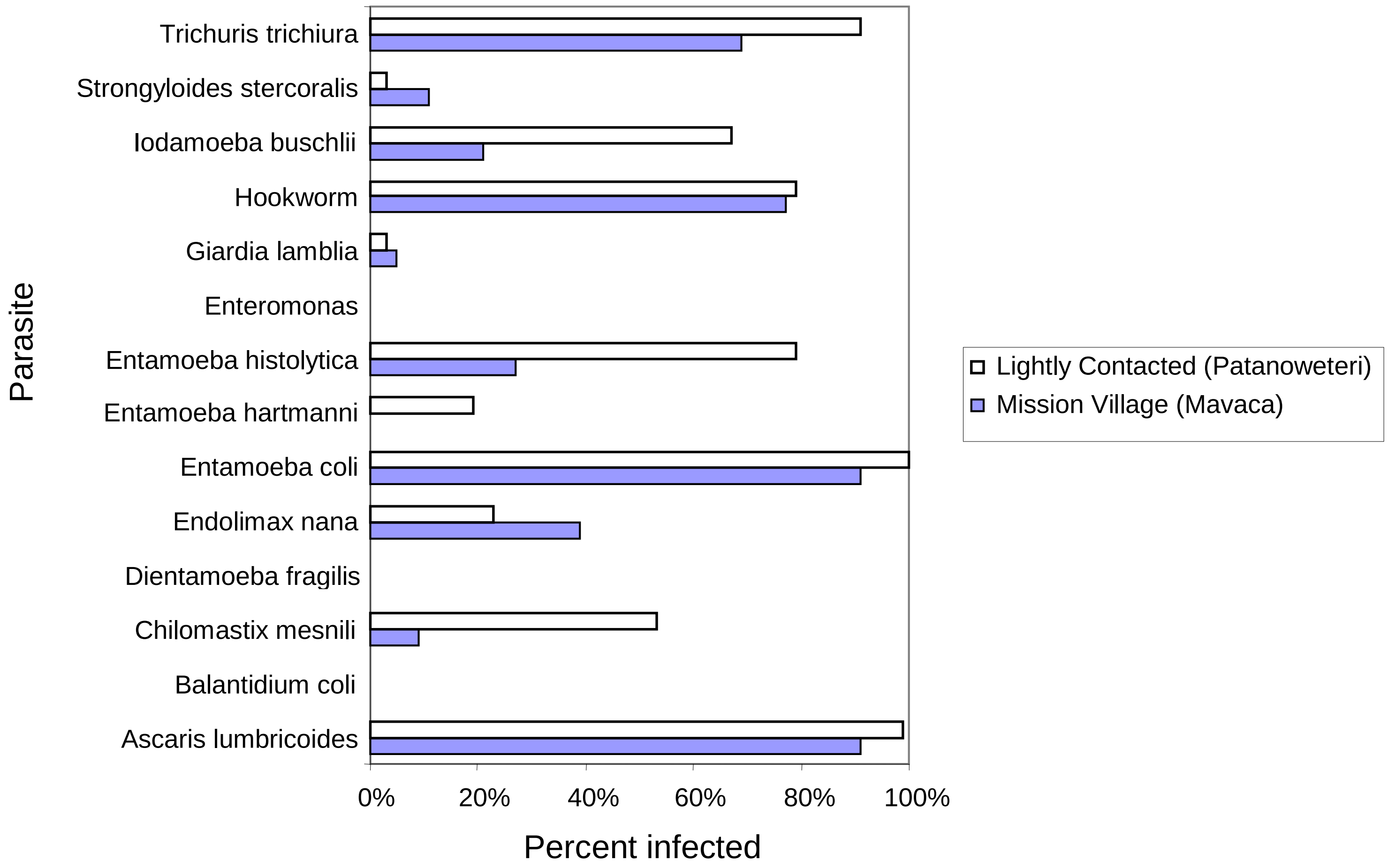
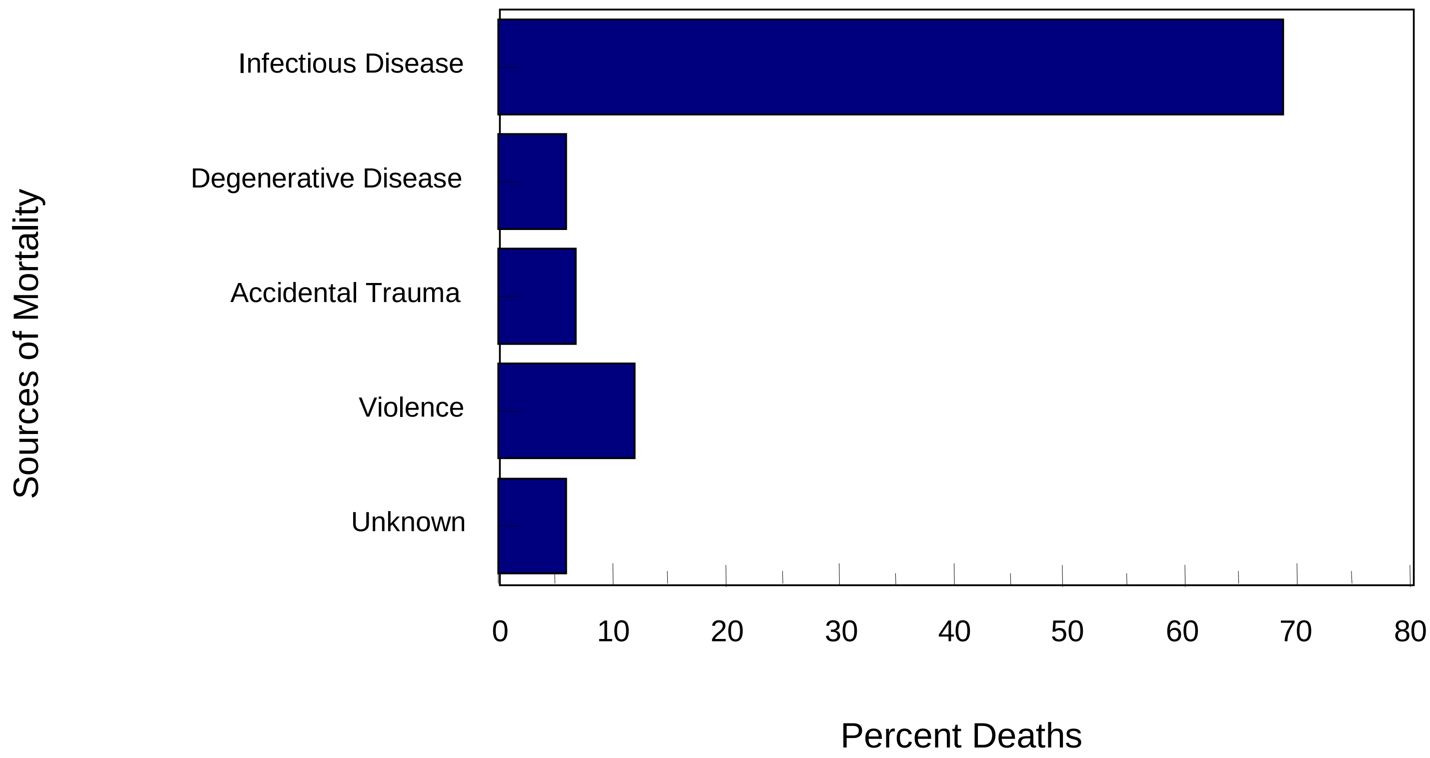


Fig. 11

Causes of Mortality among the Mavaca Yanomamö



From T. Melancon, 1982, "Marriage and Reproduction among the Yanomamö Indians of Venezuela"
Thesis, Pennsylvania State University
Anthropology Department

Fig. 12

Causes of Mortality among the Xiliana Yanomamö

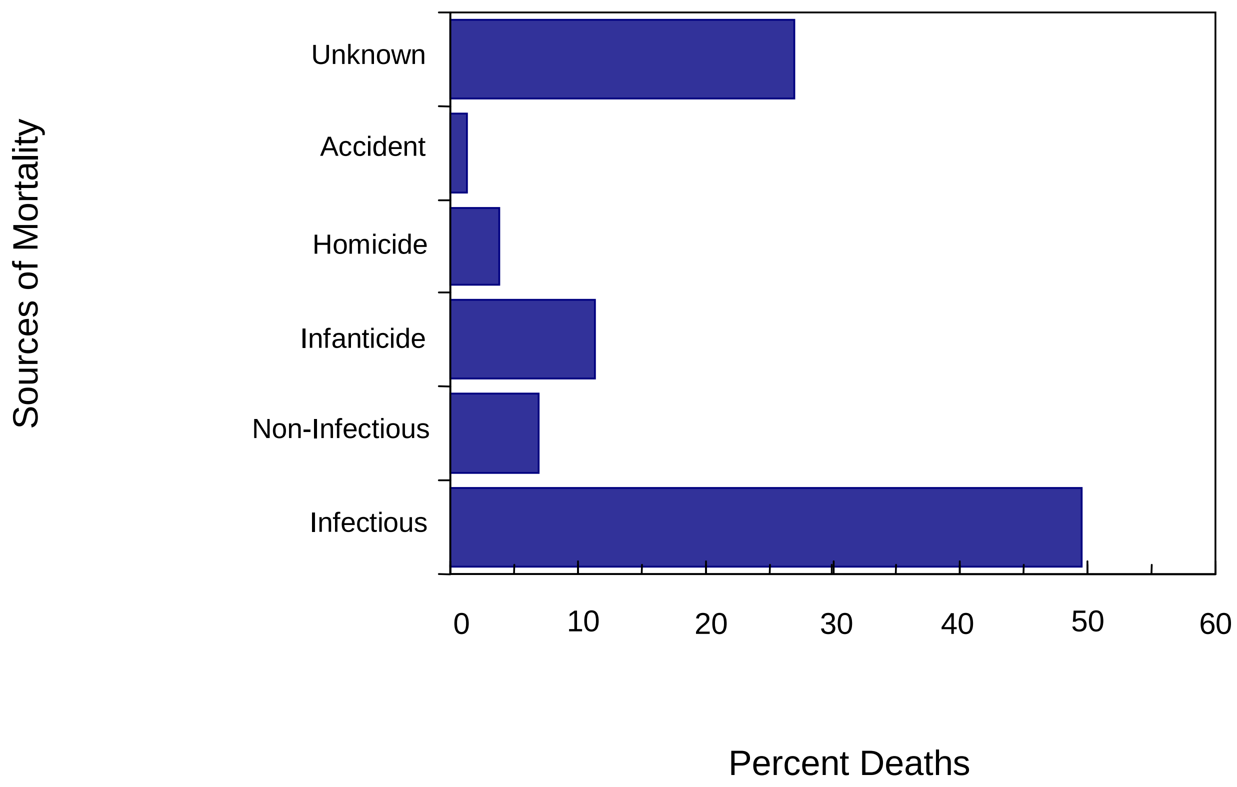


Fig. 13

Modified From Early and Peters (2000), Page 210, Table 19.6

Xiliana Mortality through Time

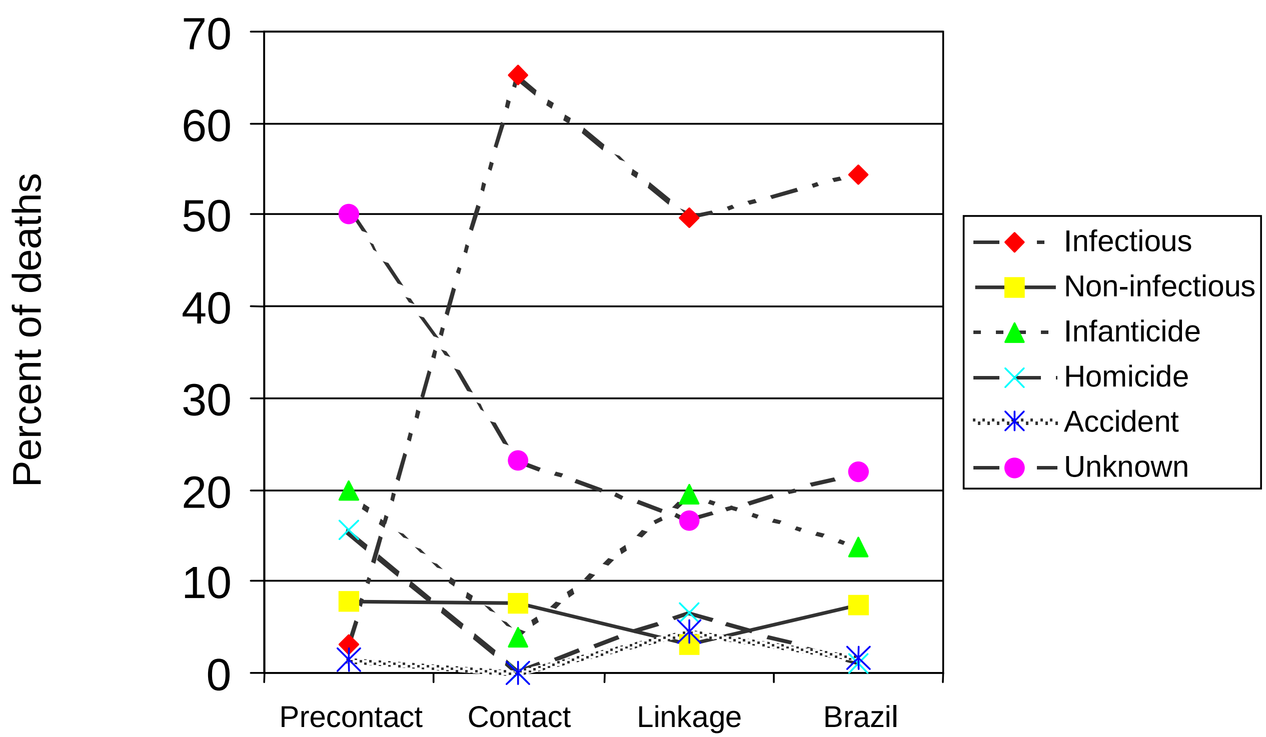


Fig. 14