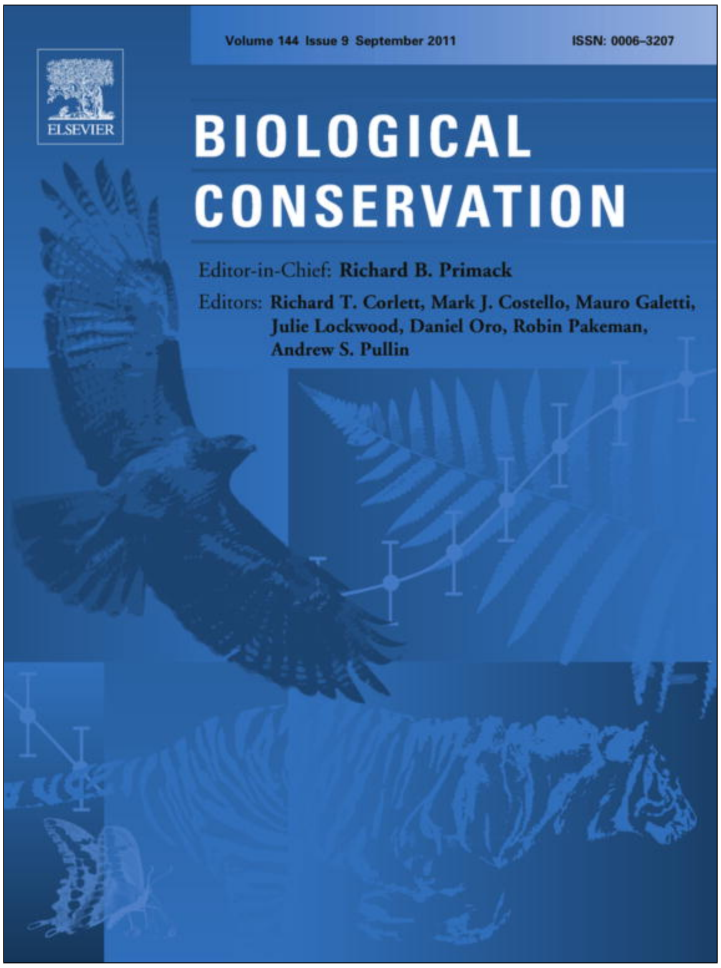
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Impacts of tourism on anxiety and physiological stress levels in wild male Barbary macaques

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ABSTRACT

Wildlife tourism is a burgeoning global industry with the potential to make a significant contribution to the conservation of endangered species. However, a number of studies have provided evidence that tourists' presence and behaviour may impact negatively on the animals involved, with potentially harmful consequences for their health, reproduction and population viability. Here, we investigate impacts of tourism on wild male Barbary macaques (*Macaca sylvanus*) in Morocco, quantifying a behavioural index of animals' anxiety (self-scratching) and a measure of their physiological stress levels (faecal glucocorticoid concentrations – FGCs). Four measures of tourist presence, number or proximity were explored: maximum number, percentage of time present, mean number while present, and closest proximity to the macaques. In addition, rates of three types of interactions between tourists and macaques – neutral (e.g. photographing), feeding and aggressive – were quantified. Males' rates of self-scratching were positively related to the mean number of tourists present and to rates of all three human-macaque interactions, but were unrelated to the other three measures of tourist pressure. FGCs were positively related to rates of aggressive interactions between humans and macaques, but unrelated to any of the other six measures of tourist pressure. These findings suggest that while tourist presence and interactions (even apparently innocuous ones) with the macaques elevate the study animals' anxiety levels, only aggressive interactions are sufficient to elicit a detectable increase in our measure of physiological stress. These results can be used to inform management of tourism both at this site, and at other locations where tourists view and can interact with wild primates.

1. Introduction

Wildlife tourism is a large – and rapidly growing – industry, and one that has the potential to make a very significant contribution to the conservation of biodiversity (Newsome et al., 2005; Fennell, 2008). However, concerns remain about the possible impacts of tourists on the animals that they have come to see (Rodger and Calver, 2005). Until quite recently, such impacts were typically explored in terms of behavioural changes brought about by the presence or behaviour of tourists. For example, Asian rhinoceros (*Rhinoceros unicornis*) showed increased vigilance time and decreased feeding when tourists were present (Lott and McCoy, 1995), and black howler monkeys (*Alouatta pigra*) exposed to tourists tended to move higher into the canopy (Treves and Brandon, 2005). Changes in animals' behaviour linked to interactions between tourists and animals have also been explored. Mann and Smuts (1999), for example, found that tourists' interactions with dolphins can change the latter's foraging behaviour and also reduce levels of maternal care. While such studies have been valuable in highlighting how tourism can change patterns of behaviour, determining whether such changes are detrimental has proved difficult; for this, more direct measures are needed.

The development of non-invasive techniques for quantification of levels of stress hormones has recently allowed researchers to investigate how exposure to tourism may impact on the physiological stress levels of wild animals (Busch and Hayward, 2009). Assessment of faecal glucocorticoid concentrations (FGCs) is particularly useful in this respect as faecal samples are easy to collect with minimal disturbance to the animal, and there is evidence that FGCs reliably reflect free cortisol levels in blood (Sheriff et al., 2010). Barja et al. (2007) found that FGCs among European pine

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martens (*Martes martes*) were positively related to the number of tourists in the area. Working with black howler monkeys (*A. pigra*), Behie et al. (2010) found that groups exposed to tourism showed higher FGC levels than groups not visited by tourists. As elevated stress levels due to tourism can impact negatively on animal health, reproductive success and survival (Romero and Wikelski, 2001; Ellenberg et al., 2007; French et al., 2010), and thus have consequences at the population level (Charbonnel et al., 2008), such effects are of clear conservation concern. Further studies of wildlife tourism impacts on stress, and in particular studies identifying causal factors in this relationship, are therefore necessary (Busch and Hayward, 2009).

While studies quantifying stress hormone levels have provided insights into the impacts of wildlife tourism, such approaches do not allow identification of factors that impact negatively on animals, but that are not in themselves sufficient to elicit a glucocorticoid output in response to the potential stressor. A powerful tool to explore impacts of this kind is the quantification of variation in rates of self-directed behaviours (SDBs), such as self-scratching. There is strong evidence that such behaviours provide an index of anxiety (Maestripieri et al., 1992). In pharmacological studies, SDBs have been found to increase among long tailed macaques (*Macaca fascicularis*) given drugs that have anxiogenic effects in humans, and to decrease when anxiolytic drugs are given (Schino et al., 1996). Behavioural studies lend further support to the idea that SDBs reflect anxiety: expression of SDBs is elevated in situations assumed to be anxiety-inducing, such as after aggression (e.g. domestic goats, *Capra hircus*: Schino, 1998) or when in close proximity to a dominant conspecific (e.g. olive baboons, *Papio hamadryas anubis*: Castles et al., 1999).

In recent years, there has been growing concern about how conservation practice may impact on animals at the emotional, as well as at the physical level (Bekoff, 2007, 2008). To our knowledge, however, there are no published studies investigating wildlife tourism impacts on both anxiety and physiological stress levels of wild animals. We aimed to investigate such impacts among male Barbary macaques (*Macaca sylvanus*) in Ifrane National Park, Middle Atlas Mountains, Morocco. Barbary macaques are the only non-human primate living wild in North Africa, being found in mountainous regions within the cedar and oak forest ecosystem of Morocco and Algeria (Ménard and Vallet, 1997; Mouna and Camperio Ciani, 2006). In 2008, the species was classified for the first time as endangered by IUCN (Butynski et al., 2008). Recent studies show that the wild population of Barbary macaques has dramatically declined since the 1980s, with fewer than 10,000 individuals now thought to remain; the Middle Atlas Mountains are home to the largest remaining populations of this species but even here numbers are in decline (van Lavieren and Wich, 2010; Mouna and Camperio Ciani, 2006). Primate viewing tourism in Morocco is a relatively recent phenomenon, and its impact on the animals involved has not previously been investigated. As interest grows in developing the tourism potential of Barbary macaques as a tool for the conservation of this endangered species (Mouna and Camperio Ciani, 2006), studies investigating such effects are urgently needed.

2. Materials and methods

2.1. Study site and animals

The project was conducted at a site in Ifrane National Park in the Middle Atlas Mountains, Morocco (33°25′N; 005°10′W) where a group of Barbary macaques has been habituated to regular tourist presence for approximately 5 years. At the time of data collection, this group was composed of 51 individuals: 12 adult males, 12 adult females, 1 sub-adult male, 1 sub-adult female, 14 juveniles, 4 one-year-old infants and 7 newborn infants. The study group falls within the normal species range documented by Ménard (2003) for both group size (13–88 individuals) and adult sex ratio (0.6–1.6). Data were collected on 11 adult males and the sub-adult male; one adult male was excluded from data collection because he was observed to be peripheral to the group.

2.2. Tourism at the study site

The study group come everyday to a tourist site located approximately in the centre of their home range. At this site, there is an area of forest of about 150 m^2 where there are stalls selling fossils of ammonites and trilobites, and also picnic tables and car parking spaces. Tourists at the site are very variable – in both nature and number – between and within days, but can be classified into two main types. The most common tourism in this area is “quick look tourism”, in which Moroccan or foreign tourists, typically on the way to the Sahara desert or to the city of Fez, stop briefly to see, feed or photograph the monkeys. These tourists vary from solitary individuals to coach tour groups of over 100 people. The second type of tourism is linked with the picnic area. Moroccan families spend much of the day enjoying a meal here; generally, these tourists are locals from the surrounding towns (Azrou and Ifrane) and they most commonly come to the site during the weekend.

2.3. Data collection

The study was carried out from 21st February to 11th May 2010 with a total of 47 days of data collection, during which the group was monitored for approximately 9 h per day. Focal behavioural observation and scan sampling techniques were used (Altmann, 1974). Scan and focal samples were alternated throughout each day, with data collection starting at approximately 7:30 am and continuing until approximately 5:30 pm. Focal samples lasting 10 min were used to quantify macaques’ rates of self-scratching (the measure of SDB most commonly used by researchers; Aureli, 1997; Carder and Semple, 2008), the rate of occurrence of human-macaque interactions and closest proximity of tourists to the macaques. Scan samples were used to quantify tourist presence, number and proximity; these samples were carried out between successive focal samples. Two focal samples were recorded for each male per day, one in the morning and one in the afternoon. The order of focal samples across males within each time block (morning/afternoon) was randomised.

All focal data were collected using a Psion WorkAbout handheld computer loaded with Observer software (version 5.0). At the beginning, middle and end of the 10 min focal watch, the closest proximity of the nearest tourist to the focal animal was recorded. Self-scratching and human-macaque interactions were recorded as events; two events were distinguished when they were separated by at least 10 s. Human-macaque interactions were separated into three categories: neutral, feeding and aggressive interactions. Neutral interactions were those in which tourists made no attempt to interact directly with the macaques, namely where tourists talked to, waved at or photographed them. Feeding interactions were scored when tourists gave food items by hand or threw such items towards the macaques. Aggressive interactions were those in which tourists pretended to throw – or actually threw – non-food items towards the macaques, or where they physically struck or pushed them. Rates of self-scratching and human-macaque interactions were averaged for each study animal across morning and afternoon focal sessions, to give a mean rate for each male for each day. Closest proximity data (i.e. those recorded at 0, 5 and 10 min) were averaged for each focal watch and the values for am and pm then averaged to give a mean closest proximity for each male for each day.

Data from the group scans were used to quantify three measures of tourist presence and number for each day: (i) 'maximum tourist number' – the highest number of tourists within a 100 m radius of a point judged to be at the centre of the study group; for ease, the number of tourists for each scan sample was recorded using 6 categories (0, 1–5, 6–10, 11–25, 26–50, 51–100 and 101–150 tourists) and the upper end of the range of each category was used as the measure of tourist number for analysis; (ii) '% time present' – the percentage of the scans in which tourists were present within 100 m around the study group (iii) 'average number of tourists present' – the mean tourist number recorded during group scans through the day when at least one tourist was present (i.e. this is not the mean number over the entire day but rather the mean number while tourists were present); again, for each scan, the upper end of the range of each category was used as the measure of tourist number. While 'maximum tourist number' is used to explore possible impacts of the highest number of tourists present at the same time at the site, 'average number of tourists present' is used to look at the possible impacts of a high mean tourist number relative to their time present at the site.

Preliminary analyses indicated that with one exception (the rates of agonistic and neutral interactions) all seven measures of 'tourist pressure' – the four measures of tourist presence/number/proximity, and rates of the three types of interactions – were correlated with each other. However, we decided not to reduce the number of these variables, for example by collapsing them using principal components analysis approaches, as we were keen to explore each measure of tourist pressure separately.

2.4. Faecal sample collection and hormone analysis

We analysed 157 faecal samples (mean = 13.08 per male; range = 10–17). Samples were collected opportunistically, but to ensure that samples for all individuals were spread across the study period we aimed to collect at least one sample per male per week. For all but two males, we were successful in doing so; for one of these males, we failed to collect a sample in two of the weeks of the study; for the other no sample was collected in three of the study weeks. Evidence from a range of primate species indicates that there is no circadian variation in FGCs (Huck et al., 2005; Ostner et al., 2008; Setchell et al., 2008); consequently, in order to maximise the number of faecal samples, samples were collected over the whole study day. Following Hodges and Heistermann (2003), samples from individuals seen defecating were collected into individual tubes (Azlon 30 ml HDPE; cat. BWH0030PN) which were placed in a freezer bag with ice packs in the field before transfer to a −20 °C freezer at the end of each day. Frozen samples were transferred to the Roehampton University hormone laboratory for analysis.

Each sample was freeze-dried and ground to a fine powder before 0.05–0.1 g were extracted in 3 ml of 80% methanol. After vortexing for 10 min, and centrifugation for 20 min at 4500 rpm, the supernatant was separated for analysis. Extraction efficiency, determined by the recovery of tritiated oestradiol added to the samples before extraction (Möhle et al., 2005), was 85.1 ± 5.2% and was thus similar to extraction efficiencies reported in other studies (e.g. Heistermann et al., 1993; Carosi et al., 1999). We analysed faecal extracts for concentrations of cortisol metabolites using a group-specific enzyme immunoassay (EIA) for the measurement of 11β-hydroxyetiocholanolone (Ganswindt et al., 2003) previously validated for monitoring glucocorticoid output in various primate species including Barbary macaques (Heistermann et al., 2006). Assay procedures followed those described in detail by Heistermann et al. (2004). The sensitivity of the assay at 90% binding was 0.6 pg/well. Intra-assay coefficients of variation, calculated from repeated measures of high and low concentration quality controls, were 7.31% (High) and 8.26% (Low); inter-assay coefficients of variation were 8.37% (High) and 11.00% (Low). Thus, values of assay precision were well within the ranges reported in other studies (e.g. Heistermann et al., 1993; Carosi et al., 1999).

Given an excretion lag for cortisol metabolites into faeces of Barbary macaque of 46 h (Heistermann et al., 2006), FGC concentrations were matched with the behavioural and tourism data from 2 days preceding the faecal sample collection.

2.5. Data analysis

Analyses of the relationships between self-scratching/FGC and measures of tourist pressure were carried out using PASW software v.18. Preliminary analyses indicated that all seven independent variables were non-normally distributed and could not be satisfactorily transformed to meet the assumptions of parametric statistics. As a result, it was not possible to use generalised linear models or other parametric approaches. Analyses thus followed methods described in Carder and Semple (2008); these two-stage methods allow non-normally distributed data to be analysed while taking account of the multiple observations per study individual.

Briefly, for each male we used Spearman's correlations to determine the relationships between self-scratching/FGC and the different measures of tourist pressure. Each pair of variables considered (e.g. self-scratching vs maximum tourist number) thus yielded twelve correlation coefficients – one for each male. The mean of these twelve correlation coefficients was then compared to a value of 0 in a one sample *t*-test, in order to determine if the pattern of relationships between the two variables was significantly consistent across the males. Thus, for example, a positive *t*-statistic and significant *p*-value in the one sample *t*-test indicates the two variables in question are significantly positively related across the study animals.

Results of the *t*-tests indicated that scratching rates were significantly positively related to rates of each of the three types of interactions with tourists; as rates of neutral and feeding interactions, and rates of feeding and aggressive interactions were also correlated, we carried out further analyses in order to test whether each interaction type was independently affecting scratching rates. The lack of normality in the data meant that it was not possible to use multivariate modelling or partial correlations to determine the effect of one variable on another while controlling for the third. In an attempt to tease apart the effects of the different types of interaction, we therefore explored the possibility of repeating the analyses described above, but using data from those focal samples where only one of the three types of interaction occurred (or none did). However, this reduced dataset did not yield a sufficient number of focal samples per male for the Spearman's correlations to be carried out. To overcome this problem, therefore, we converted data on the number of each interaction type in each focal sample to a binary variable (present/absent) to allow calculation, for each male, of a mean rate of scratching during focal samples with (i) no interactions (ii) only neutral interaction(s), (iii) only feeding interaction(s), (iv) only aggressive interaction(s). Wilcoxon signed ranks tests were then used to compare males' rates of scratching (i) between focal samples with no interactions and those with only neutral interactions, and (ii) between focal samples with no interactions and those with only feeding interactions. There were insufficient focal samples with only aggressive interactions for a similar analysis to be carried out for this type of interaction, but our main concern here was to test whether the associations between scratching and rates of neutral (and to a lesser extent feeding) interactions were an artefact of the association between these variables and rates of aggressive interactions.

All statistical tests were two tailed, with $\alpha = 0.05$.

3. Results

The mean number of tourists present over a day ranged from 0.3 to 54.6. Study animals were more frequently involved in feeding interactions with tourists (on average 5.5 events/h) than in neutral (2.4 events/h) or agonistic interactions (1.7 events/h). Assessed over the whole study period, mean FGC levels of males ranged from 512.4 to 964.0 ng/g dry faecal weight, and mean scratching rates ranged from 11.4 to 34.7 events/h.

3.1. Relationship between measures of tourist pressure and self-scratching rates

We found a strong positive association between rates of self-scratching and the mean number of tourists present during periods when tourists were at the site ($t_{11} = 4.326$; $P < 0.001$). Self-scratching rates were not significantly related to maximum tourist number ($t_{11} = -1.614$; $P = 0.135$), percentage time that tourists were present ($t_{11} = 1.472$; $P = 0.169$) or proximity of the nearest tourist group ($t_{11} = -0.0934$; $P = 0.370$). We found strong positive associations between rates of self-scratching and rates of neutral ($t_{11} = 5.136$; $P < 0.001$), feeding ($t_{11} = 7.223$; $P < 0.001$) and aggressive interactions ($t_{11} = 6.263$; $P < 0.001$). Compared to focal samples in which no tourist-macaque interactions occurred, rates of self-scratching were higher during focal samples when only neutral interactions occurred (Wilcoxon signed ranks test: $z = -2.353$; $N = 12$; $P = 0.019$) and when only feeding interactions occurred (Wilcoxon signed ranks test: $z = -2.275$; $N = 12$; $P = 0.023$).

3.2. Relationship between measures of tourist pressure and FGCs

FGCs were not significantly related to maximum tourist number ($t_{11} = 2.087$; $P = 0.061$), percentage time that tourists were present ($t_{11} = 0.043$; $P = 0.967$), mean number of tourists present during periods when tourists were at the site ($t_{11} = 1.347$; $P = 0.205$) or proximity of the nearest group ($t_{11} = -0.155$; $P = 0.879$). FGCs were positively related to the rate of aggressive interactions ($t_{11} = 2.396$; $P = 0.035$), but not significantly related to rates of neutral ($t_{11} = -0.054$; $P = 0.958$) or feeding interactions ($t_{11} = 1.929$; $P = 0.080$).

4. Discussion

We explored impacts of tourism on anxiety and physiological stress levels among wild adult male Barbary macaques in the Middle Atlas Mountains, Morocco. Our results indicate that different aspects of tourism affect the study animals in different ways: mean tourist number at the site, as well as the rates of occurrence of neutral, feeding and aggressive interactions with tourists were all positively associated with our measure of anxiety (rate of self-scratching). Only one tourism related factor – rates of aggressive interactions between tourists and macaques – was associated with a change in our measure of physiological stress (faecal glucocorticoid concentrations – FGCs). These findings indicate overall that tourism at this site may be having an impact on the animals at both an emotional and a physiological level.

To our knowledge, our findings represent the first to be published indicating a relationship between measures of tourism pressure and wild animals' rates of self-scratching, a widely used index of anxiety (Maestripieri et al., 1992). Quantifying behavioural measures of emotional state, as we have done here, will allow conservation biologists to assess tourism impacts in arguably a more direct way than is possible when using other commonly examined behavioural measures of impact, such as rates of social behaviour (de la Torre et al., 2000) or aggression (Ruesto et al., 2010). As issues regarding animals' emotional – as well as physical – welfare come increasingly to the fore in animal conservation projects (Bekoff, 2007, 2008; Linklater and Gedir, 2010; Pacquet and Darimont, 2010), such approaches are likely to become increasingly useful.

It is intriguing – and not easily explained – that males showed elevated self-scratching rates when the mean number of tourists surrounding the group was higher, but that no relationships were found between this measure of anxiety and maximum tourist number, tourist proximity or proportion of time tourists were present. Animals' coping or escape strategies may be important to consider here. While we did not collect data on this, we had the impression that monkeys generally climbed and rested up trees when very high numbers of tourists were present, when tourists were present at the site over greater durations of the day or when tourists came very close. Similar escape responses have been noted in black howler monkeys, which move higher up in the canopy as tourist numbers increase (Treves and Brandon, 2005).

Males also showed higher rates of self-scratching when there was an increase in the rates of any of the three types of human-macaque interaction. This suggests that all close interactions with tourists, even those such as being photographed that might seem apparently innocuous for the animals, are sufficient to elicit anxiety. Interactions between Barbary macaques and humans have previously been described and quantified in the introduced population in Gibraltar (O'Leary and Fa, 1993; Fuentes, 2006b) but the impact of such interactions on anxiety has not previously been analysed. For aggressive interactions, a causal link with anxiety is easy to envisage – the threat or actual occurrence of aggression leads to animals becoming more anxious. With respect to feeding interactions, elevated anxiety levels may be due to the fact that the macaques are brought into very close proximity both to the people offering food, and also to conspecifics competing to access it; direct competition with conspecifics may also occur over the food items available.

Explanations for the observed positive relationship between levels of anxiety and rates of interactions that we classified as neutral (those where tourists talked to, waved at or photographed the animals) are less obvious, but studies of reptile and birds suggest that specific noises linked to tourism, or general noise levels of tourist groups may have negative impacts on animals. Evidence has been found, for example, that the sound of a camera shutter induces fear related responses in a lizard species, the crested anole (*Anolis cristatellus* – Huang et al., 2011). A study of an Amazonian bird species, the hoatzin (*Opisthocomus hoazins*) indicates that the sound of human conversation may induce fear related behaviour, and that louder conversations lead to greater agitation (Karp and Root, 2009). These two species are of course very different from the one studied here, but tourist noise levels can be very high at the study site (L. Marechal, pers. obs.) and it is certainly possible that the loud conversations, shouting and screaming that can accompany neutral interactions may cause anxiety to the macaques.

Our index of physiological stress levels was related to only one aspect of tourism, with FGCs being positively associated with rates of aggressive interactions between macaques and tourists. This suggests that while other components of tourist pressure may induce anxiety, only when overt aggression with tourists occurs do monkeys apparently show a strong physiological stress response, i.e. a significant increase in glucocorticoid output. This is not to imply that the other, milder stressors, do not induce increased adrenocortical activity and release of cortisol, but this may not be of sufficient magnitude to be seen in our integrative FGC measure. An alternative, but not mutually exclusive, explanation is that the mild stressors associated with increases in SDBs (but not FGCs) are more associated with activation of the adrenal medulla rather than the adrenal cortex and may therefore be linked to the secretion of catecholamines rather than glucocorticoids (see Higham et al., 2009). With respect to cortisol, it is important to note, however, that it is sustained raised levels, which our methods should detect, that can impact negatively on animals' health, survival and reproduction (Busch and Hayward, 2009).

The present study is, to our knowledge, the first to investigate the impact of tourist-macaque interactions on physiological stress levels. Such interactions are extremely common at sites where macaque species are the focus of wildlife tourism activities (e.g. Fuentes and Gamerl, 2005; Fuentes, 2006b; Hsu et al., 2009; McCarthy et al., 2009). Previously, concerns have been raised about the disease risk to the animals of these close contacts with tourists (Fuentes, 2006a); such risks may be even greater if interactions also elevate stress levels, as it is well established that stress hormones can suppress the immune system and increase susceptibility to disease (e.g. Cohen and Crnic, 1983; Munck et al., 1984). Moreover, the negative effects of stress on reproductive function (Wingfield and Sapolsky, 2003; Cyr and Romero, 2007; Ellenberg et al., 2007) and survival (Romero and Wikelski, 2001; Pride, 2005) among vertebrates are well documented. Evidence for tourist-induced increases in physiological stress levels among our study animals is therefore of great concern, as tourism begins to be developed as a tool for the conservation of Barbary macaques in the wild.

Studies of this kind can inform planning for effective and sustainable management of wildlife tourism, both at this site and at the many other locations where tourists view and can interact with wild primates. At the site of the present study, several recommendations can be made to mitigate negative tourism effects on the macaques. Firstly, our findings indicate that measures that minimise or eliminate the occurrence of aggressive tourist-macaque interactions will reduce the emotional and physiological impacts on the animals. Such measures should also reduce the risk of physical injury of either party (Fa, 1992), and associated risks of zoonotic disease transmission (Honess et al., 2006). In addition, our data suggest that eliminating feeding of the macaques by tourists will reduce the animals' anxiety levels; this would have further benefit in reducing the risks of obesity and diet-related health problems documented at other macaque tourist sites (e.g. Fa, 1984; Lane et al., 2010). Finally, potential measures to mitigate the impacts of average tourist numbers and neutral interactions on macaques' anxiety levels should be considered. As the numbers of tourists cannot easily be restricted at this public site, and interactions such as photography form an integral part of the tourist experience, a workable solution may be to suggest maintenance of a minimum tourist-macaque distance, and that tourist noise levels be kept low. Systematic evaluation using the type of approaches employed here will enable the efficacy of such measures to be assessed.

These types of recommendation are likely to be broadly applicable to the many other sites around the world where relatively unregulated primate tourism currently occurs (e.g. Fuentes and Gamerl, 2005; Cunha, 2010). Importantly, our finding that apparently innocuous, non-contact interactions with tourists may impact on our study animals suggests that even where careful regulation of tourist numbers and prohibition of direct contact and/or feeding occur, it may still be advisable to explore possible low-level impacts of tourist presence or behaviour. Data on such effects can form an important part of the cost-benefit analyses that should be central to the planning and running of primate tourism projects (Macfie and Williamson, 2010).

Overall, our study contributes to an understanding of the effects of wildlife tourism on the animals involved. The results of this research highlight the value of exploring multiple components of tourism pressure when considering the consequences of wildlife tourism for the animals concerned, and also the benefit of quantifying different measures of such impacts. Tourism in Morocco has the potential to contribute to Barbary macaque conservation through a number of routes, including revenue generation for multiple stake holders (e.g. site managers, guides and local communities), education, and improved protection and monitoring of macaque populations and their habitat. Careful consideration of the effects of tourism, and how these may be mitigated, will ensure these benefits are realised while minimising or eliminating the negative impacts on the animals involved.

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