

From sago to rice, from forest to town: The consequences of sedentarization for the nutritional ecology of Punan former hunter-gatherers of Borneo

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Abstract

Background. The last nomadic peoples of the world are facing strong governmental incentives to renounce their foraging lifestyle. Nevertheless, the shift to a sedentary way of life and the adoption of agriculture do not always result in the promised improvement in diet and health conditions.

Objective. We compared the dietary regime and nutritional status of three groups of former hunter-gatherers, the Punan of Borneo. All three groups adopted extensive upland rice cultivation almost 6 decades ago, but each has some degree of dependence on agriculture versus forest resources, which varies along a gradient of accessibility of urban facilities.

Methods. The diet of three distinct Punan groups living in the dipterocarp forest of East Kalimantan was assessed both qualitatively and quantitatively and analyzed in relation to the seasonality of resources and human activities. The physical fitness of the Punan was also estimated from repeated anthropometric measurements.

Results. The more remote the Punan community was from urban facilities, the more diversified was the diet and the better were its nutritional status and physical fitness. The contribution of forest resources to the dietary regime also decreased with urban proximity. However, the higher dependency on agriculture is not the proximate cause of the deterioration in diet and physical fitness, which is rather due to the transition from the nomadic to the settled way of life.

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Conclusions. The brutal shift in lifestyle among the Punan of Borneo has profoundly affected the integrity of these societies and impacted their social, cultural, symbolic, and political features. In the long run, this may compromise their health status and ecological success.

Key words: Agriculture, diet, health, nomadism, Punan hunter-gatherers, sedentarization

Background

Governments, whatever the latitude, distrust nomadic people. For decades, promises of better access to education and health services and to markets and job opportunities have been recurrently used by authorities to persuade hunting and gathering societies to settle down. But modernization—often hastened by government incentives—generally results in increased poverty, and the fanciful advantages that development and social change are supposed to bring in often turn out to cause social and health disorders. The apparently noble arguments brandished supposedly for the sake of these people often hide a greedy lust for the rich wildlife, flora, and mining resources that are located in the vast territories extensively used by the foragers and pastoralists. In poorly inhabited areas, these nomadic people represent an appreciable mass of potential laborers, voters, taxpayers, and animists to be proselytized. They also convey an image of savageness that blurs the international credibility of countries aspiring to be viewed as developed and respectable nations. Last but not least, these peoples seldom care about administrative frontiers [1, 2].

The nomadic peoples also have to struggle with their own contradictions: in a world of growing globalization, they claim their right to continue living in close relation with nature, while at the same time, they are attracted by consumer goods and want their legitimate share of modernity. Renunciation of their former nomadic lifestyle is a heavy price to pay to

be recognized as normal citizens and to benefit from social justice.

Without any doubt, the shift to a sedentary lifestyle and the adoption of agriculture has constituted a major turning point in human evolution. But this progress can be harmful to contemporary nomadic people who are pushed to make, in just a few decades, a leap that took thousands of years for the rest of humanity to accomplish.

The direct detrimental effects of shifting from the nomadic to the sedentary lifestyle on the health of the former hunter-gatherers are numerous: pulmonary pathologies due to increased exposure to nocturnal cold in nonadapted housing conditions; poor sanitation and related fecal pollution; adoption of European clothes that are worn dirty and are propitious ground for infectious skin diseases; proliferation of rodents, which increases the risk of contracting zoonotic diseases; increased exposure to crowd diseases, which find in permanent settlements the critical mass of inhabitants in which to propagate; and weak immunity to vector-borne diseases such as malaria. Most of these effects have been described elsewhere [3, 4], but there is no clear evidence directly linking them to the adoption of agriculture.

Most recent archeological and anthropological literature on the “paleolithic diet” hypothesis [5] advocates that the food regime of former hunter-gatherers was relatively healthy: it was rich in protein and fibers, while poor in salt, milk, and sugar. In the strict nomadic lifestyle of earlier times, migrations were performed along extended and linear territorial trails that not only reduced food hazards [6], but also ensured good physical fitness. This resulted in low body adiposity and prevention of cancer and cardiovascular complications. However, such relatively good fitness was achieved at the expense of a high mortality and a relatively short life span [7].

Objective

The overarching objective of this paper is to explore the impact of the conversion to agriculture on the Punan diet. Unfortunately, in the absence of quantitative data on food consumption among the hunter-gatherer groups before the transition to more settled ways of life, a complete quantitative assessment of conversion over time is not possible. It is, in fact, very difficult to obtain accurate data on nutrition and food consumption among these communities even now.

This study compares the dietary regime and nutritional status of three Punan communities living in the dipterocarp forests in the Indonesian province of East Kalimantan. These three former hunter-gatherer communities share common sociocultural characteristics, and all adopted extensive upland rice cultivation almost

6 decades ago. However, they are distinctively positioned along a gradient of dependency on agricultural products and accessibility of urban facilities.

Methods

The setting: The Punan Tubu and Punan Benalui of East Kalimantan

The Punan* do not form a single ethnic group. Historical factors have produced strong differences among subgroups of Punan in dialect, social and economic situation, alliances with Dayak farmers, and behavior toward outsiders. Nonetheless, all Punan originate from groups of hunter-gatherers who probably started to open swiddens for upland rice cultivation at the beginning of the 20th century at the earliest. We estimate that less than 4% of Punan have remained pure foragers.

Some 10,000 Punan live in the Indonesian province of East Kalimantan (fig. 1). Here we deal with three groups: the periurban Punan Tubu, the remote Punan Tubu, and the Punan Benalui. In the early 1970s, nearly 1,000 Punan living in the lower part of the Tubu watershed—referred to as the “periurban Punan Tubu”—responded to the strong incentives of the authorities and agreed to move to larger settlements near the city of Malinau. They have consequently given up their nomadic way of life and have become lowland rice cultivators. They benefit from the facilities of the city (electricity, material goods, schools, dispensaries, etc.) and their economy highly depends on market, off-farm activities, and fees paid by concessionaires in return for the right to exploit timber and coal.

Some 800 other Punan Tubu—referred to as the “remote Punan Tubu”—have only partly followed the call from the authorities by choosing to settle down along the upper rivers in the forest. Although they are no longer nomadic, they live in small hamlets scattered all over the poorly accessible Tubu watershed. They practice upland rice swidden cultivation, but they are still seasonally mobile within a forest territory in which they exploit cyclical resource groves. Individuals, with or without their families, can move temporarily or permanently from one settlement to another or migrate to Malaysia for a month or a lifetime in search of job opportunities.

The Punan Benalui, who live on the Bahau watershed, are an isolated offshoot of 360 people out of a

* Penan and Punan are incorrect transcriptions of “pənan.” In this paper, we arbitrarily use “Punan” as a generic term to apply to all groups of hunter-gatherers of Borneo. In contrast, “Dayak” refers to groups of shifting cultivators. Interestingly, many sedentarized Punan, who want to dissimulate their forager origins—a source of mockery if not of social injustice—call themselves “Dayak.”

group of nearly 3,200 Punan who are mostly located in Sarawak on the Malaysian side of Borneo [8]. The studied community of Punan Benalui (nearly 150 people) settled down in the late 1960s in Long Belaka, the site of a former Kenyah village [9].

Although they have distinct origins and speak different languages, the Punan Tubu and Punan Benalui are facing similar changes in lifestyle. In both groups, the adoption of agriculture dates back to the first half of the 20th century, and the seasonal harvesting of forest resources provides a prominent part of their livelihood. The situation of the Punan Benalui can be considered as intermediate between that of the periurban and the remote Punan Tubu communities. They live in a remote area, in close contact with the forest, but navigation by canoe on the Bahau is much more regular than on the Tubu. They live near their Dayak proximate neighbors (which facilitates interethnic economic exchanges), whereas the Tubu area today is exclusively inhabited by Punan. They have easy access to local markets situated in the Dayak villages, whereas such markets do not exist on the Tubu watershed. The forest of the Bahau has been exploited by logging companies for a long time, whereas until recently the Tubu watershed was spared any industrial exploitation (Fig. 2). There is thus a gradient among the three groups in the accessibility to them of urban facilities.

Today 92% of the Punan Tubu and 100% of the Punan Benalui households practice rice cultivation. The amount of production varies greatly between settlements and families: only one-third of the remote



FIG. 1. Map of distribution of the Punan groups in East Kalimantan (Source: Wayanama, ©IRD, 2007).

Punan Tubu households cover their annual needs for staple food from the production of their rice fields, whereas most of the periurban Punan Tubu and Punan Benalui households are self-sufficient. Cassava, corn, taro, and a few other food crops—for instance, banana and sweet potato for the Punan Benalui—are often intercropped with upland rice for subsistence needs and are rarely commercialized. On average, upland rice cultivation requires approximately 61 person-



FIG. 2. Gradient of accessibility among the three compared communities

days per hectare, which implies a rather high return to labor, estimated at around US\$1.6 per person-day. Such a fairly low amount of time allocated to cultivation, which is mainly carried out by women, leaves a sizable amount of time for hunting, fishing, gathering, and off-farm activities. The principal animals raised are chickens and pigs. In the remotest settlements, 83% of households sell chickens to visiting traders, relying mainly on bushmeat for their own consumption.

Surveys

Studies were carried out in parallel among the Punan Tubu of the Tubu watershed in 2001–05 [10] and the Punan Benalui of the Bahau watershed in 2002–04 [9]. These studies included demographic, socioeconomic, historical, and ethnographic investigations as well as food-consumption surveys that were complemented by anthropometric measurements and biomedical analyses.

In order to assess the diversity of situations faced by the Punan, we carried out a census of almost all Punan settlements in six districts of the province of East Kalimantan. In 2002 and 2003, 77 settlements were visited with 2,096 families comprising 8,956 individuals. At the settlement level, we recorded the accessibility of facilities such as retailers, schools, dispensaries, and markets [10]. Household-level interviews covering almost all censused households were used to establish the composition of the family: age of each member, relationship to the head of household, gender, level of education, the number of young children who died, etc.

Socioeconomic data were obtained by using a semi-open questionnaire in time-series household surveys. In 2002 and again in 2004, we monitored the income and activities of 12% of the censused Punan households—more than 50% of the Punan Tubu households—in seven villages located along an upstream–downstream gradient in order to account for differences in access to forest resources and markets. Household surveys were complemented by the collection of anthropological data from nondirective interviews of local people as well as spot-check quantifications of hunting, gathering, and agricultural activities [10].

A comparative quantitative food-consumption survey was carried out in three Punan Tubu villages: one periurban settlement near Malinau city, one settlement in middle Tubu, and one of the most remote settlements of the Tubu watershed; the results presented in this paper only compare the periurban with the most remote settlements. In order to assess the influence of seasons on food strategies, we replicated the same protocol successively in June 2003, September 2003, December 2003, March 2004, and July 2004. The study was carried out in all the households (43 in total) of three villages chosen for their similar population size and their contrasting levels of accessibility: periurban,

middle Tubu, and upper Tubu. In these 43 households, representing 20% of the Tubu watershed households and 9% of the periurban households, for 2 to 4 consecutive days within each household, we used precise hand scales to systematically weigh the ingredients before cooking, the meals after cooking, food distribution between consumers, and the leftovers. A total of 1,214 dishes were measured in this way. The study also provided precious information about the social and cultural dimension of food consumption, as well as about the origin (from the wild, cultivated, or bought) and the source (produced by a member of the family, gift or exchange, or bought) of each ingredient.

The food survey among the Punan Benalui was carried out once during 20 days randomly chosen between September 2004 and November 2004. This survey was solely semiquantitative (no food were weighed): for each of the 1,074 meals monitored among all the 20 households of the Long Belaka village—20% of the total Punan Benalui households—during the period of observation, all the ingredients were noted as well as their origin and their source. The frequency of consumption of each ingredient for 346 day-households in this community was then estimated.

In parallel with the seasonal food survey, we performed a series of repeated biometric measurements to determine instantaneous nutritional status and body morphology in relation to physiological performance. In addition to weight and size, six different skinfold and perimeter measurements were performed on a seasonal basis. We measured all the inhabitants who agreed to participate and who were present in the villages during each of our repeated visits. On average we obtained measurements from nearly 400 remote villagers and 200 periurban residents (comprising 57% and 20%, respectively, of the total population) equally composed of adults and children of both genders. Altogether, nearly 14,000 measurements were performed with a Harpenden caliper according to the method recommended by Durnin and Womersley [11]. These measurements were used for the calculation of standard nutritional indexes, such as body mass index (BMI) and body fat. The mean BMI values were analyzed by one-way analysis of variance. A p value $< .05$ was taken to indicate a statistically significant difference, and Duncan's post hoc test was used to compare the groups. Indexes obtained for the Punan were compared with those of the Iban, the only group of Dayak farmers in Sarawak for whom we could find published values [12].

Simultaneously with these studies and continuing during 2005 and 2006, we proceeded, in close partnership with the local health services and the humanitarian organization Doctors of the World, to perform repeated clinical examinations (a total of 2,280 examinations were made in 50% of the total population and only on patients who spontaneously expressed their desire to

consult the doctor) and provided medical care to the remote Punan Tubu communities when necessary.

Results

Socioeconomic features of the nomadic Punan

Socioeconomic features varied among the three Punan communities (**table 1**). Cash incomes were more than three times higher in periurban than in remote settlements, since off-farm activities are more lucrative, and their contribution to total income increases with proximity to the city and its diverse job opportunities.

Access to education and health facilities attests to a similar gap between remote and periurban Punan Tubu: the respective rates of illiteracy and child mortality are 2.8 and 2.7 times higher in remote settlements. The higher child mortality upriver is not due to malnutrition or to an unhealthy life in the forest. It is a direct consequence of an increasing exposure to transmissible diseases (e.g., smallpox, measles, mumps, cholera, rubella, diphtheria, and influenza), which take advantage of improved accessibility and greater human concentrations in permanent settlements. Isolation far upriver can no longer efficiently protect the remote Punan Tubu from these communicable diseases, while at the same time it keeps their children away from vaccination campaigns.

Changing cultural behaviors regarding food habits among the periurban Punan Tubu attest that social support—based on mutual assistance, collective activities, and food sharing—is being replaced by more individualistic attitudes. For instance, the percentage of food plates that are shared between two or more consumers is 31.8% among the remote Punan Tubu and falls to 13.7% among their periurban relatives. Another illustration is the decreasing proportion of food resources that are obtained as gifts or through exchange: 18.1% vs. 5.1% among the remote and periurban Punan Tubu, respectively. By contrast, the

proportion of bought ingredients—another symptom of more individualistic economic strategies—increases with access to markets: the proportion is 26.2% for the remote Punan Tubu, 39.2% for the Punan Benalui, and 57.2% for the periurban Punan Tubu. A growing feeling of insecurity punctuates the loss of collectivism and combines with discrimination and social injustice—the result of unequal access to new job opportunities—to cause noticeable stress and depression among the periurban Punan. These emerging mental diseases sometimes lead to conjugal violence and infidelity and various types of addiction. The recent ban on all alcoholic drinks by Malinau authorities has limited the impact of alcoholism. Heavy cigarette smoking, a direct cause of emphysema and cancer, and an indirect cause of diseases such as tuberculosis, is another concern in remote and periurban villages. The local health services have confirmed the rapidly rising prevalence of sexually transmitted diseases in town (we found no cases in the remote Punan settlements), although the data are too imprecise to determine the proportion of Punan among those with sexually transmitted diseases.

Diet and fitness among the Punan

Seasonality resulting from the combination of climatic factors, crop cycles, the ecology of wild resources, and human activities in relation to ecological constraints and cultural choices has an important impact on the diets of the Punan in all locations (**fig. 3**). Communities in remote areas have a higher frequency of meat-based meals than periurban communities.

In **table 2**, the quantities of the main categories of food consumed according to season are compared between remote and periurban Punan Tubu settlements. The results for different food categories may be summarized as follows:

The sources of animal protein are mainly meat (eggs are eaten only by periurban residents) and, to a lesser extent, fish. The sources of protein are much more diversified in remote areas, and protein is consumed

TABLE 1. Socioeconomic characteristics of the Punan Tubu in 2002

Characteristic	Remote Punan Tubu (125 hh, 696 ind)	Punan Benalui (31 hh, 106 ind)	Periurban Punan Tubu (171 hh, 830 ind)
Illiteracy—% ind	65.8	47.2	23.3
Child mortality < 5 yr—% ind	36.0	30.2	7.0
Mean annual income per hh (% of total income)—US\$			
Agriculture	180 (30)	254 (29) ^a	246 (17)
Hunting and gathering	185 (31)	506 (43) ^a	433 (31)
Off-farm activities	241 (39)	365 (32) ^a	724 (52)

hh, household; ind, individual

a. The average values are given for Punan groups living in remote but easily accessible settlements.

Source: modified from Levang et al. [10].

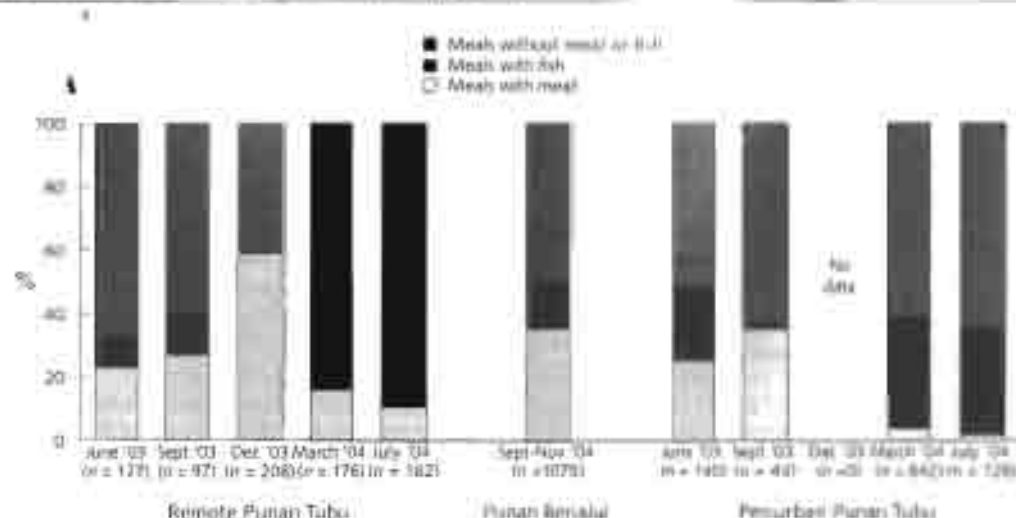


FIG. 3. Seasonal fluctuation in the major composition of meals (cumulative percentage).

in greater quantities in these areas. Meat and fish consumption is facilitated by persisting social regulations such as mutual aid and food-sharing, which impose rules of systematic redistribution of bushmeat and massive fish catches among the whole community. Downstream, where rules of mutual aid are in constant decline, opportunities to consume protein-rich food are

more erratic, and the food is more costly. Among the Punan Benalui, meat contributes to 34% of the dishes, wild boar is by far their favorite and represents 86% of the total game consumed. Fish or shellfish appear in only 13% of their dishes.

Carbohydrates, which provide energy and are the staples of the diet, are mainly provided by cultivated tuber and cereal crops. Six types of food crops are grown in the remote areas, twice the number in the other areas. Depending on the season, rice is the staple food in 80% to 100% of the meals (percentages provided hereafter indicate the percentage of meals that contain the particular food). Sage is no longer part of the diet in downriver villages well connected to the market but accounts for 12% of the meals of the most remote Punan Tubu, who consume sago starch during their temporary stays in forest camps in search of fruits, bushmeat, and honey. Sage appears in 4% of the meals of the Punan Benalui, who, unlike the Punan Tubu, occasionally eat bananas (28% of meals) and sweet potatoes (<1% of meals). Manufactured noodles, an exotic and rare delicacy for the remote Punan Tubu, appear in 5% of the meals prepared by their periurban relatives.

The periurban Punan Tubu eat twice as much vegetables as the remote Punan Tubu. The gap is even more pronounced when meat is seasonally difficult to obtain downriver, and the dietary regime of the periurbans becomes almost vegetarian. Near the city, the Punan Tubu swiddeners cultivate 45 species of vegetables, spices, and seasoning plants, 3 times as many as are cultivated by the remote Punan Tubu, and they consume them much more frequently. Upriver, fern crosiers and cassava leaves represent 85% of the total amount of vegetables consumed, as compared with only 47% near the city. With 24 different species consumed and a contribution of vegetables averaging 32% of the meals,

TABLE 2. Seasonal fluctuation of consumption of the main food categories by the Punan Tubu (g/capita/day)*

Category	Month	Remote Punan Tubu	Periurban Punan Tubu
Meat and egg	Jun 03	130.4	72.9
	Sep 03	80.9	65.1
	Dec 03	191.3	No data
	Mar 04	71.8	14.8
Fish and shellfish	Jun 03	63.9	62.2
	Sep 03	24.9	4.9
	Dec 03	0.0	No data
	Mar 04	58.9	63.9
Starchy staples	Jun 03	889.1	1,000.2
	Sep 03	545.4	1,033.4
	Dec 03	296.7	No data
	Mar 04	581.7	886.5
Vegetables	Jun 03	91.8	17.5
	Sep 03	69.1	74.8
	Dec 03	33.2	No data
	Mar 04	62.4	203.1
Oil and fat	Jun 03	2.3	9.5
	Sep 03	0.1	4.3
	Dec 03	0.0	No data
	Mar 04	0.7	11.9

* Weighed meals, 2003: June $n = 878$; September $n = 71$; December $n = 75$; 2004: March $n = 96$.

the Punan Benalui occupy an intermediate position.

The remote Punan Tubu consume oil and fat in more moderate quantities. The fat they use for cooking is mainly obtained from wild boar and is progressively replaced further downstream by manufactured palm oil, a monosaturated fatty acid that is poorly digestible but is fairly cheap to produce (without taking into account the damaging ecological impact of oil palm plantations). Palm oil is extensively used locally for cooking and is also found in snacks and many other manufactured foods. Again occupying an intermediate position, the Punan Benalui use palm oil and wild boar fat in comparable frequencies (60% and 40% of the meals containing oil, respectively).

Nutritional indexes

The absolute values of stature and weight of adults do not differ between remote Punan, periurban Punan, and Iban Dayak farmers and thus do not indicate changes in diet and lifestyle in this region (table 3). Only the results from adults are presented here, but we have noted elsewhere [13] the absence of gaps between the remote and the periurban Punan Tubu in the growth curves of children aged 3 to 12 years.

Whatever the season, the average BMI values of both men and women in both remote and periurban Punan Tubu settlements remained above the 18.5 threshold value below which chronic energy deficiency could be suspected. The remote Punan have a significantly higher BMI than the Punan Tubu, who have become farmers near the city. Nevertheless, the two Punan Tubu groups have lower BMI values than the Iban of Sarawak, a group of Dayak farmers of Borneo whose BMI values were recently measured. The BMI values of the Iban farmers are closer to the values that are theoretically considered as optimal for adults (22.7 for men and 22.4 for women). Comparisons of BMI between recently sedentarized hunter-gatherers and their immediate farming neighbors in other places of the world have revealed a similar difference [4]. The difference in fitness between former hunter-gatherers

and farming groups should thus not be attributed to the farming lifestyle alone, but should rather be considered a consequence of the disruptive change in lifestyle from nomadic to sedentary.

Body fat percentage, another frequently used nutritional index, is the fraction of the total body mass composed of adipose tissue. It is often used to monitor progress during a diet or as a measure of physical fitness. Values obtained for adults in both remote and periurban Punan Tubu settlements are within the range of those of extremely fit or athletic people. Interestingly, the trends differ with regard to gender: periurban women have a much higher score than those in remote communities. By contrast, periurban men have a lower score than those in remote communities. This may be due to the custom of assigning the "lion's share" of the rind of wild boar meat to hunters. Values from the Iban farmers indicate that the gap in fitness between men and women increases with sedentary lifestyle. According to European standards, Iban women can be considered as stout.

Overweight (but not obesity, which is extremely rare among rural Southeast Asians) clearly occurs as a consequence of sedentarization and related changes in diet. Depending on the season, 4.3% to 18.8% of periurban Punan Tubu women, but only 1.6% to 2.1% of women in remote villages, are overweight.

Conclusions

Our comparison of three Punan communities that differ in their dependency on agricultural resources shows that the more remote the community, the more diversified the diet and the better the nutritional status and physical fitness. The contribution of forest resources to the dietary regime also decreases with proximity to the city. However, the higher dependency on agriculture is not the proximate cause of the deterioration of diet and physical fitness. Rather, it seems that the easier accessibility of cities and their markets

TABLE 3. Anthropometric measurements (mean \pm SD) of adult Punan Tubu and Iban

Group	Height (cm)		Weight (kg)		Body fat (%)		BMI (kg.m ⁻²) [*]	
	Men	Women	Men	Women	Men	Women	Men	Women
Remote Punan Tubu (n = 271)	156.4 \pm 5.2	145.8 \pm 4.4	50.8 \pm 5.7	41.7 \pm 5.5	22.4 \pm 3.7	22.8 \pm 4.2	20.6 \pm 1.7 ^{ab}	19.9 \pm 2.3 ^a
Periurban Punan Tubu (n = 119)	156.0 \pm 6.8	146.9 \pm 4.4	48.9 \pm 7.8	43.6 \pm 7.8	20.4 \pm 5.3	26.2 \pm 6.2	19.9 \pm 2.7 ^a	19.6 \pm 3.3 ^b
Iban Dayak farmers (n = 753)	157.0 \pm 5.6	147.3 \pm 5.0	51.6 \pm 8.4	48.5 \pm 10.7	19.3 \pm 5.3	33.5 \pm 6.2	20.9 \pm 2.8	22.2 \pm 4.3

BMI, body mass index

* Superscript letters following BMI values indicate significant differences ($p < .05$) between periurban and remote Punan Tubu for each gender ($a > b$) by Duncan's multiple range test.

Source: modified from [3-12].

has equivocal consequences. It can be an advantage during years of drastic food shortage—corresponding to an absence of mast fruiting in the dipterocarp forests of Borneo—which have dramatic consequences for the ecological success of forest dwellers. Markets also ensure a more regular supply of a wide range of vegetables and fruits, but also of dairy products and eggs. For instance, calcium and micronutrients provided by these types of food greatly contribute to the prevention of dental problems. When combined with a minimum of education and information on hygiene and sanitation, their role in improving dental health and consequently attenuating child morbidity should not be neglected. But improved access to markets results in greater dependence on a regular cash income and more pronounced individualistic behaviors that jeopardize the fundamental collectivist principle of the Punan culture, an efficient adaptive response to seasonal food uncertainty during their nomadic past.

Industrialization and urbanization accompanying the economic boom in the interior of Borneo have had an impact on the dietary habits of the people. As we have shown in this paper, there is a trade-off between the advantageous new crop resources, which bring with them a sedentary lifestyle, and the detrimental effects of modification in the availability and distribution of wild food resources near permanent settlements. Such changes affect nutritional status, as clearly shown by the periurban Punan, who tend to have an excess intake of energy-dense foods, especially snacks, that are rich in fat and free sugars but low in complex carbohydrates. Evidence from epidemiological studies has confirmed the link between such diets and the risks of chronic degenerative diseases of middle and later adult life, especially cardiovascular diseases and certain types of cancer [14]. Although they are not yet a critical problem for the Punan, other nutritional disorders, such as anemia, excessive weight, hypertension, elevated

cholesterol levels, and diabetes, are emerging signs of dietary imbalance.

The legendary good diet and fitness of the former hunter-gatherers does not resist their brutal jump into modernity. Even if it does not have a direct effect on their health, the rapid conversion to farming has certainly contributed to their imbalanced dietary regime. In the long run, this may compromise their health status and ecological success.

Data on nutritional ecology in such environments are difficult to obtain, and too few results are available in the literature to support solid diachronic as well as synchronic comparisons. There is definitely a need for further long-term studies on these issues. But time is short, and there is also an urgent need for immediate action in favor of rapidly changing populations and environments of the forest.

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SUPPLEMENT

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