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Socio-ecological analysis of natural resource use in Betampona Strict Natural Reserve

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ABSTRACT

Without an adequate understanding of the socio-political context in which a natural environment is embedded, it is impossible to prevent, mitigate and adapt to future unwanted changes in the socio-ecological system. It is advantageous for environmental managers to see the social aspects of the socio-ecological system so that they can understand not only the effects but also the motivations of natural resource use. In Madagascar, lemurs and other mammalian wildlife are hotly contested resources because they are threatened and endemic biodiversity and yet are hunted for food throughout the island. Using semi-structured interviews in nearly 300 households in 19 communities surrounding the Betampona Strict Natural Reserve, our team found that more than 60 % of households had consumed wildlife within the past year, with approximately a quarter of wildlife harvest being illegal and nearly 95 % of wildlife harvest being directed to subsistence consumption and not for sale. Although rates of wildlife consumption were quite low throughout the region, we found a strong effect of the presence of the Madagascar Fauna and Flora Group research station. We found that the rates of wildlife consumption increased by 1.3 times for each kilometer distance from the station. Due to the low rates of wildlife consumption, we did not find a significant impact on human health and anemia (as measured through hemoglobin levels), and very low prevalence of anemia generally compared to other regions of Madagascar. Wildlife consumption does not appear to play a tremendous economic or health role in the communities surrounding this particular protected area, and thus increased enforcement of seasonal infractions of legal species and of all illegal species would be warranted. To improve current levels of nutrition, targeted interventions could focus on domesticated livestock diseases that plague the region.

RÉSUMÉ

Lorsque des changements inopinés surviennent dans un système socio-écologique, il est impossible de prévenir, d'atténuer et d'adapter si le contexte socio-politique dans lequel un environnement naturel évolue n'est pas bien compris. Les gestionnaires de l'environnement ont tout intérêt à considérer les aspects sociaux du système socio-écologique de manière à comprendre non seulement les effets de l'utilisation des ressources naturelles mais aussi ce qui motive cette utilisation. A Madagascar, les lémuriens et d'autres mammifères sont des ressources vivement contestées car ces espèces sont menacées et tout en représentant la biodiversité endémique, elles sont cependant chassées pour leur viande sur l'ensemble de l'île. En utilisant des entretiens semi-structurés auprès de 300 ménages dans 19 communautés villageoises de la périphérie de la Réserve Naturelle Intégrale de Betampona, la présente étude a montré que plus de 60 % des ménages avaient consommé du gibier au cours de l'année écoulée dont environ un quart de manière illégale et près de 95 % pour répondre à des besoins de subsistance mais pas pour la vente. Bien que les taux de consommation de gibier étaient plutôt faibles sur l'ensemble de la région, un fort effet de la présence de la station de recherche de Madagascar Fauna and Flora Group a été noté avec des taux de consommation de gibier multipliés par un facteur de 1,3 pour chaque km distant de la station de recherche. En raison des faibles taux de consommation de gibier, aucun impact significatif sur la santé humaine et l'anémie n'a été observé (tel que mesuré par le taux d'hémoglobine) et une prévalence extrêmement faible de l'anémie générale par rapport à d'autres régions de Madagascar. La consommation de gibier ne semble pas jouer un rôle économique ou sanitaire majeur pour les communautés de la périphérie de cette aire protégée en particulier, de sorte qu'il serait justifié d'appliquer plus strictement les lois portant sur le calendrier de chasse du gibier autorisé et l'interdiction de chasser d'autres espèces. Pour améliorer les niveaux actuels de la nutrition, des interventions ciblées pourraient se concentrer sur les maladies des animaux domestiques qui sévissent dans la région.

INTRODUCTION

Natural resources often play a critical role in human health and livelihoods and many suggest that conservation should attempt to meet all basic human needs (i.e., Kaimowitz and Sheil 2007). In Madagascar, more than 92 % of people live on less than $US 2/day (World Bank 2013) and thus natural resources

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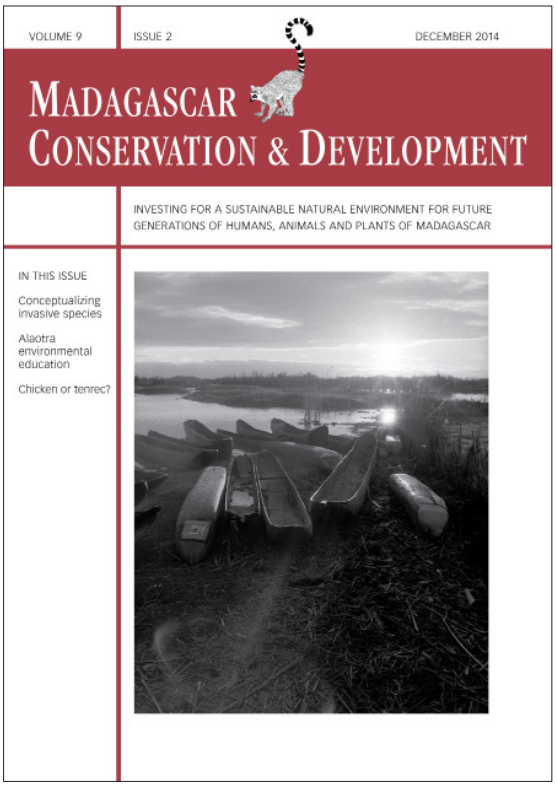

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play an instrumental role in providing what their limited financial resources cannot. Throughout Madagascar, several types of natural resources have been shown to play a major role in human livelihoods, through local use of honey (Kremen et al. 1999), construction materials (Kremen et al. 1999), traditional medicines (Golden et al. 2012a), soils/earth (Golden et al. 2012b), and the environment's role in spiritual and cultural practice (i.e., Keller 2009, Golden 2014). Because of the environment's tremendous value to local people in poverty alleviation (e.g., Gardner et al. 2013), conservation can serve to exacerbate conflict over resources, especially when resources are critical for human livelihoods or survival (West and Brockington 2006). Local people's use of wildlife as food, especially the primate diversity, is hotly contested as lemurs are endemic and often endangered (representing more than 20% of the world's primate species and 30% of family-level diversity, Schwitzer et al. 2014). Yet, local Malagasy hunt lemurs for food throughout the island (e.g., Golden 2009, Jenkins et al. 2011). Furthermore, it has been shown that this hunting is not for pleasure but rather serves a tremendous economic (Golden et al. 2014) and health role (Golden et al. 2011). These types of contested resources and the extent to which humans depend on them are necessary to explore on a site-by-site basis to further effective conservation and development programming in adaptive ways (i.e., Margules and Pressey 2000).

The concept that the practices and support of local people are important to the success of protected areas is largely understood (Keller 2009, Corson 2012), and yet, researching local systems in cost-effective ways that will facilitate adaptive conservation management plans is still lacking here in Madagascar. In order to most effectively conserve the biodiversity within protected areas, environmental managers need to understand many aspects of their respective region's environment, including its ecology, demographics, economics, human health status, and agricultural systems, among others. Here, we present the results of a six-month assessment in communities in Madagascar where we collected data concerning conservation-relevant human behaviors in order to understand current levels of environmental pressure, the socio-economic motivation of these pressures, and whether or not the exploitation had significant human welfare consequences.

This rapid assessment represents the first of seven already funded assessments that the MAHERY (Madagascar Health and Environmental Research) team has ongoing in Madagascar. The MAHERY team is a consortium of Malagasy and American researchers who have the expressed aim of understanding (i) current levels of forest pressure from human populations, (ii) the relevance of this exploitation to human livelihoods and health, and (iii) the role of varying forms of conservation governance in dictating local human behaviors vis à vis their environment.

METHODS

STUDY SITE. This study was conducted in 19 villages surrounding the Betampona Strict Natural Reserve, one of the last remaining low altitude rainforest ecosystems in Madagascar (Figure 1). Betampona, the very first protected area established in Madagascar in 1927, is located between E49°12'00"–49°15'00", S17°15'00"–17°55'00" on the east coast of Madagascar, about 40 kilometers from the principal port city of Toamasina. Despite its relatively small size (2,228 hectares),

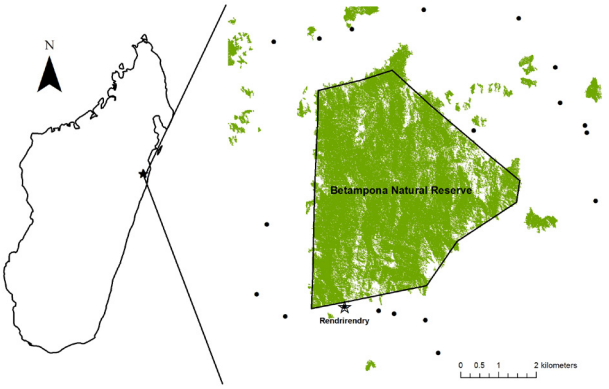

FIGURE 1. Betampona Strict Natural Reserve in eastern Madagascar detailing the protected area limits (black line), forest cover (green) and surveyed communities (black dots).

Betampona is rich in biodiversity, with 11 known lemur species, 88 known bird species and 67 reptile species identified. As a Strict Natural Reserve, access is strictly forbidden to both local people and tourists. Only students and scientists who receive a research permit through Madagascar National Parks (MNP) are allowed entry.

The local population living around the reserve was primarily Betsimisaraka, one of the 18 major ethno-linguistic groups in Madagascar, with members from other groups comprising less than 5% of the population (this study). The principal economic activity was agriculture, of which rice, corn, coffee, cloves, and bananas predominated. Animal husbandry (chickens, ducks and pigs) was conducted mainly for household consumption. Due to its close proximity to Toamasina, many inhabitants have historically left the area for hopes of prosperity in the regional city. The Madagascar Fauna and Flora Group (MFG) manages this protected area in conjunction with MNP; the MFG research station is located in Rendrirendry (Figure 1).

SURVEY PROTOCOLS. Between February and August 2013, two Malagasy researchers (Rabehatonina and Rakotosoa) surveyed 298 households (seven households declined to be interviewed) in 19 communities adjacent to the Betampona Reserve. These researchers were part of the MAHERY (Madagascar Health and Environmental Research) team and had been rigorously trained in survey protocols prior to this research. The communities were not randomly sampled but we attempted to survey all communities adjacent to the protected area. Only three of the 22 communities that surround the protected area were not surveyed due to time constraints. The two enumerators consulted with the local community chiefs and arranged schedules for interviews jointly with local leadership. A village meeting was always held prior to the commencement of surveys. However, the two enumerators were not accompanied by any local guides during the interview process to promote honest answers to sensitive questions. During the community meetings, the research was explained as work trying to understand the ways in which natural resource use and agricultural activities contributed to human food security, health and general wellbeing.

Our survey instrument was designed to gather information regarding natural resource use by administering questions to the male or female head of household. Questions pertained to household demographics, agricultural labor, livestock raising and diseases, income generation, forest resource use, hunt-

ing behavior and taste preferences of animal-source foods. In general, the interviewees were asked to recall events over the past year. Households were selected by one of two methods: i) if a household census existed at the community level, then the local research team selected every third household to participate; ii) if no household census existed at the community level, then the research team selected every third household that they passed in the community. Each head of household provided informed consent to participate in the research survey.

In addition to questions administered solely to the head of household, we also collected health statistics on all available individuals in the surveyed households, totaling 956 individuals within these 298 households. The basic information included sex, birth date, occupation and educational obtainment. The specific health information gathered included anthropometric assessments (height and weight), a history of malaria episodes, a history of deworming medication, and a hemoglobin and blood oxygen level obtained from a portable hemoglobinometer (Rainbow Pulse CO-oximeter from MASIMO). This hemoglobinometer was simple to use and was non-invasive, using photospectrometry rather than a blood sample to assess hemoglobin status. Both enumerators were trained by Golden with supervision from the Madagascar Ministry of Health to carry out these protocols.

VARIABLE CREATION AND ANALYSIS. All data were analyzed in STATA v.13.0. Simple summary statistics were calculated for most forms of environmental resource use and socio-demographic variables. Installable macros packages from the World Health Organization were used to calculate the prevalence of anemia in children and adults. We analyzed the effect of wildlife consumption on hemoglobin levels using an established generalized linear mixed model where all individuals were clustered at the level of the household, hemoglobin was an untransformed continuous outcome variable, wildlife consumption was a log-transformed continuous explanatory variable, and household income and an individual's age were controlled for within the model (Golden et al. 2011). Hemoglobin levels in this population were roughly normally distributed and did not require transformation.

RESULTS

In the 298 surveyed households surrounding Betampona Strict Natural Reserve, there was a mean household size of 3.9 individuals (median 4) with 46.2 % of the population being less than or equal to 16 years of age (Supplementary Material). Eight percent (24 households) reported no cash income in the past year demonstrating high subsistence reliance in these households in particular. Of the households reporting cash income, income was highly positively skewed (median income: $67.50 per household, mean $144.18, SE: $18.19) which demonstrated that although many households were entirely subsistence-driven, some households had entered into cash market economies.

Much like other regions of Madagascar, agricultural labor and much of life centered on rice production. Surrounding the Betampona region, there were two rice crops per year: a swidden rice crop harvested in approximately May and a paddy rice crop (although to a much lesser extent) harvested in approximately November. Local Betsimisaraka in this region participated in the agricultural practice of having a seasonal home, or hamlet, called *lasy* in Malagasy. A minority of the population (25.3%) used *lasy* in the past year, and living in a *lasy* peaked during May at the height of labor demands for swidden agriculture (Supplementary Material). The average *lasy* was a 1.1 hour walk from the center of the community (SE: 0.05 hours) with a maximum distance of 5 hours. This means that the average *lasy* was 4.8 km away if we estimate time-distance relationships and expect normal walking speeds (Ralston 1958), which are likely an overestimate here given the steep and slippery terrain.

Ninety-six percent of the population relied on firewood for cooking and harvested it themselves. Individuals traveled between 0–2 hours for collection, with most frequent collections occurring 15–30 minutes from home. Approximately four-fifths of households had harvested timber (even if just one piece of wood) and 90 % have collected thatch roofing in the past year for personal use showing high dependence on the forest for natural products that can create shelter. High reliance on the forest for healthcare was reported with nearly 82 % of households having harvested traditional medicines from the forest at a rate of approximately once per week. Only 4 % of households had collected honey in the past year. This low rate of collection was not due to preferences but to a devastating bee epidemic that had wiped out hives in the region.

More than 60 % of households had consumed at least one wild animal in the past year but it was very sporadic among households who hunt wildlife. Only 2 of 298 surveyed households possessed a shotgun and the remaining households used predominantly natural products to trap, snare and slingshot animals. All active hunting of tenrec species, as compared to opportunistic hunting, was facilitated by dogs tracking the scent of tenrecs (Table 1).

Of a total of 2,253 animals reported to have been consumed by surveyed households, 23.0 % of animals were illegal to harvest according to the most recent updates to legislation (Rakotoarivelo et al. 2011). Hunting of tenrecs is only authorized from 1 April–31 May (Ordonnance N^{o} 60-126 from Oct. 3, 1960) and this hunting is only legal if also not occurring at night or with dogs or other prohibited equipment. The local MFG staff were not aware of this obscure legislation (and not responsible for educating local people about legislation) and thus, local people were likely ignorant of these policies as well (n.b., we did not survey local people's knowledge of rules). Only 5.3 % of animals consumed were obtained through a sales transaction, and all purchases were made on a household-to-household basis. Only three species were sold: bush pig (*Potamochoerus larvatus*, n=77, mean price $US 2.25/kg), hedgehog tenrec (*Setifer setosus*, n=7, $US 0.60/animal) and the common tenrec (*Tenrec ecaudatus*, n=36, $US 0.45/animal).

When investigating the conservation impact of permanent staff presence and monitoring of infractions by MFG patrols, we found that wildlife harvesting increased by approximately 1.3 (generalized linear mixed model, p=0.035, 95 % CI: 0.1–3.1) times per kilometer distance from the Rendrirendry research station, where the MFG agents and guides are based, even after controlling for the distance to the forest. Therefore, we tended to see an exponential increase of wildlife extraction as distance from the research station increased.

The average household reported eating approximately five wild animals in the past year (Table 1). Almost one in five households had eaten a lemur in the past year, yet at very low levels of consumption. On average, 0.75 lemurs per household were consumed per year. Carnivoran hunting was at even lower

TABLE 1. The volume of mammalian wildlife consumption in communities surrounding the Betampona Strict Natural Reserve, disaggregated by hunting method. The volume of consumption was reported based on the head of household's recall of number of individuals consumed within the past year (NB: wild bird, insect, reptile and amphibian consumption was not surveyed). **P. larvatus* was reported by number of occasions consumed rather than number of individuals as it was frequently purchased as weighed pieces of meat or eaten at friends' homes.

Species	Total consumed	Active hunting [%]	Snaring [%]	Opportunistic hunting [%]	Eaten with friends [%]	Purchased [%]
Tenrec ecaudatus	1,030	53.6	0.3	17.3	10.0	18.6
Microcebus sp.	323	55.1	0.0	43.7	1.2	0.0
Setifer setosus	170	61.8	0.0	20.6	7.6	8.8
*Potamochoerus larvatus**	121	0.0	11.6	8.3	15.0	64.5
Hemicentetes semispinosus	80	53.8	0.0	38.8	3.8	3.8
Microchiroptera sp.	76	93.4	0.0	0.0	6.6	0.0
Viverricula indica	38	0.0	89.5	7.9	2.6	0.0
Galidia elegans	21	9.5	33.3	23.8	33.3	0.0
Hapalemur griseus	7	71.4	0.0	28.6	0.0	0.0
Avahi laniger	7	14.3	0.0	0.0	85.7	0.0
Pteropus rufus	6	0.0	0.0	0.0	100.0	0.0
Salanoia concolor	6	100.0	0.0	0.0	0.0	0.0
Cryptoprocta ferox	4	0.0	0.0	50.0	50.0	0.0
Daubentonia madagascariensis	4	0.0	0.0	0.0	100.0	0.0
Galidictis fasciata	3	66.7	0.0	33.3	0.0	0.0
Lepilemur sp.	2	0.0	0.0	2.0	0.0	0.0
Eulemur albifrons	1	100.0	0.0	0.0	0.0	0.0
Indri indri	1	0.0	0.0	0.0	100.0	0.0
Propithecus diadema	0	.	.	.	.	.
Varecia variegata	0	.	.	.	.	.
Cheirogaleus sp.	0	.	.	.	.	.

levels, with 10% of households participating, and an average 0.16 carnivorans per household consumed per year. Bat hunting was also rare with 2.5% of households consuming bats and on average 0.28 bats per household consumed per year. Tenrec hunting was the most common form of wildlife harvest in the area with more than 50% of household eating them at an average rate of four tenrecs consumed per household per year. More than 20% of households were eating bush pig at an average rate of 250g per year.

We found a very low prevalence of anemia throughout all sub-populations surrounding Betampona. Approximately 13% of children 0–5 years of age, 6% of children 6–12 years of age, 8% of women over 12 and 14% of men over 12 were affected by anemia (World Health Organization 1994). Only 1.2% (12 of 965) of observed subjects would be deemed in the moderate to severe anemia cutoffs (ibid). Unsurprisingly, with very low rates of wildlife harvest locally, we did not find a relationship between wildlife consumption and human nutrition here (generalized linear mixed model, p=0.581) but we did find that women and girls had significantly lower hemoglobin than their male counterparts (T-test, 0.69g/dL, 95% CI: 0.50 – 0.88 g/dL, p<0.001).

Although both the prevalence of anemia and rates of wildlife harvest were low, there was still a tremendous amount of space for dietary improvement. On average, chickens seemed to be the most prevalent type of animal-source food, followed by ducks (Table 2). These poultry also comprised nearly 50% of all individuals number one top taste preference for all animal-source foods, including wildlife (Figure 2).

However, the disease toll on chickens seemed to be the most prevalent of all domesticated meat sources. Locally, there was a disease called *bomona*. According to local descriptions of symptoms and timing, it was very likely to be Newcastle disease. The estimated case-fatality rate was 96% as measured by community perceptions of cause of death. Ducks were also affected by Newcastle disease but also likely affected by Duck plague. The case-fatality rate for ducks across all diseases was approximately 64%. Thirteen percent of households in Betampona had diseased pigs in the past year. Locally, this pig disease was called *pesta* and was characterized by loss of appetite, being unable to stand, foamy mouth, being cold to the touch, vomiting and had an 86% fatality rate. Zebus were affected by *viky* (worms) and *dinta* (flukes). Of six cases where these issues were severe, two led to premature death of the animal.

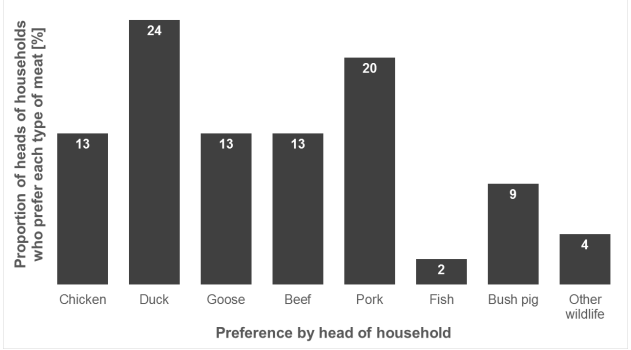

FIGURE 2. Reported number one top taste preferences for all heads of households in the Betampona Strict Natural Reserve. Taste preference rankings could not tie and all individuals surveyed had to rank all meats that they had ever tasted, even if only once.

TABLE 2. The range and mean of household livestock assets in communities surrounding the Betampona Strict Natural Reserve.

Type of livestock	Zebu	Pig	Duck	Chicken	Goose	Cat	Dog
Range (#/household)	0–6	0–9	0–25	0–80	0–40	0–5	0–6
Mean (#/household)	0.17	0.42	1.5	7.5	0.5	0.14	0.26

DISCUSSION

Natural resource use by communities in Madagascar appears to be important to local livelihoods and wellbeing, and may play a role in local poverty alleviation (Gardner et al. 2013). Surrounding the Betampona Strict Natural Reserve, the use of firewood for energy, timber and other forest products for shelter, and honey and wildlife (among many others) for food and nutrition are examples of the interface between environmental integrity and human wellbeing. The availability of these resources may change in the future given current trends in ecosystem transformation. For example, the use of honey is particularly exceptional near Betampona because the rates of collection are so low due to some sort of colony collapse that has affected local bee populations. Local people historicize this rapid decline over the past 5–10 years and this question begs for further study (though see Rasolofoarivao et al. 2013). Honey consumption can be critical to subsistence and hunter-gatherer populations, and may be a unique source of refined sugar and energy in this population (Cordain et al. 2000).

Overall rates of mammalian wildlife harvest appear to be quite low in the communities surrounding Betampona. As a point of comparison, wildlife harvest is substantially lower across all taxa when compared to rates of exploitation in another MAHERY study site, Makira Natural Park, an area over two orders of magnitude larger than Betampona that has allocated 'use' zones (Golden et al. 2014). For instance, 17% of households eat lemurs in Betampona as compared to 49% in Makira, 10% eat carnivorans as compared to 40% in Makira, 20% eat bush pig as compared to 25% in Makira, 51% eat tenrecs as compared to 91% in Makira, and 3% eat bats as compared to 15% in Makira (ibid).

The low rates of terrestrial mammal consumption surrounding Betampona are similar in level to the Alaotra-Mangoro region of eastern Madagascar (Jenkins et al. 2011). We did not focus on other types of wildlife consumed such as birds and reptiles due to lack of adequate time to explore these issues during our interview. This of course limits the reporting on the breadth of resources used which is problematic given our own research experiences in Makira, and based on others research in other parts of Madagascar (i.e., Gardner and Davies 2014).

Future analyses will be required to determine the sustainability of harvest; however, it could be assumed that most species are being sustainably harvested with the exception of species with life history traits that allow almost no levels of sustainable harvest such as the fosa (*Cryptoprocta ferox)*, which was reported to be hunted four times in our study. Assessment of sustainability for protected species is moot but these analyses should be considered for game species such as tenrecs and bats, etc. If the 23% of animals which were illegally hunted were further diminished, it is even more likely that current rates would not be of major conservation concern. Hunting techniques are mainly traditional using trapping and snaring, similar to other hunting studies in Madagascar (Golden 2009, Jenkins et al. 2011, Gardner and Davies 2014, Golden et al. 2014). Hunting with dogs is prevalent throughout the region and is verified by the frequency of dogs observed inside the protected area, as measured by phototrap incidence (Fidisoa Rasambanairivo, pers. comm.). This statistic was important as both dogs and people are prohibited from entering inside the protected area and dogs facilitate hunting of protected species, likely having major impacts on local wildlife.

It is likely that we may be witnessing low harvest rates for one of several reasons: 1) wild animals are less prevalent in this area due to small intact forest size; 2) permanent presence of MFG research staff and monitoring of infractions by local agents; and/or 3) hesitancy to report illegal activity to survey implementers especially in the context of a rapid assessment. Although we concede that the latter reason is certainly possible, we attempted to minimize this bias in several ways. First, the survey implementers were trained in our ongoing longitudinal survey effort in Makira to learn effective methods for gathering information (Golden et al. 2013, 2014). Second, the survey was framed in the context of food security and livelihoods and thus the questions regarding consuming wildlife were not asked from a conservation perspective but rather from one of food security and human health. Lastly, one of our surveyors was born and raised in this region which lends legitimacy to our efforts. Even with these conditions, it is likely that our results were biased and that the levels of wildlife consumption (particularly of protected species) may represent conservative estimates of exploitation.

Assuming that survey bias did not unduly influence our results, it is possible that the permanent presence and monitoring of infractions by the Madagascar Fauna and Flora Group (MFG) do play some role in the low rates of wildlife harvest in the region. To credibly believe our results that permanent research presence and monitoring of infractions affect community levels of wildlife harvest, we must assume that the distance from the MFG research station measure may serve as a proxy for monitoring and enforcement intensity because more direct measures were not collected. Ecological monitoring has been shown to be effective in engaging local people and reducing pressures on the forest in Madagascar (Kremen et al. 1994, Andrianandrasana et al. 2005). From 2009–2010 in Betampona, there were a total of 203 patrols throughout the Betampona region to search for signs of illegal forest activities (MFG, internal report). Patrols were very high during this period (typically only eight patrols per month per year) because research was postponed in Betampona during the Madagascar presidential political transition. Across all forms of infractions, a total of 46% of patrols indicated the presence of illegal forest use. Peaks in illegal activity (as proxied by numbers of patrols indicating infractions on a monthly basis) were parallel to seasons in which local people spent more time in their *lasy* (or seasonal agricultural homes). This is a similar result to our ongoing observations in Makira Natural Park (Golden, unpub. data) and perhaps presents an opportunity for

targeting increased education to particular groups for whom forest policies may not be apparent.

Throughout all age and sex sub-groups disaggregated, we found consistently low rates of anemia. Also, we did not find a significant association between wildlife consumption and anemia in this region. This does not mean that wildlife is not important to the diet as a variety of micronutrients such as fatty acids, zinc, and vitamin B12 may not be consistent with an individual's hemoglobin level (Kraemer and Zimmerman 2007). With that said, the extraordinarily low rates of wildlife harvest in each household appears to not significantly contribute to their health. This presents a fortunate opportunity to increase conservation efforts without fear of negative human health repercussions.

In order to complement local people's reduced access to wildlife as a food source, local populations could improve their health by increasing the productivity of local poultry stocks. And, chicken and ducks comprise 50 % of their top taste preferences, a similar result to Gardner and Davies (2013). Increasing the productivity of these types of livestock will likely lead local people away from wildlife hunting for economic reasons. As a price per kilogram, all species of wildlife are much less expensive than domesticated meat prices. This is consistent with findings from Makira; wildlife is less desirable (as proxied by taste preferences) but also less expensive because it is not market-oriented and the time invested in hunting is not internalized into the price (Golden et al. 2014). If an intervention made domesticated meat more productive and available, the price would drop and local people may naturally wean themselves from wildlife as a food source. Furthermore, because wildlife consumption does not appear to play a tremendous economic or health role in the communities surrounding this particular protected area, increased enforcement of seasonal infractions of legal species and of all illegal species would be warranted.

CONCLUSION

Research on socio-ecological systems is important globally, but particularly essential in Madagascar where local people live in close dependency on the natural resources in their surrounding environments. Understanding the motivations driving natural resource use and the types of benefits received from this resource access may help environmental managers to find parallel goals between environmental conservation and human wellbeing. Until we empirically frame conservation as a benefit to local people, managers will struggle to garner support for community-based natural resource management programs.

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SUPPLEMENTARY MATERIAL.

AVAILABLE ONLINE ONLY.

FIGURE S1. Demographic composition of households surrounding the Betampona Strict Natural Reserve.

FIGURE S2. Proportion of households living in seasonal forest homes (*lasy*).