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Examining Short-Term Nutritional Status Among BaAka Foragers in Transitional Economies

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ABSTRACT Foragers in transitioning economies are at an increased risk of negative health outcomes as they undergo changes in subsistence patterns and diet. Here, we provide anthropometric data and examine the nutrition and health of adult BaAka foragers in relationship to declining wildlife and economic change in the Dzanga Sangha Protected Areas (APDS), Central African Republic. From June to August 2012, we collected biological data and dietary recall surveys from individuals in Mossapoula (MS) and Yandoumbé (YDBE) villages using standard anthropometric techniques and a single capillary blood finger prick. In our analysis, we identified variation in anthropometric measurements and hemoglobin levels by village (MS = 66, YDBE = 75) and gender (64 men, 77 women). Immigration, increased gun hunting and wildlife trades have reduced forager reliance on forest resources. These changes are evidenced in the marginal health of contemporary BaAka foragers of APDS. Although anthropometric measures of nutritional status do not significantly differ between communities, hemoglobin data highlight inequities in access to forest products between villages with different proximity to community hunting zones. Further, poor dietary diversity and low frequency of purchased foods in the diet indicate that the transition to a market economy has not been fully realized and diets are impoverished. Economic changes appear to have had the most impact at MS village, where forest use is most restricted and consumption of meat and forest products was reduced. This work highlights the nutritional and health needs of foragers in rapidly transitioning economies; especially those impacted by conservation management and zoning policies. Am J Phys Anthropol 154:365–375, 2014.

Across central Africa, the growing global trade in forest resources, increase in agricultural lands, and fluctuating economies have had varied impacts on communities reliant on forest resources for their subsistence, economic, and cultural livelihoods (Froment, 2001; de Merode et al., 2004; Wilkie et al., 2006). Ickowitz et al. (2013) found a positive relationship between forest cover and nutrition in children from 21 African countries. Proximity to the forest was found to increase dietary diversity and consumption of micronutrient rich foods, but the study was not able to address differences between modes of food production, subsistence, or market foods. Our smaller scale study demonstrates the critical importance of collecting forest foods for forager health in economies in transition, and highlights the role of place and natural resource management in shaping that access.

Using biocultural techniques, we examine aspects of short-term nutritional status and health among adult foragers in transition to cash economies in the Dzanga Sangha Protected Areas (APDS), Central African Republic (CAR). The BaAka of APDS are not yet fully integrated into the cash economy and have experienced deteriorating long-term trade relationships with other regional groups and the abandonment of traditional hunting practices in the face of increased migration, gun hunting, and wildlife declines (Hardin and Remis, 2006; Jost Robinson, 2012; Remis and Jost Robinson, 2012). To evaluate short term nutritional status and health of adults, we use anthropometric measurements [body mass index (BMI), mean upper arm circumference (MUAC), and sum of skinfold (SS) thicknesses; Yamauchi et al., 2000; Godoy et al., 2006] and hemoglobin levels (Zimmerman and Hurrell, 2007; Golden et al., 2011) contextualized within 24-h dietary recall data and simple indices of subsistence and market participation (Dewey, 1981), to help us better understand complex, biosocial outcomes for marginalized forest foragers in protected areas (Dufour, 2006; Vercellotti and Piperata, 2012).

The growing wildlife trade has bolstered food security in the Congo Basin where most countries do not produce sufficient supplies of non-wild meat protein. Yet, models have projected declines in regional wildlife populations that will result in protein insufficiency and malnourished populations in the long term (Fa et al., 2003). In rural forested areas like APDS, a decline in wild game availability coupled with the increasing importance of

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cash economies, changing subsistence, and wildlife exchange strategies, further marginalize indigenous forager groups (Daspit, 2011). To date, few Congo Basin studies have adequately documented the implications of coupled, biosocial systems for changes in the nutritional status for the health and well-being of foragers in protected areas.

Gender dynamics among forager subsistence practices in transition in Central Africa are crucial to considerations of adult diet and health. Among Central African foragers, men and women traditionally have complementary, overlapping roles in hunting and other divisions of labor (Grinker, 1994; Noss and Hewlett, 2001). Among BaAka net-hunters, subsistence work has been more evenly shared among men and women, relative to other foragers where males may provide a bulk of the calories through spear or bow hunting (Bahuchet, 1988; Hurtado and Hill, 1990; Bailey, 1991). During the 1990s, BaAka at APDS lived in permanent settlements with increasing signs of acculturation and involvement in wage labor, but visits to temporary forest camps were common and few planted their own fields. At this time, bitter manioc (*Manihot escuelenta*) was the only agricultural food regularly present in their diet (Hodgkinson, 2009) and women's contribution to hunting was high; BaAka women even net hunted in all female groups (Noss and Hewlett, 2001).

In contrast, more recent data from APDS indicate that hunting is increasingly done with guns; net hunting returns have declined and women spend more time as hired hands in the agricultural fields of their neighbors (Jost Robinson et al., 2011; Remis and Jost Robinson, in prep). BaAka at APDS do not own guns and rarely hunt on their own, with hunting now contributing little to the daily nutritional requirements of their groups (Jost Robinson, 2012). As BaAka men turn away from traditional subsistence practices to pursue wage labor opportunities, women play an increasingly important role in providing foraged or traded food to their families (Daspit, 2011). In turn, we expect that the increasing diversification in male and female modes of production within transitioning economies may be reflected differently in the short-term nutritional status of male and female foragers.

In this context, we collect information on nutritional and health status that may relate to changes in subsistence and lifestyle patterns observed over decades. Many of these changes parallel those documented among other foraging communities where agricultural products have replaced traditional foods (see Bahuchet, 1988; Hewlett, 1991), but are occurring here later, and in a conservation context intended to support traditional forager livelihoods. Yamauchi et al. (2000) report relatively low protein and calorie intake among the sedentary Baka in Cameroon, relative to neighboring farmers and forest living Aka in the Congo (Kitanishi, 1995; also Dounias and Froment, 2006). An increased dependence on agricultural products and increased marginalization of BaAka from wildlife trade in the APDS may result in secondary effects of poor caloric, nutrient, or protein intake.

Reduced dietary diversity among foragers in transition may result in poor micronutrient intake (Kennedy et al., 2007). Golden et al. (2011) found that diminished access to wildlife in particular, resulting from declining animal population sizes and inadequate governance of natural resources, increased the incidence of childhood iron deficiency anemia in rural Madagascar. Severe childhood anemia and anemia in adults have been found to increase individuals' disease risk, negatively affect gestation, and lower cognitive function (Neumann et al., 2003; Zimmerman and Hurrell, 2007). Linkages between current nutritional status and physical activity (Martorell and Arroyave, 1988; Bender and Durfour, 2012) can also have implications for work productivity among foragers or horticulturalist men and women in transition, especially when coupled with helminth or other parasitic infections (Tanner et al., 2013). We acknowledge that the interactions between dietary intake of meat and vegetable foods, iron and vitamin levels, and malarial and helminth infections are complex (Huddle et al., 1999; Abrams et al., 2005) and require further examination but limit the current discussion to short-term nutritional status.

The Dzanga Sangha Protected Area (APDS), CAR was zoned as a multiple-use conservation area in 1990, with an eye toward promoting a viable future for wildlife and local residents. However, APDS has experienced varying success in conservation management, tourism, and development initiatives in the face of long-term civil unrest and bleak economic outlooks. In this study, we examine the short-term nutritional status and health of adult BaAka women and men undergoing a transition from foraging to agricultural and cash economies. In a transitional economy, increased reliance upon agricultural or market goods coupled with a decreased reliance on forest products and low access to wild game is predicted to result in (1) short-term nutritional stress as evidence by chronic energy depletion resulting from low BMI, upper arm circumferences, and SSs and (2) low hemoglobin values. Further, we expect to find differences in indicators of short-term nutritional status among members of two communities that vary in ease of access to forest resources, market integration, dietary diversity, and increased nutritional stress in the northern village of Mossapoula (MS).

METHODS

Field location and local communities

This study was conducted among BaAka (Aka) foragers in the Dzanga-Sangha Protected Area (APDS), also known as Dzanga Sangha Reserve, in the southwestern corner of the CAR (4,200 km^2, 2°13′26N, 16°11′26E), recently named a UNESCO World Heritage site (Fig. 1). Fieldwork was conducted from June to August 2012, prior to the recent civil unrest and instability following a violent coup in March 2013. The APDS has a population of 6,468 people; most non-Aka live in the main town of Bayanga. BaAka populations account for approximately 24% of the total population, dispersed across five villages: the two largest villages are MS (598) and Yandoumbé (YDBE; 261; Ngbo-Ngbangbo et al., 2010). The BaAka in APDS are culturally and linguistically distinct from Baka, Mbuti, and other Congo Basin foragers groups (Bahuchet, 1992). BaAka of APDS share a language, and many cultural patterns including communal child rearing and subsistence practices with the Aka better studied in other regions of the CAR and Northern Congo (Bahuchet, 1988, 1992; Hewlett, 1991; Kitanishi, 1995; Meehan, 2005). Following local precedent in APDS we refer to them as BaAka (the prefix *ba* indicates plural; Woodburne, 2011).

The BaAka foragers of APDS have not yet been a focus of long-term, behavioral ecology research, although

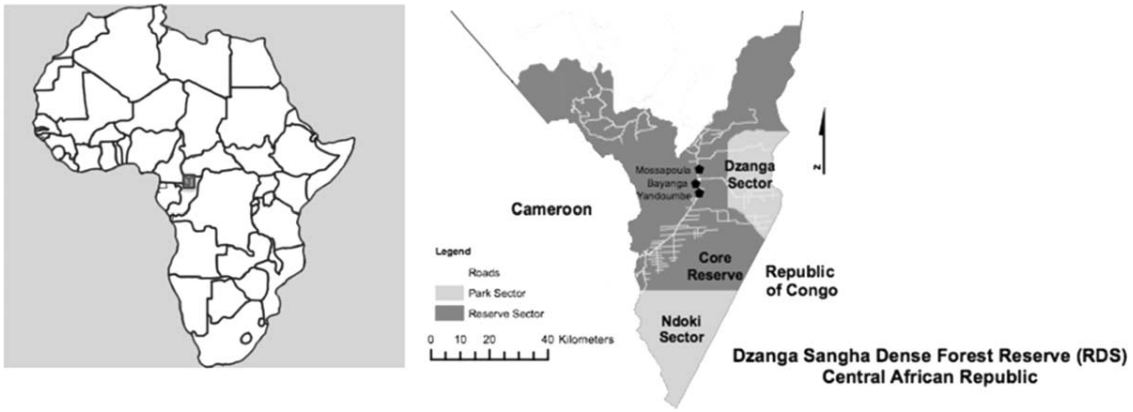

Fig. 1. Map of the Dzanga-Sangha Protected Areas, Southwestern Central African Republic in Context

ethnographic work has been conducted on their social and political lives, land tenure, and demographic patterns (Kretsinger and Hardin, 2003; Woodburne, 2011). The current study complements these efforts and provides follow up to initial biological and genetic studies conducted in 1968 (Cavalli-Sforza, 1986; Pennetti et al., 1986), research on hunting patterns by Noss (1995) and our own earlier work on changing patterns of forest use in a conservation context (Hardin and Remis, 2006; Jost Robinson et al., 2011). Those biological data collected during Cavalli-Sforza's 1986 study represent a broader geographic sample of Aka foragers in the CAR; whereas we are focusing on BaAka living within APDS.

APDS was officially gazetted in 1990; the majority of the area has undergone several cycles of selective logging since the 1970s resulting in a boom and bust economy drawing thousands of migrants to the region. Recent studies describe a widespread transition from a hunting economy based on commercial cable snaring by non-Aka and subsistence net hunting by local BaAka populations to large-scale extraction of wildlife with firearms, primarily by immigrant hunters (Noss, 1995; Ghiurghi and Lakara, 2002; Jost Robinson, 2012; Jost Robinson et al., 2011). The BaAka community of MS is situated north of the main town of Bayanga and is closest to the Park headquarters, the center of the Park and the Dzanga saline, while the BaAka of YDBE live further south of town in closer proximity to the community hunting zone. Thus, BaAka populations in these communities have been differently impacted by conservation zoning, with disparities in legal access to traditional hunting territories and eco-guard monitoring. Further, these communities have also experienced varied levels of elephant damage in agricultural fields. A combination of these factors has likely resulted in differences in time spent in the forest with subsequent effects on diet and health for the two study communities.

Participants

In June of 2012, Remis (MR), Jost Robinson (CJR), Robert Sambo (RS), and Viktor Baboin (VB) recruited adult BaAka across two study villages (YDBE and MS). Upon arriving in each village, we met with village elders to discuss the research project. With their support and participation we held a town hall meeting with potential participants to address their concerns and questions. Because of our long-term research presence of more than 24 years in the region (Hardin and Remis, 2006; Jost Robinson et al., 2011), most BaAka community members were familiar with us, and felt comfortable participating or declining to participate in the project. We collected partial data from a total of 172 individuals in our two main study villages. We restrict the current analysis to those 141 adult BaAka (64 men and 77 women) who consented to the collection of anthropometric (height, weight, skinfold thicknesses, and MUAC) and hemoglobin data. The same individuals also participated in dietary surveys and subsequent semi-structured interviews. All data collection methods were reviewed and approved by the Instructional Review Board for Human Subject at Purdue University [institutional review board (IRB) 1203012023].

We conducted interviews and surveys in the national language Sango, although on a few occasions our BaAka research assistants assisted by translating into BaAka for some older women. Individuals were provided with an identification number to be used through the duration of the study. All potential participants were screened, and per IRB regulations (IRB Protocol 1203012023) those who reported that they were pregnant or ill were not included in the sample.

Data collection

Anthropometric data were collected by MR and CJR following standard protocols (Lohman et al., 1988). All adults were measured in light clothing without shoes. Stature was measured to the nearest millimeter using a portable SECA stadiometer and body weight to the nearest 0.1 kg using a standing scale. Although there are debates regarding the effectiveness of BMI as a measure among the Aka, we chose to determine BMI (kg/m^2), as it is a standard measure for adult nutritional status (WHO, 1995; Frisancho, 2008) and allows for comparison across current and historical datasets.

We collected MUACs, skinfold thicknesses, and hemoglobin as indicators of overall short-term nutritional status. MUAC, as indicators of protein and energy status, were measured to the nearest millimeter using a plastic tape measure (Frisancho, 1990). SSs, a measure of short-term change in subcutaneous fat stores, was determined from the average of bicep, tricep, subscapular, and suprailiac skinfolds measured to the nearest 0.5 millimeter using Lange skinfold calipers (Frisancho, 1990). All anthropometric measurements were collected in triplicate

and averaged for use in subsequent analyses. Capillary blood was collected from a single finger prick and analyzed using a portable Hemocue for on-site notification of hemoglobin levels (g/dL) and anemia (Garrett et al., 2011).

Following the anthropometric data collection, demographic and dietary interviews were conducted by MR and research assistant RS, using 24-h dietary recalls to assess the relative frequency of consumption of particular subsistence (including meat, gathered payo nuts, or other forest products (OFPs) and purchased market foods (Quandt and Ritenbaugh, 1986). During the interviews, which generally lasted about 30 minutes, we also conducted food frequency questionnaires on the relative weekly consumption of meat and manioc (*Manihot esculenta*), and their originating sources (i.e., purchased, foraged, fields, gift). No attempt was made to quantify intake during this brief study of respondents who generally prepared and ate foods from a communal pot. Previous studies have noted that the accuracy of dietary recall data is improved when researchers engage multiple methods (Smith et al., 1996; Bernard, 2011). Data from 24-h recalls were coded into several indices of dietary diversity and change. Food lists were converted into a proxy measure of dietary diversity that expressed the total number of foods consumed (TFC; Kennedy et al., 2011). A subsistence index (SI) was developed by averaging the total number of foods that were hunted or gathered for each individual to address the degree of the diet obtained through tradition means (including exchange). Similarly, a market index (MI) was used to represent the average of the total number of foods purchased in the formal and informal markets with cash (Dewey, 1981).

We acknowledge that measures of body weight, BMI, and skinfolds to indicate fat reserves should be used cautiously for food limited foragers as ways of detecting variation in energetic status. In lean populations, BMI may be less accurate at low body weights (Frisancho, 1990; Sherry and Marlowe, 2007). Further, Wilson et al. (2011) have suggested that BMI may sometimes be less accurate in short or stunted populations and advocated for the use of multiple measures of body composition. Skinfolds may be more likely to vary seasonally than indices of body weight (Panter-Brick, 1997); both are used in the current study.

For data analysis, biological and dietary recall data were examined for all individuals for whom the full complement of data had been collected, as well as by gender and village of residence. Age estimates were developed during interviews, as BaAka knew their relative ages within cohorts and in reference to community wide historical events. These age estimates were confirmed by one of our research assistants (RS) and a community nurse (VB) who had maintained long-term contact with these communities (Kretsinger, unpub). Following precedent in the BaAka literature, age-categories (adapted from Yamauchi et al., 2000) rather than age in years were used (e.g., 18–30, 31–40, 41–50, and >51).

Data were analyzed using student's *t*-tests to compare the short term measures of nutrition (BMI, MUAC, and combined skinfold data), and hemoglobin values by gender and village. We used raw scores rather than standardized age-scores because many BaAka did not know their exact age. Data from each gender and age-classes were compared to the distributions for normative values of BMI, MUAC, and SS as presented in Frisancho (2008). Hemoglobin values of participants were measured against values suggested by the World Health Organization (2001) and the Scripps-Kaiser index (Beutler and Waalen, 2006). Pearson's correlations were used to examine the potential relationships between indicators of short-term nutritional status and dietary variables (TFC, SI, MI). Student's *t*-tests were also used to compare dietary indices across geographic location and gender.

TABLE 1. Average BMI of former mobile Hunter-Gatherer Populations relative to their farmer neighbors in African contexts (adapted from Dounias and Froment, 2006)

	Males	Females
Coastal Kola (Cameroon)[a]	20.2	19.7
Coastal Mvae farmers[a]	22.0	22.5
Continental Kola Pygmies (Cameroon)[b]	20.0	19.8
Continental Bulu Farmers (Cameroon)[b]	20.7	21.0
Efe foragers[c]	20.2	20.2
Lese farmers[c]	21.6	21.7
BaAka, APDS[d]	21.1	20.5
Yandoumbé	21.2	20.4
Mossapoula	21.1	20.8
Baka, Cameroon[e]	20.8	20.6

[a] Froment et al. (1993).
[b] Kesteloot et al. (1996).
[c] Bailey et al. (1993).
[d] Present study.
[e] Yamauchi et al. (2000).

In order to parse out the effects of health deterioration as a result of the aging process versus differential access to resources we used an analysis of covariance (ANCOVA). ANCOVA and student's *t*-tests were also used to examine the relationship between household sizes, numbers of children in the household and village of residence among dietary variables. Pearson's correlations were used to assess relationships between dietary and biological variables. All data were analyzed using PAWS (SPSS) 18.0.

RESULTS

A total of 172 individuals participated in this pilot project across the two villages. Additional data were also collected opportunistically at one forest camp ($n = 21$) south of YDBE. Given the small sample size, data from the forest camp are not included in the primary analysis but are referred to later for comparative purposes. Here we report on anthropometrics, hemoglobin, and dietary data from a total of 141 adult foragers for whom all data were collected.

We first provide overall biological data for comparison to other studies of Congo Basin foragers (Table 1). Then we move to a systematic analysis of anthropometric data including BMI, MUAC, and SS for all BaAka sampled between villages and by gender. This is followed by an analysis of on-site hemoglobin values. These biological measures of short-term nutritional status are subsequently evaluated within the context of 24-h dietary recall interviews to address dietary diversity, market integration, and the potential impacts of declining reliance on meat and other forest resources.

Indices of short-term nutritional status (BMI, MUAC, SS, hemoglobin)

General anthropometric data collected on BaAka in APDS yielded an average adult height of 154.53 cm [standard error (SE) = 0.68] for males and 145.1 cm (SE = 0.60) for adult females. The average weight of adult males was 50.45 kg (SE = 0.78) and 43.48 kg for

adult females (SE = 0.68). There were no significant differences in the BMI of adult males ($n = 64$) and adult females ($n = 77$) within APDS (Table 1). In all, 6% of men sampled had a BMI less than 18.49 kg/m^2 compared to approximately 18% of women sampled in APDS. [Correction added on 2 May 2014, after first online publication: The percentage of men was incorrectly listed as 60% and is now correctly listed as 6%.]

Statistically significant differences were observed between overall male and female samples for MUAC [$t = -5.51$, $df = 139$, $P < 0.001$; females = 23.2 (SE = 0.24) and males = 25.09 (SE = 0.25)], and SSs [$t = 2.62$, $df = 139$, $P = 0.01$; females 29.8.14 (SE = 1.01) and males = 26.07 (SE = 0.97); Tables 2 and 3].

Hemoglobin values (g/dL) were low overall for both men and women in this population relative to published standards. We found that 61% of adult women tested had a hemoglobin value that was less than 11.5 g/dL and 60% of adult men had a hemoglobin value less than 12.9 g/dL (Beutler and Waalen, 2006). Adult females had significantly lower hemoglobin values ($n = 71$; 11.24 g/dL, SE = 0.15) than adult males ($n = 54$; 12.62 g/dL, SE = 0.14; $t = -6.49$, $df = 123$, $P < 0.001$).

Examining variation in nutritional indices by village. Tables 2 and 3 provide descriptive data for all measures of short-term nutritional status by gender and age category across villages. Within-village comparisons between males and females were consistent with the overall sample. There were no significant differences in BMI among males and females from either MS or YDBE. Overall MUAC was larger in men than women across villages (MS: $t = -4.99$, $df = 64$ $P < 0.001$; YDBE: $t = -3.52$, $df = 73$, $P = 0.001$). Across both villages, SS was larger in females than males. However, while females had a significantly greater SS than men in MS ($t = 3.60$, $df = 64$, $P < 0.001$), differences did not reach significance in YDBE.

A comparison among males indicated a significant difference in mean SS between villages with a higher average sum among men from YDBE than MS (Table 3). Adult males in MS had a significantly greater MUAC than adult males from YDBE. However, there were no differences between males of each village when comparing average BMI and hemoglobin values. Further, no statistically significant differences were found between adult females from YDBE and MS for any of the variables examined.

Figure 2 shows the average hemoglobin values for adult male and female foragers in each study village as they compare to the proposed lower limits of normal hemoglobin values (Beutler and Waalen, 2006). A broad comparison of hemoglobin values between males and females indicated significant differences between genders. In both MS and YDBE, men had significantly higher hemoglobin levels than women (MS: $t = -5.48$, $df = 57$, $P < 0.001$; YDBE: t: -3.76, $df = 64$, $P < 0.001$). Hemoglobin values were low in both villages; 59% of men in MS and 63% of men in YDBE had hemoglobin values lower than 12.9 g/dL. In all, 56% of women at MS and 61% of women in YDBE had hemoglobin values less than 11.5 g/dL (Fig. 2).

Variation in diets, subsistence practices, and market integration

Interviews demonstrate that current BaAka diets included wild-meat (hunted or purchased), fish, *payo* nuts (*Irvingia wombolu*), OFPs (most commonly *koko* leaves (*Gnetum africanum*), mushrooms, yams or fruit), and bitter manioc root. Overall, BaAka surveyed report an aver-

TABLE 2. Age, gender, and geographic variation in short-term measures of nutritional status for adult women, APDS, 2012

Adult females	BMI, (SE)			Mean upper arm circ, cm (SE)			Sum of skinfolds, SE mm (SE)			Hemoglobin, g/dL (SE)		
	YDBE ($n = 38$)	MS ($n = 39$)	P value	YDBE ($n = 38$)	MS ($n = 39$)	P value	YDBE ($n = 38$)	MS ($n = 39$)	P value	YDBE ($n = 38$)	MS ($n = 39$)	P value
Overall	20.37 (0.34)	20.83 (0.35)	0.35	22.81 (0.40)	23.50 (0.27)	0.16	30.22 (1.54)	29.36 (1.32)	0.16	11.37 (0.20)	11.11 (0.22)	0.38
18–30 ($n = 33$)	20.48 (0.62)	20.97 (0.37)	0.50	23.04 (0.62)	23.65 (0.36)	0.39	31.86 (2.88)	31.11 (1.50)	0.80	11.49 (0.35)	11.00 (0.29)	0.29
31–40 ($n = 17$)	21.16 (0.60)	22.34 (0.73)	0.23	22.80 (1.06)	24.31 (0.47)	0.23	34.85 (3.36)	31.71 (3.42)	0.52	11.16 (0.46)	11.15 (0.52)	0.99
41–50 ($n = 16$)	19.94 (0.49)	19.46 (0.67)	0.57	23.36 (0.49)	22.45 (0.65)	0.28	31.66 (2.87)	24.92 (2.55)	0.11	11.56 (0.34)	11.33 (0.58)	0.73
51+ ($n = 11$)	19.86 (0.89)	17.91 (3.05)	0.41	22.00 (0.96)	22.17 (1.67)	0.94	22.17 (1.79)	16.41 (4.42)	0.21	11.24 (0.52)	11.40 (0.80)	0.90

TABLE 3. Age, gender, and geographic variation in short-term measures of nutritional status for adult men, APDS, 2012

Adult males	BMI (SE) (Range)			Mean Upper Arm Circ (cm) (SE) (Range)			Sum of Skinfolds (mm) (SE) (Range)			Hemoglobin (g/dL) (SE) (Range)		
	YDBE (n = 37)	MS (n = 27)	P value	YDBE (n = 37)	MS (n = 27)	P value	YDBE (n = 37)	MS (n = 27)	P value	YDBE (n = 32)	MS (n = 32)	P value
Overall	21.19 (0.35)	21.09 (0.33)	0.83	24.66 (0.33)	25.68 (0.34)	0.04[a]	28.10 (1.53)	23.43 (0.66)	0.01[a]	12.46 (0.20)	12.83 (0.20)	0.21
18–30 (n = 33)	21.26 (0.44)	21.17 (0.51)	0.91	24.63 (0.41)	25.79 (0.44)	0.12	29.46 (1.97)	24.28 (0.94)	0.12	12.44 (0.29)	12.93 (0.49)	0.38
31–40 (n = 17)	20.58 (0.65)	21.22 (0.67)	0.54	24.23 (0.64)	24.29 (0.64)	0.23	29.49 (3.78)	24.22 (1.66)	0.34	12.13 (0.29)	13.10 (0.35)	0.17
41–50 (n = 16)	22.45 (1.22)	21.13 (0.74)	0.34	25.23 (0.96)	26.13 (0.79)	0.52	25.40 (2.62)	22.70 (1.56)	0.36	12.78 (0.50)	12.51 (0.21)	0.62
51 + (n = 11)	21.01 (1.37)	20.80 (0.83)	0.89	25.07 (1.72)	25.12 (0.90)	0.98	21.83 (2.72)	22.03 (0.96)	0.94	12.75 (0.31)	12.75 (0.57)	1.00

age of 3.48 food items/day (SE = 0.16). Locally known as *gozo*, bitter manioc root is the primary agricultural product present in BaAka diet of nearly all individuals surveyed. It was purchased in the market, obtained through trade in forest plants, or exchanged for women's labor in the fields of non-Aka. We report on village differences in patterns of reported food consumption, particularly in overall number of foods consumed, indices of market use, and forest subsistence (Table 4). Inhabitants of YDBE consumed a significantly greater number of foods per day than individuals from MS. Further, they had a significantly higher average MI and although not significantly different, the average SI of individuals from YDBE was also greater than that reported for MS (Table 4).

Of the 141 individuals interviewed, only 50 reported any meat consumption during the previous 24 h. Within this group, 22 individuals obtained the meat through hunting, while 28 purchased the meat in the village. Approximately 79% of participants from MS reported consuming no meat at all (wild or domestic) during the previous 24 h, compared to 52% from YDBE (see Fig. 3). Adult male and female foragers in YDBE reported significantly more frequent consumption of wild animal meat than those from MS ($t = -3.49$, $df = 142$, $P = 0.001$). There were no significant differences in the reported consumption of *payo* nuts or OFPs (most commonly *koko* leaves, mushrooms, yams or fruit) between villages. Although not significant, individuals from MS more frequently reported consumption of fish (Fig. 3).

Among women, wild meat consumption was reported on more days at YDBE, (48.7%) than MS (20.5%). Women from YDBE also reported a greater consumption of OFP than women from MS, as well as males from either village, though results are not statistically significant. Moreover, women from YDBE were more likely to report consumption of a more diverse range of types of OFP's than women from MS. After controlling for the number of adults and children in the household, geographic location (village) was the greatest predictor of whether or not an adult female reported any meat consumption (ANCOVA $F = 9.67$, $df = 1$, $P = 0.04$).

When examining gender and village differences in the types of food present in the diet, we see differences in reported patterns of food consumption (see Fig. 3). In YDBE, adult female foragers report consuming significantly greater numbers of OFP's than adult male foragers ($t = 2.07$, $df = 73$, P 0.04); however, the consumption of OFP's is similar and relatively low in both adult male and female foragers in MS.

A comparison of total foods consumed, sustainability and market indices found no significant differences between adult male and female foragers within either study village. In YDBE, women reported a greater diversity of foods consumed than adult men, but results did not reach statistical significance. Adult males from both study villages reported similar average total food items consumed, subsistence, and market indices. On the other hand, adult females from YDBE and MS villages differed in all three indices (Table 4).

We examined the relationships between the three dietary indices (TFC, SI, and MI) and the anthropometric and hemoglobin measures. As reported in Table 5, among adult female foragers from Mossapouala, diversity in diet (TFC) and a higher SI were positively correlated with BMI and MUAC. In YDBE there was a significant negative correlation between hemoglobin (g/dL) and TFC. Among adult males from MS the MI was positively correlated with SSs.

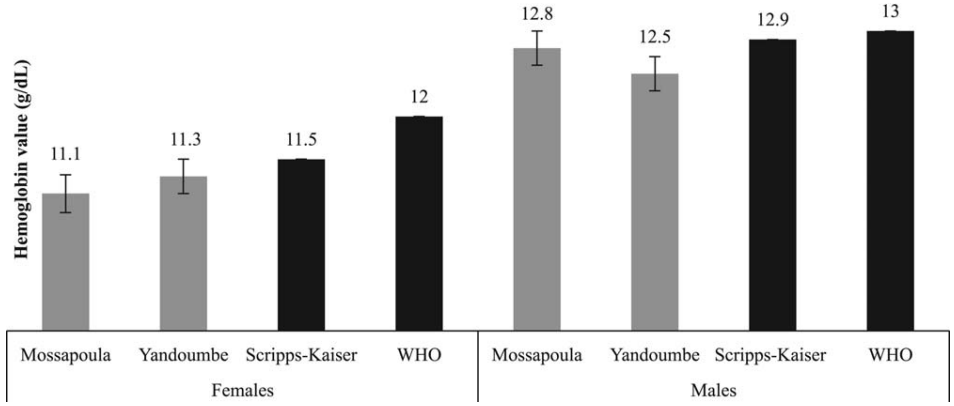

Fig. 2. Average hemoglobin values of individuals compared to proposed estimates for lower limits of normal hemoglobin values. Scripps–Kaiser values are for African-Americans (Beutler and Waalen, 2006). WHO values are for nonpregnant adult females and adult males (WHO, 2001).

DISCUSSION

Overall, our data support our predictions about the relationships between the indicators of short-term nutritional status and the declining diversity and importance of forest foodstuffs in BaAka diets at APDS. We did not find the levels of expected increasing market integration or increasing reliance on agricultural products or domestic meats that have been observed in other forager communities undergoing similar transitions to cash economies. The physical nutritional status of both men and women are marginal in this sample. While variation exists, we did not find significant differences in the anthropometric measurements of physical nutritional status between the two villages in this study. Although no significant differences were detected in average BMI, MUAC, or SS between the Aka pygmies sampled regionally in 1968 and our data from 2012, we observe a major decline in average hemoglobin values before and after the establishment of the implementation of the management plan for APDS (1968 = 14.3 g/dL versus 2012 = 11.8 g/dL).

Dietary diversity is currently low in this population relative to other published reports (Kennedy et al., 2011), and is likely an important explanation for the poor health status of many in the community. Despite the long term presence of logging and conservation economies, the BaAka of MS and YDBE are yet to be fully integrated into the market economy in APDS. As predicted, village differences in markers of nutritional status between villages at APDS corresponded with variation in market integration and the ease of community access to forest resources since conservation zoning in 1990. Our dietary recall and interview data also document persistence in the critical importance of forest products and access to wild foods for foragers in transition to the market economy but who have little access to regular, substantial cash income.

Traditionally, egalitarian relations and communal subsistence patterns in foraging societies (Ivey, 2000), including sharing, may serve to reduce individual energetic costs of reproduction and sex differences in nutrition and health outcomes as reflected in BMI (Table 1). For example, among the Hadza in Tanzania, researchers have suggested that few sex differences in adult BMI or

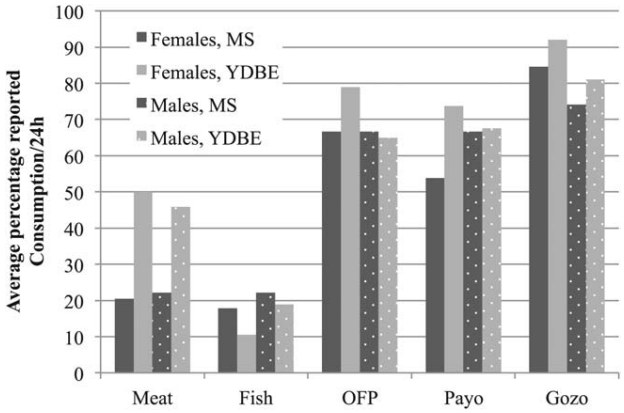

Fig. 3. Comparison of gendered and geographic variation in reported consumption values during 24 h recalls. OFP, other forest products (e.g., not meat or *payo*).

body fat may indicate long-term maintenance of female energetic condition throughout the reproductive lifespan, buttressed by food sharing (Sherry and Marlowe, 2007). Previous anthropometric studies among Aka men and women have found similar height to weight ratios (BMI) across the life span (Hewlett, 1991), consistent with the results of our study.

Although short-term measures of health, such as BMI, are expected to be similar between adult male and female foragers who practice egalitarian subsistence strategies, gendered disparities in health could emerge in foragers in transitioning economies. Walker and Hewlett (1990) reported that in a study of BaAka in the Lobaye (CAR), who were experiencing transition to an agricultural lifestyle, adult men had better dental health with fewer dental caries and lower rates of tooth loss than women. Hemoglobin levels were lower among women than men in the Lobaye study population (Cordes and Hewlett, 1990). Researchers attributed these differences to the demands of lactation among women, but also to higher carbohydrate consumption and lower protein and fat intake by the women relative to the men in their study.

TABLE 4. Variation in mean dietary indices by gender and geographic location

	Total number of food items reported in 24 h			Subsistence index			Market index		
	YDBE	MS	*P* value	YDBE	MS	*P* value	YDBE	MS	*P* value
All adults	3.80	3.12	0.03	2.73	2.24	0.11	1.48	1.12	0.004
	(0.20)	(0.20)		(0.22)	(0.21)		(0.09)	(0.08)	
	1–11	1–8		0–10	0–7		0–3	0–2	
Females	4.21	3.05	0.01	3.00	2.15	0.06	1.53	1.18	0.03
	(0.35)	(0.27)		(0.34)	(0.28)		(0.12)	(0.10)	
	1–11	1–8		0–10	0–7		0–3	0–2	
Males	3.38	3.22	0.71	2.46	2.37	0.83	1.02	0.85	0.27
	(0.28)	(0.32)		(0.27)	(0.33)		(0.11)	(0.10)	
	1–7	0–3		0–7	0–5		0–3	0–2	

TABLE 5. Correlations values for relationships between dietary indices and anthropometrics (n=)

	Total number of food items reported in 24 h		Subsistence index		Market index	
	YDBE	MS	YDBE	MS	YDBE	MS
Adult females						
BMI	0.12 (38)	0.54[a] (39)	0.08 (38)	0.50[a] (39)	0.17 (38)	0.17 (39)
Hemoglobin (g/dL)	−0.34[b] (36)	0.06 (35)	−0.29 (36)	0.13 (35)	0.11 (36)	−0.35[b] (35)
MUAC	0.05 (38)	0.46[a] (39)	0.03 (38)	0.42[a] (39)	0.25 (38)	0.02 (39)
SS	−0.24 (38)	0.21 (39)	−0.24 (38)	0.17 (39)	0.04 (38)	0.24 (39)
Adult males						
BMI	0.10 (37)	−0.02 (27)	0.07 (37)	−0.06 (27)	−0.10 (37)	0.12 (27)
Hemoglobin (g/dL)	0.05 (30)	−0.08 (24)	0.02 (30)	−0.13 (24)	0.01 (30)	0.20 (24)
MUAC	0.20 (37)	−0.006 (27)	0.15 (37)	0.007 (27)	0.05 (37)	−0.15 (27)
SS	−0.15 (37)	0.10 (27)	−0.19 (37)	−0.09 (27)	−0.00 (37)	0.41[b] (27)

[a] ≤ 0.05.
[b] ≤ 0.01.

At APDS BaAka men engaged in formal employment as forest guides, trackers, or research assistants are likely to regularly receive protein and calorie-rich meals during overnight or longer stays of 2–6 weeks away from the village. Women do not typically participate in the formal labor economy and do not often eat or sleep away from their families. However, our anthropometric data fail to show consistent patterns of gender difference in short-term nutritional status. Men in our overall sample and those at MS had greater MUAC than women, whereas women had a greater mean SS value than men. However, at YDBE, differences between the SS values of men and women did not vary significantly. Adult males from YDBE had marginally higher BMI and SS than males from MS. While the differences between villages in some of the anthropometric variables are small, they are suggestive of future health disparities between villages. Such signals of overall better condition among males at YDBE, and variation in gendered differences between villages may likely be attributable to the village level variation in accessibility of the community-hunting zones within APDS. Inhabitants of MS must travel further than their counterparts to find legal hunting grounds with substantial numbers of wildlife. Indeed, 10 out of 22 of the men that reported having eaten meat had hunted it themselves; 7 of these were from YDBE.

Consistent with predictions, our 2012 data show that 18% of the BaAka women ($n = 77$) in our study may be chronically energy depleted (BMI < 18.49 kg/m^2, Bailey and Ferro-Luzzi, 1995). Similarly, Lartey (2008) reported that 5–20% of all women in sub-Saharan Africa have low BMI resulting from chronic hunger. Interestingly, the only significant correlations between a dietary variable and nutritional indicators in this study were observed between MUAC, BMI and the reported consumption of OFP's for women in MS village. While we cannot demonstrate a causal linkage between the two, this significant relationship could suggest that women in MS who are reportedly consuming less meat, relative to women from YDBE, are nutritionally reliant on access to OFPs.

It is likely that the nutritional indicators reflect variations in intensity of food insecurity between villages at APDS, with those in MS having less access to their own fields or forest resources. Our interview data suggest that YDBE populations currently spend more time in the forest and in forest camps than those in MS, with higher diversity of foods in the diet; both subsistence and market foods. Traditionally the wet season is a busy time in the forest, when BaAka establish forest camps for gathering honey and hunting (Bahuchet, 1988; Hardin and Remis, 2006). However, in the course of our 2-month study during the honey season of 2012 none of the BaAka from MS reported overnight stays in the forest. On the other hand, we found about one-third of the residents of YDBE camped in two different campgrounds away from the village during the same time period.

Our study at APDS was conducted during a period of resource scarcity, when wild meat, a primary protein source, and bitter manioc, the staple carbohydrate, were both in short supply. With low return rates of traditional net hunting, most BaAka had little access to meat or cash to purchase protein or calorie-rich foods. As such, BaAka did not appear to be replacing declining forest

foodstuffs with domestic alternatives as has been observed in other transitional forager groups. While we did not document caloric intake, dietary recall surveys and interviews indicated that during our study period most individuals were eating only a single meal per day, usually comprised simply of wild *G. africanum* leaves and *I. wombolu* nuts (Remis and Jost Robinson, unpublished). Foragers, especially those in the forest, typically snack on fruit, yams, or nuts during the day, and may wake to eat at night if food is available. Those in the village with access to cash might be able to purchase bread, fried dough beignets or small pieces of fried fish. However, those interviewed in our study frequently lamented a lack of cash to purchase prepared food and that they were eating only once a day. Further, no one reported eating bread or beignets and very few reported eating leftovers or an additional meal in the 24-h recalls. While some unreported snacking probably occurred, during our day-long stays in villages during data collection, little food processing, snacking, or eating was observed. In our study, women reported consuming a greater variety of foods, especially OFPs than men. We found no sex differences in the frequency of meat consumption in the dietary recalls, though admittedly these are coarse and do not account for any gendered differences in quantity of foods eaten.

Although Central Africans are typically known for their high levels of meat consumption relative to populations in other regions (Wilkie and Carpenter, 1999), meat or fish was only consumed in small amounts during our study, and only on 21% of days surveyed at MS village ($n = 66$) and 47% of days at YDBE village ($n = 75$), but on 67% days for a YDBE forest camp ($n = 21$; Remis and Jost Robinson, unpublished data). Long-term ethnographic research on Congo Basin foragers describes wild meat as the only "true" and psychologically fulfilling food, where foragers who report "meat hunger" exhibit signs of malaise and depression (Motte-Florac et al., 1993). Our future studies quantifying intake and the nutrient composition of these nonmeat forest products will be important in more fully understanding the nutritional status, and physical and psychosocial health of BaAka populations who are currently consuming little meat or fish.

BaAka in transition in a conservation economy: Comparisons to other studies

Declining biodiversity has been documented to have negative impacts on the health and diet of forest foragers (Froment, 2001; Piperata et al., 2011). Froment et al. (1993) found that Bakolo foragers in Cameroon exhibited signs of nutritional deficiency resulting from reduced dietary diversity with the transition from hunting and gathering to a more sedentary lifestyle. Moreover, Golden et al. (2011) point to the critical nutritional importance of wildlife in the diet of human communities in rural Madagascar. They used their data on high levels of anemia among children who consumed little animal protein to design predictive models, calculating that if access to wildlife was removed, there would likely be a 30% increased risk of anemia in the population. Our data lend support to Golden's findings; we can go further to provide a counterpoint to previous investigations of health among BaAka in the Bayanga region in the late 1960s, before logging or conservation economies came to the region (Cavalli-Sforza, 1986). Despite the intention of APDS at the time of the zoning of the multi-use area to permit BaAka to maintain a hunting-gathering lifestyle, the BaAka continue to undergo transformation in their subsistence practices. Now, following declines in wildlife diversity and access to forest resources, their levels of low hemoglobin have increased dramatically.

We plan to conduct more quantitative assessments of nutrient and caloric intake coupled with examinations of energy expenditure, analysis of parasitic infection and other biomarkers to more fully understand the impacts of nutritional transition on BaAka health at APDS. However, our current data lead us to expect that the BaAka of APDS are following a similar trajectory to other indigenous peoples who have adopted sedentary lifestyles and practice full-time horticulture, with apparent consequences for poor health (Kuhnlein and Receveur, 1996).

Overall, we found few differences between the anthropometric measures of the BaAka in this study and other Central African populations. On average, the BaAka in the APDS region in 2012 were slightly heavier and taller than those in Pennetti's earlier combined study of the APDS region and the Lobaye, a pattern also noted by the earlier researchers (Pennetti et al., 1986). Our 2012 BMI data from APDS were comparable to the averages of those collected more broadly in the 1960s (BMI males: 20.5, females: 20.2, Pennetti et al., 1986). Given expectations about the impact of transition on stature, we might expect that the BaAka at APDS could have declined in stature or BMI over the more than 40 years between datasets, but the available data do not allow us to separate individuals from the two regions in order to examine this possibility.

The similarity of male and female BMI in our study is consistent with other forager literature. For example, Yamauchi et al. (2000) reported little difference in the BMI values for males and females among settled agriculturalist Baka in Cameroon. In the Baka study, Yamauchi et al. (2000) found significant gender differences in upper arm circumference and skinfold thicknesses that mirror those observed in our overall sample. The Cameroonian Baka, like the BaAka in our study, also had a relatively low intake of meat and fish and high intake of agricultural starches compared to forest living BaAka populations studied by Kitanishi (1995).

Nevertheless, the temporal comparison between our BaAka data set and the one collected by Cavalli-Sforza's team does signal a health decline over time. Our most critical finding is low hemoglobin levels. Pennetti et al. (1986) report that 15.6% of the BaAka women in their sample had low hemoglobin levels (measured below 12 g/dL—the data reported by Pennetti et al. (1986) are compared to the proposed WHO values, rather than those used here which reflect the Scripps–Kaiser index of 11.5 g/dL as a lower limit for adult women). In our comparison, we see a substantial increase in the number of women with reportedly low hemoglobin values, with 63% of the women having hemoglobin levels below 12 g/dL (61% below the value of 11.5 g/dL). We note that hemoglobin status can also relate to multiple factors in addition to nutritional deficiency, particularly malarial and helminthic parasitic infections (Huddle et al., 1999; Abrams et al., 2005; Zimmerman and Hurrell, 2007). Yet it is important to note that the World Health Organization suggests a public health crisis is imminent if more than 40% of a female sample population has Hemoglobin values <12 g/dL (WHO, 1995).

This article identifies spatial variation in nutritional status in indigenous communities within a protected forested area. Consistent with our predictions based on wildlife declines and forest zoning, we see evidence of chronic energy depletion and identify low hemoglobin levels and village differences in integration into the market economy. This work complements previous exploration of the nutritional and health outcomes associated with transitional economies, and recent work on the critical relationship between forest cover and nutrition. Our results highlight the importance of access to the nutritional forest resources that are maintaining health and productivity in managed zones. Future work to integrate nutritional and energetics studies with ethnography and conservation medicine will better explore the nature of subsistence in transition and food security among contemporary foraging societies. Further, integrated analyses of biosocial systems in protected areas have outcomes for understanding gender roles, nutrition, social health disparities, and the sustainability of lifeways and livelihoods of foragers. In this case, the increasing diversification in modes of production of male and female foragers at APDS may result in gendered health disparities that could reduce resilience in the face of civil, agricultural, and economic disruptions that have subsequently occurred throughout the country.

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