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# An evaluation of the interactions among household economies, human health, and wildlife hunting in the Lac Alaotra wetland complex of Madagascar

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## ABSTRACT

In Madagascar, wildlife conservation and human food security and nutrition are deeply interconnected as many people rely on wild foods for sustenance. The Lac Alaotra wetland complex is an ecoregion which is indispensable to both the future food security of Madagascar's people and the conservation of its endemic wildlife. The region is Madagascar's largest rice production area, providing thousands of tons of rice and fish to the residents of one of the world's least food secure nations. The wetland complex also provides habitat to numerous threatened species, including two Critically Endangered mammals found only in the Lac Alaotra wetland complex. Environmental managers must understand how people affect their local environment and how the environment, in turn, affects these people, their livelihoods, and their motivations for future natural resource use. Without an adequate understanding of the complex interactions of local people and their natural environment, it will be impossible to prevent, mitigate, or adapt to future unwanted changes in this complex social-ecological system. We used health assessments of 1953 residents and semi-structured interviews of members of 485 households in 19 communities within the Lac Alaotra wetland complex to investigate human-environmental interactions (including current natural resource use and hunting, and how these behaviors affect local economies and human wellbeing). Our team found that, while rates of wildlife consumption were very low throughout the region, the members of 485 surveyed households ate 975 mammals in 2013, including at least 16 Alaotra gentle lemurs. Thirteen percent of households had consumed wildlife in 2013 and less than 1% of hunted wildlife was sold. Employment rates and annual income were both higher than other regions in Madagascar, and food costs were comparatively low. Nevertheless, 98% of households experienced food insecurity, and coping mechanisms (e.g., reducing portion sizes) appear to disproportionately affect young children and non-working members of households. Half of households did not receive the minimum recommended kilocalories per person per day. We found high rates of child malnutrition consistent with national rural statistics. While wildlife consumption does not appear to have significant economic or health benefits in the communities in the Alaotra wetland complex, high food insecurity significantly increased the number of forest and marshland mammals eaten by households. To improve child nutrition and wildlife conservation, we recommend targeted interventions that improve food security.

## RÉSUMÉ

À Madagascar, la conservation de la faune, la sécurité alimentaire et la nutrition humaine sont étroitement liées, car de nombreuses personnes dépendent des aliments sauvages pour leur subsistance. Le complexe des zones humides du lac Alaotra est une écorégion indispensable à la fois pour la sécurité alimentaire future de la population malgache et pour la conservation de sa faune endémique. Cette région est la plus grande zone de production de riz de Madagascar, fournissant des milliers de tonnes de riz et de poissons aux habitants de l'un des pays les plus touchés par l'insécurité alimentaire. Ce complexe des zones humides abrite également de nombreuses espèces menacées, notamment deux espèces de mammifères gravement menacées de disparition qui ne se trouvent que dans les zones humides du lac Alaotra. Les gestionnaires de l'environnement doivent comprendre comment les gens affectent leur environnement local et comment l'environnement, à son tour, affecte ces personnes, leurs moyens de subsistance et leurs motivations pour l'utilisation future des ressources naturelles. En l'absence d'une compréhension adéquate des interactions complexes entre les populations

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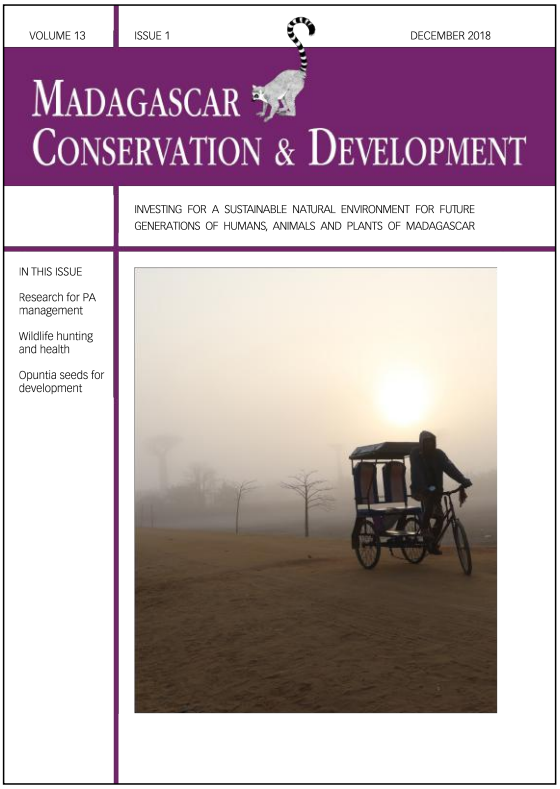


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locales et leur environnement naturel, il sera impossible de prévenir, d'atténuer ou de s'adapter aux futurs changements qui pourraient être néfastes dans ce système socio-écologique complexe. Nous avons conduit des évaluations sanitaires auprès de 1953 personnes, et des entrevues semi-structurées auprès de 485 ménages dans 19 communautés du complexe des zones humides du lac Alaotra pour étudier les interactions entre l'homme et l'environnement (y compris l'utilisation actuelle des ressources naturelles et la chasse, et comment ces derniers affectent le bien-être). Bien que le taux de consommation de la faune soit très faible dans toute la région, nous avons constaté que les membres des 485 ménages qui ont fait l'objet de nos enquêtes ont consommé 975 mammifères en 2013, dont au moins 16 Hapalémurs du lac Alaotra. Treize pour cent des ménages avaient consommé des animaux endémiques au cours de l'année 2013 et moins de 1% des animaux chassés avait été vendu. Les taux d'emploi et le revenu annuel étaient tous les deux plus élevés que dans les autres régions de Madagascar, et les coûts alimentaires étaient relativement bas. Néanmoins, 98% des ménages ont souffert de l'insécurité alimentaire, et les mécanismes d'adaptation (par exemple, la réduction de la taille des portions) semblaient affecter de manière disproportionnée les jeunes enfants et les membres des ménages qui ne travaillaient pas. La moitié des ménages n'avait pas reçu les kilocalories minimales recommandées par personne et par jour. Nous avons trouvé des taux élevés de malnutrition infantile, cette situation étant conforme avec les statistiques rurales nationales. Bien que la consommation d'espèces sauvages ne semble pas avoir d'avantages économiques ou sanitaires significatifs dans les communautés du complexe des zones humides de l'Alaotra, l'insécurité alimentaire élevée a augmenté de manière significative le nombre de mammifères forestiers et des zones humides consommés par les ménages. Pour améliorer la nutrition des enfants et la conservation de la faune, nous recommandons des interventions ciblées qui améliorent la sécurité alimentaire.

## INTRODUCTION

In Madagascar, wildlife conservation, human food security and nutrition are deeply interconnected as many people rely on wild foods for sustenance (Golden et al. 2011, 2016). Madagascar ranks within the ten least food-secure countries in the world (The Economist Intelligence Unit 2016). Poverty and food-price inflation are significant barriers to national food security (EIU 2016). Because of market-based barriers to food access, natural resources serve as a safety net for Malagasy households (Kremen et al. 1999, Golden et al. 2012, 2016, Borgerson et al. 2016), in a country where more than 92% of people live on less than $US 2/day (World Bank 2013) and where diets are lacking in diversity and foods rich in micronutrients and high quality sources of protein (The Economist Intelligence Unit 2016). One especially controversial safety net is the hunting of lemurs for food throughout the island (e.g., Golden 2009, Jenkins et al. 2011, Borgerson 2015, 2016, Golden et al. 2016, Reuter et al. 2016a). This hunting has economic (Golden et al. 2014a) and health benefits (Golden et al. 2011) and in some regions, poverty, poor health, and child malnutrition can best predict an individual's decision to hunt lemurs (Borgerson et al. 2016). For the successful integration of adaptive public health and environmental policy, it will be necessary to understand the use of natural resources and the extent to which humans depend on them on a site-by-site basis.

The Lac Alaotra wetland complex is indispensable to both the future food security of Madagascar's people and the conservation of its endemic wildlife. The region is Madagascar's largest food production area, producing 300,000 tons of rice and 2500 tons of fish (Plan Régional de Développement 2005) to the residents of one of the world's least food secure nations. The complex also provides habitat to numerous threatened species, including two Critically Endangered (CITES 2014) mammals found only in the Lac Alaotra wetland complex: the Alaotra gentle lemur (*Hapalemur alaotrensis*) (Andriaholinirina et al. 2014, Waeber et al. 2017, 2018a,b) and the recently described euplerid *Salanoia durrelli* (Durbin et al. 2010). The human population of the Alaotra region is rapidly growing and has affected the lake and its freshwater marshes through water eutrophication and hypoxia (Lammers et al. 2015), land clearing and erosion (Lammers et al. 2015) and the introduction of invasive species (Andrianandrasana et al. 2005, Rakotoarisoa et al. 2015). Further, land-use practices, including the clearing of vegetation (which increases water evaporation and the erosion of shore sediment) and the diversion of water for the irrigation of rice fields, have reduced the lake to one-third of its original size (Bakoariniaina et al. 2006). Land-users in the Alaotra face difficult decisions when coping with these changes in the environmental system, and adaptation is largely reactive and not proactive (Reibelt et al. 2017a, Stoudmann et al. 2017). Environmental managers must understand how people affect their local environment and how the environment, in turn, affects these people, their livelihoods, and their motivations for future natural resource use. Without an adequate understanding of the complex interactions of the local people of the Alaotra and their natural environment, it will be impossible either for mangers or local residents to prevent, mitigate, or adapt to future unwanted changes in this complex social-ecological system. Here, we present the results of a five-month assessment of communities in the Lac Alaotra wetland complex of Madagascar where we collected data concerning conservation relevant human behaviors in order to understand: (i) the current status of household economics, health and food security; (ii) the current levels of environmental pressure; (iii) whether variation in household socio-economics and health affects natural resource use; and (iv) whether variation in natural resource use has significant human welfare consequences.

## METHODS

STUDY SITE. Lac Alaotra and its surrounding freshwater marshes and wetlands cover 43,000 hectares of habitat which border human settlements and degraded lowland sub-humid tropical forests in the northeastern region of Madagascar's high plateau. Our study was conducted in 19 villages within the Lac Alaotra wetland complex. The principal ethnolinguistic group is Sihanaka and the principle economic activity of local people is agriculture, which is supplemented primarily by fishing, wage labor, and sales (this study). Numerous NGOs including Durrell Wildlife Conservation Trust, GERP (The Madagascar Primate Group), and Madagascar Wildlife Conservation have worked extensively in the region, supporting the conservation efforts for the Alaotra gentle lemur (*Hapalemur alaotrensis*) since 1994 and community-based participatory ecological monitoring since 2001 (Andrianandrasana et al. 2005, Ralainasolo et al. 2006). Madagascar Wildlife Conservation manages the 85 hectare Park Bandro on the eastern side of the lake (Rendigs et al. 2015) and Madagasikara Voakajy manages a network of 7 newly created protected areas in

the Alaotra-Mangoro region, protecting more than 30,800 hectares (Madagasikara Voakajy 2017).

SURVEY PROTOCOLS. Between August and December of 2014 MAV and TV surveyed 485 households, including 1953 individuals, in 19 communities surrounding Lac Alaotra. They consulted with the local community leaders and then held a local community meeting to discuss the goals of the project before beginning household interviews in each village. During the community meetings, the research was described as an effort to understand the ways in which natural resource use and agricultural activities contributed to human food security, health and general wellbeing.

Households were selected by one of two methods: (i) if a household census existed at the community level (often maintained by the president of the community), then the local research team selected every third household to participate; or (ii) if no household census existed in the community, then the research team selected every third household that they passed in the community. Each head of household consented to participate in the research survey. We interviewed either the male or female head of each household to gather information on household demographics, diet, food security, agricultural labor, livestock raising and diseases, income generation, commercial good ownership, taste preferences, natural resource use, and hunting behavior. Commercial goods included shoes, bicycles, radios, watches, flashlights, and guns. In general, we asked interviewees to recall events over the prior year as this had been demonstrated to be successful with regard to wildlife harvest surveys historically (Golden et al. 2013). Food security was determined using the Coping Strategies Index (CSI) (CARE 2008), a tool which asks household members to report the number of days during the prior week they used various coping strategies to deal with household food insecurity. In addition to questions administered solely to the head of household, we recorded the sex, age (to the nearest year), and occupation of each household member. We also collected data on the health of all available individuals in the surveyed households (1953 individuals within these 485 households), this included specific health information including anthropometric data (height and weight), history of malaria episodes, history of deworming medication, and hemoglobin and blood oxygen level obtained using a portable hemoglobinometer (Rainbow Pulse CO-oximeter from MASIMO). This simple, non-invasive hemoglobinometer uses photospectrometry rather than a blood sample to assess hemoglobin levels. Focus groups were also conducted in each village to determine how to weight the coping strategies used in the CSI (CARE 2008) based on cultural perceptions of the severity of food insecurity. During these focus group meetings, we also recorded information on poultry disease, cost, husbandry, and mortality.

VARIABLE CREATION AND ANALYSIS. All data were analyzed in JMP (www.jmp.com). Simple summary statistics were calculated for most forms of environmental resource use and sociodemographic variables. Thresholds from the Centers for Disease Control and Prevention (CDC) (2000) were used to calculate the prevalence of stunting, underweight, and wasting or low BMI for age in children and young adults age 2–20. We used WHO (2011) guidelines for hemoglobin cut-offs when determining anemia in children and adults. Children under 59 months were considered anemic if their hemoglobin values were less than 11.0, 5–11 year-olds if less than 11.5, 12–14 year-olds if less than 12.0, women 15 years and older if less than 12.0, and men 15 years and older if less than 13.0. Dietary diversity was measured using the Women's Dietary Diversity Score (WDDS) (Kennedy et al. 2010) and nutrient composition and the caloric content of foods were calculated using Stadlmayr et al. (2012). The fatality rates of diseases and illnesses afflicting livestock were calculated by dividing the number of animal deaths reported for a given disease over the prior year by the number reported to have been afflicted by that disease. We used a partition analysis to characterize food-secure and -insecure households. We analyzed the effect of wildlife consumption on child malnutrition and hemoglobin levels using an established generalized linear mixed model where all children were clustered at the level of the household (Golden et al. 2011). The deviation from the minimum recommended hemoglobin level was an untransformed continuous outcome variable that controlled for the age and sex of the individual and wildlife consumption was a log10+1 transformed continuous explanatory variable. We controlled for household income (log10+1 transformed) and food insecurity (roughly normally distributed and determined using CSI methods). Hemoglobin levels and the z-scores for child growth in this population were roughly normally distributed and did not require transformation.

## RESULTS

In the 485 surveyed households in the Lac Alaotra wetland complex, mean household size was 3.75 individuals (median 4). Just less than half of the population (41.7%) was less than or equal to 16 years of age and 8.2% were under age 2.

HOUSEHOLD ECONOMY. The principal economic activity of local people was agriculture, which was supplemented primarily by fishing, wage labor, and sales. Household income was high; households earned an average of 1,632,402 Malagasy Ariary (MGA) (or approximately $US544.13 using conversion rates at the time of study) in the prior year (median 1,105,000 MGA ($US386.33); SE 2,255,363 MGA ($US751.79)). This provided an average income of 488,164 MGA ($US162.72) per person during the prior year (median 287,500 MGA ($US95.83); SE 733,634 MGA ($US244.54)). Almost 16% of households reported earning cash income on a consistent daily basis, and more than 99% of households reported cash income in the prior year. Of all economic activities, the highest percentage of households (73.6%) sold rice in the prior year, yet the sale of rice crops supplied only 13.2% of all forms of income earned. Rice production was supplemented with earnings from other crops (23.7% of all income earned: 41.5% of which was from beans), sales of market goods and prepared foods (18.4%), salary and wages earned through services (15.9%), fish and other aquatic animals (14.4%), forest or marshland products (6.9%), livestock products (6.5%), and woven goods (1.1%).

Malagasy people often reside in a seasonal home, or *lasy*, close to their rice fields during the harvest season; however, a minority of the Alaotra population (15.1%) made any use of *lasy* during the prior year. Living in a *lasy* peaked during June at the height of labor demands for swidden agriculture (46.6% of all lasy were occupied during this time). The average *lasy* was a 2.5 hour walk from the center of the community (SE: 1.9 hours) with a maximum distance of 15 hours. Therefore, the average *lasy* was approximately 10.73 km away if we estimate time-distance relationships

and expect normal walking speeds (Ralston 1958). This is likely an overestimate due to the challenging terrain.

HEALTH AND FOOD SECURITY. We found a high prevalence of child malnutrition (Table 1) and a mild prevalence of anemia throughout all sub-populations measured in the Alaotra region. Approximately 12.1% of children 2–5 years of age (N=91), 6.6% of children 6–11 years of age (N=271), 9.9% of women 12 and older (N=615) and 8.7% of men 12 and older (N=516) were affected by anemia. Only 9.0% (135 of 1493) of all observed subjects were anemic. We found no significant differences between males and females in their prevalence of anemia.

The most frequently reported mechanisms for coping with food insecurity were to reduce the number of meals eaten in a given day (45% of all incidences of coping strategies used), harvest immature crops (26%), and restrict consumption of food by non-working household members in order to feed working members (14%). Rarely reported strategies included hunting wildlife (5%), eating next years' seed stock (3%), harvesting wild vegetables (2%), borrowing food (1%), eating at friends or families (1%), limiting the portion size of all household members (1%), reducing the portion size of food given to adults in order to feed children (1%), purchasing food on credit (1%), and begging for food (<1%). Only two coping strategies were not reported to have been used during the prior week; these were to reduce the portion size of food given to adults in order to feed children, and to not eat for an entire day and night.

Only 54.8% of people ate the minimum recommended number of kilocalories (kcal) per day during the prior week. This is perhaps not surprising given that CSI results show that 47.3% of households restricted the food consumption of non-working household members to feed working household members an average of 3.42 days over the prior week, or half of all days. The number of kcal consumed per person significantly decreases with household size (F=129.06, R2=0.23, DF=440, p<0.0001). Rice accounted for an average of 52% (± 16.33%) of the daily kcal consumed. Further, the number of cups of rice a person eats per week significantly predicted that individual's kcal consumption (F=1095.09, R2=0.71, DF=457, p<0.0001) and CSI (F=25.56, R2=0.07, DF=358, p<0.0001). Income per person (transformed using $\log_{10}$) significantly predicted that individual's consumption of rice (normally distributed) (F=80.01, R2=0.15, DF=451, p<0.0001). A partition analysis showed that food security was in fact best predicted by the ownership of commercial goods, yearly income, and household size, although these factors only explained 20% of the household variation in food security (R2=0.20, n=360, n splits=3). Food secure households were best characterized by their ownership of more than five commercial goods, having more than one adult (aged 17–39), and a combined income of greater than 1,000,000 MGA per year (highly variable exchange rate, but roughly $US330 at the time of data collection). When controlling for household income, household food security is significantly negatively correlated with child wasting (T=-3.10, P=0.003).

Pork and chicken comprised 57% and 29% (respectively) of all individuals' number one top taste preference for all animal-source foods, including wildlife, and nearly 19% and 17% of all top-ranked food choices (Table 2). Eighty-six percent of measured households ate at least one source of fish or meat in the prior week, and 50% ate the meat of domestic animals. On average, chickens were the most commonly owned domestic livestock, followed by ducks (Table 3). Focus groups in each village reported that chicken meat cost an average of 3,736 MGA per kilogram (just over $US1), and duck meat cost 5,444 MGA per kg (just under $US2). Duck meat was reported to be more expensive than chicken meat because duck husbandry comparatively requires a higher financial and time investment.

Fifty-three percent of households owned chickens which died from disease during the prior year. All deaths were reported to be caused by a disease locally referred to as *barika* or *moafo*. The epidemiology of the disease, including its symptoms and timing (peaking during the holiday season of Christmas through the New Year), is consistent with Newcastle disease. The estimated fatality rate was 79%. Ducks were also reported to be affected by *barika* or *moafo* with symptoms consistent with Duck cholera. The fatality rate for ducks across all diseases was 80%. Four percent of households in the Alaotra had pigs that contracted a disease during the prior year. Locally, this disease was called *pesta* and was characterized by a loss of appetite, being unable to stand, having foamy mouth, being cold to the touch, and vomiting. The fatality rate for *pesta* was 83%. Zebu were affected by *viky* (worms) and *dinta* (flukes). Of the thirty-eight cases where manifestations were severe, only one led to the premature death of the animal.

Table 1. Percentages of individuals classified as stunted, underweight, and wasted in villages within the Alaotra wetland complex. (Children are defined as stunted, underweight, or wasted if their height-for-age, weight-for-age, weight-for-height, or BMI-for-age is more than two standard deviations below the CDC (2000) Child Growth Standards median.)

| Age range (yrs) | Sex | Sample size (n) | Stunted | Underweight | Wasted |
|---|---|---|---|---|---|
| 2<5 | Male | 74 | 29.50% | 29.70% | 28.40% |
| 2<5 | Female | 59 | 27.10% | 22.00% | 16.90% |
| 5<12 | Male | 164 | 23.80% | 15.20% | 7.90% |
| 5<12 | Female | 143 | 21.00% | 15.40% | 8.40% |
| 12<20 | Male | 123 | 48.00% | 14.60% | 3.30% |
| 12<20 | Female | 139 | 35.30% | 14.40% | 2.90% |
| 2<20 | Male & Female | 759 | 31.40% | 17.70% | 9.00% |

Table 2. Reported taste preferences of heads of households in the Alaotra wetland complex. Taste preference rankings could not tie (1=most preferred meat, 2=second most preferred, and so on).

| | Number of times each animal received a given ranking | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Ranking in Taste Preference | Chicken | Pork | Beef | Goose | Fish (*Tilapia* spp.) | Carnivoran (*V. indica*) | Lemur (*H. alaotrensis*) | Bushpig (*P. larvatus*) | Tenrec (*T. ecaudatus*) | Tenrec (*S. setosus*) |
| 1 | 21 | 41 | 5 | 0 | 5 | 0 | 0 | 0 | 0 | 0 |
| 2 | 6 | 15 | 38 | 5 | 6 | 0 | 0 | 2 | 0 | 0 |
| 3 | 13 | 11 | 20 | 19 | 8 | 0 | 0 | 1 | 0 | 0 |
| 4 | 23 | 3 | 7 | 25 | 8 | 1 | 2 | 2 | 1 | 0 |
| 5 | 2 | 4 | 2 | 16 | 31 | 1 | 1 | 1 | 4 | 1 |
| 6 | 1 | 0 | 0 | 2 | 7 | 1 | 2 | 0 | 8 | 2 |
| 7 | 1 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 6 | 2 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 3 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| TOTAL | 67 | 74 | 72 | 68 | 65 | 3 | 6 | 6 | 21 | 8 |

Table 3. The range and mean of household pets and livestock assets in communities surrounding the Lac Alaotra wetland complex.

| Type of livestock | Cows | Pigs | Ducks | Chickens | Geese | Cats | Dogs |
|---|---|---|---|---|---|---|---|
| Range (#/household) | 0–32 | 0–50 | 0–105 | 0–70 | 0–50 | 0–4 | 0–5 |
| Mean (#/household) | 1.41 | 0.70 | 3.09 | 10.07 | 2.67 | 0.24 | 0.48 |

NATURAL RESOURCE USE. Eighty-five percent of the population relied on firewood for cooking and harvested it themselves daily. Individuals spent a median of 30 minutes (mean of 47.3 ± 37.5 minutes) to collect firewood, and only 3.7% of collected firewood was sold. We found a high dependence on the forest for natural products that can create shelter; 6.3% of households had harvested timber (even if just one piece of wood) and 47.0% had collected thatch roofing in the prior year. While 61.7% of timber was sold, only 4.5% of thatch was sold. Households traveled a median of 60 minutes (mean of 77.6 ± 40.3 minutes) to collect timber and 90 minutes (mean of 107.9 ± 68.7) to collect thatch roofing. There was a low prevalence of local people (5%), who relied on the forest and marshlands for ethnobotanical healthcare (e.g., by collecting plants for the preparation of traditional medicines), but those who used it harvested these traditional medicines at a median rate of two times per week (mean 1.9 ± 1.3). They collected these ethnomedicines at a median distance of 12.5 minutes from the home (mean of 25.0 ± 59.1 minutes). Only 2.5% of households had collected honey in the prior year and honey was collected a median of two hours from their homes (mean of 95.0 minutes ± 36.7). Just over one percent of households had collected precious stones and metals (including sapphires, rubies, and gold); these were collected a median of five hours from the collector's home (mean of 612.0 minutes ± 26.8).

There were distinct gender roles in the collection of some natural products. While firewood was collected by both adult men and women in the household (38.4% and 40.7% respectively), the collection of precious stones and metals, honey, timber, and thatch were predominately male activities (men collected 100%, 90.9%, 88.9%, 61.2% of these products), and the collection of traditional medicinal plants was predominantly a female activity (75.0% of all collection was done by women).

One in eight households (12.8%) ate wildlife during the prior year. Of the 975 mammals eaten by the members of 485 surveyed households, 97.2% were tenrecs, 1.6% were lemurs (specifically the Alaotra gentle lemur; *Hapalemur alaotrensis*), and 1.2% were introduced carnivorans (the Indian civet; *Viverricula indica*) (Table 4). The average household reported eating a median of one forest mammal during the prior year (mean of 2.0 ± 43.4; Table 4). One in ten households (9.9%) ate tenrec meat during the prior year. Of households that ate tenrec meat, each household ate a median of 1.5 tenrecs (mean of 19.7 ± 48.6). Only 2.5% of households ate lemurs during the prior year. Of those households that ate lemur meat, each household ate a median of one lemur (mean of 1.3 ± 0.9) during the prior year. Carnivoran hunting was even less frequent, with 1.2% of households participating, with each household that hunted eating a median of two carnivorans during the prior year (mean of 2.0 ± 0.9). No one surveyed reported eating endemic carnivorans (Euplerids), bats (which were reportedly rarely seen), or tenrecs other than the species *Tenrec ecaudatus* during the prior year.

At least 73.5% of hunting was conducted illegally either because of national prohibitions against hunting (e.g., lemurs) or prohibited equipment (e.g., hunting tenrecs using dogs), according to the most recent updates to legislation (Decree number 2006-400). However, it is important to note that this prior year recall data may include animals that may be legal to hunt but were not hunted during the legal season. The hunting of lemurs is strictly prohibited and the hunting of tenrecs is only authorized during the day, without dogs or other prohibited equipment, between 1 April and 31 May (Ordonnance No 60-126 from Oct. 3, 1960). Most hunting was targeted pursuit hunting (710 of 975 mammals caught).

Only one of 485 surveyed households owned a shotgun and the remaining households predominately used dogs to hunt wildlife. Pursuit hunting was supplemented by snare trapping using natural products (199 animals), and opportunistic hunting (16 animals). Members of households ate 47 forest mammals at the household of a family member or friend during the prior year and purchased only 3 animals (which were bartered using rice for payment, Table 4).

Table 4. The volume of mammalian wildlife consumption in communities within the Lac Alaotra wetland complex, disaggregated by hunting method. The volume of consumption was reported based on the head of household's recall of number of animals consumed during the prior year. (Local people reported an absence of bush pigs (*Potamochoerus larvatus*) in the region. No members of surveyed households ate the meat of bush pigs during the prior year, yet it was listed among preferred foods (Table 2).)

| Species | Local name | Total consumption (n) | Pursuit hunting | Trapping | Opportunistic hunting | Eaten with friends or family | Purchased |
|---|---|---|---|---|---|---|---|
| TENRECS | | | | | | | |
| *Tenrec ecaudatus* | Trandraka | 947 | 74.00% | 19.00% | 1.70% | 5.00% | 0.30% |
| *Setifer setosus* | Sokina | 0 | - | - | - | - | - |
| BATS | | | | | | | |
| *Pteropus rufus* | Fanihy | 0 | - | - | - | - | - |
| EUPLERIDS | | | | | | | |
| *Eupleres goudotii* | Fanaloka | 0 | - | - | - | - | - |
| *Cryptoprocta ferox* | Fosa | 0 | - | - | - | - | - |
| *Galidia elegans* | Vontsiramena | 0 | - | - | - | - | - |
| *Galidictis fasciata* | Vontsirafotsy | 0 | - | - | - | - | - |
| *Salanoia concolor* | Vontsira | 0 | - | - | - | - | - |
| LEMURS | | | | | | | |
| *Cheirogaleus major* | Tsitsihy | 0 | - | - | - | - | - |
| *Avahi laniger* | Fotsife | 0 | - | - | - | - | - |
| *Daubentonia madagascariensis* | Hay-hay | 0 | - | - | - | - | - |
| *Hapalemur occidentalis* | Bokombolo | 0 | - | - | - | - | - |
| *Hapalemur alaotrensis* | Bandro | 16 | 43.80% | 56.30% | 0.00% | 0.00% | 0.00% |
| *Eulemur rubriventer* | Barimaso | 0 | - | - | - | - | - |
| INTRODUCED SPECIES | | | | | | | |
| *Viverricula indica* | Jaboady | 13 | 23.10% | 76.90% | 0.00% | 0.00% | 0.00% |

INTERACTIONS. Forest mammal consumption (the number of forest or marshland mammals eaten by household members during the prior year) was significantly negatively correlated with household food security ($R^2$=0.15, DF=54, F=5.56, p=0.02). In fact, in a multiple linear regression on the effects of household size, income, food security, and the health of household members (rates anemia), only food security significantly predicted the number of forest mammals that household consumed in the prior year (t=2.35, p=0.02). Unsurprisingly, with very low rates of wildlife harvest locally, we did not find an effect of wildlife consumption on anemia here (generalized linear mixed model, p=0.84).

When investigating the conservation impact of the presence of a protected area, we found that wildlife harvesting in each village increased by approximately one animal per household per year (bivariate linear regression model; $r^2$=0.30, F=7.13, DF=18, p=0.02) per hour of travel time from a protected area. Forest mammal catch continued to increase (albeit moderately) with increasing distance from the park, even when controlling for distance from the forest (multiple linear regression model; $R^2$=0.33, F=3.99, DF=18, p=0.04), although it is possible that this difference may be due to reduced reporting near park borders.

## DISCUSSION

CURRENT STATUS OF HOUSEHOLD ECONOMICS, HEALTH AND FOOD SECURITY. Madagascar is a highly food insecure country with one of the highest rates of stunting in the world (The Economist Intelligence Unit 2016, International Food Policy Research Institute 2016), and the Lac Alaotra wetland complex is a key region in securing the food security of Madagascar's people (Plan Régional de Développement 2005). We found that employment rates and yearly income were both higher in Alaotra than other regions in Madagascar, and food costs were comparatively low (Golden et al. 2014b, Borgerson et al. 2016). The yearly income of residents of Alaotra was nearly four times that of Betampona (Golden et al. 2014b), and 16% of all households in Alaotra contained a member earning daily wages. Further, incomes may have also risen significantly in the prior decade as households in 2013 reported annual incomes three times those reported in 2005 (Ministère des Finances 2006). Yet 98% of households experienced food insecurity, and coping mechanisms appear to disproportionately affect young children and non-working household members. Half of households did not receive the minimum recommended kilocalories per person per day, and nearly half restricted food consumption by non-working household members. We found high rates of child malnourishment. However, the prevalence of child malnutrition is consistent with, even slightly lower than, that across rural Madagascar (18% stunted, 31% underweight, and 9% wasted in Alaotra vs. 50%, 38%, and 14% nation-wide (WHO 2012, rural Madagascar data)). Rates of anemia were lower than those found in Makira (Golden et al. 2011), but consistent with rates found in Betampona, another area of Madagascar with low rates of wildlife harvest (Golden et al. 2014b).

Consistent with previous studies across Madagascar (Golden et al. 2014b, Reuter et al. 2016a) and in the Alaotra region (Jenkins et al. 2011) the meat of domestic animals was preferred over the meat of wild-caught mammals. People ate the meat from domestic animals more often than those in northeastern Madagascar (Borgerson 2016); 50% of households in Alaotra ate the meat of domestic animals in the prior week. As found in other regions of Madagascar (e.g., Golden et al. 2014b, Rasamoelina-Andriamanivo et al. 2014), poultry were negatively impacted by Newcastle disease, albeit at a slightly lower fatality rate; 79% in Alaotra vs. 96% in Betampona. Newcastle disease outbreaks can have significant impacts on household economies in Madagascar (Rasamoelina-Andriamanivo et al. 2014), and controlling Newcastle disease has been identified as a potential means to both reduce wildlife hunting and improve household nutrition, food security, and economy (Alders and Pym 2009, Golden et al. 2014a). Targeted efforts to identify Newcastle disease early at key node live-bird markets have been recommended for the early identification and control of a Newcastle disease outbreak throughout the Alaotra region (Rasamoelina-Andriamanivo et al. 2014).

CURRENT LEVELS OF ENVIRONMENTAL PRESSURE. Communities in the Lac Alaotra wetland complex were less dependent on forests and marshlands for access to nutritious foods, housing materials, and healthcare than in other areas of Madagascar, and people traveled further to access these resources (Golden et al. 2014b, Borgerson 2016). Overall, few people ate wild mammals during the prior year and those households ate species with high reproductive capacities (and thus high population resilience). As is true in other regions of Madagascar (Razafimanahaka et al. 2012, Golden et al. 2013, 2014a,b, Borgerson 2016, Reuter et al. 2016a), tenrecs were the most commonly hunted forest mammal in the area. *Tenrec ecaudatus* comprised more than 97% of household wildlife consumption by biomass. *T. ecaudatus* is a Least Concern (Stephenson et al. 2016) game species that can be legally hunted in Madagascar, albeit only during open season and without the use of dogs (Decree Number 2006-400, Ordonnance Number 60-126). However, at least 73.5% of all hunting was conducted illegally in the Alaotra region (primarily from using dogs to hunt tenrecs). Particularly concerning, however, was the hunting of Critically Endangered Alaotra gentle lemurs (*Hapalemur alaotrensis*). The surveyed households ate 16 of the remaining population of Alaotra gentle lemurs during the prior year. While population estimates are uncertain, as few as 2500 Alaotra gentle lemurs may remain in the wild (Ralainasolo et al. 2006, Ratsimbazafy et al. 2013, Reibelt et al. 2017b).

The Lac Alaotra wetland complex has notable similarities and differences in comparison to other areas across Madagascar where hunting has been studied. While Razafimanaka et al. (2012) found that more than 70% of respondents in this region had eaten wildlife during the prior year, only 13% of the respondents in this study reported eating wildlife during the prior year. Alaotra residents ate fewer forest mammals per capita (both in total number and in range of species) during the prior year than residents in Betampona (Golden et al. 2014b), Makira (Golden et al. 2013), the Masoala (Borgerson 2016), western Madagascar (Razafimanahaka et al. 2012), or central and north-western Madagascar (Reuter et al. 2016a,b). As a relative percentage of the surveyed households, more than ten times as many households had eaten forest meat in Betampona in the prior year (Golden et al. 2014b) than had in Alaotra.

The techniques used to hunt forest mammals differed in the Alaotra from other regions in Madagascar, but similar to those found by Reuter et al. (2016b) in central and northwestern-Madagascar; hunters in the Alaotra primarily used pursuit hunting methods with dogs, whereas passive snare traps were predominantly used to trap forest mammals in Betampona, Makira, and Masoala (Golden et al. 2014a,b, Borgerson 2016). This difference is

likely because most wild meat was that of *T. ecaudatus*, a species most efficiently hunted by dogs, especially in areas with degraded habitat (Golden et al. 2014b, Reuter et al. 2016b).

Deforestation and forest fragmentation can significantly affect local livelihoods (Urech et al. 2015). People within the Lac Alaotra wetland complex, a region of increasing forest fragmentation, were less dependent on the forest for natural products that can create shelter than those in the Betampona forest region (Golden et al. 2014b). Far fewer people collected timber or thatch roofing during the prior year than in Betampona (6% vs. 80%; 47% vs. 90% respectively). Fewer households relied on firewood for cooking than those in Betampona (85% vs. 96%) and household members travelled 1.5–3 times farther to collect this wood (Golden et al. 2014b). Further, Alaotra residents relied far less on forest or marshland resources for healthcare, 5% of households having harvested traditional medicines from the forest at a rate of approximately twice per week, 25 minutes from the home in Alaotra vs. 82% of households having harvested traditional medicines from the forest at a rate of approximately once per week in Betampona. Overall forest resources were less relied upon and individuals travelled further to reach them (e.g., up to five hours each way to collect forest resources of high economic value including precious stones).

Seasonal residences occupied during rice harvest, or *lasy*, were also twice as far away as those in Betampona. *Lasy* were also used by only a minority of residents; proportionally, 40% fewer surveyed residents (relatively) in Alaotra utilized *lasy* during rice harvest than those in Betampona (Golden et al. 2014b). Differences in local ecology may, however, explain much of this variation. People in the Lake Alaotra Wetland complex can also reduce biodiversity by converting marshland (as opposed to forest lands) into irrigated rice fields when confronted with insufficient rice yields (Reibelt et al. 2017b).

CONNECTIONS BETWEEN HOUSEHOLD ECONOMICS, HUMAN HEALTH, ENVIRONMENTAL PRESSURES AND HUMAN WELFARE. Wildlife harvest and consumption does not appear as critical to economic or nutritional wellbeing in the communities in the Lac Alaotra wetland complex as in other regions of Madagascar (Golden et al. 2011, 2014b). The region's financial security, strong access to rice and livestock products, degraded forest ecology, or regional conservation efforts, may explain the low rates of wildlife consumption over the prior year. Yet, food insecurity was still high, and its presence in households was positively correlated with the number of forest mammals consumed. This is consistent with other findings suggesting that improving regional food security and public health outcomes through integrated conservation and development programming may both improve environmental and human health outcomes (Barrett et al. 2011, Golden et al. 2014, Borgerson et al. 2016, Wilkie et al. 2016). Madagascar faces complex and nuanced challenges in achieving food security and reducing malnutrition. The nation has low public expenditure on agricultural research and development and food is comparatively expensive and poor in quality (The Economist Intelligence Unit 2016). Severe inflation has caused food prices to more than triple since the year 2000, and these foods are low in micronutrient availability, protein quality, and diversification (ibid). Thus, it will be necessary to find avenues to secure adequate nutrition in a way that preserves Madagascar's unique biodiversity. Further, because of the strong gender differences in the collection of some natural resources (e.g., 75% of all medicinal plant collection was done by women and 91% of all honey collection was done by men) it will be necessary to ensure that these policies and efforts strive to integrate both men and women into their approaches. To improve child nutrition and wildlife conservation, targeted interventions in the Alaotra could focus on: (1) increased tracking of nutritional outcomes; (2) nutrition-sensitive agricultural policies to increase the focus on, consumption of, and productivity of nutritious crops and small-livestock (especially in remote, hard to access villages); (3) targeted efforts to identify and control Newcastle disease through poultry vaccination; (4) micro-nutrient fortification of key imported food staples such as rice; and (5) efforts to integrate fish-rice paddy aquaculture to offset the short-term reduced nutritional access to wild fish during seasonal fishery closures (Copsey et al. 2009, Wallace et al. 2015); and (6) maintenance of lake water quality (and quantity) to facilitate fish consumption (Lammers et al. 2015). By addressing Alaotra's barriers to food security, policy makers and resource managers can improve both human health and conservation outcomes in this region of key importance to national food security and conservation.

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## REFERENCES

Alders, R. G. and Pym, R. A. E. 2009. Village poultry: still important to millions, eight thousand years after domestication. World's Poultry Science Journal 65, 2: 181-190. <https://doi.org/10.1017/S0043933909000117>

Andriaholinirina, N., Baden, A., Blanco, M., Chikhi, L., Cooke, A., et al. 2014. *Hapalemur alaotrensis*. The IUCN Red List of Threatened Species 2014: e.T9676A16119362. <https://doi.org/10.2305/IUCN.UK.2014-1.RLTS.T9676A16119362.en>

Andrianandrasana, H. T., Randriamahefasoa, J., Durbin, J., Lewis, R. E. and Ratsimbazafy, J. H. 2005. Participatory ecological monitoring of the Alaotra wetlands in Madagascar. Biodiversity & Conservation 14, 11: 2757-2774. <https://doi.org/10.1007/s10531-005-8413-y>

Bakoariniaina, L. N., Kusky, T. and Raharimahefa, T. 2006. Disappearing Lake Alaotra: Monitoring catastrophic erosion, waterway silting, and land degradation hazards in Madagascar using Landsat imagery. Journal of African Earth Sciences 44, 2: 241-252. <https://doi.org/10.1016/j.jafrearsci.2005.10.013>

Barrett, C. B., Travis, A. J. and Dasgupta, P. 2011. On biodiversity conservation and poverty traps. Proceedings of the National Academy of Sciences of the United States of America 108, 34: 13907-13912. <https://doi.org/10.1073/pnas.1011521108>

Borgerson, C. 2015. The effects of illegal hunting and habitat on two sympatric endangered primates. International Journal of Primatology 36, 1: 74-93. <https://doi.org/10.1007/s10764-015-9812-x>

Borgerson, C. 2016. Optimizing conservation policy: The importance of seasonal variation in hunting and meat consumption on the Masoala peninsula of Madagascar. Oryx 50, 3: 405-418. <https://doi.org/10.1017/S0030605315000307>

Borgerson, C., McKean, M. A., Sutherland, M. R. and Godfrey, L. R. 2016. Who hunts lemurs and why they hunt them. Biological Conservation 197: 124-130. <https://doi.org/10.1016/j.biocon.2016.02.012>

Borgerson, C., Johnson, S. E., Louis, E. E., Holmes, S. M., Anjaranirina, E. J. G., et al. 2018 (In press). The use of natural resources to improve household income, health, and nutrition within the forests of Kianjavato, Madagascar. Madagascar Conservation & Development 13, 1. <https://doi.org/10.4314/mcd.v13i1.6>

CARE. 2008. Coping strategies index: field methods manual. Available at <https://goo.gl/W4aaEi>

Centers for Disease Control and Prevention. 2000. National Center for Health Statistics growth charts, United States. <http://www.cdc.gov/growthcharts/cdc_charts.htm> accessed on 25 May 2017.

Copsey, J. A., Rajaonarison, L. H., Randriamihamina, R. and Rakotoniaina, L. J. 2009. Voices from the marsh: livelihood concerns of fishers and rice cultivators in the Alaotra wetland. Madagascar Conservation & Development 4, 1: 25-30. <https://doi.org/10.4314/mcd.v4i1.44008>

Decree No 2006–400. Portant classement des espèces de faune sauvage. Repoblikan'i Madagasikara, Ministère de l'Environnent, des Eaux et Forêts.

Durbin, J., Funk, S. M., Hawkins, F., Hills, D. M., Jenkins, P. D., et al. 2010. Investigations into the status of a new taxon of *Salanoia* (Mammalia: Carnivora: Eupleridae) from the marshes of Lac Alaotra, Madagascar. Systematics and Biodiversity 8, 3: 341-355. <https://doi.org/10.1080/14772001003756751>

The Economist Intelligence Unit. 2016. Global food security index 2016: an annual measure of the state of global food security. Available at <https://foodsecurityindex.eiu.com/Index>

Golden, C. D. 2009. Bushmeat hunting and use in the Makira Forest north-eastern Madagascar: a conservation and livelihoods issue. Oryx 43, 3: 386-392. <https://doi.org/10.1017/S0030605309000131>

Golden, C. D., Fernald, L. C. H., Brashares, J. S., Rasolofoniaina, B. J. R. and Kremen, C. 2011. Benefits of wildlife consumption to child nutrition in a biodiversity hotspot. Proceedings of the National Academy of Sciences of the United States of America 108, 49: 19653-19656. <https://doi.org/10.1073/pnas.1112586108>

Golden, C. D., Rasolofoniaina, B. J. R., Anjaranirina, E. J. G., Nicolas, L., Ravaoliny, L. and Kremen, C. 2012. Rainforest pharmacopeia in Madagascar provides high value for current local and prospective global uses. PLoS ONE 7, 7: e41221. <https://doi.org/10.1371/journal.pone.0041221>

Golden, C. D., Wrangham, R. W. and Brashares, J. S. 2013. Assessing the accuracy of interviewed recall for rare, highly seasonal events: the case of wildlife consumption in Madagascar. Animal Conservation 16, 6: 597-603. <https://doi.org/10.1111/acv.12047>

Golden, C. D., Bonds, M. H., Brashares, J. S., Rasolofoniaina, B. J. R. and Kremen, C. 2014a. Economic valuation of subsistence harvest of wildlife in Madagascar. Conservation Biology 28, 1: 234-243. <https://doi.org/10.1111/cobi.12174>

Golden, C. D., Rabehatonina, J. G. C., Rakotosoa, A. and Moore, M. 2014b. Socio-ecological analysis of natural resource use in Betampona Strict Natural Reserve. Madagascar Conservation & Development 9, 2: 83-89. <https://doi.org/10.4314/mcd.v9i2.4>

Golden, C. D., Gupta, A. C., Vaitla, B. and Myers, S. S. 2016. Ecosystem services and food security: assessing inequality at community, household and individual scales. Environmental Conservation 43, 4: 381-388. <https://doi.org/10.1017/S0376892916000163>

International Food Policy Research Institute. 2016. Global Nutrition Report 2016: From Promise to Impact: Ending Malnutrition by 2030. Washington, DC. <https://doi.org/10.2499/9780896295841>

Jenkins, R. K. B., Keane, A., Rakotoarivelo, A. R., Rakotomboavonjy, V., Randrianandrianina, F. H., et al. 2011. Analysis of patterns of bushmeat consumption reveals extensive exploitation of protected species in eastern Madagascar. PloS ONE 6, 12: e27570. <https://doi.org/10.1371/journal.pone.0027570>

Kennedy, G., Ballard, T. and Dop, MC. 2010. Guidelines for measuring household and individual dietary diversity. Rome: Nutrition and Consumer Protection Division, Food and Agriculture Organization of the United Nations. Available at <http://www.fao.org/docrep/014/i1983e/i1983e00.pdf>

Kremen, C., Razafimahatratra, V., Guillery, R. P., Rakotomalala, J., Weiss, A. and Ratsisompatrarivo, J.-S. 1999. Designing the Masoala National Park in Madagascar based on biological and socioeconomic data. Conservation Biology 13, 5: 1055-1068. <https://doi.org/10.1046/j.1523-1739.1999.98374.x>

Lammers, P. L., Richter, T., Waeber, P. O. and Mantilla-Contreras, J. 2015. Lake Alaotra wetlands: how long can Madagascar's most important rice and fish production region withstand the anthropogenic pressure? Madagascar Conservation & Development 10, S3: 116-127. <https://doi.org/10.4314/mcd.v10i3.4>

Madagasikara Voakajy. 2017. <http://www.madagasikara-voakajy.org> accessed 31 July 2017

Ministère des Finances 2006. L'Enquête Périodique Auprès des Ménages 2005. USAID and Institut National de la Statistique, Antananarivo. Available at <http://www.ilo.org/surveydata/index.php/catalog/1001/study-description>

Plan Régional de Développement 2005. Région Alaotra-Mangoro, Province Autonome de Toamasina. Unpubl Report.

Rakotoarisoa, T. F., Waeber, P. O., Richter, T., Mantilla-Contreras, J. Water hyacinth (*Eichhornia crassipes*), any opportunities for Alaotra wetlands and livelihoods? Madagascar Conservation & Development 10, 3S:128-136. <https://doi.org/10.4314/mcd.v10i3.5>

Ralainasolo, F. B., Waeber, P. O., Ratsimbazafy, J., Durbin, J. and Lewis, R. 2006. The Alaotra gentle lemur: population estimation and subsequent implications. Madagascar Conservation & Development 1, 1: 9-10. <https://doi.org/10.4314/mcd.v1i1.44044>

Rasamoelina-Andriamanivo, H., Duboz, R., Lancelot, R., Maminiaina, O. F., Jourdan, M., et al. 2014. Description and analysis of the poultry trading network in the Lake Alaotra region, Madagascar: Implications for the surveillance and control of Newcastle disease. Acta Tropica 135: 10-18. <https://doi.org/10.1016/j.actatropica.2014.03.008>

Ratsimbazafy, J. H., Ralainasolo, F. B., Rendigs, A., Mantilla Contreras, J., Andrianandrasana, H., et al. 2013. Gone in a puff of smoke? *Hapalemur alaotrensis* at great risk of extinction. Lemur News 17: 14-18.

Razafimanahaka, J. H., Jenkins, R. K. B., Andriafidison, D., Randrianandrianina, F., Rakotomboavonjy, V., et al. 2012. Novel approach for quantifying illegal bushmeat consumption reveals high consumption of protected species in Madagascar. Oryx 46, 4: 584-592. <https://doi.org/10.1017/S0030605312000579>

Reibelt, L. M., Moser, G., Dray, A., Randriamalala, I. H., Chamagne, J., et al. 2017a. Tool development to understand rural resource users' land use and impacts on land type changes in Madagascar. Madagascar Conservation & Development. <https://doi.org/10.4314/mcd.wetlands.3>

Reibelt, L. M., Woolaver, L., Moser, G., Randriamalala, I. H., Raveloarimalala, L. M., et al. 2017b. Contact matters: Local people's perceptions of *Hapalemur alaotrensis* and implications for conservation. International Journal of Primatology 38, 3:588-608. <https://doi.org/10.1007/s10764-017-9969-6>

Reuter, K. E., Randell, H., Wills, A. R., Janvier, T. E., Belalahy, T. R. and Sewall, B. J. 2016a. Capture, movement, trade, and consumption of mammals in Madagascar. PLoS ONE 11, 2: e0150305. <https://doi.org/10.1371/journal.pone.0150305>

Reuter, K. E., Randell, H., Wills, A. R. and Sewall, B. J. 2016b. The consumption of wild meat in Madagascar: drivers, popularity and food security. Environmental Conservation 43, 3: 287-283. <https://doi.org/10.1017/S0376892916000059>

Rendigs, A., Reibelt, L. M., Ralainasolo, F. B., Ratsimbazafy, J. H., Waeber, P. O. 2015. Ten years into the marshes—*Hapalemur alaotrensis* conservation, one step forward and two steps back? Madagascar Conservation & Development 10, 1: 13-20. <https://doi.org/10.4314/mcd.v10i1.S3>

Stadlmayr, B., Charrondiere, U. R., Enujiugha, V. N., Bayili, R. G., et al. 2012. West African food composition table. Rome: Food and Agriculture Organization of the United Nations. Available at <http://www.fao.org/docrep/015/i2698b/i2698b00.pdf>

Stephenson, P. J., Soarimalala, V. and Goodman, S. 2016. *Tenrec ecaudatus*. The IUCN Red List of Threatened Species 2016: e.T40595A97204107. <https://doi.org/10.2305/IUCN.UK.2016-1.RLTS.T40595A97204107.en> accessed 25 May 2018.

Stoudmann, N., Waeber, P. O., Randriamalala, I. H. and Garcia, C. 2017. Perception of change: Narratives and strategies of farmers in Madagascar. Journal of Rural Studies 56: 76-86. <https://doi.org/10.1016/j.jrurstud.2017.09.001>

Urech, Z. L., Zaehringer, J. G., Rickenback, O., Sorg, J.-P. and Felber, H. R. 2015. Understanding deforestation and forest fragmentation from a livelihoods perspective. Madagascar Conservation & Development 10, 2: 67-76. <https://doi.org/10.4314/mcd.v10i2.5>

Waeber, P. O., Ratsimbazafy, J. H., Andrianandrasana, H., Ralainasolo, F. B. and Nievergelt, C. M. 2018a (In press). Hapalemur alaotrensis, a conservation case study from the swamps of Alaotra, Madagascar. In: Primates in Flooded Habitats: Ecology and Conservation. A. Barnett, I. Matsuda and K. Nowak (eds.). Cambridge University Press, Cambridge, UK.

Waeber, P. O., Ralainasolo, F. B., Ratsimbazafy, J. H. and Nievergelt, C. M. 2018b (In press). Consequences of lakeside living for the diet and social ecology of the Alaotran gentle lemur. In Primates in Flooded Habitats: Ecology and Conservation. A. Barnett, I. Matsuda and K. Nowak (eds.). Cambridge University Press, Cambridge, UK.

Waeber, P. O., Reibelt, L. M., Randriamalala, I. H., Moser, G., Raveloarimalala, L. M., et al 2017. Local awareness and perceptions: Consequences for conservation of marsh habitat at Lake Alaotra for one of the world's rarest lemurs. Oryx. <https://doi.org/10.1017/S0030605316001198>

Wallace, A. P. C., Milner-Gulland, E. J., Jones, J. P. G., Bunnefeld, N., Young, R. and Nicholson, E. 2015. Quantifying the short-term costs of conservation interventions for fishers at Lake Alaotra, Madagascar. PloS ONE 10, 6: e0129440. <https://doi.org/10.1371/journal.pone.0129440>

WHO (World Health Organization). 2011. Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity. Vitamin and Mineral Nutrition Information System. World Health Organization, Geneva. Available at <https://goo.gl/5ehnrH>

WHO (World Health Organization). 2012. WHO Global Database on Child Growth and Malnutrition, Madagascar. 13 January 2012. Available at <https://goo.gl/1JsvCd>

Wilkie, D. S., Wieland, M., Boulet, H., Le Bel, S., van Vliet, N., et al. 2016. Eating and conserving bushmeat in Africa. African Journal of Ecology 54, 4: 402-414. <https://doi.org/10.1111/aje.12392>

World Bank. 2013. Madagascar. Measuring the Impact of the Political Crisis. <https://goo.gl/15LZ8z> accessed 25 May 2018.