RESEARCH ARTICLE

Human Behavior and Opportunities for Parasite Transmission in Communities Surrounding Long-Tailed Macaque Populations in Bali, Indonesia

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Spatial overlap and shared resources between humans and wildlife can exacerbate parasite transmission dynamics. In Bali, Indonesia, an agricultural-religious temple system provides sanctuaries for long-tailed macaques (Macaca fascicularis), concentrating them in areas in close proximity to humans. In this study, we interviewed individuals in communities surrounding 13 macaque populations about their willingness to participate in behaviors that would put them at risk of exposure to gastrointestinal parasites to understand if age, education level, or occupation are significant determinants of exposure behaviors. These exposure risk behaviors and attitudes include fear of macaques, direct contact with macaques, owning pet macaques, hunting and eating macaques, and overlapping water uses. We find that willingness to participate in exposure risk behaviors are correlated with an individual’s occupation, age, and/or education level. We also found that because the actual risk of infection varies across populations, activities such as direct macaque contact and pet ownership, could be putting individuals at real risk in certain contexts. Thus, we show that human demographics and social structure can influence willingness to participate in behaviors putting them at increased risk for exposure to parasites. Am. J. Primatol. 76:159–167, 2014. © 2013 Wiley Periodicals, Inc.

Key words: risk; gut parasite; long-tailed macaques; human behavior

INTRODUCTION

Transmission of zoonotic parasites often occurs when high-density human and wildlife populations coexist and share resources [Daszak and Cunningham, 2003; Daszak et al., 2001; Jones-Engel et al., 2008; Murphy, 1998; Wolfe et al., 1998]. While land use practices that affect human–wildlife interactions are recognized as important in widespread parasite transmission, the mechanisms of parasite transmission events in the landscape are not fully understood. In particular, how human–wildlife interactions and land use practices enhance transmission opportunities, especially for gastrointestinal parasites, is largely neglected [Lafferty and Gerber, 2002; Nunn and Altizer, 2006]. The source of many diarrheal infections, one of the most common causes of mortality and morbidity in the developing world [Alum et al., 2010; Cleaveland et al., 2001; Stepek et al., 2006; WHO, 2007], is exposure to infected feces or contaminated water. Many gastrointestinal parasites are transmissible in water, enabling them to spread beyond the source of the original infection [Cleaveland et al., 2001; Meyer, 1985; WHO, 2007]. Gastrointestinal parasites, especially those transmitted through the fecal–oral route, can produce environmentally viable infectious stages, increasing the risk of exposure via contaminated soil or water long after the infective stage was deposited. The impact of diarrheal diseases is drastically greater in regions of the world where access to clean water and public sanitation measures may be limited [Alum et al., 2010; Stepek et al., 2006; WHO, 2007].

On the island of Bali, Indonesia, increases in human density have substantially increased the frequency of contact between humans and long-tailed macaques. The agricultural-religious temple system provides sanctuaries for these macaques (Macaca fascicularis), concentrating them in areas in close proximity to humans. This study contributes to understanding the drivers of susceptibility to gastrointestinal infections in this context.
macaques (*Macaca fascicularis*), especially in areas where they coexist [Fuentes et al., 2005; Jones-Engel et al., 2008]. Non-human primates, including long-tailed macaques, have been identified as hosts and reservoirs of several infectious diseases found in humans, including microfilarias, giardiasis, enterobiasis, and schistosomiasis [Alum et al., 2010; Fuller et al., 1979; Hahn et al., 2000; Huffman and Chapman, 2009; Mak et al., 1982; Nunn and Altizer, 2006; Pederson et al., 2005; Taylor et al., 2001; Wolfe et al., 2004], and recently, simian foamy virus (SVF) was detected among humans living and working in Balinese monkey forests [Jones-Engel et al., 2004]. Given that many primates are a potential source of parasite risk for humans, it is central to understand how human behaviors may potentially facilitate exposure to and transmission of these parasites.

The long-tailed macaque is found throughout Southeast Asia, including Bali, Indonesia, where a system of agricultural-religious temples exists [Fuentes et al., 2005; Lansing, 1995; Lane, 2010]. Relatively large macaque populations live at monkey forests, or community temple sites, surrounded by remnant forest patches and often linked by streams and rivers (Fig. 1). The maintenance of resident populations of macaques at these temples demonstrates a dichotomy of attitude among the Balinese. Macaques figure prominently in Balinese Hindu philosophy and tradition, and it is this role in culture that has led some to suggest a sacredness of macaques [Wheatley, 1999]. However, evidence has revealed that this view is highly context dependent [Loudon et al., 2006; Schillaci et al., 2010], with different treatment of macaques inside versus outside of temple complexes. Recent reductions in overall forest cover on the island have resulted in a number of high-density macaque populations co-occurring in areas of high-density human communities, some with densities reaching as high as 500 people/km² [Fuentes et al., 2005; Wheatley, 1999]. The Balinese landscape reflects the island’s economic shift from traditional rice agriculture towards international tourism over the last four decades, resulting in an increase in urban development and reduction in land dedicated to rice agriculture [Fuentes et al., 2005; Lane et al., 2010; Lansing, 2007]. This change in land use has brought human and macaque populations closer together, living around temple sites and sharing community water sources, and potentially increasing the risk of non-human pri-mate-to-human parasite exposure.

The ability of human attitudes to directly influence their behaviors has been demonstrated repeatedly [Eyal and Kunkel 2008; Stulhofer et al., 2007]. McCleery [2009], studying urban wildlife–human aggression, demonstrated that attitudes towards wildlife can be changed, and that predictive models of wildlife–human interactions are more accurate when human attitudes and beliefs are included in these models. This point is especially salient given recent work demonstrating macaque-to-human transmission of SFV and human-to-macaque transmission of gastrointestinal parasites with pet macaques [Jones-Engel et al., 2004, 2005, 2008] and

Fig. 1. Map of Bali with monkey forest distribution. Populations marked in black represent those temple sites in which surveys were performed.
could be important in identifying opportunities to reduce parasite transmission opportunities wherever human and non-human primate populations coexist [Altizer and Nunn, 2006; Gillespie et al., 2005; Goldberg et al., 2008; Wolfe et al., 1998, 2004, 2007]. Differences in attitude towards long-tailed macaques, related to occupation, education level, and age could prove to be a key factor in understanding the transmission dynamics of gastrointestinal parasites in this system.

The focus on the interface between humans and wild macaques here is especially relevant in light of three factors. First, macaques are an established source of infectious zoonotic diseases and carriers of anthropootic diseases, including cryptosporidiosis, giardiasis, and microsporidiosis [Edmonson et al., 1998; Ekanayake et al., 2006; Engel et al., 2002; Jiang et al., 2008; Jones-Engel et al., 2008, 2005, 2004; McClure et al., 1980; Ye et al., 2012]. Second, previous work in this system has found intestinal helminthes, including hookworms, tapeworms (Taenia spp.), and roundworms (Ascaris spp.), and protozoa, including Entamoeba spp. and Giardia spp., to be prevalent across populations [Lane et al., 2011]. These intestinal parasites, and others with similar transmission strategies, have all been reported in human populations as well, allowing for the opportunity for continued infection and reinfection to cycle between macaques and humans [Pederson et al., 2005; Sutisna et al., 1999]. Finally, and most importantly, the overlap between humans and macaques, especially concentrated at these monkey forests, has the potential to exacerbate infection dynamics in these communities [Fuentes, 2006]. In this study, we explore how an individual's attitude towards wildlife, specifically interactions with non-human primates, can impact potential risk of exposure to parasites. To do this, we investigate how an individual's age, occupation, education level, and community of residence correlates with his or her willingness to participate in exposure risk behaviors, that is, those behaviors that put an individual in direct contact with a macaque or macaque feces. We hypothesize that individuals working directly with macaques, such as priests or temple staff, the youngest age group sampled (or those individuals between the ages 15 and 24), and those individuals with the lowest levels of education will report the greatest participation in exposure risk behaviors. We also investigate whether increased participation or willingness to participate in exposure risk behaviors could translate to increased risk of actual infection via exposure to gastrointestinal parasites from local macaques. We hypothesize that if there is a perceived risk of infection via exposure to macaques, individuals will be more likely to participate in high levels of exposure risk behaviors in communities surrounding macaque populations with the lowest parasite prevalence and intensity. These behaviors include direct contact with macaques, recognized and unrecognized water sharing, and pet ownership. Alternatively, if there is no perceived risk of infection from exposure to macaques, we hypothesize that the relationship between the incidence of exposure risk behaviors in humans and parasite loads in macaques will vary randomly across all communities.

METHODS

Study Sites

Previous studies [Fuentes, 2006; Fuentes et al., 2005; Lane et al., 2011; Loudon et al., 2006] have documented 43 temples with well-established, long-term populations of M. fascicularis on the island of Bali, Indonesia. Native Balinese visitors at 13 of these monkey forests (Fig. 1) were interviewed (n = 113) during the summer of 2007. All individuals asked to participate did so willingly. Interview sites, described in Table I, were chosen in order to capture the full range of available habitat type (described as the amount in m² of contiguous forest, rice agriculture, and urban areas surrounding each monkey forest), amounts of foreign tourism (Tourism Days, defined as the number of days non-Balinese tourists were present), and water availability (Water Days, defined as the number of days in which standing water is available) [Lane et al., 2011]. Macaque population size was determined by repeated censuses from 2002 to 2005 [Fuentes et al., 2005] and via repeated daily population censuses (n ≥ 4 per site visit). At each site, direct observations were also made of macaque water use.

Interviewees

Interviews focused on individuals living and working in or near established monkey forests (Fig. 1). Interviews were opportunistic in that all available Balinese individuals in the area of the selected temple, throughout the collection day, were asked to participate. Both men and women were actively solicited for participation, and attempts were also made to include individuals from across a broad spectrum of age classes, with the exception of children (Table II). Respondents include farmers, temple staff, priests, vendors, and local village members. For the comfort of the interviewees, interviews were conducted, as much as possible, by our team members who are native Balinese. No tourists were interviewed for this work [HSIRB Protocol 07-152].

Ethnographic Data Collection

Interview questions asked were based on previous successful ethnographic data collections [Loudon et al., 2006] and were expanded to assess perceptions
related to exposure risk involving macaques. Interviews were conducted in Bahasa Indonesia or Bahasa Bali, depending on the comfort of the interviewee and in a manner that encouraged direct answer and elaboration when appropriate. We limited our investigation to those questions and answers that allowed us to both understand the nature of risk to parasite exposure and to avoid highly subjective interpretation of the results. Questions largely focused on identifying perceptions and behaviors that have been previously identified to increase the potential for exposure to the etiological agents of diarrheal diseases and that addressed the overall risks associated with direct contact with macaques [Engel et al., 2002; Jones-Engel et al. 2004]. With our questions, we sought to identify the willingness to participate in risk behaviors associated with overall attitude toward macaques through direct questioning (i.e., How do you feel about the macaques?) and indirect questioning (i.e., Do you hunt macaques?). We also sought to identify the frequency and type of overlapping water use between people and macaques and the perceived safeguards or limits to water sharing. Specifically, we used the designation of “shared water use” to signify behaviors practiced by the Balinese that reflected knowingly sharing water with macaques, such as swimming in the same pool of water. Alternatively, we used the designation of “macaque water uses” to indicate behaviors practiced that reflected unknowingly sharing water with macaques, such as washing food upstream of the area frequented by macaques. Water sources for each monkey temple were the most apparent source of community-available water. Uses for shared water include bathing, drinking, washing, and use as “sacred water.” Although we used additional questions to gain information regarding potentially taboo subjects, such as education and income levels in order to understand how these factors influenced risk behaviors, questionnaires were designed to minimize any discomfort caused by these questions. Survey questions were read to the interviewee to overcome any potential literacy issues. Answers were recorded in the language spoken (English, Bahasa Indonesia, or Bahasa Bali) and were transcribed into English (for the full set of interview questions, please see Appendix 1). All collections were approved by the University of Notre Dame IACUC (protocol 07-001) and HSIRB (protocol 07-152) and the Indonesian Institute of Science (permit number 662.02/1090.

### TABLE I. Study Site Details

<table>
<thead>
<tr>
<th>Population</th>
<th>Population abbreviation</th>
<th>Number of interviews</th>
<th>Macaque N</th>
<th>Water days</th>
<th>Tourism days</th>
<th>Forest (m²)</th>
<th>Rice (m²)</th>
<th>Urban (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Padangtegal</td>
<td>PU</td>
<td>20</td>
<td>350</td>
<td>244</td>
<td>365</td>
<td>36,002</td>
<td>807,051</td>
<td>72,013</td>
</tr>
<tr>
<td>Uluwatu</td>
<td>U</td>
<td>15</td>
<td>300</td>
<td>91</td>
<td>365</td>
<td>0</td>
<td>0</td>
<td>23,372</td>
</tr>
<tr>
<td>Batur</td>
<td>BT</td>
<td>4</td>
<td>25</td>
<td>91</td>
<td>244</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Angseri</td>
<td>AN</td>
<td>7</td>
<td>40</td>
<td>244</td>
<td>91</td>
<td>536,319</td>
<td>123,203</td>
<td>102,191</td>
</tr>
<tr>
<td>Bedugal</td>
<td>BD</td>
<td>8</td>
<td>200</td>
<td>244</td>
<td>244</td>
<td>536,319</td>
<td>0</td>
<td>9,473</td>
</tr>
<tr>
<td>Batupageh</td>
<td>BP</td>
<td>7</td>
<td>45</td>
<td>91</td>
<td>91</td>
<td>0</td>
<td>0</td>
<td>6,546</td>
</tr>
<tr>
<td>Pulaki</td>
<td>PL</td>
<td>10</td>
<td>200</td>
<td>244</td>
<td>244</td>
<td>106,198</td>
<td>0</td>
<td>87,969</td>
</tr>
<tr>
<td>Tejakula</td>
<td>TK</td>
<td>6</td>
<td>75</td>
<td>91</td>
<td>91</td>
<td>417,946</td>
<td>114,393</td>
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<tr>
<td>Alas Nengahn</td>
<td>AN</td>
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<td>365</td>
<td>510,781</td>
<td>724,907</td>
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<tr>
<td>Lempuyang</td>
<td>LM</td>
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<td>91</td>
<td>180,053</td>
<td>0</td>
<td>127,074</td>
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<tr>
<td>Bukit Gumang</td>
<td>BG</td>
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<td>100</td>
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<td>244</td>
<td>0</td>
<td>131</td>
<td>0</td>
</tr>
<tr>
<td>Mekori</td>
<td>MK</td>
<td>12</td>
<td>60</td>
<td>365</td>
<td>91</td>
<td>566,899</td>
<td>298,983</td>
<td>87,969</td>
</tr>
<tr>
<td>Pejuritan</td>
<td>PJ</td>
<td>3</td>
<td>30</td>
<td>244</td>
<td>91</td>
<td>566,899</td>
<td>123,203</td>
<td>0</td>
</tr>
</tbody>
</table>

Population abbreviation corresponds with map (Fig. 1) detail. Descriptive details (water days, tourism days, forest, rice, and urban) show the number of available water, frequency of tourists, and type of overall habitat surrounding each site.

### TABLE II. Numbers of Surveys Collected Total and Relating to Each Category

<table>
<thead>
<tr>
<th>Age of interviewees</th>
<th>Occupation</th>
<th>Education</th>
</tr>
</thead>
<tbody>
<tr>
<td>15–24</td>
<td>Priest</td>
<td>No education</td>
</tr>
<tr>
<td>25–34</td>
<td>Teacher</td>
<td>Elementary</td>
</tr>
<tr>
<td>35–44</td>
<td>Laborer</td>
<td>Junior high school</td>
</tr>
<tr>
<td>45–54</td>
<td>Farmer</td>
<td>High school</td>
</tr>
<tr>
<td>55–64</td>
<td>Vendor</td>
<td>Post secondary</td>
</tr>
<tr>
<td>65+</td>
<td>Temple staff</td>
<td>6</td>
</tr>
</tbody>
</table>

Regions were determined by the grouping of macaque populations based on likelihood of corridors for gene flow in the landscape.
RESULTS

Human–Macaque Interactions

While most interviewees (90%) responded that macaques are “sacred,” or considered components of the Balinese religious structure in which they reside, 75% of those questioned believe that macaques are responsible for raiding crops, either their own or others in their community, 3% of the respondents admit to eating macaques, and a surprising 12% admit to hunting macaques, despite widespread social taboos against hunting. Most respondents reported positive feelings about the macaques’ presence (81%), with only 19% reporting a fear of macaques.

Shared Water Consumption

Across the island, 68% of the respondents acknowledge their own shared water use with macaques; however, many individuals also report using water frequently and for purposes that would result in consuming water without recognizing the macaques’ use of water. Balinese were observed washing food directly in shared water sources at every location, yet this behavior went unreported entirely. Although not incorporated directly into the data presented here, several interviewees acknowledged a risk of infection from macaques using community water sources and made efforts to minimize their individual risks by using “clean” water for specific behaviors (e.g., drinking and cooking) upstream of where they believe macaques use water sources while using water downstream or “contaminated” water for other behaviors (e.g., bathing and washing). However, these individual reports were often given while participants were actively not practicing these behaviors and often with the acknowledgement that these behaviors were not practiced community wide. Further, while many respondents accept the localized view of minimizing exposure by participating in exposure risk behaviors only upstream of the perceived source of infection (i.e., macaques or macaque feces), no single respondent acknowledged the more global, island-wide view that locally upstream is systematically downstream of neighboring monkey forests as well as downstream of neighboring villages and other domesticated and wild animal use. This likely explains the lack of reports on filtering or boiling water before consumption.

Exposure Risk Behaviors

Log-linear analysis of respondents’ reports of fear of macaques shows a significant overall pattern ($\chi^2: 51.95, P = 0.019$), suggesting that independent of subcategory, respondents report high levels of fear of macaques. Further, every question examined showed a significant difference overall in respondents’ answers (direct contact: $\chi^2: 77.26, P = 0.0001$; pet ownership: $\chi^2: 61.68, P = 0.0018$; hunting/eating macaques: $\chi^2: 87.65, P = 0.0001$; recognized water sharing: $\chi^2: 84.23, P = 0.0001$; macaque water use (unrecognized): $\chi^2: 86.31, P = 0.0001$). Scaling down to compare across education, age, occupation, and temple, for fear of macaques, direct contact, shared water, and macaque water use, temple is the only significant explanatory variable (fear of macaques: $\chi^2: 21.72, P = 0.041$; direct contact: $\chi^2: 44.69, P = 0.0001$; shared water: $\chi^2: 56.12, P = 0.0001$; macaque water use: $\chi^2: 36.88, P = 0.0002$), suggesting that for these questions, the most important factor determining a respondents’ willingness to participate in these exposure risk behaviors is the community temple into which they were born. However, willingness to own pets and to hunt and eat macaques had an additional explanatory variable. Both temple and level of education were significant in explaining patterns of pet ownership (temple: $\chi^2: 35.46, P = 0.0004$; pet ownership: $\chi^2: 12.91, P = 0.012$), while
temple and age were significant factors explaining willingness to hunt and eat macaques (temple: $\chi^2$: 63.51, $P = 0.0001$; age class: $\chi^2$: 31.77, $P = 0.0004$).

Within category analyses (i.e., across age classes or occupations), we found no significant differences among any group’s response to fear of macaques. However, community temple and at least one other category had a subgroup that showed a significantly higher or lower willingness to participate in exposure risk behaviors for all other response categories. For direct contact and pet ownership, both temples and occupation had subgroups with significant explanatory variables. Two temples (AS and MK) had significantly lower contact rates, while one temple (PU) had significantly greater contact rates ($\chi^2$: 42.93, $P = 0.0001$). One temple (TK) had significantly greater reports of pet ownership, while one temple (MK) had significantly fewer reports of pet ownership ($\chi^2$: 29.37, $P = 0.0002$). Perhaps not surprisingly, temple staff reported significantly greater rates of contact while individuals in the education field (teachers and students) reported overall significantly lower rates of direct contact with macaques ($\chi^2$: 11.31, $P = 0.047$). However, individuals in the education field reported significantly greater amounts of pet ownership; farmers reported significantly lower levels of pet ownership ($\chi^2$: 13.83, $P = 0.038$). Two categories—temple and age class—had significant explanatory subgroups for reports of hunting and eating macaques. Two temples (BT and PL) and two age classes (20–24 and 60–64) had a significantly greater number of reports of hunting and eating macaques (temples: $\chi^2$: 27.21, $P = 0.0043$; age classes: $\chi^2$: 18.68, $P = 0.0031$). Finally, for both metrics of water sharing—shared use (recognized) and macaque use (unrecognized)—temple and education level had significant explanatory subgroups. Two temples had significantly lower reports of both shared water use and macaque water use (BD and MK); one additional temple (BT) had significantly lower reports of shared water use (shared water use: $\chi^2$: 47.31, $P = 0.0001$; macaque water use: $\chi^2$: 70.32, $P = 0.0001$). Only one education class showed a significant explanatory relationship with water use—no education. Individuals with no education reported significantly lower levels of both shared water use and macaque water use (shared water use: $\chi^2$: 17.84, $P = 0.009$; macaque water use: $\chi^2$: 21.97, $P = 0.0002$).

**DISCUSSION**

Our results demonstrate the people living in and around Balinese monkey forests participate in exposure risk behaviors. Most significantly, community temple was a significant explanatory variable for every question of interest and was the only significant explanatory variable in the case of reports of fear of macaques, direct contact, and both types of shared water uses.

We hypothesized that fear of macaques would result in fewer direct interactions with macaques. However, we found that temple site was the only explanatory variable, island wide, for reports of fear of macaques. This could be explained by personal stories shared between community members and suggests that individually reported attitudes toward macaques are not separable from an individual’s home temple as an important determinant in the willingness to participate in exposure risk behaviors. Direct contact with macaques was hypothesized to be higher among the young, the uneducated, and those with occupations that place them at temple sites directly. We found that the temple staff reports the greatest amount of direct contact with macaques. With 100% of temple staff reporting frequent direct contact with macaques while other groups report significantly less, the disparity between the views of temple staff and other individuals, including temple priests, likely reflects additional, underlying demographic and social factors, such as social position and the role staff play in the temples. We also found that individuals at PU reported the greatest amount of direct contact with macaques. This temple is home to the largest macaque population on the island, with recent estimates nearing 600 macaques [Brotcorne et al., 2011]. It is also the temple with the most international tourism, greatest amounts of provisioning, and most organized management staff. Thus, it is especially important when considering the risk of exposure to parasites. For example, Jones-Engel et al. (2008) documented transmission of SFV from macaques to individuals working in a monkey forest, suggesting transmission has already and will continue to occur between humans and macaques at these temples.

Ownership of non-human primates as pets is common throughout Bali, and throughout rural regions of Indonesia. There exists a disparity between what individuals consider direct contact associated with risk (e.g., bites and scratches) and other types of direct contact (e.g., sharing living quarters), despite the opportunity of parasite exposure from this latter category as well. Both temple site and education level were significant predictors of pet ownership, with the temple TK and those in the education field reporting the greatest amount of pet macaques within these subgroups. Thus, those in the education field report the greatest amount of pet ownership while concurrently reporting the least amount of direct contact with macaques, suggesting that pet macaques are considered a special case of contact to these individuals.

There is both a social and religious taboo against hunting and eating macaques on Bali, and it is likely that this practice was under-reported. Despite these taboos, both age and temple site were significant explanatory variables of willingness to hunt and eat macaques. The two populations—BT and PL—that
report the greatest amount of these exposure risk behaviors are both dry and difficult terrain in relatively impoverished areas of the island, possibly making hunting an attractive option in order to supplement an individual’s diet. Also, two specific age groups—15 to 24 and 55 to 64 report the greatest amount of hunting and eating macaques. Overall, while the risk of parasite transmission is generally greatest from hunting and eating macaques, through exposure to potentially infective blood, intestinal system, muscle, and brain matter [Wolfe et al., 2005], these behaviors contribute a small, yet significant, exposure risk to the subset of the Balinese population engaging in these practices [Wolfe et al., 1998, 2005].

Gastrointestinal parasites infect 1 billion people, and most of these parasites are water- and soil-borne parasites [Alum et al., 2010; Stepek et al., 2006]. Thus, it was surprising to discover that most Balinese do not recognize the extent of overlap in water use patterns between themselves and the wildlife with which they share the island. Despite the recognition that macaques use community water sources, the prevalence of recognized shared water use within the overall Balinese community structure is low, with those with no education reporting significantly lower levels of recognized shared water use. Given the recent programs in Balinese schools focused on clean water, this low level of recognized shared water use is surprising and has ramifications in potentially increasing parasite transmission opportunities. Coupled with the high levels of unrecognized macaque water use, this trend of water use throughout Bali can substantially contribute to the spread of parasites, specifically gastrointestinal parasites, throughout the island.

While all temples are known to have a gastrointestinal parasite burden, previous work has shown that the temples AS, TK, LM, and PU have significantly greater gut parasite burden and BD, MK, U, and AN have significantly lower gut parasite burden than surrounding macaque populations [Lane et al., 2011]. This increase or decrease in gastrointestinal parasite burden at these populations has been shown previously to be associated with amount of anthropogenic land use in the surrounding communities. Interestingly, five of these temples—BD, MK, AS, TK, and PU—also showed a significant reporting of at least one exposure risk behavior. Thus, it is these communities that are of particular interest for understanding the relationship between actual and perceived risk of exposure to gastrointestinal parasites from local macaques. For example, two populations—BD and MK—previously found to have low parasite burden co-occur with significantly lower levels of reported shared water use and macaque water use, as well as significantly lower levels of reported pet ownership and direct contact in MK. As such, individuals in these communities, even when participating in exposure risk behaviors, are unlikely to become infected with gut parasites originating with macaques. One population—AS—previously found to have a high parasite burden co-occurred with significant decreases in reports of direct contact, suggesting that while individuals in this community rarely participate in exposure risk behaviors, when they do, the risk of infection is great. Finally, two communities—TK and PU—were previously shown to have a high parasite burden and were found to have a significant increase in either pet ownership (TK) or direct contact (PU). As a result, individuals in these communities are at a real risk of becoming infected with gastrointestinal parasites, originating with macaque populations, via either direct contact or pet ownership. In summary, our results show that the willingness to participate in exposure risk behaviors of the Balinese is largely context specific and varies most by community, independent of the actual exposure risk to gut parasites from macaque populations. Therefore, local cultural and demographic factors are likely more important in determining participation in exposure risk behaviors in the context of local macaques much more so than actual parasite burdens carried by those macaques.

Understanding the demographic patterns influencing exposure to parasites is an important component of minimizing transmission opportunities. While this research focuses directly on risk parameters on the island of Bali with an emphasis on risk associated with long-tailed macaques, we demonstrate that human socioeconomic factors can influence specific behaviors, which, in the context of wild primate populations, may affect the risk of exposure to infectious agents. While this is significant for diarrheal diseases due to their clear environmental transmission strategies, this knowledge is also important for understanding the overarching role of the anthropogenic environment in opportunities for infectious disease transmission and emergence more generally.

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Appendix 1

1. How long have you and/or your family lived in this area?
2. What is your profession?
3. What is your level of education?
4. What is your religious affiliation?
5. How often do you visit a temple?
6. Do macaques frequent this temple? If so, how often?
7. How often does your family use the temple associated with macaques?
8. What is the origin of the macaques at this temple?
9. How do you feel about the macaques? Is this feeling shared by all members of your family? How does it differ?
10. Do others in your village have a different view of the macaques than you?
11. Where do the macaques live?
12. How many macaques come to this place?
13. Are the macaques sacred?
14. Do you have direct contact with the macaques? What kind?
15. Do you pester the macaques? How? How often?
16. Do the macaques at this site raid your crops? How often and when?
17. How do you deter the macaques from coming to the temple or raiding your fields?
18. Have you ever been injured by a macaque?
19. Have you seen any dead macaques here?
20. Does anyone keep macaques as pets?
21. Do the macaques eat trash?
22. Do you eat the macaques?
23. Do you hunt the macaques for any reason?
24. Are you afraid of the macaques?
25. Do you think there will be a change in the way people perceive macaques here?
26. Have you seen the macaques using rivers, irrigation channels, or sawah?
27. How often do macaques use the water?
28. How often do they use the water sources here?
29. How does your village use the water here?
30. How often does your village use the water here?
31. Has there been a change in water use in reference to the macaques?
32. Do you share a water source with the macaques?
33. How do you use this shared water?
34. How do the macaques use this water?
35. Where do the macaques drink from?
36. Have you seen the macaques swim?

REFERENCES


