unstable slip reaches a maximum near $\zeta = 10$. Other investigators (*7, 9*) have inferred that fault slip reaches a maximum of 4 to 8 m at $\zeta = 2$ km before declining toward the surface.

A similar updip migration of fault slip has been inferred by Thatcher (*6*) who modeled fault slip with edge dislocations. That model predicts increasing preseismic subsidence south of the fault trace unless a decreasing fault dip with depth is also proposed. Several other studies favor an increasing dip with depth (*7, 9–11*). By comparison, the instability model uplift agrees in sign with the observed preseismic uplift south of the fault trace. In addition, such dislocation models impose the amount and distribution of fault slip at constant remote (boundary condition) stress, whereas fault slip in the instability model is part of the solution and remote stresses increase and then decrease prior to instability.

Scaling the friction law, Hooke's law, and the equilibrium equations by a representative length ζ_0, stress S, and displacement a shows that mechanically similar solutions are characterized by two dimensionless variables $\mu' = \mu a/S\zeta_0$ and $b' = b/\zeta_0$ for fixed plate geometry and fault dip. Thus doubling μ has the same effect on stability as halving S. The results (Fig. 2) correspond to $\mu' = 0.3$, $b' = 1$. As in the strike-slip fault models (*2, 3*), increasing μ' or decreasing b' causes unstable deformation to be replaced by temporarily rapid quasi-static deformation. The boundary between unstable and stable deformation is near $\mu' = 2$ for $b' = 1$.

Uplift profiles for stable cases differ from those for unstable cases by being broader in space and showing more gradual changes with increasing U. The origin of the differences is readily seen in view of the fact that increasing $\mu' = \mu a/S\zeta_0$ inhibits instability. For example, μ' might be increased by a higher μ. A less flexible crust will tend to smooth deformation gradients.

I made additional simulations to determine the effect of varying the dip, μ', and b' in turn. In all the simulations, I used dimensionless variables and chose values of ζ_0 and $S\zeta_0/\mu$ to match the amplitude and position of the observed 1969 profile. Increasing the dip to 40° makes the epicentral uplift profiles slightly more peaked but increases by about 50 percent the uplift jump at the fault trace. Setting $\mu' = 1$ increases the uplift jump at the fault two to three times, but unstable uplift is about one-half that for $\mu = 0.3$. With $b' = 2$, the overall fit is slightly better than with $b' = 1$, but ζ_0 must be increased to 20 km, giving a distance from the fault trace to the epicenter of 16 km. For fixed dip, μ', and b', halving $\Delta U/\Delta t$ decreases the 1965 and 1968 uplifts by about 1 cm. The quantity $\Delta U/\Delta t$ is poorly constrained by field observations.

The changes in elevation shown in Fig. 2a are part of the much broader (~ 150 km wide) Palmdale uplift, which started in 1960 (*13*). The Palmdale uplift is qualitatively consistent with uplift expected from slip-softening on a northeast-dipping thrust fault of comparable space scale, part of which may have slipped to cause the San Fernando earthquake. The temporarily rapid but aseismic Palmdale uplift episodes may correspond to inertially stable deformation modes; the San Fernando earthquake would correspond to a smaller-scale unstable mode.

If the instability model assumptions are generally valid, one should expect accelerating precursory fault slip, mainly near the earthquake focus. Enhanced fault slip rates may be large enough to produce observable deformation changes at the free surface in the vicinity of the epicenter and ground breakage at the fault trace. Because gound deformation is theoretically different between unstable and stable models, an examination of the observations may make it possible to estimate the probability of earthquake instability. However, too few observations have been made thus far to permit such an attempt.

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Protein Deficiency and Tribal Warfare in Amazonia: New Data

Abstract. *Increasing numbers of anthropological studies about native Amazonian warfare and demographic practices attempt to explain these phenomena as competition over or a response to scarce game animals and other sources of high-quality protein. Recently completed field research among the Yąnomamö Indians living at the Venezuela-Brazil border indicates that their protein intake is comparable to that found in highly developed industrialized nations and as much as 200 percent more than many nutritional authorities recommend as daily allowances. Recent data on other Amazonian tribes likewise fails to indicate a correlation between protein intake and intensity of warfare patterns.*

This report summarizes recently collected data on protein consumption among the Yąnomamö, a tribe of Tropical Forest Indians living at the Venezuelan-Brazilian border. While the data contribute to a more complete understanding of the nutritional status of the Yąnomamö, who have been the subject of extensive biomedical studies (*1*), our main objective is directed toward the growing tendency evident among exponents of cultural ecological theories to assume that Tropical Forest Indians subsist on a substandard diet that is deficient in high-quality protein. The Yąnomamö Indians constitute an important example of the possible relationship between protein consumption, warfare, and demographic practices such as infanticide and male-female dominance relationships. We have previously expressed our doubt that a protein shortage exists and have questioned the arguments that a protein shortage could adequately explain the complex relationships between demographic patterns, warfare, and social organization in this society (*2, 3*).

In a historical sense, the current anthropological interest in protein consumption among Amazonian tribes represents a specific component in the more general tendency for U.S. anthropologists to attempt to explain cultural forms of Amazonia by invoking environmental or ecological factors that are alleged to limit population growth, community size, and cultural complexity. Since the 1950's, a prevailing explanatory theme held that the deficient nature of the tropical forest soil accounted for the im-

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Table 1. Yąnomamö animal protein consumption.

Item	Fishing	Hunting	Fishing and hunting combined
Number of days sampled	60	216	
Kilograms taken	228.5*	2179†	
Kilograms edible portion	182.4	1307.4	
Bulk grams per capita per day	87.1	173.0	260
Bulk grams per capita per day, adult standard	125.4	250.0	375
Grams protein per capita per day	17.4	34.7	52
Grams protein per capita per day adult standard	25.1	50.3	75

*Fish. † Game.

permanence of native settlements, their relatively small size, and reasons why formerly more-advanced societies, when they moved into the Amazon Basin, devolved to a lower level of cultural complexity (*4*). That set of hypotheses was effectively challenged and shown to be grossly misleading by Carneiro, who recorded native garden size, economic productivity, fallow cycles, and village history (*5*). He demonstrated that, whatever else might be cited as limiting factors to village permanence and cultural development, the poor or limited character of Amazonian soils and the nature of slash-and-burn cultivation was not a very persuasive explanation (*5*). Since Carneiro's insightful empirical test of the soil poverty hypothesis, very few anthropologists hazard explanations of native Amazonian cultural forms and cultural limitations by invoking a soil-depletion or soil-poverty argument.

More recent cultural-ecological arguments, beginning in the early 1970's, have tended to emphasize protein as a major limiting resource in Amazonia (*6*–*9*). But very little data on nutrition or production and consumption exist; for groups like the Yąnomamö, extensive biomedical data cast serious doubts on suggestions that their nutritional status is precarious. Our earlier multidisciplinary work with a team of medical scientists revealed that the Yąnomamö are in good physical condition, are well nourished by world standards, and show no signs of protein deficiency (*1*). Moreover, our ethnographic reports (*2, 3, 10*) give little support to the notion that material resources shortages exist in the population and question whether the Yąnomamö are actually fighting over game animal reserves (*2, 3*). Despite these data, prominent exponents of the protein-deficiency hypothesis continued to argue that the Yąnomamö were suffering from a shortage of protein, apparently because the theory suggested that this should be the case. As one of the observers (*7*) summarized the situation, allegedly based on our published data,

> The Yąnomamö have "eaten the forest"—not its trees, but its animals—and they are suffering the consequences in terms of increased warfare, treachery, and infanticide, and a brutal sex life [p. 102] . . . [They] have already degraded the carrying capacity of their habitat [p. 105].

This interpretation of the then-available facts was not warranted, and in our attempts to resolve similar convictions (*8, 9*) among a growing number of U.S. anthropologists that our previous field research had not adequately addressed the issue of a possible protein shortage, we met, in 1975, with a number of these colleagues on the eve of the 15-month field project that we were then initiating and agreed to collect the data considered by the group to be most relevant. We now report of some of the findings of that field research.

Quantitative data collected by one of us (R.H.) on Yąnomamö fish and game capture from 1975 through 1976 (13 months of observation) provide evidence that the protein intake of the Yąnomamö is more than adequate, and that it is higher than all but two of the Tropical Forest cultures surveyed by Gross (*9*). Hames' study was conducted in the Yąnomamö village of Toropo-teri, a small group of 35 individuals who live along the lower course of the Padamo River, a large affluent of the Upper Orinoco. Historical records indicate that the Padamo basin has been inhabited continuously for at least 200 years by both Yąnomamö and Ye'kwana Indians (*11*), the latter group being an unrelated Carib-speaking tribe. At present, this area of the Padamo River basin contains 450 Yąnomamö (seven villages) and 140 Ye'kwana (three villages) Indians, exploiting an area of approximately 850 square miles; that is, the population density is slightly less than one person per square mile, a figure comparable to but somewhat higher than the densities found in other parts of the Yąnomamö region (*2*).

Over the 13-month observation period, the game-capture study lasted 216 days and the fish-capture study lasted 60 days. The sampling periods were designed to cover all seasonal fluctuations in hunting and fishing opportunities. Deep-forest hunting is the single most important source of high-quality protein for the Yąnomamö. While the traditional repertory of weapons and methods includes the lance, clubs, fires, smoke, and the use of dogs, 94 percent of all animals killed during this study were taken with the bow and arrow. During the sample period, the Yąnomamö hunters killed 2179 kg of animals, the yield thus being 250 g of edible meat, or 50.3 g of animal protein per capita per day. These figures are based on an adult-standard consumption rate that adjusts for age and sex differences as outlined by Taylor and Pye (*12*).

Fishing occupies much less of the subsistence time-budget and the yields from this source are correspondingly lower when compared to hunting. Most fish are now taken by hook and line (a method introduced by Westerners). Native poisons (*13*) are sometimes used, in connection with damming up small creeks and collecting, with baskets, the stunned fish as they rise to the surface. The bow and arrow are also occasionally used in quiet, deep pools; and periodically, large amounts of fish are obtained by hand at the end of the dry season when large concentrations of fish are stranded in slowly dessicating ponds left behind as the rivers gradually recede. During the 60-day sampling period, 228.5 kg of fish were taken (mostly by hook and line), yielding 125 g of edible fish, or 25 g of protein per capita per day.

Table 1 summarizes the data used in arriving at these estimates and how they were calculated. The estimates of protein consumption were not based on an actual dietary survey, but on the amount of fish and game actually brought into the village during the sampling periods. All data, therefore, refer only to game and fish butchered and prepared in the village for consumption there; the data do not include what the hunters ate while on extended or overnight hunting forays. These figures do not include the protein derived from insects (caterpillars, grubs, termites, ants, and bee larvae) exploited by the Yąnomamö, the protein that comes from crustaceans such as crabs (which are abundant in some regions during particular seasons), or protein from frogs and tadpoles. The figures in Table 1, therefore, represent somewhat less than the actual protein intake among the Yąnomamö and should be regarded as a minimal estimate of the actual consumption. Similar studies of Yąnomamö protein consumption (*14, 15*) in other regions of the tribe suggest that these sources amount to at least another 5 percent of animal protein in the diet. Gross' estimates (*9*) of protein consumption for eight Tropical Forest societies differ in one crucial methodological aspect compared to ours. He claimed that, since pertinent data on the age and sex composition of the Indian populations for which he estimated protein consumption were not available, he had to express his per capita protein consumption estimates without normalizing them for age and sex variables (*16*). Consequently, in his estimates, nursing infants and children were given the same consumption status as full adults, resulting in the impression that protein consumption is much lower than it actually is. We have decided that the best way to calculate our own estimates of protein consumption would be on an adult standard basis (*12*), which gives a truer representation of actual protein consumption. However, for comparative purposes, we provide summaries using both methods to permit comparisons with the data summarized by Gross.

Table 2. Animal-derived protein consumption in some Amazonian societies.

Society	Per capita	Per adult	Source*
Jívaro	79.3	(103.0)	(*20*)
Jívaro	84.4	(116.2)	(*21*)
Yąnomamö	29.7	36	(*15*)
Yąnomamö	51.9	77	(*15*)
Yąnomamö	52	75	(New data)
Wayana	(77.7)	108	(*22*)
Boni	(82)	114	(*22*)
Mamainde	26.3	(36.2)	(*23*)
Bari	86.8	(119.5)	(*24*)
Ye'kwana	77.3	95.5	(*25*)
Siona-Secoya	64.3	96.7	(*26*)
Average	64.6	88.8	

*Some of the data from the sources presented were incomplete so estimations had to be made. The data collected by Hurault (*22*) and Vickers (*26*) is for total protein consumption (plant and animal sources combined). In order to estimate what fraction of protein consumption derived from animal sources alone we subtracted 20 g from their totals because full-scale dietary surveys by Ross (*21*) and Lizot (*15*) indicate that from 15.6 to 23.3 g of protein derive from plant sources. Protein consumption figures marked by parentheses indicate that either data on per capita or per adult animal protein consumption was lacking. In order to estimate these figures we used two conversion factors: where a society's per capita consumption was absent we multiplied per adult consumption by 0.7; where per adult consumption was lacking we multiplied that society's per capita consumption by 1.3. These conversion factors were derived from the above studies that did contain both figures and represents the averaged ratio of per capita to per adult and per adult to per capita consumption.

According to the nutritionists' recommendations cited by Gross, adequate protein intake for normal adults ranges from 30 to 50 g per capita per day. By this standard, our data indicate that Yąnomamö protein consumption (75 g per capita per day) is 250 percent higher than the lowest estimated requirement and 150 percent higher than the highest estimated requirement. This would put them on a par with national populations from the world's most developed countries, and, indeed, indicates that they consume more animal protein per capita per day than most of the world's populations whose protein consumption is summarized in Harris' own work (*8*). But, these absolute figures underestimate the degree of adequacy of Yąnomamö protein intake, since the above suggested requirements are based on the assumption that individuals fall within the normal size range of most contemporary populations. The Yąnomamö, however, are among the world's smallest people; the average stature for adult males is just 5 feet (153.2 cm) and for adult females, 4 feet 8 inches (142.3 cm) (*17*). They are also slightly built people, averaging approximately 110 pounds (50 kg) for adult males and approximately 90 pounds (42 kg) for females (*18*). If we adopt the standard recommended by the National Research Council (*19*), which suggests a generous intake of mixed proteins of 0.8 g per kilogram of body weight per day, an adult Yąnomamö male would require 40 g of mixed protein per day. Our data clearly show that 75 g of animal protein alone places them well beyond the generous level recommended by the National Research Council; if their protein intake from plant foods, insects, and other sources not included in this study were added, they would exceed the requirements by an even larger margin.

From the protein consumption data presented above, Harris' general hypothesis about the relation between protein availability and warfare practices (*7*) would permit the prediction that the Yąnomamö of the Padamo River basin should be pacific and unlikely to engage in warfare: they have very substantial amounts of game and fish protein in their diets. However, the data on mortality due to violence, the history of warfare between villages, the alliance patterns, and the settlement patterns show that this is not the case. The Padamo Yąnomamö do not differ significantly in these respects from the Shamatari/Namoweiteri Yąnomamö whom we described earlier (*2, 3, 10*). During the field study (by R. H.), for example, the male members of Toropo-teri participated in an ambush at the nearby village of Yamaho-teri, their friends and allies. The two groups invited the members of a distant village, Kobariwä-teri (4½ days' walk away), to a feast at Yamaho-teri. When the unsuspecting visitors arrived, they were treacherously attacked by their hosts and five men were killed. Several weeks later, the men from Toropo-teri and Yamaho-teri, supported by additional allies, made the arduous trip to Kobariwäteri to attack them again. This pattern is found over much of the tribe (*2, 3, 10*).

Yąnomamö warfare practices raise important doubts about the accuracy of predictions about warfare and relative abundance of protein in the Harris model; that is, that warfare is, in effect, competition for locally scarce resources like protein. But a very common feature of Yąnomamö warfare, inexplicable in these terms, is the fact that the most intensive and enduring wars occur between members of villages that do not share overlapping or adjacent hunting territories. Harris' model would predict that warfare should be most intense between groups that are in close proximity and therefore actively competing for the same limiting resource. But the opposite condition is actually far more common; friendly or allied villages are located much closer to each other than are villages whose members are conducting active hostilities. A second intractable aspect of Yąnomamö warfare and settlement patterns, as these might relate to protein shortages, has to do with the geographical ranges within which the members of some villages, including very large villages, are known to confine their movements. Even where options exist for large populations to abandon an area and move into a pristine region where game would presumably be more abundant, a large number of Yąnomamö groups appear to prefer to move around in a fairly restricted region—one whose "boundaries" can be easily reached within a day's walk from a central point. Thus, the members of one large village, known today as the Patanowä-teri, have remained in a relatively small region for nearly 50 years, a region that is dotted with more than 25 different abandoned gardens. This region is small enough so that individuals can easily reach almost any particular abandoned garden in a single day's walk. The attractiveness of this area to them can be partially explained by the large number of cultivated peach palm trees that continue to produce in the old gardens and partly because, as they themselves claim, the hunting is good there. To their south lies a vast and poorly populated area. Should protein resources be a pressing limit to their continuing residence in this region, they seem not to perceive it, for they clearly could abandon this area and move on to presumably better hunting grounds.

Evidence is beginning to accumulate from ethnographic studies of other Yąnomamö subpopulations that protein consumption is more than adequate and that levels of protein consumption do not correlate with patterns of warfare intensity. The work of Lizot is the most detailed on this score (*14, 15*). He recently conducted a very complete dietary study of two Yąnomamö villages located about 25 miles to the east of the villages on which we are here reporting. He found that, although consumption of animal protein varied between the two groups (36 and 77 g per capita per day), their patterns of warfare were identical (*14, 15*).

Protein consumption data on other Amazonian populations is emerging and likewise calls into question the often repeated suggestion that Amazonia is a protein desert. The earlier survey conducted by Gross (*9*) has been superseded by protein consumption studies in which superior data collection methods were used. Table 2 presents a compilation of dietary surveys for a number of Amazonian tribes, most of which were not available at the time of Gross' publication. Although we had to estimate some of the data because of differences in individual reporting techniques, a number of generalizations are possible: (i) The average per capita consumption in our sample (Table 2) is slightly greater than that given for the society with highest consumption in Gross' entire sample, (ii) the average per capita consumption in our sample is 80 percent higher than the average reported in Gross' survey, and (iii) our figure for average per capita consumption is higher than that found in the world's most developed nations (*8*, p. 430, figure 20-2). Ironically, the Jívaro and Bari, aside from the Yąnomamö, are considered by most anthropologists to be very warlike tribes, yet they consume more meat than the more peaceful tribes described (Table 2).

In conclusion, where quantified data on animal protein consumption has been collected in Amazonian native populations characterized by relatively intense warfare patterns, there appears to be little support for the hypothesis that a shortage of protein in the native diet explains intergroup warfare. Past attempts at such explanations have often advocated the existence of a protein shortage, and to the extent that empirical evidence has any bearing on these kinds of explanations of, for example, Yąnomamö warfare, the explanations fail. They would probably be inadequate explanations even if there were significant protein deficiencies, for warfare in any society is sufficiently complex that no single variable can account for its ultimate or proximate causes, its character, timing, duration, and consequences.

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Accessory Optic Projections upon Oculomotor Nuclei and Vestibulocerebellum

Abstract. *Displaced retinal ganglion cells in birds are the sole source of the retinal projection onto the nucleus of the basal optic root, the main component of the accessory optic system. This nucleus has direct bilateral axonal projections onto the oculomotor nuclear complex, the trochlear nucleus, and folia IXc,d and paraflocculus of the vestibulocerebellum. The cerebellar projection terminates within a superficial band of the granule cell layer adjacent to the Purkinje cell layer as a mossy fiber system. This bisynaptic projection onto oculomotor neurons and the cerebellum may play a functionally distinct and specific role in oculomotor reflexes.*

The accessory optic system had been recognized as a constituent of the visual system as early as 1881 by Gudden (*1*) and has been described in all vertebrate classes (*2*). The accessory optic system is characterized by the accessory optic nuclei, which are located at the meso-diencephalic border, and a distinct fascicle of retinal axons that terminate on these nuclei (*2*). Recently, in birds, a unique class of retinal ganglion cells, the displaced ganglion cells of Dogiel, have been demonstrated to be the sole source of a retinal projection onto the main component of the accessory optic system, the nucleus of the basal optic root (nBOR) (*3*). Dogiel (*4*) and Cajal (*5*) first characterized displaced ganglion cells as large retinal ganglion cells located at the border of the inner nuclear layer and in-

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