A GLOBAL ASSESSMENT OF MACAQUE-HUMAN INTERACTIONS

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Abstract- This literature review provides a contemporary and comprehensive global assessment of human interaction with the most widely distributed genus of non-human primate (NHP), the macaque (Genus: Macaca), with a focus on macaque-human interactions, societal perceptions of macaques and the management of the macaque-human interface. Rates of macaque-human interaction are high, but vary substantially between geographical locations, with the highest reported rates of interaction occurring in Gibraltar. Aggressive macaque-human interaction receives particular attention and is found to correlate with several factors, especially important being the recorded increase in rates of aggressive interaction in the presence of food triggers. The enforcement of a feeding ban at locations where macaques interact with humans is therefore essential to reduce rates of aggressive macaque-human interaction. Other management strategies used vary between locations, but few techniques are effective at excluding macaques permanently on a large scale, except for lethal control and long-distance translocation, both with severe limitations. A suite of techniques therefore needs to be employed to manage macaque-human interaction in order to minimise human-macaque conflict, which is shown to be of societal importance and to pose a conservation threat for macaques, especially when concurrent with primary threats, such as habitat loss or human harvesting. Societal perceptions of macaques matter because they shape choice of management strategies, but even positive local perceptions may be undermined by repeat interactions involving personal loss or damage. Substantial data absences exist in the global literature; the standard collection of basic interaction data is recommended for all studies working with macaque-human interaction and a list of data to report is suggested. Six key locations for further research are identified: Morocco and Algeria, Taiwan, South-eastern Tibet (North-east India and South-west China), Vietnam, Peninsular Malaysia, and Myanmar (Burma).

Index Terms- Human dimensions of wildlife management, macaque-human interaction, primate populations, societal perceptions of macaques

I. INTRODUCTION

Macaques (genus Macaca) are the most widely distributed genus of non-human primate (NHP) and, as highly adaptable, highly opportunistic omnivores (Fooden, 1995), often live in close proximity to human communities. Proximity to human communities and interaction around potential macaque food sources results in an exceptionally high rate of primate-human interaction for macaques (Hsu et al., 2009). With close proximity to, and high rates of interaction with, humans, by macaques, it therefore comes as little surprise that at many sites around the world there are high rates of macaque-human conflict, which may take the form of individual interactions (such as macaque-human bites, or other aggressive interactions) or wider landscape level competition or conflict (for example crop raiding). Incidents of macaque-human conflict have been well documented in locations where macaques and humans overlap (Wheatley and Harya Putra, 1994; Malik and Johnson, 1994; Srivastava, 1999; Stephenson et al., 2002; Hsu et al., 2009), but ‘to date, there has been very little quantitative study of human-macaque interactions from across these locales’ (Fuentes, 2006a: 170). While geographical coverage has been poor, those quantitative studies which have been conducted have been inconsistent in their methodological approach (Fuentes, 2006b), limiting valuable analysis of trends between locations.

This literature review aims to draw together the research on macaque-human interactions which has been conducted to date, in order to provide a global assessment of macaque-human interactions and suggest directions for future research in the field. This is important because human-macaque conflict has societal implications (Southwick et al., 2005; Chalise and Johnson, 2005) and is of conservation concern (Forthman et al., 2005). Macaque-human conflict can be seen as a conservation concern because it effects societal perceptions of macaques (Southwick and Siddiqi, 1984), which in turn shapes societal preference for management strategies, for example, leading to support for eradication even where previously favourable attitudes towards primates occurred (Srivastava and Begum, 2005). In order to address the consequences of macaque-human interaction, this literature review therefore considers the research that has been conducted to date on societal perceptions of macaques and macaque management strategies, and how this relates to the rate and nature of macaque-human interaction.

II. MACAQUE-HUMAN INTERACTIONS

A. Rates of Interaction

There is an absence of quantitative data on macaque-human interactions across many of the locations where macaques occur (Fuentes, 2006a). An
assessment of the reported rates of human-macaque interaction (Table I) suggests rates of interaction in Gibraltar are substantially higher than in other geographical locations, although exact calculations there wildly vary; O’Leary and Fa (1993) report 99.6 interactions per hour, while Fuentes (2006a) reports 30.6 interactions per hour, which Fuentes accounts for as due to changes in the population structure of the Barbary macaques of Gibraltar, an increase in the number of tourists in the time period and the fact that multiple interaction sites occur where these tourists might interact with macaques (Fuentes, 2006a). The rate of interaction was particularly low in Singapore, while rates of aggressive interaction were low in Hong Kong and Singapore. Although rates of interaction at Shou-Shan Nature Park, in Taiwan, do not appear to be especially notable, the spatial pattern of interactions perhaps is as Hsu et al. (2009) note that, perhaps uniquely, macaques in Shou-Shan Nature Park, do not venture out into urban areas, suggesting that rates of macaque-human interaction outside of the nature park would be very different to other locations where they do (Kathmandu, Nepal – Southwick et al., 1991; India – Srivastava and Begum, 2005; Gibraltar – Fuentes, 2006b).

<table>
<thead>
<tr>
<th>Study</th>
<th>Site</th>
<th>Rate of interactions per hour</th>
<th>Rate of aggressive interactions per hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sha et al. (2009)</td>
<td>Bukit Timah Nature Reserve and Central Catchment Nature Reserve, Singapore</td>
<td>2.03</td>
<td>0.39</td>
</tr>
<tr>
<td>Fuentes et al. (2008)</td>
<td>Shou-Shan Nature Park, Taiwan</td>
<td>12.7</td>
<td></td>
</tr>
<tr>
<td>Hsu et al. (2009)</td>
<td>Shou-Shan Nature Park, Taiwan</td>
<td>11.9 (Weekends)</td>
<td></td>
</tr>
<tr>
<td>Hsu et al. (2009)</td>
<td>Shou-Shan Nature Park, Taiwan</td>
<td>8.4 (Weekdays)</td>
<td></td>
</tr>
<tr>
<td>Fellowes (1992)</td>
<td>Hong Kong, Bali, Indonesia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuentes (2006a)</td>
<td>Singapore</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southwick et al. (1976)</td>
<td>India</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southwick et al. (1976)</td>
<td>India</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O’Leary and Fa (1993)</td>
<td>Gibraltar</td>
<td>99.6</td>
<td></td>
</tr>
<tr>
<td>Fuentes (2006a)</td>
<td>Gibraltar</td>
<td>30.6</td>
<td></td>
</tr>
<tr>
<td>Fuentes (2006a)</td>
<td>Apes Den, Gibraltar</td>
<td>34.8</td>
<td></td>
</tr>
<tr>
<td>Fuentes (2006a)</td>
<td>Anglian Way/St, Michael’s, Gibraltar</td>
<td>20.4</td>
<td></td>
</tr>
<tr>
<td>Fuentes (2006a)</td>
<td>Cable Car, Gibraltar</td>
<td>7.8</td>
<td></td>
</tr>
<tr>
<td>Fuentes (2006a)</td>
<td>Prince Philip’s Arch, Gibraltar</td>
<td>66.0</td>
<td></td>
</tr>
</tbody>
</table>

Table I. Studies Which Have Calculated Rate of Macaque-Human Interactions

As rates of interaction have been shown to vary between locations (Table I), which has consequences for local management policy, there is a need to expand geographical coverage of the study of macaque-human interactions, rather than rely on previous work conducted at other locations.

There is also the need for more extensive data reporting; some studies only reported rate of aggressive interactions per hour, while others only reported raw interaction rate per hour, both approaches being limiting to further analysis. Furthermore, variability in methodological approaches from one study to another limits spatial analysis and means ‘certain direct comparisons are not possible’ (Fuentes, 2006a: 179). The work of Sha et al. (2009), in Singapore, was particularly valuable in this as it provided an assessment of human-macaque conflict concerning both visitors and residents in Singapore, while providing a comprehensive data reporting effort, including, for instance, both rate of interactions per hour and rate of aggressive interactions per hour.

Little research has, however, been done with an inter-state perspective and with a consistent methodology. It is therefore difficult to objectively compare rates of macaque-human interactions in different global locations; for example, one study might report total bites observed while another reports rate of aggressive interaction per hour, which gives little context to the results it is possible to draw from considering one site in isolation. Adoption of a standardised methodology, or standard data to collect and report, would allow more extensive analysis between different global locations.

B. Causes of Interaction

Studies working in different locations and with different macaque species have consistently shown that food triggers increase the likelihood for macaque-human aggression and conflict, as they increase the frequency and duration of aggression in Rhesus macaques, *Macaca mulatta* (Southwick et al., 1976), Formosan macaques, *Macaca cyclopis* (Hsu et al., 2009), Long-tailed macaques, *Macaca fascicularis* (Wheatley, 1999), Barbary macaques,
Macaca sylvanus (Fa, 1992), and Japanese macaques, Macaca fuscata, (Saito, 1996). Saito (1996) recorded that aggression was 36 times more likely to occur in areas with food provisioning, than areas without. This is of particular concern as numerous studies have found food to be a major factor in macaque-human interactions in locations where high levels of interaction occur (Fellowes, 1992; Pirta et al., 1997; Zhao, 2005; Sha et al., 2009; Hsu et al., 2009). Food provisioning occurs in different contexts between locations. In Gibraltar macaques are formally provisioned by the Gibraltar Ornithological & Natural History Society (GONHS), which provides the majority of the macaques’ daily consumption (Fuentes, 2006b), while in other locations, including Japan (Watanabe and Muroyama, 2005) and Indonesia (Fuentes, 2006b), monkey parks or monkey forests exist where macaques are provisioned on a regular basis. In such examples, provisioning is legal and regulated by a management authority (private or public) and some authors have even considered this as an appropriate management technique to reduce human-macaque conflict (Srivastava and Begum, 2005). This stands in contrast to sites where sporadic, and often illegal, provisioning of macaques by visitors occurs, as has been documented in numerous locations (Gibraltar – Fa, 1992; Mt Emei, China – Zhao, 2005; Japan – Watanabe and Muroyama, 2005; Singapore - Sha et al., 2009; Taiwan – Hsu et al., 2009).

Biting is the highest level of macaque-human aggression and therefore attracts substantial interest in the literature. Rates of biting also vary between locations and populations, with the rate of biting by Barbary macaques (Macaca sylvanus) in Gibraltar, at 2.1% of aggressive interactions (Fuentes, 2006b), substantially lower than by long-tailed macaques (Macaca fascicularis) in Bali, Indonesia, at 11.4% of aggressive interactions (Fuentes, 2006b). Fuentes (2006b) theorises that this might not be due to differences in interaction context alone, but rather ‘species specific differences’ (Fuentes, 2006b: 181) between Macaca sylvanus and Macaca fascicularis. The literature tends not to support this theory; Sha et al. (2009), who also worked with long-tailed macaques in Singapore, recorded no bites at all over an extensive data collection effort, suggesting that interaction context, rather than species specific differences, are more significant in determining bite rate. Sha et al. (2009) commented that bite rates in general appeared to be much lower in Singapore than had been published previously for Gibraltar (Fa, 1992; Fuentes, 2006b) or Bali (Fuentes and Gamerl, 2005; Fuentes, 2006b), but it is difficult to quantitatively compare locations because of the lack of a standardised methodology or data collection effort across studies and no known rate of detection (i.e. the probability that a given methodology will detect, or fail to detect, a bite in the study area).

Sha et al. (2009) consider that a thorough assessment of the ‘number of people and macaques interfacing and amount of area in which they interface’ (Sha et al., 2009: 837) would also be required to allow comparison of bite rates between locations. There is debate in the literature as to whether the number of humans, or number of macaques, actually influences macaque-human interactions. Hsu et al. (2009) claim that rates of macaque-human interaction were influenced by both the number of humans and the number of macaques, which is supported by Wheatley (1999) and O’Leary and Fa (1993), but Fuentes (2006a) found no evidence of any such relationship in Gibraltar, suggesting the reason for this being that the macaques there are fully acclimatised to human interaction. There is less evidence that human or macaque numbers affect either the rate of macaque-human aggression or bite rates. Fuentes (2006b), Ruesto et al. (2010) and Usui et al. (2014) ‘did not find a significant correlation between macaque aggression rate and tourist number’ (Usui et al., 2014: 555).

Adult male macaques are over-represented in interaction data in Gibraltar and Bali, Indonesia (Fuentes, 2006b), while Hsu et al. (2009) found that human males and adult male macaques were more likely to be involved in aggressive interactions in Taiwan and were more likely to respond to an aggressive interaction with counter-aggression.

C. Landscape Scale Interaction

In contrast to macaque-human interaction as individual interactions (such as bites), on a landscape scale macaque-human interaction can take many forms and may have societal importance (Southwick et al., 2005; Chalise and Johnson, 2005). At a landscape scale, macaque-human interaction can be understood as commensalism (one species benefits from macaque-human interaction, while the other neither benefits nor is disadvantaged), beneficial co-existence (both species benefit from macaque-human interaction), or conflict (one, or both, species are disadvantaged, to a varying degree, by macaque-human interaction).

Crop-raiding by macaques has attracted substantial interest (Chandrappa et al., 1993; Chakravarthy and Thyagaraj, 2005; Chalise and Johnson, 2005) and has been found to have led to human-macaque conflict (Sinha, 2001), while landscape changes driven by human activity impact the behaviour of macaque populations (Watanabe and Muroyama, 2005) and the pattern and nature of macaque-human interaction (Srivastava and Begum, 2005). Crop-raiding by macaques is most significant in terms of actual and perceived economic impact for individual farmers (Chalise and Johnson, 2005), its effect on societal perceptions of macaques (Malik and Johnson, 1994) and, therefore, in its implications for the management of human-macaque conflict (Srivastava and Begum, 2005).
III. IMPACT OF MACAQUE-HUMAN INTERACTION ON NON-HUMAN PRIMATES

Interaction and contact with humans is of salience for many macaque populations and may influence macaque social behaviour (Fuentes, 2006b), ecology (Fuentes, 2006b; Wenz-Muecke et al., 2013) and pathological health (Jones-Engel et al., 2001; Wenz-Muecke et al., 2013). This is most evident in the population of Barbary macaques in Gibraltar (Fa, 1984; O’Leary and Fa, 1993; Fa and Lind, 1996; Fuentes, 2006b), but the impact of human interaction can be seen to a lesser extent in other macaque populations worldwide (Maréchal et al., 2011; Wenz-Muecke et al., 2013).

Table 3. Societal perceptions of macaque management in Singapore, from Sha et al. (2009)

<table>
<thead>
<tr>
<th>Management Strategy</th>
<th>Response rate [Millions and Residents in Singapore]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exterminate macaques from Singapore</td>
<td>2.2%</td>
</tr>
<tr>
<td>Reduce macaque population</td>
<td>10.9%</td>
</tr>
<tr>
<td>Remove nuisance macaques</td>
<td>2.2%</td>
</tr>
<tr>
<td>Keep nuisance macaques away from urban areas</td>
<td>15.1%</td>
</tr>
<tr>
<td>Education on co-existence</td>
<td>63.6%</td>
</tr>
</tbody>
</table>

Many macaque populations benefit from interaction with humans, again most clearly illustrated by Gibraltar where food provisioning by humans forms a majority of the macaques’ diet, or in Bali, Indonesia, where Fuentes (2006b) calculates that about 70% of the diet of macaques comes from provisioning. Interaction and contact with humans can, however, also negatively affect macaque populations. The risk of zoonotic and reverse zoonotic disease transmission, between humans and macaques, has received extensive focus (Wallis and Lee, 1999; Jones-Engel et al., 2001; Jones-Engel et al., 2005; Engel et al., 2006; Jones-Engel et al., 2006). Study of the risk of reverse zoonotic disease transmission for macaques has focussed on the risk of transmission of respiratory pathogens and associated diseases, such as measles and influenza (Jones-Engel et al., 2001; Fuentes, 2006b; Fuentes et al., 2008), as well as specific outbreaks of reverse zoonotic diseases, such as the outbreak of pneumonia among the macaque population of Gibraltar in 1987 which killed all the infants from that year (O’Leary and Fa, 1993). Fuentes (2006b) illustrated this for a given location in terms of the risk of pathogen transmission between humans and Barbary macaques in Gibraltar, due to relatively high levels of contact between the species at the location, especially encouraged by some local tour guides and taxi drivers who encourage macaques to climb onto tourists’ shoulders and heads. Wenz-Muecke et al. (2013) illustrated how human contact influences both foraging behaviour and parasite communities in long-tailed macaques in Thailand. While reverse zoonotic diseases have a clearly understandable impact on macaques, zoonotic diseases may also be of consequence for macaque populations, because the risk of their transmission may lead to the culling of macaque populations as a disproportionate response by concerned authorities (Jones-Engel et al., 2006). There is also a growing body of evidence that close contact is not necessarily required for interaction with humans to impact individual macaques. Maréchal et al. (2011) demonstrated the impact of tourism on anxiety and physiological stress levels in wild male Barbary macaques in Morocco, while Vancatova (1991) claimed that a change in environmental conditions may affect macaque social structure, noting that aggressive behaviour increased in macaques which inhabited smaller areas, which could occur due to land conversion.

IV. SOCIETAL PERCEPTIONS OF MACAQUES

In a human-dominated world, societal perceptions of a species are significant for its long-term conservation. Nowhere is this more apparent than the Barbary macaque of Gibraltar, where the population, which was likely introduced by human actions, either intentional or accidental (Shaw and Cortes, 2006), is extensively managed by humans and receives the vast majority of its annual consumption from organised human provisioning by GONHS (Fuentes, 2006b). In contrast, Cortes and Shaw (2005) highlight how societal demand for drastic action led to the 2003 culling of a group of macaques in Gibraltar. The survival of the small Barbary macaque population of Gibraltar is, in this way, entirely dependent on societal perceptions of the macaques. The body of literature on societal perceptions of macaques is reasonably limited, with a major emphasis on how religion shapes the macaque-human interface, with specific focus on Bali, Indonesia (Wheatley and Harya Putra, 1994b; Wheatley, 1999; Peterson et al., 2015) and India (Richard et al., 1989; Southwick and Siddiqi, 1994), with other work published in Thailand (Aggimarangsee, 1992; Eudey, 1994), Japan (Knight, 1999) and China (Zhao, 1994). Societal perceptions of macaques have importance for macaque conservation and management. Srivastava and Begum (2005) document how changes in social perceptions of macaques, particularly in the context of repeated personal loss to macaques (Southwick and Siddiqi, 1984), can change local perceptions of management strategies for human-macaque conflict, even in the presence of religious norms or values that encourage favourable attitudes to macaques and discourage lethal control. The case for a more extensive focus on societal perceptions of macaques, in the context of the implications for macaque management and conservation, is clear. The work of Sha et al. (2009) considered societal
perceptions of macaque management by asking visitors and residents about a choice of management strategies. As shown in Table II, 63.6% of respondents in their survey favoured education on coexistence as a management strategy, an overwhelming majority.

Sha et al. (2009) also reported a low rate of aggressive macaque-human interaction for Singapore (0.39 aggressive interactions per hour), as displayed in Table 1, and whether that facilitates a societal preference for education on coexistence as a management strategy would be an interesting comparison with other locations, where rates of aggressive macaque-human interaction were higher, using the same methodology. It is possible to theorise that low rates of aggressive macaque-human interaction in Singapore contribute to a high demand for education on coexistence, as Sha et al. (2009) found that past experiences affected opinions on management strategies and therefore a low rate of aggressive macaque-human interaction would encourage a higher demand for education based strategies, whereas the demand for lethal control may well be higher in locations where higher rates of aggressive interaction occur, much as the demand for lethal control of primates increases where landscape scale human-macaque conflict occurs. Other studies have tended to comment generally on societal perceptions at a given study location, even if data collection on societal perceptions of macaques was not a major part of the study. For example, in the case of Gibraltar, the site with the highest rate of macaque-human interactions, Cortes and Shaw (2006) argue that many locals see macaques as pests and are actively calling for removal or culling of some of the population, although there has been little quantitative work on societal perceptions. Enari and Suzuki (2010) suggest that in northern Japan local residents consider macaques to be serious pests, while Wong and Ni (2000) reported that during their research (1992-1993) in Hong Kong, many individuals complained about the aggressiveness of the macaques and that Hong Kong’s population of macaques remained controversial. This seems to contrast with the reported rate of aggressive interactions per hour for Hong Kong, which at 0.26 (Fellowes, 1992) was particularly low compared to other study locations.

V. IMPLICATIONS OF HUMAN-MACAQUE CONFLICT FOR CONSERVATION OF SPECIES

Forthman et al. (2005) argued that direct conflict between humans and primates poses a threat to the long-term survival of different species of non-human primate. It is almost impossible to quantify the impact factor of human-macaque conflict as a conservation threat, relative to other threats such as habitat loss, because there are few documented examples where a macaque population faced extirpation or extinction due to human-macaque conflict and because many other conservation threats are also mediated through humans (Camperio Ciani and Mouna, 2006; Modolo, 2006).

Table IV. Studies Which Have Reported Macaque Management

<table>
<thead>
<tr>
<th>Study</th>
<th>Location</th>
<th>Macaques threatened as human disturbance?</th>
<th>Feeding ban enforced?</th>
<th>Management strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fauvet et al. (2000b)</td>
<td>Singapore</td>
<td>N</td>
<td>Y</td>
<td>Controversion program. Reduce feeding by encouraging the production of macaques.</td>
</tr>
<tr>
<td>Fauvet et al. (2000)</td>
<td>Singapore</td>
<td>N</td>
<td>Y</td>
<td>Controversion program. Reduce feeding by encouraging the production of macaques.</td>
</tr>
<tr>
<td>Uria et al. (2000)</td>
<td>Taiwan</td>
<td>N</td>
<td>N</td>
<td>Feeding ban, but not enforced</td>
</tr>
<tr>
<td>Fauvet et al. (2000a)</td>
<td>Gibraltar</td>
<td>Y</td>
<td>N</td>
<td>Feeding ban, but not enforced</td>
</tr>
<tr>
<td>Fauvet et al. (2000a)</td>
<td>Bali, Indonesia</td>
<td>Y</td>
<td>N</td>
<td>Feeding ban, but not enforced</td>
</tr>
<tr>
<td>Watanabe and McCann (2005)</td>
<td>Okinawa, Japan</td>
<td>Y</td>
<td>N</td>
<td>Feeding ban, but not enforced</td>
</tr>
</tbody>
</table>

Lee and Priston (2005) note that although the major conservation threats for primates, including macaques, are usually associated with habitat loss or human harvesting (for bushmeat or the biomedical trade), the impact of declines associated with those threats was more centred in areas where human-primates conflict occurred. Much of the best data on this comes from India, where Malik and Johnson (1991) estimated there was an 80% population decline in rhesus macaques over a 30 year period (1961-1991) due to extensive trapping associated with human harvesting, and Table III displays examples of studies from India where human-macaque conflict occurred in the context of other pressures and was associated with a conservation threat to a local macaque population.

Mouna and Camperio Ciani (2006) identify the impact of competition for resources, an indirect form of macaque-human conflict at a landscape scale, as a principal cause for the decline of wild populations of Barbary macaques in North Africa. The pace of this decline has been rapid and has included impact on the species’ stronghold of the mixed oak and cedar forest of the Middle Atlas mountains (Camperio Ciani and Mouna, 2006). Competition for resources, including water, and reduction in macaque food sources, in the Middle Atlas resulted from changes in human land-use patterns and poor management (Camperio Ciani and Mouna, 2006).
VI. MACAQUE MANAGEMENT

The management of the macaque-human interface varies substantially over time and space (Fuentes et al., 2008). One widely used approach in macaque management is the use of a feeding ban, designed to deter food provisioning by visitors and residents. While most locations where macaques exist in close proximity to human communities have feeding bans (Fuentes, 2006a; Fuentes, 2006b; Fuentes et al., 2008; Hsu et al., 2009), previously studies have found that only a few locations actively enforce feeding bans (Table IV) and studies consistently recommend enforcement of feeding bans as part of a management strategy (Cortes and Shaw, 2006; Hsu et al., 2009; Wenz-Muecke et al., 2013).

As food triggers were previously shown to increase the frequency and duration of aggression in macaques in macaque-human interactions (Southwick et al., 1976; Fa, 1992; Saito, 1996; Wheatley, 1999; Hsu et al., 2009), we would expect rates of macaque-human aggression where a feeding ban is enforced (Hong Kong and Singapore) to be lower than in locations without a feeding ban or where a feeding ban was not enforced. While data has only been collected for a few locations, the data which is available seems to support this theory (Figure 1).

It remains a challenge to manage macaque-human interaction, especially limiting interaction around a food context at both individual interaction (macaque-human aggression) and landscape level (crop-raiding; intrusion into urban areas) scales, because the high mobility and intelligence of macaques pose significant issues for management (Watanabe, 2000). Particular challenges arise at a landscape level, relative to crop-raiding (Chalise and Johnson, 2005; Watanabe and Muroyama, 2005; Southwick et al., 2005), as exclusion-based management techniques are either expensive when applied at a large scale (complete cover), or become ineffective when macaques learn to evade them or lose their fear of them (guard dogs, flares, sound recordings). Watanabe and Muroyama (2005) note that the effectiveness of management techniques changes over time and that most techniques are most effective when interaction first occurs, suggesting a combination of measures to create a holistic management strategy.

There are a range of other techniques to manage human-macaque conflict, both at an individual interaction and landscape level scale. Population control can be an important tool and includes contraceptive programs, as well as lethal control and translocation. Hong Kong introduced a regular contraception program following a sustained population increase of macaques in the Kowloon Hills (Wong and Ni, 2000; Fuentes et al., 2011).

Although the benefits of translocation of macaques, especially problem individuals, have been repeatedly stressed (Mohnot, 1978; Malik and Johnson, 1991; Iman, 1993; Malik and Johnson, 1994), translocation may only provide a temporary solution because macaques may simply return to human-populated areas. Furthermore, translocation is either not possible, or cannot provide a long-term solution, for certain geographical populations. For example, Sivastava and Begum (2005) highlight Guwahati, India, where rapid population growth has seen human populations encroach on traditional forest areas which, when coupled with severe deforestation, has created a situation where there is little suitable adjacent habitat for translocation. Questions about most effective resource use also surround translocation, as an often temporary solution, and it therefore may not be appropriate on a large scale in the majority of locations where macaques occur. Translocation may simply transfer the problem to the area of relocation (Southwick et al., 2005) and carries risks associated with the introduction of infectious diseases to new areas in the process (Caldecott and Kavanagh, 1983). For individual residents in areas where human-macaque conflict occurs, however, translocation remains popular, often despite biological limitations to its application. Sha et al. (2009) reported that residents favoured reducing the macaque population (21.5% of respondents supporting this approach) to eradicating it (0.8% respondents), and one way to reduce the local macaque population is through translocation. The authors note, however, that translocation in Singapore is limited due to habitat constraints (Sha et al., 2009).

Long-distance translocation offers a response to local habitat constraints as a limitation for translocation. Long-distance translocation reduces, or prevents, macaques returning to an area they are removed from, and can be used to support vulnerable populations (Malik and Johnson, 1991), thus avoiding many of the objections to reducing macaque populations through lethal control. Cortes and Shaw (2006) note that the option is favoured by the Gibraltar authorities, in terms of relocating groups of Barbary macaques from...
Gibraltar, where the population has been maintained at around 200 individuals by culling (Shaw and Cortes, 2006), to North Africa, where populations in Morocco and Algeria are considered vulnerable (Butynski et al., 2008). Modolo (2006) supports such an approach on the basis of increasing the gene flow between otherwise isolated populations and therefore preventing inbreeding depression, as well as directly increasing the numbers in vulnerable populations in North Africa.

As macaques are marketed as tourist attractions at several locations where they occur (Table 4), the economic benefit of macaques in terms of tourism (Fuentes et al., 2005; Fuentes and Gamerl, 2005) should be considered in the case for developing appropriate management strategies. Locations that appear to benefit most from macaques as a tourist attraction seem to be those which already have general tourist appeal (for instance because of geographic location, spiritual value, or other factors), but which otherwise have relatively few tourist attractions. For example, the work of Zhao (2005) found that tourists were keen to watch Tibetan macaques (Macaca fascicularis), while macaques make a considerable contribution to Gibraltar’s tourist attractions (Fa, 1992) and monkey parks in rural Japan have attracted visitors away from the more heavily visited major cultural sites and urban centres (Mito, 1995; Watanabe and Muroyama, 2005). In this way, the management of macaque populations can be of local economic importance.

VII. FUTURE RESEARCH AGENDA

There are substantial discrepancies in study focus between locations where macaques occur: Gibraltar is one of the most heavily studied macaque populations in the world, being Europe’s only wild, non-human primate population and living in close proximity to human populations, while macaque populations in Hong Kong (Fellowes, 1992; Wong and Ni, 2000) and Mt Emei in China (Zhao, 1994; Zhao, 2005), Bali in Indonesia (Wheatley and Harya Putra, 1994; Wheatley, 1999; Fuentes, 2006b), Singapore (Fuentes et al., 2008; Sha et al., 2009) and Japan (Watanabe, 2000; Watanabe and Muroyama, 2005) have also received extensive focus.

Many other macaque populations have had little or no research conducted on macaque-human interactions, either because rates of interaction are perceived to be comparatively low or because of the relative difficulty of conducting research in the given location. Many of these populations also have had very little biological data collected. For example, in contrast to the extensive study focus on Barbary macaques (Macaca sylvanus) in Gibraltar, rates of interaction with humans for the Endangered population of Barbary macaques in Morocco (Butynski et al. [online], 2008) is unknown, despite the fact that macaque-human conflict is known to occur with documented accounts of the shooting of crop-raiding macaques (Deag, 1977), although Butynski et al. ([online], 2008) note that the extent of this practise is unknown. Further research is therefore required to address limitations to geographical coverage of the work that has been conducted to date on macaque-human interactions.

More uniform data collection is also required to prevent incompatible analyses. Adoption of an approach to collect basic standardised data, as part of any study on macaque-human interactions, would allow comparison across spatial locations and would put results for a given location in context. Fuentes (2006b) calls for ‘efforts to record salient demographic, cultural, and contact characteristics of interactions between humans and NHPs’ (Non-Human Primates) (Fuentes, 2006b: 895). Where possible, reporting rate of macaque-human interaction, rate of aggressive macaque-human interaction, bite rate and basic management data (is there a feeding ban, are feeding bans enforced, is the population controlled through either a contraception program or lethal control, are tourists encouraged to interact with macaques) would be of value for analysis.
needed, different species of macaques having been considerably better studied than others. Among the macaque genus, Hsu et al. (2001) consider Macaca cyclopis, to be among the least well understood of species and certainly there is relatively limited data available on its distribution and population status within its native Taiwan (Masui et al., 1986; Lee and Lin, 1991). The recent claim for the white-cheeked macaque (Macaca leucogenys) as a new species of macaque (Li et al., 2015), following the description of a new species of macaque (Macaca munzala) in 2005 (Sinha et al., 2005), indicated there is still much to be understood even regarding the number, population status and distribution of macaque species.

Figure 2 identifies six key locations for further research, selected either because macaque populations there are biologically important (for example, representative of rare genetic lineages, or large number of newly identified species), have been poorly studied, or because there is little or no information on macaque-human interactions in that location.

Morocco and Algeria represent the last stronghold of the Barbary macaque in the wild (Taub, 1977), which is the only living representative of the genus in Africa (Hodges and Cortes, 2006). The population is considered Vulnerable (Butynski et al., 2008) and there are documented examples of macaque-human conflict (Deag, 1977), with little data on the extent or rate of occurrence.

Taiwan is home to the native Formosan rock macaque, the distribution and population status of which is little known (Masui et al., 1986; Lee and Lin, 1991). Little research on macaque-human interactions has occurred outside of a single nature park located in the southern city of Kaohsiung, Shou-Shan Nature Park.

Two new species of macaque have been discovered in the Tibetan region of North-East India and South-West China in the past 15 years (Sinha et al., 2005; Li et al., 2015). The area is therefore of significant interest, having remained relatively unstudied until recently and with little information on the biological status of macaques, or macaque-human interactions, in the region.

In Vietnam, which has a high diversity of primates including macaques, the distribution of different macaque populations is largely unknown. Work by Nguyen et al. (2012) made some progress in assessing the distribution of macaques in central Vietnam and documented high rates of close interaction between macaques, kept as pets, with human owners, indicative of high levels of poaching of macaques and the live trade in macaques.

There is limited data on the population status of macaques in Peninsular Malaysia and those studies which have been conducted to date (Ullah and Anuar, 2012) have had severe limitations. Eudey (2008) therefore highlights conservation concern over macaque management in Malaysia being based on unverified estimates of macaque numbers. Preliminary work on societal perceptions of macaque-human interactions in Malaysia found a belief that macaque-human interactions and human-macaque conflict were increasing (Hambali et al., 2012), as was also found at a local scale (Md-Zain et al., 2014). Md-Zain et al. (2011) found that few studies, however, had attempted to quantify the extent of macaque-human conflict in Malaysia.

In Myanmar (Burma) there occur at least five species of macaque, Myanmar constituting the majority of the habitat of a distinct subspecies of long-tailed macaque, Macaca fascicularis aurea, the range of which extends from Bangladesh to Thailand (San and Hamada, 2011). Little information exists on the biology or evolutionary history of Macaca fascicularis aurea, however, and poor documentation exists for its distribution in Myanmar (San and Hamada, 2011).

CONCLUSION

This study reviews the scientific literature that evaluates macaque-human interactions and highlights the high rate of macaque-human interactions at the majority of locations where macaques occur. The exact rate and nature of macaque-human interaction varies substantially between locations, with Gibraltar registering the highest rate of macaque-human interaction globally. Across the literature, adult male macaques are the most likely to interact with humans and are more likely to be involved in aggressive macaque-human interactions. With the exception of locations where macaques are fully acclimatised to humans, human and macaque density seems to have an impact upon the rate of macaque-human interaction, but there is little evidence that human or macaque density affects either the rate of macaque-human aggression or bite rates. There is also little evidence in the literature for ‘species specific differences’ in macaque-human interaction. Instead, management practises seem to determine the rate and nature of macaque-human aggression, with substantial evidence that food triggers, which can be controlled through management practises, increase both the frequency and duration of aggression in macaques (Southwick et al., 1976; Fa, 1992; Saito, 1996; Wheatley, 1999; Hsu et al., 2009).

There has been limited quantitative data on macaque-human interactions collected in the majority of the locations where macaques and humans interface, and even less on societal perceptions of macaques, despite the fact that macaque-human interactions influence societal perceptions of macaques and, in turn, societal perceptions of macaques influence choice of management strategy. The limited focus to date is surprising considering that macaque-human interaction is of societal importance. This review calls for an increase in the geographical...
coverage of studies of macaque-human interaction and adoption of standardised data collection on basic biological and interaction data to allow comparison between locations. Six key locations, of biological importance or lacking detailed study, are identified for further research: Morocco and Algeria, Taiwan, South-eastern Tibet (North-east India and South-west China), Vietnam, Peninsular Malaysia, and Myanmar (Burma).

Management practises vary substantially between locations, with a noted difference between locations where macaques are marketed as a tourist attraction and feeding bans are not enforced, to locations where macaques are not marketed to tourists and feeding bans are enforced. Control of feeding cues through a feeding ban appears critical in keeping rates of aggressive macaque-human interaction low. Singapore and Hong Kong both register low rates of macaque-human interactions and of aggressive macaque-human interactions, with Hong Kong having introduced a regular contraception program following sustained population increase of macaques in the Kowloon Hills (Wong and Ni, 2000; Fuentes et al., 2011).

The challenge that human-macaque conflict presents to macaque conservation is, as of yet, unquantified, and there is a need for further research, but the literature to date suggests that it has conservation implications, most notably as a secondary threat, whereby the impact of declines associated with primary threats (including habitat loss or human harvesting) are more accentuated in areas where human-primate conflict occurs. As human encroachment on macaque habitat continues to increase the area in which the macaque-human interface occurs, the challenges for management into the future will only increase.

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