

The roles of traditional knowledge systems in orang-utan *Pongo* spp. and forest conservation: a case study of Danau Sentarum, West Kalimantan, Indonesia

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Abstract The orang-utan *Pongo* spp. is protected by national and international legislation, yet populations continue to decline. Many reports implicate local people in the poaching and illegal trade in orang-utans, yet community participation has been promoted as an alternative conservation strategy. To explore how community-based orang-utan conservation could be developed, we conducted a study to understand informal institutions, particularly local people's perceptions, traditional beliefs, taboos, norms and knowledge, related to orang-utan conservation within and around the wetlands of Danau Sentarum. The majority of Dayak communities interviewed practised traditional taboos, which supported the protection of orang-utans and their habitat. Statistical analysis using generalized linear modelling indicated that more orang-utan nests were found in areas with both good habitat condition and strong informal institutions. Despite applying traditional systems that are similar to conservation, local people have negative perceptions about the term 'conservation'. We describe the underlying causes of these negative perceptions and highlight their implications for conservation programmes and policies. We conclude that conservation of orang-utans and other species should not focus on single species but on maintaining social and natural capital, cultural diversity and ecological functions at various institutional levels and across geographical scales.

Keywords Biocultural diversity, customary beliefs, Danau Sentarum, forest, governance and institutions, local people, orang-utan, taboo

Introduction

The orang-utan *Pongo* spp. is the only remaining Asian great ape and is found only on the islands of Sumatra and Borneo (Rijksen & Meijaard, 1999; Singleton et al., 2004). Both species, the Sumatran orang-utan *Pongo abelii* and the Bornean orang-utan *Pongo pygmaeus*, are categorized as Critically Endangered on the IUCN Red List (Singleton et al., 2008; Ancrenaz et al., 2016). There are estimated to be c. 6,624 Sumatran orang-utans in the wild, and 3,000–4,500 north-west Bornean orang-utans *P. pygmaeus pygmaeus*, 34,975 south-west Bornean orang-utans *P. pygmaeus wurmbii* and 15,800 north-east Bornean orang-utans *P. pygmaeus morio* (Wich et al., 2008).

In Indonesia the orang-utan is protected by national legislation but its habitat is not, unless it is within protected areas. Orang-utan populations continue to decline, mainly as a result of habitat loss for agriculture, plantations and mining, as well as hunting, killing and trading. Although policies for protection are in place, enforcement is weak and inconsistent (e.g. Rijksen & Meijaard, 1999; Robertson & van Schaik, 2001; Nijman, 2005). The importance of protecting orang-utans (and other key species) is not reflected in government programmes or land-use policies. National and district land use planning prioritizes large-scale industrial plantations and mining, with little (if any) protection of orang-utan habitat outside protected areas by either the National Planning Agency or the agriculture and mining sectors. Thus, orang-utans are regarded as pests when they are present in commercial plantations, and hundreds have been killed (e.g. Tribun Kaltim, 2011; Gayle, 2012). However, it is rare that the perpetrators are prosecuted (Antara Kaltim, 2012). This shows that formal institutions are weak, infractions are often ignored and sanctions are insignificant.

Local people have been implicated in the hunting, poaching and illegal trade of orang-utans (Rijksen & Meijaard, 1999; Nijman, 2005). Whether or not they hunt may be related to their ethnicity and religion (Sugardjito & van Schaik, 1991). An alternative discourse frames local communities as a potential solution. Their informal institutions, including nature-related social taboos, customary beliefs and

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traditional knowledge systems, are an important component of their social capital and have important applications for biodiversity conservation (Gadgil et al., 1993; Colding & Folke, 2001; Wadley & Colfer, 2004; Berkes, 2007; Luo et al., 2009; Parotta, 2012). However, informal institutions have been largely neglected in conservation planning in biodiversity-rich, developing countries (Alcorn 1995; Robbins 1998). To improve the protection of great apes, including orang-utans, efforts focusing on the preservation of traditional values and long-term support for community initiatives have been recommended (Caldecott, 2005).

Studies have shown positive correlations between traditional knowledge and biodiversity conservation (Nyhus et al., 2003; Riley, 2010; Etiendem et al., 2011; Stacey et al., 2012), and highlighted the need for location- and species-specific understanding of traditional belief systems in assessing their potential application to conservation efforts (Uyeda et al., 2016). However, there is a lack of such studies specifically related to orang-utan protection. We aim to fill this knowledge gap by (1) describing perceptions and informal institutions of the major ethnic groups around Danau Sentarum wetlands, including traditional beliefs, taboos, norms, knowledge and practices, which are related to orang-utan and broader forest conservation, and (2) evaluating how these informal institutions could contribute to improving the protection of orang-utans and their habitat. We focus on nature-related social taboos as a subset of informal institutions (Colding & Folke, 2001), and adopt the definition of taboo as 'a prohibition against touching, saying or doing something for fear of immediate harm from a supernatural force; or a prohibition imposed by social custom or as a protective measure' (Merriam-Webster, 2004).

Study area

The Danau Sentarum wetlands are located in West Kalimantan, 700 km north-east of Pontianak, the provincial capital city (Fig. 1). The wetlands comprise 83 interconnected seasonal lakes, hill forests, lowland dipterocarp forests, peat swamp and swamp forests, and dwarf forests (Giesen & Aglionby, 2000). In 1999 the core area of 1,320 km² was gazetted as a National Park by the Indonesian government. The Park has at least 211 fish species (Kottelat & Widjanarti, 2005), 27 reptile and 143 mammal species (Meijaard & Jeanes, 2000), and 282 bird species (van Balen & Dennis, 2000). In 1997 it was home to an estimated 2,056 orang-utans (Russon et al., 2001). However, the wetlands' catchment areas were subjected to illegal logging during 2000–2005 and the development of large-scale oil palm plantations since 2005, both of which are significant threats to the orang-utan (Heri et al., 2010; Yuliani et al., 2010).

Two of the largest ethnic groups, the Dayak and Malay, had been living in the area long before Danau Sentarum was



FIG. 1 Danau Sentarum National Park and its surrounding areas, West Kalimantan, Indonesia. Source of spatial data: Margono et al. (2014) and Hansen et al. (2013).

designated a National Park. The Dayak live in the surrounding hills, and their main income is from fish, rubber, pepper, and paid labour in Malaysia. Subsistence rice production is an important part of their livelihoods (Eilenberg & Wadley, 2009). The Malay live on the riversides, and their main income comes from fish, honey and rubber extraction (Yuliani & Erman, 2005; Indriatmoko, 2010). Some Malay villages inside the Park were initially seasonal settlements of fishers who came from the Kapuas river to fish in the wetlands in the 1970s and 1980s, but some are several hundred years old (Giesen, 1987). All have strong ties with larger Malay towns along the Kapuas river (R.L. Wadley, unpubl. data).

Methods

To explore customary beliefs and institutions related to orang-utans we conducted in-depth semi-structured interviews and 23 gender-disaggregated focus group discussions (14 with Dayaks and nine with Malays) and undertook participant observation from November 2009 until February 2013. We selected interview and discussion group participants based on the following criteria: (1) they possessed good knowledge of culture, traditional norms and belief systems, and histories of the community or the hamlet specifically related to orang-utans; (2) they had good knowledge of formal regulations (or individuals that represent formal institutions); (3) they represented a diversity of ethnic groups and points of view; and (4) they were willing to participate in our study. We first consulted the chief of the hamlet and then expanded our selection using snowball methods (i.e. during conversations in the initial interviews we identified more potential participants who met the above criteria and were willing to provide additional information). We abided by the ethical principles of human subject research,

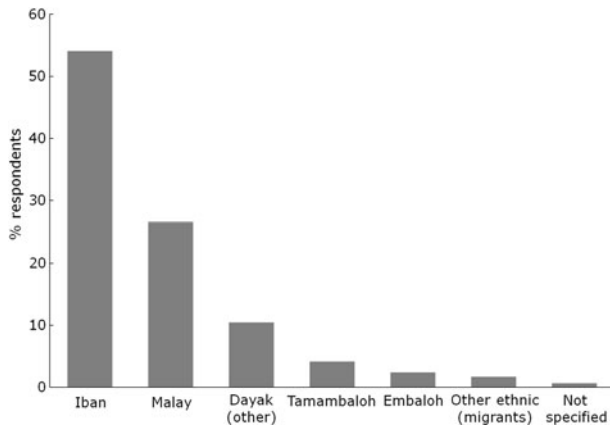


FIG. 2 Percentages of study participants belonging to various ethnic groups.

including maintaining participants' privacy and respecting their choice whether or not to participate in the study.

A total of 435 participants from 107 hamlets located within and around Danau Sentarum National Park took part in our study, comprising 56 Dayak hamlets and 51 Malay. Participants consisted of 316 men and 119 women, of which 19.63% were customary leaders, 28.97% represented formal institutions, and 51.40% were ordinary members of the community. Customary leaders have knowledge of tradition, beliefs, norms and history; representatives of formal institutions have more general knowledge of tradition and formal regulations; and ordinary members of the community have general knowledge, including the current level of understanding and adoption of these cultural traditions. By involving these three categories of participants we aimed to assess whether or not the taboos and norms were present and practised, as well as eliciting the younger generation's views on tradition and culture. The following ethnic groups were represented: Dayak (Iban, Tamambaloh, Embaloh, Kantu, Mantan, Kalis, Senganan, Kendayan) and Malay (Fig. 2).

One of most important factors influencing orang-utan populations is habitat health. Therefore we coded the condition of the forest in the proximity of a subsample of 20 of the study hamlets, based on the percentage of forest cover of a strip transect (40 m width, 2.12–6.14 km length), as follows: good, > 50% covered by forest, or old regrowth ex-cultivation area, or mixed agroforestry; medium, 25–50% coverage; bad, < 25% coverage. In parallel, we used these 20 transects to conduct a nest survey to estimate the orang-utan population (Russon et al., 2001; Mathewson et al., 2008) in those locations, which will be reported separately.

As our focus is on informal institutions and collective action we refer to the hamlet or longhouse as the social unit. Both interviews and focus group discussions focused on collective beliefs and practices in each social unit, forest use, and changes such as in the availability and accessibility of forest resources, orang-utan behaviour and perceived threats. Participants were

also asked how many orang-utans they had seen in the wild during 2010–2012 vs 1990–2000, based on the following categories: often, > 2 sightings per year; occasionally, 1–2 sightings per year; rare, one sighting in 3 years; never.

To obtain qualitative data for 1990–2000 we used a timeline and life history methodology, which is a primary methodology of anthropological fieldwork (Atkinson, 1998). We linked past forest conditions and orang-utan sightings with significant events for participants, such as a wedding, birth or death in the family, or working in Malaysia, or with wider social, political and environmental events that occurred in that period, such as the operation of a concession company, extreme drought, extreme flooding, presidency, illegal logging, or the first conservation research project. We used photographs, films and drawings to confirm a common understanding of local terms.

To study traditional land-use systems we focused on two major ethnic groups in the area: Iban Dayak and Malay. We used participatory sketching in five hamlets of Iban Dayak (Pelaik, Pengerak, Meliau, Seriang and Ensanak) and five of Malay (Semangit, Leboyan, Vega, Sekulat and Empanang). The hamlets were selected to coincide with the locations of the orang-utan population study.

In each hamlet participants were asked to discuss and draw the physical layout of their village and indicate the traditional land-use systems, the main natural resources essential for their livelihoods, the locations where orang-utans were commonly encountered, and other information related to the function of the forest from their perspectives. Information generated during discussions was fully documented and investigated further through in-depth individual interviews.

All interviews and focus group discussions were documented comprehensively. Data were clustered, coded and analysed by cross-tabulation. To identify factors that may have contributed to orang-utan nest densities we used generalized linear modelling to analyse data from the subsample of 20 locations, assigning number of nests as the dependent variable and existence of taboos or customary rules and habitat condition as independent variables. The null hypothesis was that the presence of orang-utan nests was affected by habitat condition, the presence of taboos or customary rules that prohibited people from disturbing or killing orang-utans, and the length of the transect. Transect length was included in the model as a covariate. Although the length of transect was standardized at 6 km, actual lengths were 2.12–6.14 km, adapting to geographical conditions in the field. To run the analysis we used *SPSS v. 22* (IBM, Armonk, USA). The model is as follows:

$$S_{\text{nest}} = f(\text{habitat, taboos, length})$$

The research team consisted of four facilitators, two ecologists (one female and one male), one anthropologist (male),

TABLE 1 The local typology of the orang-utan *Pongo pygmaeus pygmaeus* in the study area in Danau Sentarum, West Kalimantan, Indonesia (Fig. 1).

Local typology	Characteristics	Scientific typology
Mayas kesak	Small, with pale red hair	Juvenile female or male
Mayas rambai (Iban) or Mayas timbau (Malay)	Larger than the kesak, with darker red hair	Young female or male
Mayas capan	The largest individuals, with dark hair & cheek pads; sometimes aggressive	Adult flanged male

one statistician (male) and one geographical information system specialist (male). The facilitators were native to the area and thus able to communicate in the local languages: two Dayak males, one Dayak female and one Malay male.

Results

Local knowledge and perceptions of orang-utans

In the Dayak and Malay languages orang-utans are called *Mayas* and grouped into three distinct types (Table 1). This local typology is based on the orang-utan's body size, hair colour and whether their faces are flanged or non-flanged.

The majority of participants (64.12%) knew that orang-utans were protected by national legislation but only 4.76% could correctly specify the relevant law or sanctions. None of the participants knew of the existence of the National Strategy and Action Plan on Orang-utan Conservation. Despite this lack of knowledge about specific laws and sanctions we found that most participants belonging to Dayak sub-ethnic groups from the northern part of Kapuas Hulu, in particular Iban, Tamambaloh and Embaloh communities in 49 hamlets, were cognizant of, and respected, traditional beliefs, taboos and norms that facilitate the protection of orang-utans. There are five fundamental beliefs, taboos, norms and anecdotal stories that are well known, respected and have been practised by communities in those hamlets since 'they were children' or 'the era of their ancestors', the timeline they used to indicate decades ago.

The people in these hamlets believe that orang-utans are reincarnations of respected community members (e.g. their great grandfathers or customary leaders), and therefore disturbing or killing orang-utans is strictly prohibited. They also believe that their ancestors learned from orang-utans how to help with the delivery of human babies, take care of the newborn and the mother, and use medicinal plants, such as ginger. The Iban were told by their grandparents and great grandparents that they were helped by orang-utans during the ethnic war in the 1900s by driving away the enemies. In certain hamlets there are anecdotal stories about orang-utans protecting people from predators; for example, in the 1980s an orang-utan rescued a boy from a crocodile, and a male orang-utan rescued a woman from a

clouded leopard. Participants told these stories in detail and many claimed to have witnessed these events. Another belief shared by the majority of participants was that some orang-utans can become human during the day and return to being orang-utans after dark.

These beliefs have generated an aura of respect around orang-utans. Some participants said they always let orang-utans come into their gardens, especially when there was a scarcity of food for orang-utans in the wild. Although the majority of participants were not conversant with formal legislation, they fully observed and adhered to the traditional norms and taboos that prohibit disturbing, killing and eating orang-utans. In terms of gender differentiated data, we found that Dayak men and women share similar traditional knowledge and perceptions, yet play different roles in society. As acknowledged by the Dayak respondents, women play an important role in the transmission of beliefs, knowledge and values from generation to generation, whereas customary leaders play an important role in the cultural internalization among community members. The importance of the transmission and internalization of traditions, and their role in conservation, is increasingly recognized (Colding & Folke, 2001; Berkes et al., 2000). However such critical roles cannot be performed effectively. Many children move to other villages or towns to continue their education, and are therefore far away from their parents. Another challenge is the worry among young people that they will be called old-fashioned or irrational by outsiders if they maintain traditional beliefs.

Being in the same ethnic group does not always mean having and practising the same beliefs and taboos. In seven of the Dayak hamlets, hunting and consumption of orang-utans were not prohibited. Participants argued that Dayak men are well-known hunters, and if men return from the forest empty-handed this represents a loss of face for them and their families. They reported an increase in the human population and a decrease in forest area, with wildlife becoming scarce. Hunters often shoot any wildlife, 'including orang-utans, to avoid returning home empty-handed'. We interpret that these groups hunt orang-utans more for cultural reasons than for meat.

The Malay people do not have traditional beliefs and taboos specific to orang-utans. They enter the forest less frequently than the Dayak and are therefore relatively less

familiar with wildlife. Their religion prohibits them from eating fanged animals, and they interpret orang-utans as being in this category. However, prohibition to eat does not mean prohibition to shoot, and they have no social taboos related to orang-utans. Malay men in some hamlets, where rubber gardens and settlements are near the forest, admitted to killing orang-utans to protect their families when the animals come in close proximity.

As the Malay do not have informal institutions that support orang-utan protection, after each interview and focus group discussion with this group we provided information about orang-utans and the regulations for their protection, and observed their reaction. In one discussion, after learning of the dependence of orang-utan babies on their mothers, a customary leader shared his experience of seeing an orang-utan mother shot by his colleague in a concession area. The mother fell to the ground hugging her baby, and tried to expel her breastmilk into a leaf for the baby before she died. The customary leader now tells this story and reminds people not to shoot or disturb orang-utans. We observed that participants quickly developed empathy towards orang-utans when they learned of the dependence of babies on their mothers; however, they reacted with cynicism when informed about formal regulations.

Perceptions of the forest and conservation

When we asked participants what they thought about the forest, all (100%) answered that the forest is important for human well-being. We were surprised by the uniform answer and wondered if there was some bias (i.e. participants gave the answer that would please the research team) or if the question itself was leading. We therefore cross-checked by asking some more provocative questions to uncover any negative perceptions about the forest (e.g. 'You could be employed by companies, many facilities could be built, and you could have better lives if forests were converted for development projects such as oil palm or transmigration. Don't you think so?'). Their responses were consistent. They did not believe such development projects would improve their livelihoods, as they had been disappointed by previous oil palm projects. They were also aware that transmigration in other areas had marginalized indigenous people and caused conflict between indigenous people and migrants. They noted that the water quality and fish production in the wetlands had declined following the conversion of forest upstream for oil palm.

Their answers regarding the multiple roles of forest for human well-being can be categorized as follows: source of wild food, medicinal plants, timber and fibre (34.42%), wildlife habitat (24.04%), water (21.62%), sacred groves (16.36%), and other (includes maintaining ecosystem stability, the prevention of erosion, flood control, providing cooler air and oxygen, and regulating the dry and rainy seasons; 3.56%; Fig. 3).

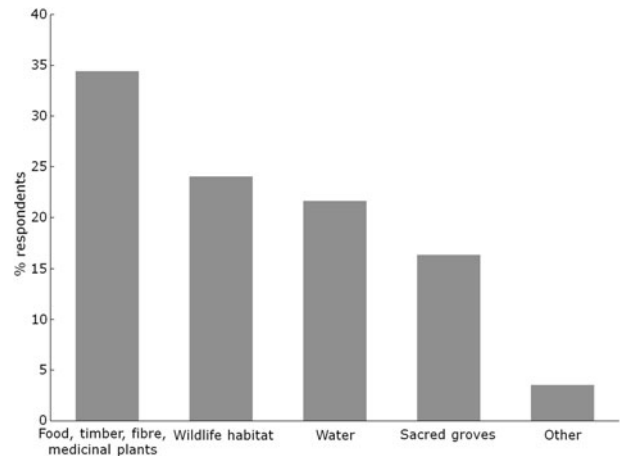


FIG. 3 Perceptions of the importance of forest among study participants.

Communities whose forests have been given over to oil palm companies expressed similar positive perceptions of the forest. We then asked them why they had given up the forests for oil palm plantations if the forests had been so important. They responded that they were more aware or had a better appreciation of the benefits of the forest (particularly water, timber for non-commercial purposes, and wildlife) after those benefits became scarce or were lost completely.

When asked what they felt or thought about the term conservation, participants indicated they had often heard the term, but their understanding of the meaning varied. They interpreted conservation as the formal institutions managing protected areas (e.g. national park authorities or conservation agencies) or as programmes or institutions that have tried to alienate indigenous people (e.g. by putting boundary markers and notice boards in place without communicating with the local people).

For balance we also interviewed the national park authority. They claimed they had communicated with people through socialization (*sosialisasi*, a term commonly used when the government announces new regulations or decisions). This kind of participation is categorized as passive participation, to announce what has been decided or has already happened. It involves 'unilateral announcements by an administration or project management without listening to people's responses' (Pretty, 1995). This shows the park authority's lack of understanding of participation and its primary objectives.

Traditional land-use systems

The importance of forests is also reflected in traditional land-use systems, which include customary protected forests and sacred groves, especially in the Iban communities. Iban land use in general consists of customary protected forests (*hutan lindung adat*), sacred groves (*pulau*), current

and past cultivation areas (*umai* and *damun*), forbidden lakes (*danau tutupan*), communal lakes and rivers for fishing, lowland and swamp forests, and community rubber gardens.

Sacred groves include graveyards (*pendam*) located in forests where hunting and collecting forest resources are strictly prohibited to respect those who are buried there. Former sites of longhouses (*tembawai*) are also considered to be sacred because they provided shelter and resources for their ancestors. These areas are generally covered by semi-natural mixed gardens of fruit, wood, spices, rubber and other plant species. *Ulit* forest is a patch of forest preserved for a recently deceased family member. Fishing in forbidden lakes is strictly prohibited at certain times to maintain fish populations. Communal lakes and rivers are managed as common resources, using local rules. Community rubber gardens are not traditional but are a new land use.

The Malay manage their land and water, based on the following uses: sacred forests believed to be guarded by spirits, communal forests for non-commercial uses of timber and non-timber forest products, graveyards, small-scale rubber gardens, cultivation areas, natural beehive areas, and protected and non-protected lakes and rivers for traditional fisheries. Unlike the Iban, Malay graveyards are located outside the forest and are not considered to be sacred. As wild-bee honey has become an important source of income, the Malay maintain beehive areas in as natural a state as possible (e.g. by preventing fire through regular monitoring). Indirectly, this has helped to protect the area from degradation.

Estimates of the orang-utan's minimum home range vary across studies (40–2,500 ha, depending on duration of the study, definition of home range, methods, and external pressures on the home range; Singleton & van Schaik, 2001). Sacred groves are considerably smaller than the the orang-utan's minimum home range, at c. 0.05–1 ha. However participants reported seeing orang-utans in protected forests and sacred groves, especially graveyards and former sites of longhouses, more frequently than in other land uses. This may be attributable to the presence of forest and complex agroforestry corridors, including fruit gardens, connecting the sacred groves.

Orang-utan sightings

Participants in both focus group discussions and in-depth interviews reported that sightings of orang-utans had been less frequent in the previous 2 years (2010–2012) than during 1990–2000 (Fig. 4). A χ^2 test with three degrees of freedom to compare the frequency of orang-utan sightings in 2012 vs 1990–2000 indicated a significant difference, with $P = 0.003$.

According to respondents the main causes of the decline in sightings are habitat loss caused by deforestation, forest

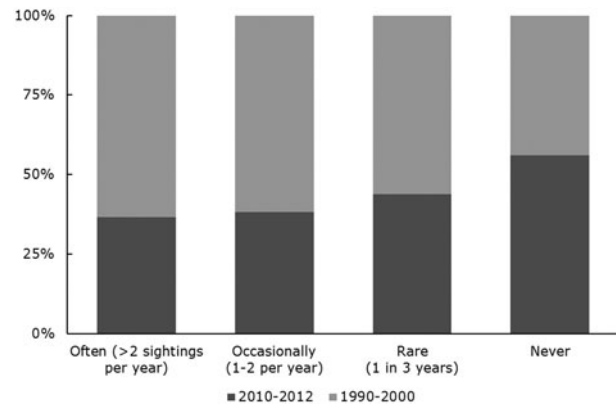


FIG. 4 The frequency of orang-utan *Pongo* spp. sightings during 2010–2012 compared to 1990–2000 shows significant decline ($P = 0.003$).

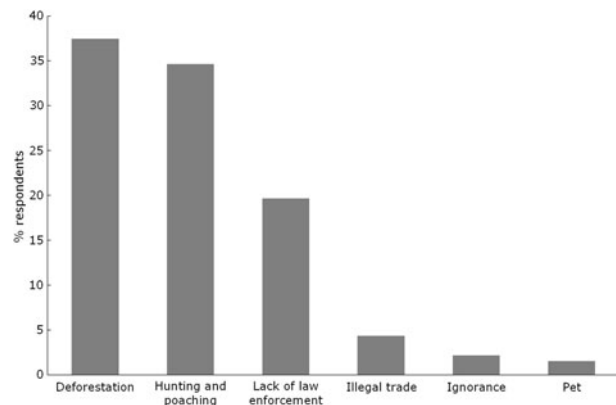


FIG. 5 Perceptions of the causes of decline in the orang-utan population among study participants.

conversion for oil palm and illegal logging (37.38%), followed by hunting, killing and poaching (34.58%), lack of law enforcement (19.31%), illegal trade (4.38%), ignorance in relation to customary and formal rules (2.19%), and taking of orang-utans for pets, which mostly involves outsiders, such as plantation staff (1.56%; Fig. 5).

The roles of informal institutions in orang-utan protection

The results of our generalized linear modelling show that the density of orang-utan nests was affected by the interaction between customary beliefs or taboos and habitat condition, with $P = 0.036$ (Table 2). The highest number of nests was found in locations with both taboos or beliefs and good habitat condition (Table 3). Each variable, when it occurred independently, did not have a significant effect on the number of nests. This shows the importance of informal institutions in addition to good habitat condition in protecting orang-utans in the wild.

We recorded one instance of the presence of orang-utan nests (mean number of nests = 33) in habitat of medium

TABLE 2 Results of generalized linear modelling of number of orang-utan nests, with independent variables.

Source	Type III sum of squares	df	Mean square	F	P
Corrected model	9,166.005*	5	1,833.201	2.641	0.070
Intercept	0.347	1	0.347	0.000	0.982
Length of line transect	764.944	1	764.944	1.102	0.312
Habitat type	305.377	2	152.689	0.220	0.805
Taboos	1.735	1	1.735	0.002	0.961
Habitat type × taboos	3,739.703	1	3,739.703	5.387	0.036
Error	9,718.945	14	694.210		
Total	28,609.000	20			
Corrected total	18,884.950	19			

* $R^2 = 0.485$ (adjusted $R^2 = 0.302$).

TABLE 3 Descriptive analysis of the interaction of habitat condition and taboos with number of orang-utan nests.

Habitat condition	Taboos	Mean no. of nests ± SD	No. of cases
Bad	Yes	1.50 ± 3.000	4
	Total	1.50 ± 3.000	4
Medium	No	33.00	1
	Yes	3.67 ± 3.215	3
	Total	11.00 ± 14.900	4
Good	No	0.00 ± 0.000	3
	Yes	43.44 ± 36.118	9
	Total	32.58 ± 36.535	12
All	No	8.25 ± 16.500	4
	Yes	25.50 ± 33.780	16
	Total	22.05 ± 31.527	20

condition where there were no taboos. Based on participatory sketching and focus group discussions, the people (Malay) in this particular location do not have livelihood activities in and around the forest, and therefore do not go there often. Their main sources of livelihood are traditional fisheries and small-scale rubber gardens, which are located far from the orang-utan habitat. We assume the infrequency of the people going to the forest and the isolation of the habitat have minimized disturbance to orang-utans. However, lack of dependence on the forest has another implication: the people do not attempt to protect the forest from threats, for example from fire. In 2013 there was a long dry season and some parts of the forest were burnt. The local people did not know the cause of fire. Their lack of motive to actively protect the forest could become an indirect threat to orang-utans and their habitat.

Discussion

The role of traditional knowledge systems in conservation

We have shown the presence of traditional beliefs and knowledge systems that facilitate the protection of orang-utans and

their habitat. The beliefs of most Iban communities have prevented hunting and killing of orang-utans, and the sacred groves and customary forests of the Iban and Malay have become refuges for orang-utans. Sacred groves are important in maintaining local identity, tradition and culture, and although the extent of individual sacred groves is too small for orang-utans to survive, people in most of the study hamlets protect the whole landscape, with its complex forest and agroforestry system, rather than sacred groves alone. Therefore, the extent of traditionally protected areas together with their connecting corridors is large enough to support a small population of orang-utans.

These traditional systems have been self-enforced, and customary rules are obeyed more than formal regulations. These are called intrinsic motives; i.e. they are psychological drivers of behaviour that do not depend on external stimuli (Ryan & Deci, 2000). Given the lack of law enforcement, a community's intrinsic motives and self-organization are important factors in achieving conservation objectives. We have shown that good habitat condition alone is not sufficient to support orang-utan populations. It needs to be supported by the presence of traditional knowledge, in particular taboos, and strong informal institutions that ensure transmission and internalization of the traditions. However, these traditional systems are challenged by a lack of proper recognition from formal institutions, coupled with social-cultural transitions and loss of ancestral heirlooms.

The importance of informal institutions vs lack of recognition

As shown by generalized linear modelling, the presence of good habitat alone without taboos was not effective for orang-utan protection. High densities of orang-utan nests were found in locations that had both strong traditional knowledge systems and good habitat condition, which is evidence of the importance of traditional knowledge systems for biodiversity conservation. Local people also possess knowledge and awareness of the major threats to the orang-utan.

Formal conservation institutions are not legally obliged or trained to recognize or to collaborate with traditional systems and informal institutions. Relations between communities and formal institutions are characterized by conflict and distrust, as both institutions consider themselves to be the owners and managers of the same land. To date, there are no regulations or formal technical training to facilitate collaboration or integration between the two. Ministerial Decree P.85/Menhut-II/2014 arranges collaboration mechanisms in the management of protected areas but only focuses on scientific and intervention activities and does not mention integration or recognition of traditional systems. Recognition of traditional systems largely depends on the willingness, capability and commitment of the leaders and members of both sides. Revisions of Forestry Law No. 41/1999 and Conservation Law No. 5/1990, which were underway at the time of writing, are expected to explicitly oblige formal institutions to respect and collaborate with informal institutions.

Social-cultural transitions and loss of heirlooms

Our respondents recognized that customary beliefs and traditional systems are challenged by strong social-cultural transitions. Young respondents were worried about being called old-fashioned for practising beliefs or obeying taboos. In addition, many children and young people have to move away from home to pursue their education, and thus away from their mothers, whose role includes passing along cultural values to their children.

Loss of ancestral heirlooms such as traditional musical instruments, weapons and other sacred heirlooms in the event of fire is another factor consistently mentioned as a cause of cultural degradation. There is a strong interdependence between biological and cultural diversity (Baer, 1989; Maffi, 2001), and therefore the degradation of traditional systems could impair the protection of orang-utans and customary forest. This highlights the need to adopt biocultural approaches in conservation, which are defined as 'conservation actions made in the service of sustaining the biophysical and sociocultural components of dynamic, interacting, and interdependent social-ecological systems' (Gavin et al., 2015).

We faced some methodological challenges, particularly in defining the unit of analysis for this study. Studying a community's informal institutions has to refer to a small social unit (e.g. hamlet, village or longhouse) where traditional norms and collective action are practised, whereas a study of an orang-utan population needs to be conducted at a larger scale, possibly encompassing several social units. Each location for our study of the orang-utan population comprised several hamlets, and therefore the forest condition and presence or absence of orang-utans may have been influenced by the application or non-application of informal institutions

of those hamlets. Although initially we aimed to conduct in-depth studies in 10 hamlets, to overcome these challenges we involved 107 hamlets to cover the entire area where the orang-utan population study was conducted; and the area where different or opposing views may have been present and may have influenced the orang-utan population.

Conclusions

Conservation of the orang-utan, or other species, is not a single-species issue. It requires maintaining social and natural capital, cultural diversity and ecological functions at various institutional levels and across geographical scales. Formal institutions need to be willing to share power, authority and responsibilities with informal institutions, and develop good communication and mutual understanding with them. Laws, regulations and performance indicators need to be revised to accommodate biocultural approaches. Formal institutions should be equipped with knowledge on environmental humanities, as well as practical skills to deal with multiple objectives and to conduct true participatory processes. As emphasized by Bennet & Roth (2015), the environmental humanities, including environmental history, environmental ethics and philosophy, eco-literary and eco-cultural studies, and the arts can help us to better understand and communicate about historical, current and envisioned relationships between people and nature. We also recommend that taboos and traditional regulations should be strengthened and accommodated in formal conservation regulations. Large-scale development programmes that could cause extinction of biocultural diversity should be prevented.

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Author contributions

ELY led the U.S. Fish and Wildlife Service-funded project Saving the Remaining Orang-utan Population Within and Surrounding the Danau Sentarum National Park, developed the overall research framework and research questions, collected data, and compiled, clustered and coded data for further analysis. HA developed methods and variables for social studies including traditional knowledge systems, formal and informal institutions, and policy, collected data, and facilitated focus group discussions. RA provided statistical guidance in developing the research framework, and conducted statistical analysis. DB, VH and JS provided input on local context, conducted field-testing to ensure the research framework and methods were relevant, and collected data. MAS conducted spatial data analysis of forest cover and land-use change. TS supervised the research to ensure it met scientific requirements and consensus for the great ape. All authors contributed to the writing of the article.

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