Journal of Threatened Taxa

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ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

Article

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26 October 2017 | Vol. 9| No. 10 | Pp. 10741–10756
10.11609/jott.3348.9.10.10741-10756

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 October 2017 | 9(10): 10741–10756

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Abstract: The Hamadryas Baboon is the only nonhuman primate to inhabit the Arabian Peninsula. In Saudi Arabia, Hamadryas Baboons are known to rely on both human and natural plant foods. We examined the relationship between artificial food supply and natural food selection in two commensal hamadryas troops in different habitats in Saudi Arabia. Alhada had richer vegetation, while the Dam Site featured ground vegetation heavily damaged by overgrazing. The baboons' diets, including dependency on artificial foods, reflected the status of the natural habitat. The availability of fresh vegetation following significant rainfalls at both sites reduced the Baboons' dependence on artificial foods. In the richer habitat, rainfall was significantly correlated with natural diet diversity and time spent feeding on natural foods. Both troops spent more time feeding during periods of high provisioning of artificial food, and the percentage of feeding on natural foods decreased when provisioning was high. The baboons fed on natural foods throughout the year despite the availability of human foods. We suggest the need for a nutritionally balanced diet has kept the baboons from becoming completely dependent on human foods. Effectively preserving natural vegetation should enable commensal baboons to spend more time feeding on natural foods, thereby reducing human-wildlife conflict.

Keywords: Baboons, commensalism, feeding strategy, natural diet, *Papio hamadryas*, Saudi Arabia, human-wildlife conflict

DOI: http://doi.org/10.11609/jott.3348.9.10.10741-10756

Editor: Ian Redmond, UNEP Convention on Migratory Species, Lansdown, UK. **Date of publication:** 26 October 2017 (online & print)

Manuscript details: Ms # 3348 | Received 19 February 2017 | Final received 08 September 2017 | Finally accepted 22 September 2017

Citation: Boug, A., M.Z. Islam, T. Iwamoto, A. Mori, A. Yamane & A.L. Schreier (2017). The relationship between artificial food supply and natural food selection in two troops of commensal Hamadryas Baboons *Papio hamadryas* (Mammalia: Primates: Cercopithecidae) in Saudi Arabia. *Journal of Threatened Taxa* 9(10): 10741–10756; http://doi.org/10.11609/jott.3348.9.10.10741-10756

Funding: The study funded by the Saudi Wildlife Authority & Prince Saud al Faisal Wildlife Research Center.

Competing interests: The authors declare no competing interests.

For **Author Details, Author Contribution** and **Arabic abstract** see end of this article.

Acknowledgements: We would like to thank Dr. Hany Tatwany, Vice President of Saudi Wildlife Authority, SWA, members of The Ecology and Behavioral Department and librarians at the Primate Research Institute, Kyoto University, as well as members of the Biology Department in Miyazaki University for supporting this study. All colleagues at the Prince Saud al Faisal Wildlife Research Center are acknowledged, especially Ms. Parveen Khan (Librarian), who provided references and published papers to be referred.

INTRODUCTION

Hamadryas Baboons range throughout the horn of Africa (in parts of Ethiopia, Eritrea, Djibouti, Sudan, and Somalia) and the Arabian Peninsula in Saudi Arabia and Yemen (Kummer 1968; Biquand et al. 1992; Al-Safadi 1994; Zinner et al. 2001). In fact, the Hamadryas Baboon is the only nonhuman primate species to inhabit the Arabian Peninsula. In Saudi Arabia, hamadryas are found along the Sarawat mountains which run parallel to the west coast of the Arabian Peninsula and the Red Sea (Biquand et al. 1992).

Hamadryas Baboons are known to have among the longest daily path lengths of all primate species, and a unique multi-level social organization in which large groups (troops and bands) break into smaller foraging parties (one-male units and clans) during daily travel. These ranging and social patterns have often been attributed to the scarce and widely dispersed distribution of food resources in their semi-desert habitats (Kummer 1968; Sigg & Stolba 1981; Swedell 2002, 2006; Schreier 2010; Schreier & Swedell 2012a). Hamadryas Baboons rely on *Acacia* species for subsistence throughout their range (Kummer 1968; Nagel 1973; Kummer et al. 1981; Al-Safadi 1994; Schreier 2010). In Ethiopia, Nagel (1973) reported that Hamadryas Baboons at the Awash River most commonly fed on the flowers, seeds, and fresh shoots of *Acacia senegal, A. nubica, A. tortilis,* and *A. clavigera*, and appeared to prefer the flowers when they were available. At Erer Gota, *Acacia* species comprised the majority of the diet across seasons, and the Baboons preferred *Acacia* flowers and grass seeds when they were available (Kummer 1968). At Filoha, Hamadryas Baboons predominantly fed on *A. senegal* and *A. nubica* (Swedell et al. 2008; Schreier 2010). Saudi Arabian hamadryas populations also feed primarily on *Acacia* trees and other semi-desert plants such as *Grewia* spp. and *Dobera glabra* (Kummer et al. 1981; Al-Safadi 1994).

Seasonal dietary patterns are common, with hamadryas feeding on items such as flowers, young leaves and grass seeds when they are available, and switching to less preferred items during the dry season (Kummer 1968). Band 3 at Filoha, Ethiopia consumed fewer food species during the dry season months and a greater number of species in the wet season (Swedell et al. 2008). The baboons at Filoha also fed predominantly on Doum Palm Fruit *Hyphaene thebaica*—a high quality food source not available elsewhere in hamadryas range—when it was available, and they preferred *A. senegal* flowers to leaves (Schreier 2010).

In addition to feeding on natural plant resources, some Hamadryas Baboons also rely on human food, via crop raiding or being directly fed by humans (i.e., commensalism). For example hamadryas in Awash National Park, Ethiopia were known to occasionally raid crops both outside and within the park (Nagel 1973). Raiders and commensal baboons account for 35% of the entire estimated Arabian hamadryas population (Biquand et al. 1992). Crop raiders in agricultural areas were much more common than were commensal groups (Biquand et al. 1992). Baboon reliance on human food, however, conflicts with both urban and agricultural activities throughout their entire range in Saudi Arabia (Kamal & Brain 1989; Biquand et al. 1992), increasing human-wildlife conflicts.

Feeding on human foods, by either raiding or being provisioned, has been proposed to be the major cause of population increase in non-human primate troops that frequent human settlements (Sugiyama & Ohsawa 1982; Fa 1988; Kurita et al. 2008). No free-ranging primates, however, have been reported to cease feeding on natural foods after starting to consume human foods (Iwamoto 1988; Boug 1995; Saj et al. 1999).

Based on their extensive surveys on the distribution of Hamadryas Baboons in Saudi Arabia, Biquand et al. (1992) found that few cases of raiding were observed where the availability of natural foods was high, especially where perennial species remained rich on the ground. Specifically, Baboons seldom raided crops in *Acacia* woodlands and wadis where vegetation was rich. In contrast, crop-raiding frequency was high in certain dry regions as well as in areas where the natural vegetation did not include plant species in the Baboons' diet. Baboons tended to raid crops and houses and to be provisioned in the extreme case of when their habitat was severely destroyed by overgrazing (Biquand et al. 1992).

The purpose of this study is to investigate whether Biquand et al.'s (1992) findings apply to two local Saudi Arabian Hamadryas Baboon populations. We seek to gain a better understanding of hamadryas feeding strategy by attempting to clarify the relationship between the level of artificial food supply and natural food selection in two troops of commensal Hamadryas Baboons living in different habitats in Saudi Arabia. One site had higher amounts of natural plant foods and was a less damaged habitat overall. We predicted that baboons at the site with richer vegetation would spend less time feeding than those in the damaged habitat. We also predicted that baboons at both sites would spend more time feeding when provisioning was highest and that they would consume less natural food during these periods. Conversely, we predicted that dependency on human foods would decrease during periods of high natural food availability.

METHODS

Study sites

Alhada: Alhada is a mountainous area located 18km northwest of Taif City, which is the most famous recreation site in southwestern Saudi Arabia. It is a part of the Sarawat range (Fig. 1), and the mountains' peak elevation reaches 2,100m. At the escarpment facing the Red Sea, a road crosses the area connecting Taif and Makkah (the holy place of Islam).

During the study period at Alhada (September 1990 to August 1991) the baboon troop (Image 1) living at the top of the escarpment was composed of 220 individuals who shared a sleeping site. For most of the year people using the road connecting Taif and Makkah presented food (e.g., bananas, carrots) to the baboons (Boug 1995). In January and February 1991, however, the road was closed for maintenance construction, and thus significantly fewer people visited this area, resulting in a dramatic decrease in provisioning level. This provided the opportunity to study the effects of reduced provisioning on the foraging strategy of this baboon troop (Boug et al. 1994).

Alhada and the Dam Site (see below) have no weather stations, and as a result, we employed meteorological data for the relevant study periods from the Taif airport located 40km east of the escarpment. It is important to note that the weather data may not always represent the exact conditions of the Alhada habitat. The temperatures for the study period at Alhada varied between a maximum of 36.1^{0}C in August and a minimum of 4^{0}C in January, with monthly averages ranging from

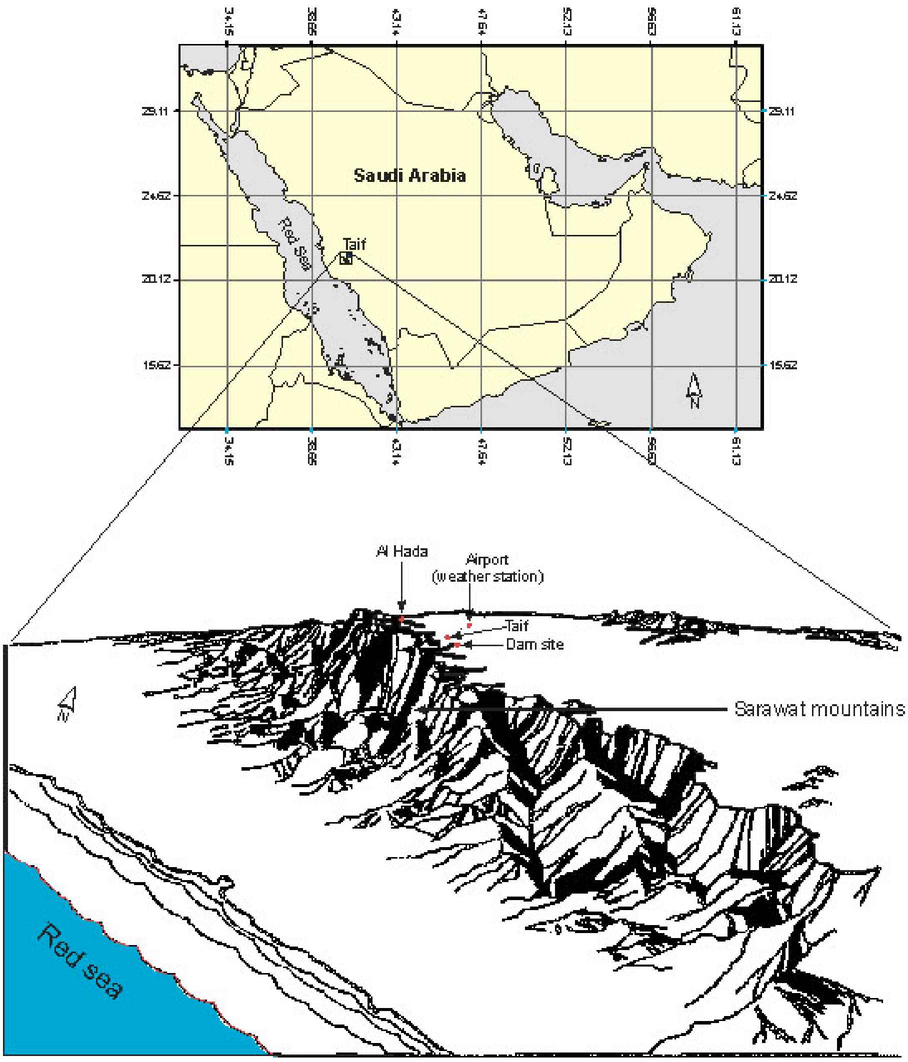

Figure 1. Map showing the study sites Alhada and Dam Site along the Sarawat mountains around Taif city, southwestern Saudi Arabia (modified from Biquand et al. 1992).

Image 1. Commensal behavior of Hamadryas Baboons were studied at Al Hada area

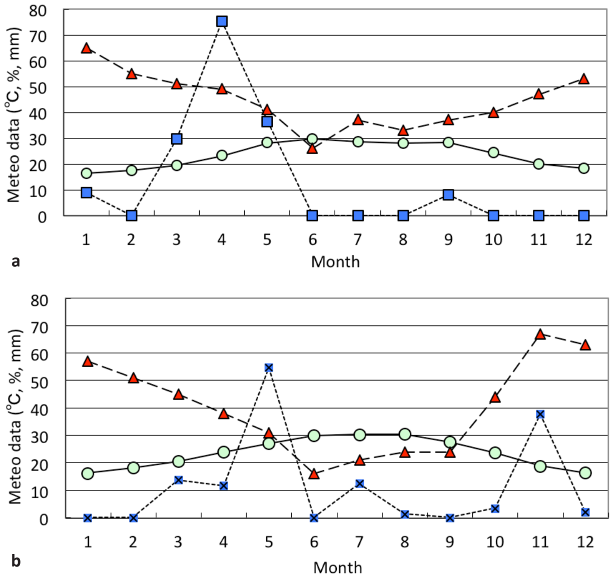

Figure 2. Monthly changes of meteorological data in Alhada (a) and Dam Site (b) Solid line, broken line and dotted line show temperature, relative humidity and rainfall, respectively.

9.2–24.3 ^{0}C (Fig. 2). Annual rainfall during the study period was 158.1mm, but intra-annual variation was great (Fig. 2). An analysis of 14 years (1990–2003) of rainfall data from the meteorological station at Taif airport shows that the highest and most stable peak occurs in April with frequent additional peaks occurring in August and November at two to three year intervals.

Like other mountainous areas facing the Red Sea, the considerable variation in daily temperature causes frequent fog to develop, which adds moisture to the area and creates favorable conditions for varied plant growth. For example, these weather conditions permit *Juniperus* forest to grow at high altitudes of 1,800m (Biquand et al. 1992). *Juniperus* spp. are the dominant species here, followed by several *Acacia* species, such as *A. origena.* This area is considered to be representative of west Sarawat mountain habitat.

Dam Site: The Dam Site—a hilly and wadi area called Al Ruddaf—is located 7km southeast of the Taif City center (25km southeast of Alhada) and is known as the city's recreational site (Fig. 1). We carried out our field studies at the Dam Site from January to December 2000. It is located in the rain shadow of the eastern Sarawat mountains, where the western cliff facing the Red Sea is the side of Alhada. The elevation is 1,500m.

During the study period, the baboon troop here was composed of 475 individuals who shared a sleeping site beside the Wadi Liyah Dam (Mori et al. 2007). From 1998–2000 this Baboon troop was intensively studied through a collaborative project of the Saudi Wildlife Authority of Saudi Arabia (SWA), Kyoto and Miyazaki Universities, and Kitakyushu Municipal Museum, Japan. People who visited the Dam Site area (including the Al Ruddaf Park) during the study period often presented food to the Baboons. The level of provisioning was influenced by school and national vacations. For example, during summer vacation (June–September) people from nearby cities visit the area to watch the baboons and feed them fruit and vegetables.

The temperature at the Dam Site varied from a maximum of 37.3^{0}C in August 2000 to a minimum of 7.3^{0}C in January 2000, with monthly averages ranging from 16.2–30.4 ^{0}C (Fig. 2). The cumulative rainfall for 2000 was 136.9mm. Inter-annual variation over a 14-year period (1990–2003) at Taif airport ranged between 78.7–360.3 mm, with an average of 200mm. The location of this site as a rain shadow causes a much drier environment than that of Alhada. Two *Acacia* species are dominant in this area: *A. asak* in the hilly part of the area and *A. gerrardii* in the wadi. This area is representative of habitat in the east Sarawat mountain area. Housing, roads, cultivation, and overgrazing associated with the significant human population in this area have disturbed the habitat of the hamadryas here. The Dam site is, therefore, a more damaged site than Alhada.

Vegetation cover

We assessed habitat quality by estimating the coverage of different vegetation types at each study site. We set transects across different topographical features at each site, i.e., three transects each in slope and wadi at the Dam Site, and two transects each in flat, slope and wadi in the Alhada area, for a total of six transects at each site. Each transect was 180x10 m, providing a total area of 1,800m^2. We measured the diameter at breast height (DBH) and crown size (the longest and the shortest diameter) of each tree/shrub for all plants within the area located within 5m of each side of the transect line. We also recorded the phenology status for each plant, and that include flowers, fruits, seeds and green leaves. In addition, we set quadrats 3x3 m in size (9m^2) every 30m along the transect line to measure the coverage of ground vegetation, such as small shrubs, grasses and herbs. We estimated the percentage of plant cover of each species in these quadrats by eye. We developed a computer program to calculate the coverage of tree/shrub layers in each transect, considering the projection of slopes onto the map and parts of tree crowns that should be excluded from the coverage calculation. Based on the home range area drawn on the 1:50,000 scale map, we assessed the vegetation richness for each troop as the total coverage of tree/shrub layer and herb/grass layer.

Observations and analyses

We followed the baboons from sunrise to sunset, and determined activity profiles by scan sampling of all visible animals (Altmann 1974), based on scans taken at 15 min intervals over a period of five full days each month. In Alhada we conducted 720 hours of observations and 2,880 scans. As we defined one activity record as the activity of each individual, we obtained 40,536 activity records in Alhada. We also recorded the plant species and part ingested when Baboons were feeding. We conducted the same number of hours of observation at the Dam Site, obtaining a total of 75,915 activity records during 720 hours of observation.

We calculated the following variables to determine the monthly changes and relationships among vegetation, feeding and weather data:

1) The percentage of the number of feeding records to total activity records (time spent feeding; Feed_Total)

2) The percentage of the number of records feeding on natural foods to total activity records (Nat_Total)

3) The percentage of the number of records feeding on natural foods to the total feeding records (Nat_Feed)

4) The diversity index for natural foods calculated by the Shannon-Weiner's equation (Nat_Div_Index)

We determined diet composition from the activity scan data. We established a checklist of plant species, and calculated the relative contribution of each food item/species eaten to total feeding records to compare feeding habits at the two study sites. We statistically compared monthly changes in feeding profiles in both study sites by Spearman's rank correlation and Wilcoxon sign test for the level of significance. Significance level was set at $p<0.05$. For Alhada, we carried out the analyses for two sets of data, one for 12 months (September 1990–August 1991) and another for 10 months (September–December 1990 and March–August 1991) to measure the effect of the road closing in January and February on the baboons' dietary patterns.

RESULTS

Plant availability

Plant coverage was higher in sloped regions in Alhada compared to the Dam Site. The percentages of trees and shrubs in two slope transects in Alhada were 10.5% and 14.2% (mean=12.3%), while in three slope transects at the Dam Site the percentages were 4.7%, 13.6% and 4.7% (mean=7.6 %; Table 1). Ground cover (i.e., grass/herb percentages) in slopes was also higher in Alhada than in the Dam Site. In two slope transects in Alhada the percentages of grass and herb cover were 53.3% and 27.2% (mean=40.25), while in three slope transects at the Dam Site the percentages were 18.3%, 15.0%, and 15.0% (mean=16.1). In wadi areas, the percentages of trees and shrubs were 14.2% and 16.7% (mean=15.4%) in Alhada, and 15.9 %, 21.9%, and 47.4% (mean=28.4%) at the Dam Site. Despite the higher tree/shrub coverage in wadis at the Dam Site, ground cover in these areas was higher in Alhada (mean 5.85%) than at the Dam Site (mean=1.67%). Considering that the home ranges of both troops were mainly sloped, Alhada has denser vegetation cover than the Dam Site.

We also estimated total vegetation cover in both tree/shrub and grass/herb layers for the two sites from the size of each geographical feature in the baboon home ranges (Alhada, 6.69km^2; Dam Site, 6.70km^2). The tree/shrub layer covers 10.6% and 9.4%, and the grass/herb layer covers 21.7% and 14.2% in Alhada and the Dam Site, respectively. These data confirm that the Alhada habitat provides richer vegetation cover than the Dam Site.

At both sites there was one major plant emergence corresponding with the first period of heavy rainfall that took place during March–April. The second period of heavy rainfall (July–August) had a more moderate effect on plant emergence and growth. Plant species included annuals, biennials and perennials. Most plants were herbaceous and a few were woody. Leafing, flowering, and fruiting periods varied among species; however, these plant parts including leaves, flowers, and fruits were most prevalent from March to November. Growth of most species was minimal during winter.

Table 1. Plant coverage in each geographical feature for both study sites

	Transect Area (m^2)	Tree & Shrub (%)	Grass & Herb (%)
AlHada			
Slope1	1724.35	10.5	53.3
Slope2	1765.77	14.1	27.2
Wadi1	1704.99	14.2	11.7
Wadi2	1729.13	16.7	0.0
Flat1	1798.90	21.9	8.3
Flat2	1787.66	16.0	11.6
DamSite			
Slope1	1774.72	4.7	18.3
Slope2	1648.48	13.6	15.0
Solpe3	1765.93	4.7	15.0
Wadi1	1800.00	21.9	5.0
Wadi2	1800.00	47.4	0.0
Wadi3	1800.00	15.9	0.0

Diet composition

Hamadryas Baboons in the study areas showed a wide range of dietary selection. We recorded a total of 65 plant species consumed by the baboons; 42 in Alhada and 23 at the Dam Site (Appendix 1). Baboons chose one to seven plant parts (bark, flowers, fruit, stems, seeds, roots, gum) depending on the species (*Acacia gerrardii* and *A. asak* at the Dam Site, and *Juniperus* and *Ficus* species at Alhada).

The flowering, fruiting and seeding season of preferred species played a strong role in the food choice and feeding strategy of the Hamadryas Baboons in this study (Fig. 3). The Alhada troop depended on the seeds of *A. gerrardii* for 50% and 24.7% of its natural foods diet during January and February, respectively (Fig. 3). Baboons in Alhada ate fruits of *J. phoenicia* intensively, accounting for 47% and 31% of the feeding records in April and May, respectively. As the dominant plant species in Alhada, its bark accounted for 59.6% of the feeding records in February and its leaves for 26.2% in August. They ate fruits of *Ficus carica* during June (12.8%), July (16.7%) and August (14.5%). Ingestion of *F. ingens* fruits made up 45.5%, 14.5%, and 28.6% of feeding records in June, July and August, respectively.

The Dam Site troop fed mainly on the flowers of *A. gerrardii*, making up 60.9%, 47.8% and 22.4% of the total natural feeding records collected in June, July and August, respectively (Fig. 3). They also depended heavily on fruits making up 78.4% and 40.4% of the total feeding records in September and October, respectively.

Table 2. Spearman's rank correlation coefficients among four variables, rainfall, Nat_Feed, Nat_Total, Feed_Total and Nat_Div_Index. The 10- and 12-month study periods at Alhada are shown separately. * = significant at p<0.05 See text for the explanation of variables.

Dyad of correlation	Alhada	Alhada	Dam Site
	12 months	10 months	12 months
Rainfall - Nat_Feed	0.615 *	0.797 *	-0.227
Rainfall - Nat_Total	0.603 *	0.724 *	-0.500
Rainfall - Feed_Total	-0.140	-0.221	-0.381
Rainfall - Nat_Div_Index	0.545	0.621 *	0.428
Nat_Feed - Feed_Total	-0.643 *	-0.527	-0.524
Nat_Feed - Nat_Div_Index	0.448	0.733	0.037
Nat_Total - Feed_Total	-0.400	-0.176	-0.077
Nat_Total - Nat_Div_Index	0.414	0.661 *	-0.110
Feed_Total - Div_Index	-0.294	-0.479	-0.253

The Dam Site troop fed on flowers of *A. asak* in 11% of the feeding records in August and on its fruits for 26.8% of the records in November. This species is dominant on the slope areas at the Dam Site.

It is clear that preferred plant species play an important role in the food choice of Hamadryas Baboons and their feeding strategy. Both troops fed heavily on ground vegetation sprouting shortly after rainfalls in spring; however, once the young plants on the ground were depleted, baboons in the richer/less damaged habitat (Alhada) shifted their main diet to parts of *Juniperus* and *Ficus* trees in spite of an abundance of *Acacia* trees, while those in the less rich/more damaged habitat (Dam Site) changed their diet mainly to *Acacia* parts.

Feeding Activity

H Feeding activity records accounted for 18% and 33% of the total activity records collected in Alhada and the Dam Site, respectively (Fig 4a). Baboons at the Dam Site spent significantly more time feeding than those at Alhada (Wilcoxon sign test, p=0.003). The curve trends of monthly change were different (Spearman rank correlation, r=0.194611, p=0.547) between sites.

The Baboons at Alhada spent less time feeding in January and February (13.4% and 15.0% of the activity records) than did the Baboons at the Dam Site (22.5% and 33.9%). These months were when the road connecting Taif and Makkah was closed for maintenance, preventing provisioning by people at Alhada. During this time, provisioning at the Dam Site was high.

At both sites, the baboons spent the most time feeding during summer, which corresponds to school

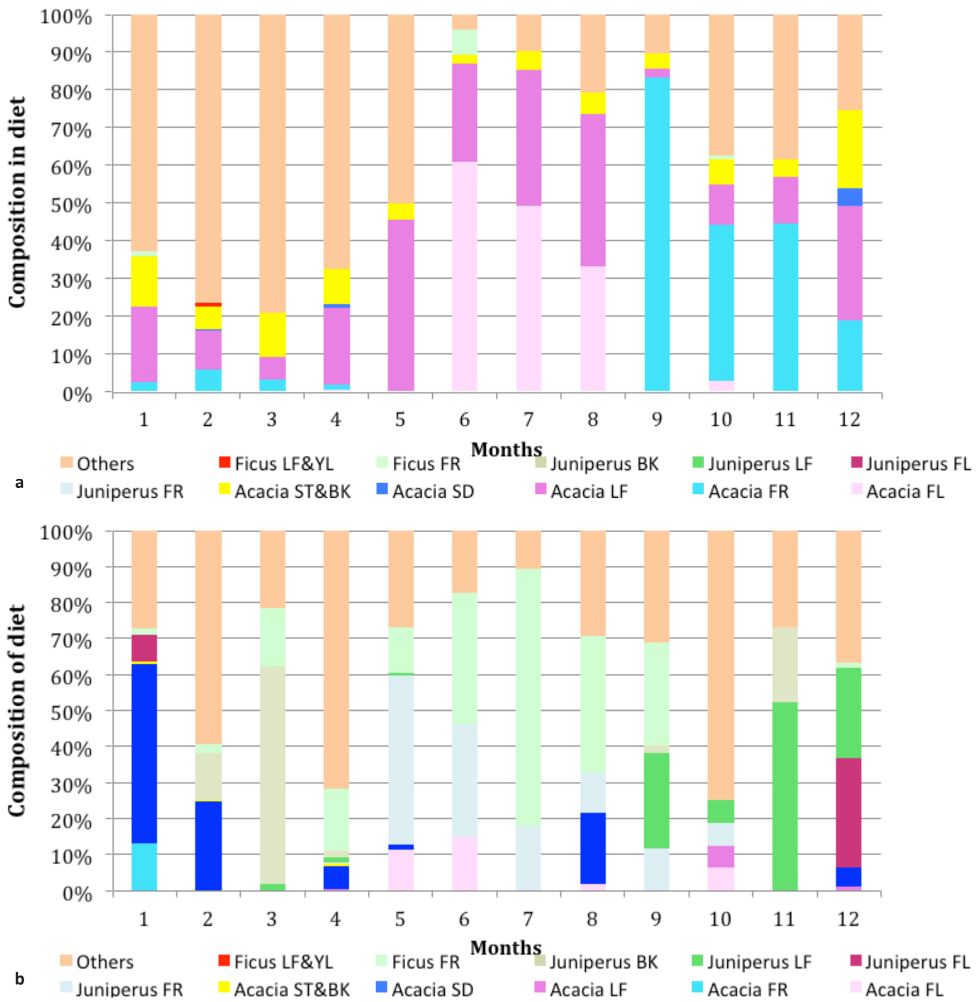

Figure 3. Monthly diet composition of baboons in Alhada (a) and Dam Site (b).

vacation and thus higher numbers of visitors and increased provisioning. In Alhada the Baboons spent 25.0% of their time feeding in July and 24.1% in August. At the Dam Site, the baboons spent 32.7% of the time feeding in June, 37.6% in July, and 39.9% in August. Here these summer months also coincided with the flowering season of *A. gerrardii*, a preferred plant species. The next highest levels of feeding at both sites corresponded with when availability of natural plants was high due to peaks in monthly rainfall (Fig. 2). Baboons at Alhada spent 22.5% of activity records feeding in May, while baboons at the Dam Site spent 30.6% of activity records feeding in April.

The largest difference in monthly feeding time between the two sites occurred in December when the Alhada baboons spent 17.9% of the time feeding while those at the Dam Site spent 43.0% of their time feeding. This difference can be attributed to an increased number of visitors to the Dam Site associated with a delayed Islamic vacation season in 2000.

The monthly patterns of feeding on natural foods were similar across sites (Fig. 4b; Spearman rank correlation (correlation coefficient) r=0.668521102, p=0.018), and there is no significant difference in the position (Wilcoxon signed rank test, p=0.433). In Alhada, the peaks in feeding on natural foods during January (51.3%) and February (45.6%) are likely due to a reduction of provisioning during these months when the road was closed. In contrast, feeding on natural food was relatively low at the Dam Site at this time of the year (28.7% of feeding records in January and 23.4% in February). Baboons at both sites consumed high percentages of natural foods in April (42.2% in Alhada, 46.5% at Dam Site) which may be related to the increased rainfall during this time. In September, natural food feeding was high at the Dam Site (30.3%) due to the fruiting season of preferred plant species *A. gerrardii*. In June, July and August, dependency on natural plants was

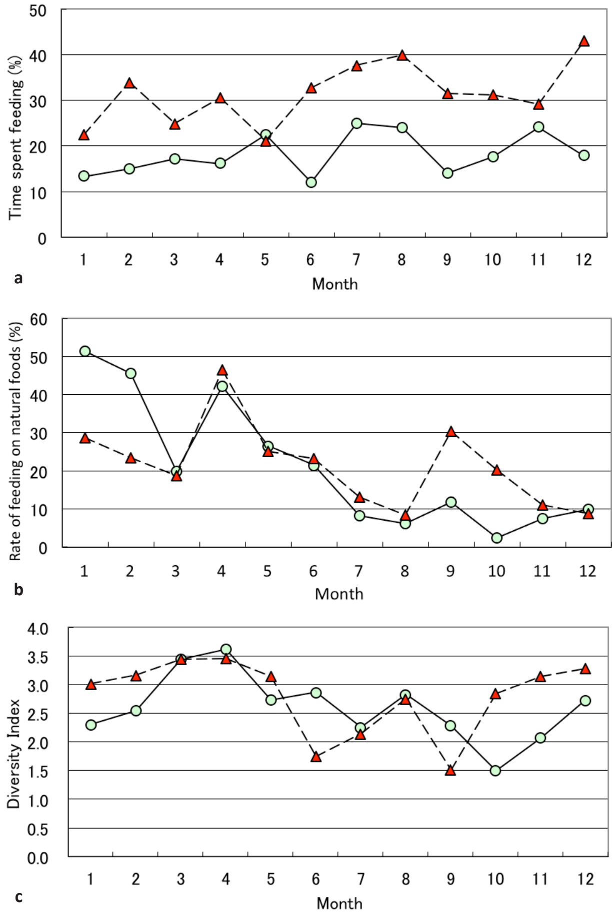

Figure 4. Time spent feeding (Feed_Total: a), rate of feeding on natural foods to total feeding (Nat_Feed: b) and natural food diversity (Nat_Div_Index: c). The solid line indicates Alhada and the broken one indicates Dam Site.

considerably lower at both sites likely due to the low natural plant availability during the hot summer season and low rainfall.

There was no significant difference between the mean monthly values of diversity index for natural foods across sites (Wilcoxon signed rank test, r=0.014751, p=0.424; Fig. 4c). The diversity index peaked at both sites in March and April (3.4–3.6). The lowest diversity index occurred in October at Alhada (1.5) and in September at the Dam Site (1.5). There were higher diversity values during autumn and winter (October to February, range 2.8–3.3) at the Dam Site compared to Alhada (1.5–2.6). Baboons at the Dam Site fed on many food items (mainly fruits) from *Acacia* species during October to December, and fallen *Acacia* seeds and food items from the herb/grass layer in January and February. During these months, the diversities are high despite the lower dependency on natural foods during this period (Fig. 4b).

Analysis of factors influencing feeding activities

We examined the relationships among several variables (rainfall, Feed_Total, Nat_Total, Nat_Feed and Nat_Div_Index) employing Spearman's rank correlation coefficients analysis (Table 2). Both Nat_Feed and Nat_Total for Baboons in Alhada showed significant positive correlations with rainfall in both the 12-month and 10-month analyses (r_s=0.615 and 0.603, respectively; p<0.05). Feed_Total and Nat_Feed were negatively correlated (r_s=-0.643; p<0.05) in Alhada only in the 12-month analysis, indicating that the Baboons spent less time feeding overall when a higher proportion of their diet came from natural foods. In January and February, baboons at Alhada were forced to collect a lot of *Acacia* fruits and seeds (Fig. 3) because provisioning by humans was very limited. There were, however, no statistically significant correlations between Nat_Feed and Feed_Total at the Dam Site or for the 10-month analysis in Alhada.

When excluding January and February in Alhada, Nat_Div_Index showed significant positive correlations to both rainfall (0.621; p<0.05) and Nat_Total (0.661; p<0.05). This suggests that natural food diversity rose with both increasing rainfall and time spent feeding on natural foods under regular provisioned conditions. There were no significant correlations among those variables at the Dam Site, however. These results suggest a clear relationship between feeding activities and natural food conditions at Alhada but not the Dam Site.

DISCUSSION

Our results suggest that three variables influence the baboons' feeding behavior at our study sites and affect their dependency on natural plant foods: (1) level of natural plant availability, (2) level of provisioning, and (3) seasonality of preferred food species. As predicted, the baboons at Alhada (where there is more dense vegetation) spent less time feeding than those at the Dam Site (the less dense habitat). Furthermore, as expected the troops at both sites spent more time feeding during periods of the year when provisioning by humans was highest. Moreover, the baboons spent more time feeding on natural foods when numbers of human visitors were low. In fact, the greatest difference between the two troops in the percentage of feeding on natural foods occurred in January and February, when humans were precluded from visiting Alhada because of road closure. These were the two months of the year that the Alhada baboons spent the most time feeding on natural foods. With respect to seasonality, fresh shoots of ground vegetation that sprouted after prominent spring rainfall resulted in high levels of feeding at both sites.

A molecular genetic study by Winney et al. (2004) revealed that the ancestor of present Hamadryas Baboons might have immigrated to Saudi Arabia passing a southern bridge between the horn of Africa and Arabian Peninsula that was available during an interglacial age. The baboons' inhabitation of this peninsula might have been guided by the relatively rich ground (perennial and bushy) and arboreal (*Juniperus*, *Ficus* and *Acacia*) vegetation formed by the cooler and wetter climate due to high altitude, as observed at our study sites. The Baboons' preferred habitat, however, is also favored by humans. Presently, the Sarawat mountain region has high human population density (General Statistic Commission of Saudi Arabia 2013) and the area therefore suffers from severe degradation of the natural environment due to cultivation, nomadism and urbanization. The grazing of ground vegetation by cattle is responsible for high levels of degradation in this area.

Following their extensive surveys throughout Saudi Arabia, Biquand et al. (1992) concluded that the degree of interaction between baboons and humans, such as raiding and commensalism, is closely related to the preservation status of the natural habitat, especially with respect to ground vegetation. Our study confirms that their findings also apply to two nearby troops living in different habitats, namely, the feeding behavior of baboons living in the denser habitat (Alhada) reflected the natural food resources, but this was not the case for Baboons living at the Dam Site. The more commensal troop lived in the less dense habitat and heavily depended on artificial foods.

Sugiyama & Ohsawa (1982) reported that an artificially provisioned troop of Japanese macaques showed a higher birth rate, earlier primiparous age, and lower infant mortality rate resulting in a larger troop size compared to a natural troop. Iwamoto (1988) analyzed nutritional content of both natural and artificial foods, and reported that many artificial foods given to Japanese macaques contained more soluble carbohydrates than natural foods. Monkeys can readily convert carbohydrates into energy. Provisioned foods thus appear to provide high energy content but they are not nutritionally balanced (Iwamoto 1988; Saj et al. 1999). This may explain why the baboons in our study sites continued to spend a substantial amount of time feeding on natural foods, despite the high availability of artificial foods. In other words, baboons need a nutritional balance even under energetically rich food conditions, which may prevent them from relying solely on human foods. For example, the baboons appear to depend on natural foods for protein. Fresh grass and herb shoots are likely rich in protein, as are *Acacia* fruits and flowers, fruits, and leaves of *Juniperus* and *Ficus*, all preferred foods by the Baboons (Hausfater & Bearce 1975; Wrangham & Waterman 1981; Isbell et al. 2012; Rothman et al. 2012). Natural foods may also provide baboons with many kinds of minerals, vitamins, and sometimes medicinal chemicals (Hausfater & Bearce 1975; Wrangham & Waterman 1981; Isbell et al. 2012; Rothman et al. 2012). We suggest that the need for a nutritionally balanced diet has kept the baboons from becoming completely dependent on human foods.

Interestingly, the proportion of time spent feeding on artificial foods is almost the same for the two troops, despite the significant difference in total feeding time. The only differences between the Alhada and Dam Site troops in time spent feeding on artificial foods appeared in January and February, when the main road in Alhada was closed and provisioning was limited, and in September and October when the Dam Site troop preferred *Acacia* fruits to human foods. The percentages of the diet from natural and artificial foods were almost identical across sites for the other months of the year. We also found the same pattern of seasonal trends in natural diet diversity across the two sites. The similarity in findings for the two troops suggests that the baboons used a strategy of balancing their feeding on natural and artificial foods that prevents them from becoming too dependent on human diets.

Our results suggest that baboons favor natural foods over artificial foods if they can freely choose their diet under free ranging conditions. Considering their evolutionary radiation (Kummer 1968), Hamadryas Baboons might have initially adapted to an environment that was basically arid but locally covered by highland *Juniperus*, *Acacia* and *Ficus* forests with richer ground vegetation than at the present time. This characteristic hamadryas habitat is much harsher than that typical of most primates in the tropics; Hamadryas Baboons have been able to cope with the limited food availability throughout their range by employing large home ranges and long daily paths, as well as by altering group size in response to different levels of food availability (Kummer 1968; Swedell 2006; Mori et al. 2007; Schreier & Swedell 2009, 2012a,b). In these environments, they particularly require foods containing low fiber and high soluble carbohydrates (Hausfater & Bearce 1975; Wrangham & Waterman 1981; Isbell et al. 2012; Rothman et al. 2012). It is likely that the Saudi Arabian Hamadryas Baboons discovered that artificial foods provide them with ready energy, providing another means to overcome the low abundance of food resources in typical hamadryas habitat. Commensal and crop-raiding baboon troops frequenting urbanized areas are virtually guaranteed access to such high energy foods.

The fundamental problem in places like Alhada and the Dam Site is that human and baboon activities overlap. The baboons enter human-inhabited areas in order to obtain human food, which can lead to human-baboon conflict. Furthermore, eating human foods has been proposed to be the major cause of population increase in non-human primate troops that frequent human settlements (Sugiyama & Ohsawa 1982; Fa 1988; Kurita et al. 2008). The Saudi Wildlife Authority (SWA) developed a management plan to reduce the number of conflicts caused by baboon commensalism (Boug et al. 1991). Several projects have been implemented in various areas of the country to test the feasibility of the management plan (Boug et al. 1991, 1994), however, urban and cultivated areas still suffer from raiding and crop damaging by baboons. Our study suggests that in order to satisfy their particular nutritional needs, Hamadryas Baboons are unlikely to completely abandon feeding on natural foods in favor of artificial foods. Thus, it seems possible for the baboons to revert to natural and healthy populations with lower densities. This can be realized by restricting provisioning by tourists of ready to use human foods during the severe periods in summer and winter, when natural food availability is low and provisioning level is high, ultimately decreasing human-wildlife conflict.

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Appendix 1. Diet composition (%) of Hamadryas Baboons living in two habitats, Alhada and Dam Site near Taif City, Saudi Arabia.

species name	Family	Part eaten	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
			H a	D	H	D	H	D	H	D	H	D	H	D	H	D	H	D	H	D	H	D	H	D	H	D
Trees																										
Acacia gerrardii	Leguminosae	BK b	0.5	1.5	0.4	3.6		7.0		5.9		0.5		1.0		4.1				2.6		5.8		2.4		16.2
		FL									5.9		15.1	60.9		47.8	1.8	22.4								
		FR	9.3			1.6		3.3												78.4		40.4		17.6		
		LF		3.5		6.9		5.3		8.1		27.0		23.1		30.2		35.6		1.0		9.5		0.8		20.8
		SD	50.0		24.7	0.3			5.6	1.0	1.6						20.0								5.1	4.6
		ST				0.3				0.2																
Acacia asak	Leguminosae	BK		12.0		2.1				2.9		3.6		1.2		0.8		5.9		1.4		0.6		2.4		4.6
		FL														1.6		11.0				2.8				
		FR		2.4		4.1				1.3										5.0		1.2		26.8		18.8
		LF		16.5		3.4		0.7		12.3		18.4		2.9		3.3		4.6		1.4		1.2		11.6		9.6
		ST						4.6		0.5																
Acacia ehrenbergiana	Leguminosae	FL								0.5																
		LF										0.3				2.4										
Acacia etbaica	Leguminosae	FR	3.7																							
Acacia origena	Leguminosae	SD							0.6																	
		BK							0.6																	
		LF							0.6												6.3					
		FL									5.4										6.3					
Acacia tortilis	Leguminosae	LF																							1.3	
Juniperus phoanicea	Cupressacae	FR							0.6		47.0		31.4		18.2		10.9		11.9		6.3					
		FL	7.4																						27.8	
		BK			8.8		59.2		1.9										2.4				4.2			
		LF					2.0		1.2		0.5								26.2		6.3		9.9		6.3	
Juniperus excelsa	Cupressacae	BK			4.2		1.0																16.9			
		LF																					42.3		19.0	
		FL																							2.5	

species name	Family	Part eaten	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Faidherbia albida	Leguminosae	FR								12.8																
Ficus ingens	Moraceae	FR			1.8		15.3		0.6		4.3		12.8		45.5		14.5		28.6							
Ficus carica	Moraceae	FR	1.9				1.0				3.2		12.8		16.7		14.5								1.3	
Ficus salicifolia	Moraceae	FR			0.7				16.8		5.4		10.5	6.9	9.1		9.1									
		LF				0.3																				
Ficus sp	Moraceae	FR		1.5																		1.2				
		YL				0.9																				
Ziziphus spina-christi	Rhamnaceae	BK														0.4										
		FR		0.6		28.1		0.0																		
		LF						0.7				1.3		0.5										2.8		
Pistacia falcata	Anacardiaceae	FR							0.6		0.5		5.8													
		LF																	4.8							
		BK																					1.4			
Rhus retinorrhoae	Anacardiaceae	FR					12.2																			
Palm tree	Palmae	SD								0.0										1.0						
		ST								0.3																
		LF			0.7																					
Pine tree	Pinaceae	FR				0.7																				
Jacarenda tree	Bignoniaceae	LF		4.1				14.9		1.3		0.5								0.5		1.5		0.8		6.6
Shinus molle	Anacardiaceae	FR						22.2		2.2																
		LF										0.5														
Calotropis procera	Asclepiadaceae	BK														0.4										
		ST				0.2		0.7				0.8														
Dried acacia	Leguminosa	BK								1.7																
		LF								0.2																
Shrubs																										
Barlena trispinosa	Acanthaceae	FR						3.3																		
		LF		0.2																0.3				2.0		
		RT		0.2																						

species name	Family	Part eaten	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
		UN c																				0.6				
Capparis cartilagea	Capparidaceae	FR	4.6											0.5			21.8									
Euphorbia schimperi	Euphorbiaceae	FL				0.7				1.0																
		LF																				0.3				
		ST				0.2																				1.5
Lycium shawii	Solanaceae	FR						3.6																		
		GM										0.8														
		LF	0.9	4.4	2.8	3.3	1.0	1.0	3.7	3.5		3.1		1.2		6.5		3.2		1.0		4.3		3.2		6.1
		FL	0.5						3.1																	
Ochradenus baccatus	Resedaceae	FL		0.4	2.5					0.1	0.5				3.0								4.2		6.3	
		FR				1.2					0.5															
		LF		0.2														0.5				0.3				
Otostegia fruiticosa	Labiatae	FR										0.3														1.0
		LF		1.7								1.0						0.5		0.2				2.4		0.5
Solanum incanum	Solanaceae	BK																		0.2		0.3				
		LF								0.1																
		ST		1.1		1.0		1.0		0.1		0.3				0.8		1.4								
		RT																	2.4							
Withania somnifera	Solanaceae	FR	4.6		0.4		2.0		11.8	0.1	9.2	0.8	2.3				3.6			0.6	6.3	3.1	5.6		5.1	
Rumex nervousus	Polygonaceae	LF	1.4						0.6				4.7		4.5		1.8						4.2		11.4	
		FR							2.5																	
		FL									3.8								9.5							
Solanum villosum	Solanaceae	FR							6.2																	
Dodonea viscosa	Sapindaceae	LF																							3.8	
Dodonia angustitole	Sapindaceae	FL						4.6																		
Grasses and herbs																										
Grass dry	Gramineae	LF		1.1		0.3																				

species name	Family	Part eaten	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Grass	Gramineae	LF	5.6	5.2	38.5	26.6	3.0	17.2	9.9	18.5	7.6	26.0	2.3		1.5			5.5	9.5	3.5	68.7	21.7	5.6	8.8	10.1	6.1
		RT	2.8																							
Echonopis sp	Compositae	FL	0.5							0.4																
		BU	1.9		0.4																					
		FR							1.2		1.1															
		RT									1.1															
Fagonia indica	Zygophyllaceae	FR				1.4						0.3														1.0
		LF						0.3				0.5						0.5								
		UN		0.2																						
Indigofera spiniflora	Leguminosae	FR				0.3																		15.6		
		LF								0.8		1.3		0.2		1.6		8.2								0.5
		RT		40.7		11.9		7.9		0.1										0.5				1.6		0.5
		UN		0.2																						
Lavandula dentata	Labiatae	RT		0.2																						
		LF			1.1				0.6																	
Ostiospermum valantii	Compositae	FL	2.3		11.7		3.1		9.9	0.4	1.1	2.6					1.8									
		FR							10.6															0.4		
		LF		0.2	0.7																					
		SD	0.9								1.1				1.5											
		RT											2.3													
		BK			0.4																					
Rumex vosicaris	Polygonaceae	FL							0.6																	
		FR							3.1																	
Echinops spinosissimus	Compositae	FR							1.2																	
		LF							1.2																	
Cissus rotundifolus	Vilacae	BK							3.1																	
Salsola kali	Chenopodiaceae	LF																					4.2			
Hypoestes forskalel	Acanthacae	FL																					1.4			

species name	Family	Part eaten	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Unidentified sp (1)		UN		0.4		0.2		0.3		1.0		3.4										0.3				
Unidentified sp (2)		BK				0.2		0.3				0.3		1.5						0.3						
		LF																		0.6						1.0
		ST								0.1																
Unidentified sp (3)		FR										1.3														
Grewia tembensis	Molvaceae	LF	0.5																							
Cucumis prophetarum	Cucurbitaceae	FL	0.5						1.2																	
Commicarpus grandiflorus	Nyctaginaceae	FL	0.5																							
		LF																	2.4							
Asparagus africanus	Liliaceae	LF			0.4																					
Pluchea dloscoridis	Compositae	LF																	2.4							
Commecarpus sinuatus	Nyctaginaceae	LF										0.3														
Commefora sp		LF		0.4																						
Hibiscus micranthus	Malvaceae	FR																				2.8				
		LF										2.9														
Lantana camara	Verbenaceae	FR										1.6														
		LF										0.5														
Legumenosa sp	Leguminosae	FR								22.5																
Pulicaria crispa	Compositae	FL								0.2																
Argemone mixicana	Papavoraceae	RT		0.2		0.2		1.0										0.9		1.6		2.1		0.8		
Blepharis ciliaris	Acanthaceae	UN		0.2																						
Animals																										
Unidentified insects				1.1																						

a H and D show Alhada and Dam Site, respectively.
b BK, FL, FR, LF, SD, ST, RT and GM show bark, flower, fruit, leaves, seed, stem, root and gum, respectively.
c UN shows unidentified part.

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Arabic abstract:

العلاقة بين التغذية البشرية واختيارات التغذية الطبيعية لمجموعتين من قرود بابون الهامادرياس المستأنس "بابيوهامدرياس" (الثدييات: الرئيسيات: سيركوبيثيسيدا) في المملكة العربية السعودية

أحمد البوق، محمد ظفر الاسلام، توشيتاكا أواموتو، أكيو موري، أكهيروا ياماني، ايمي سشرير

المستخلص

يعد بابون الهامادرياس النوع الوحيد من الرئيسيات المستوطن في المملكة العربية السعودية وشبه الجزيرة العربية، ومن المعروف أن قرود بابون الهامادرياس المستأنس تعتمد في تغذيتها على ما يقدمه الناس إضافة للنباتات الطبيعية. فقد اختبرنا العلاقة بين التغذية البشرية المقدمة للقرود وبين تغذيتها من النباتات الطبيعية في مجموعتين من البابون المستأنس في بيئات مختلفة في المملكة العربية السعودية. منطقة الهدا تحتوي على تنوع نباتي أكبر، من منطقة الردّف " قرب السد " والتي تأثرت كثيراً بالرعي الجائر. تغذية القرود تشمل اعتمادها على التغذية البشرية وبعكس ذلك حسب حالة الغطاء النباتي الطبيعي.

وفرة الغذاء الطبيعي يتبع هطول الامطار في المنطقتين مما يقلل الاعتماد على الغذاء البشري. في المنطقة الأغنى تنوعاً نباتياً يرتبط هطول الأمطار معنوياً بالتنوع الغذائي الطبيعي والوقت المقضي للتغذية الطبيعية. وكلا المجموعتين تقضيان وقتاً أطول في التغذية خلال التغذية البشرية العالية. ويقل الاعتماد حينها على التغذية الطبيعية. البابون يتغذى طبيعياً على مدار العام بغض النظر عن تقديم الأغذية البشرية. ونقترح أن حاجة القرود للمحافظة على التوازن الغذائي جعلته لا يعتمد كلياً على الغذاء البشري. وأن حماية الغطاء النباتي من شأنه أن يجعل المجموعات المستأنسة من القرود تقضي وقتاً أطول في التغذية الطبيعية مما يقلل مشاكل التداخل بين البشر والحياة الفطرية

مفاتيح الكلمات: البابون، الاستئناس، استراتيجية التغذية، التغذية الطبيعية، بابون الهامادرياس، المملكة العربية السعودية، التداخل بين الناس والحياة الفطرية

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Author Contribution: Primary data on baboons was collected by Boug, Iwamoto, Mori, and Yamane, while Islam collected secondary data used for analysis and updated the paper. All authors did analysis except Schreier, who reviewed/edited the article and added a few important references.

ISSN 0974-7907 (Online); ISSN 0974-7893 (Print)

October 2017 | Vol. 9 | No. 10 | Pages: 10741–10864
Date of Publication: 26 October 2017 (Online & Print)
DOI: 10.11609/jott.2017.9.10.10741-10864
www.threatenedtaxa.org