Population status of the Bornean orang-utan *Pongo pygmaeus* in a vanishing forest in Indonesia: the former Mega Rice Project

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Abstract As peat-swamp forests in Borneo become progressively more fragmented, the species that inhabit them are increasingly threatened, notably the Endangered Bornean orang-utan *Pongo pygmaeus*. The area of a failed agricultural project known as the Mega Rice Project in Central Kalimantan, Indonesia, is composed of fragments of peat-swamp forest that are reported to contain orang-utans, although no comprehensive survey has previously been conducted. In a portion of this area we identified remaining forest fragments, using satellite imagery, and surveyed line transects for orang-utan sleeping nests to determine the density, abundance and distribution of the species. The total area of peat-swamp forest in the study area is 76,755 ha, 59,948 ha of which comprises patches at least as large as the home range of a female orang-utan (250 ha). We estimate a mean population density of 2.48 ± SE 0.32 individuals km^{-2} and a population of 1,700 ± SE 220 or 1,507 ± SE 195 individuals, based on a 25 and 250 ha minimum patch size threshold, respectively. This is c. 40–45% of the original population, and the fragmented population is unlikely to be viable in terms of long-term demographic and genetic stability. To ensure persistence of this population of orang-utans, direct conservation action to connect forest fragments and prevent further loss of peat-swamp forest will be required, including re-establishing the hydrological regime, reforesting barren areas and fighting fires.

Keywords Borneo, distance sampling, Endangered species, orang-utan, peat-swamp forest, *Pongo pygmaeus*, population status, remote sensing

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Introduction

In their natural condition, lowland peat-swamp forests in South-east Asia provide invaluable ecosystem services at local and global scales. They prevent flooding, resist large-scale fires and sequester and store carbon (Page & Rieley, 1998; Page et al., 2002, 2006; Hooijer et al., 2006; Yule, 2010). They are also rich in endemic, rare and threatened flora and fauna (Ng et al., 1994; Yule, 2010). However, peatland areas all over South-east Asia, including in Kalimantan, Indonesia, are being degraded and fragmented, in part as a result of the development of oil palm plantations, other forms of agriculture, logging and the secondary effects of these disturbances, including drainage, peat subsidence and fire (Barr, 2002; Hooijer et al., 2006; Koh et al., 2011). By 2006 c. 45% of South-east Asia's 27 million ha of peat forest had been deforested (Hooijer et al., 2006) and projections of deforestation under a business-as-usual scenario indicate that just under half of the peat-swamp forest in Central Kalimantan may be lost by 2020 (Fuller et al., 2011).

As the forests of South-east Asia become more sparse, species that depend on these areas for habitat or breeding are increasingly threatened (Sodhi et al., 2004). Of particular note is the Bornean orang-utan *Pongo pygmaeus*, because some of the highest densities of this species are found in lowland peat-swamp forest (Husson et al., 2009). The Bornean orang-utan is categorized as Endangered on the IUCN Red List (Ancrenaz et al., 2008), with a decreasing population trend attributed primarily to forest loss (Singleton et al., 2004; Ancrenaz et al., 2008). Some researchers predict that the extinction of the orang-utan is imminent if current trends of forest loss continue (Rijksen & Meijaard, 1999; Williams, 2007; but see Meijaard & Wich, 2007).

Effective conservation efforts for these great apes will require accurate baseline information on their density and distribution. This information will be particularly important in unprotected areas, which are home to the majority of orang-utans (Singleton et al., 2004; Wich et al., 2012) and which remain vulnerable to conversion for commercial purposes. We present the first spatially explicit, landscape-scale analysis that aims to describe the status of the population of southern Bornean orang-utans *P. pygmaeus wurmbii* that inhabit an unprotected area known as Block C of the former Mega Rice Project, Central Kalimantan, Indonesia. Specifically, our objectives are (1) to identify the remaining forest patches in Block C that contain

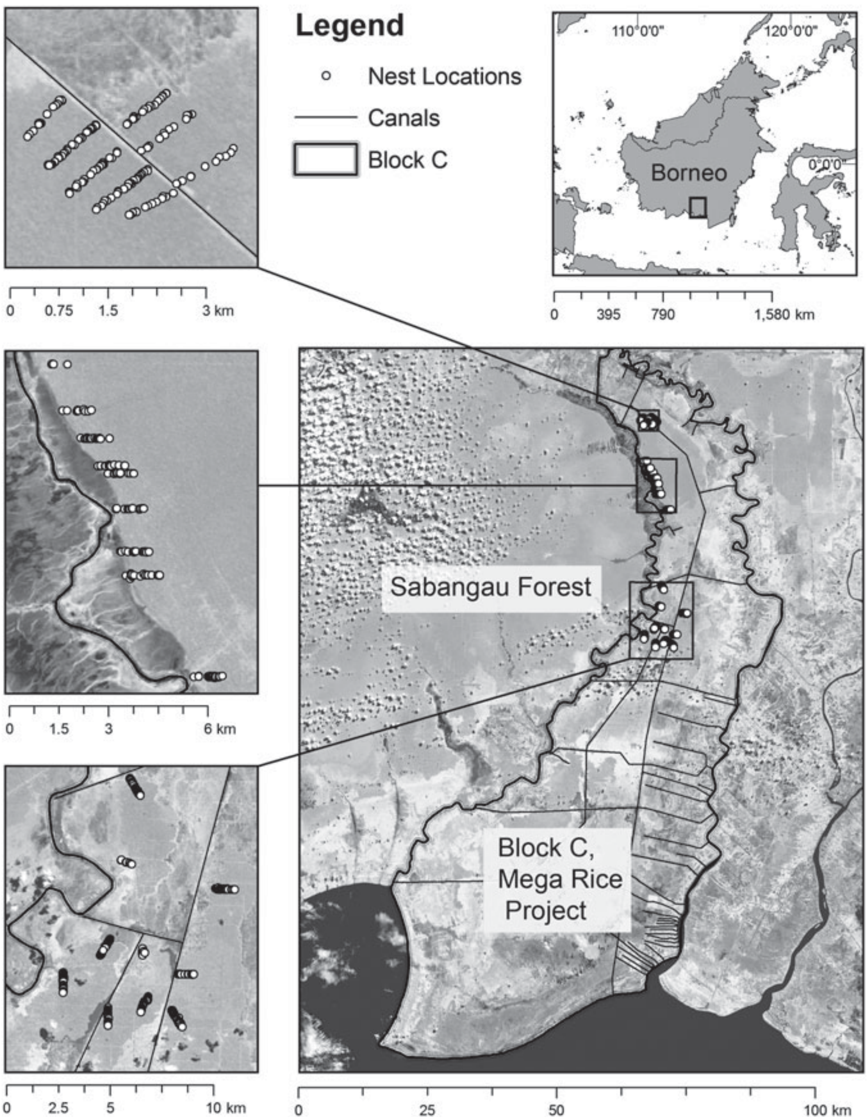

FIG. 1 Block C of the former Mega Rice Project in Central Kalimantan, Indonesia, including locations of orang-utan *Pongo pygmaeus* nests along survey transects.

orang-utans and quantify the total area of habitat remaining, and (2) to estimate the density and size of viable populations of orang-utans in these patches.

Study area

The Mega Rice Project in Central Kalimantan, Indonesia, is a failed agricultural project that was initiated in 1995 (Presidential Decree RI/82-26, 1995). Over 1 million ha of lowland peat-swamp forest, of a total of 6.8 million ha in Kalimantan, were targeted for conversion into rice paddies (Boehm & Siegert, 1999; Sabiham, 2004). Drainage and irrigation canals were constructed and forest was cleared. However, the project was abandoned because the soil proved to be too acidic for rice cultivation and the canals had drained the peat (Aldhous, 2004).

Our study area is Block C of the Mega Rice Project, which comprises five blocks in total (Fig. 1). Drainage canals were built throughout Block C but the forest was never cleared. Nevertheless, nearly 70% of the original peat-swamp forest in Block C had been lost as of 2000 (Boehm & Siegert, 2001), primarily as a result of fires caused by a combination of drought and drainage by canals during 1997–1998. Further forest loss was recorded during the dry seasons of 2002, 2004, 2006 and 2009. Block C remains designated for conversion to agriculture, and oil palm development has begun in the far south although the majority of Block C is protected under a temporary moratorium on logging and conversion. All of the fragmented forest patches in Block C are reported to contain orang-utans, but prior to this study no comprehensive census of the area had been conducted.

Methods

Land cover analysis and habitat identification

A land cover assessment of the study area was conducted using satellite data (Landsat 7 ETM+ data acquired 19 May

2008, the closest date prior to the study period for which relatively cloud-free data are available). The data were radiometrically and atmospherically corrected and we completed a supervised classification, using a maximum-likelihood decision rule, to categorize the data for Block C into the following land cover/land use categories: mature forest, degraded or secondary forest, grassland/shrubland, sparsely vegetated, barren or recently burned, cloud, cloud shadow, and water/inundated. Training sites for spectral signatures were based on our on-the-ground knowledge of the study area and global positioning system points that we collected in the field for each land cover/land use category (i.e. ground-truthing points). Focal statistics were used to reassign values to the pixels with no data or classified as cloud and cloud shadow. Although agricultural areas were difficult to distinguish from other categories because of their high spectral variability, the visible fine-scale irrigation canals running throughout made it possible to hand-digitize the agricultural areas. We used an error matrix to conduct an accuracy assessment using the ground-truthing points that were withheld from model development. Overall classification accuracy was > 85%. Irrigation canals (referenced shapefiles provided by Agata Hoscilo of Leicester University, UK) were incorporated into this classified image using *ArcGIS v. 9.3* (ESRI, Redlands, USA). We distinguished peat-swamp forest from other forest, including freshwater swamp, mangrove and heath forests, based on our on-the-ground knowledge and ground-truthing points. To identify patches of suitable orang-utan habitat, we retained only the mature and secondary or degraded peat-swamp forest classes and excluded patches < 25 ha, which are unlikely to provide habitat for orang-utans. We chose a 250 ha minimum patch size threshold, at the lower end of the best estimate of minimum home range size of female *P. pygmaeus wurmbii* in Sabangau (Singleton et al., 2009), to quantify remaining habitat that is likely to support orang-utans in the long term. Although it is possible that forest fragments < 250 ha contain resident orang-utans, fragments are isolated by burnt and deforested land, thus impeding movement between fragments and reducing the long-term viability of these fragments for orang-utans.

Density and population size estimation

Line-transect distance sampling (Buckland et al., 1993, 2001) for sleeping nests, a standard method for calculating ape abundance (Kuhl et al., 2008), was conducted during June–July 2009 as part of a multi-disciplinary research project run jointly by the Orangutan Tropical Peatland Project and the Center for International Cooperation in the Sustainable Management of Tropical Peatlands. Line transects were hand-cut systematically, with random starting points, through all accessible forested patches in Block C (Fig. 1). We did not survey patches that were physically inaccessible or that the property owner did not give us permission to access. A total of 27 transects (with a total length of 26.3 km) were surveyed. Observers walked slowly along the transects, looking in all directions for orang-utan sleeping nests. For each nest sighted, the distance along the transect and the perpendicular distance from the nest to the transect were measured.

We used *DISTANCE v. 6.0* (Thomas et al., 1998, 2010) to estimate orang-utan nest density. The software fits several possible robust, semi-parametric models to the data to determine the probability of detection as a function of the distance of the observed nest from the transect, or the effective strip width. The effective strip width was estimated regionally (across Block C). We selected a half-normal + cosine model key function/series expansion based on the lowest Akaike Information Criterion (AIC = 4,038.73). We divided the data into 10 equal intervals to smooth the histogram and improve the model (AIC = 2,620.34; probability of a greater χ^2 goodness-of-fit value, P = 0.19). Nest density was estimated locally (per patch) using the formula $d_n = N/L \times 2w$, where d_n is nest density (nests per km^2), N is the number of observed nests per patch, taking into account a 30 m truncation, L is the sum of the lengths of the transects (in km) per patch, and w is the effective strip width (in km); variance was derived using analytical estimates. We assigned the regional nest density estimate to the patches that were not surveyed.

To estimate population density we used the formula of van Schaik et al. (1995): $d_o = d_n/(p * r * t)$, where d_o is orang-utan density (individuals per km^2), d_n is nest density, p is the proportion of nest-builders in the population, r is the rate at which nests are produced (nests per day per individual) and t is the decay rate of nests, or time during which a nest remains viable (days). Accurate values of p, r and t are vital for producing accurate density estimates (Marshall & Meijaard, 2009) and these values, particularly t, can vary considerably between field sites (van Schaik et al., 1995, 2005; Morrogh-Bernard et al., 2003; Mathewson et al., 2008). We used parameter values derived from the adjacent Sabangau Forest ($p = 0.89$, $r = 1.17$, $t = 365.16 \pm$ SE 8.76; Husson et al., 2009), which is geographically close to, recently contiguous with, and ecologically similar to the Mega Rice Project area. We also included density estimates calculated using the full range of values reported for the parameters p, r and t in peat-swamp forests in Borneo (Table 3).

We estimated orang-utan numbers for each forest patch by extrapolating density estimates and the associated standard error to patch sizes derived from the satellite data. We applied a correction factor of 1.475, as suggested in Husson et al. (2009), to produce a standardized density estimate, which can be compared with standardized density estimates of other populations, calculated based on different survey methods. This correction factor accounts for depressed

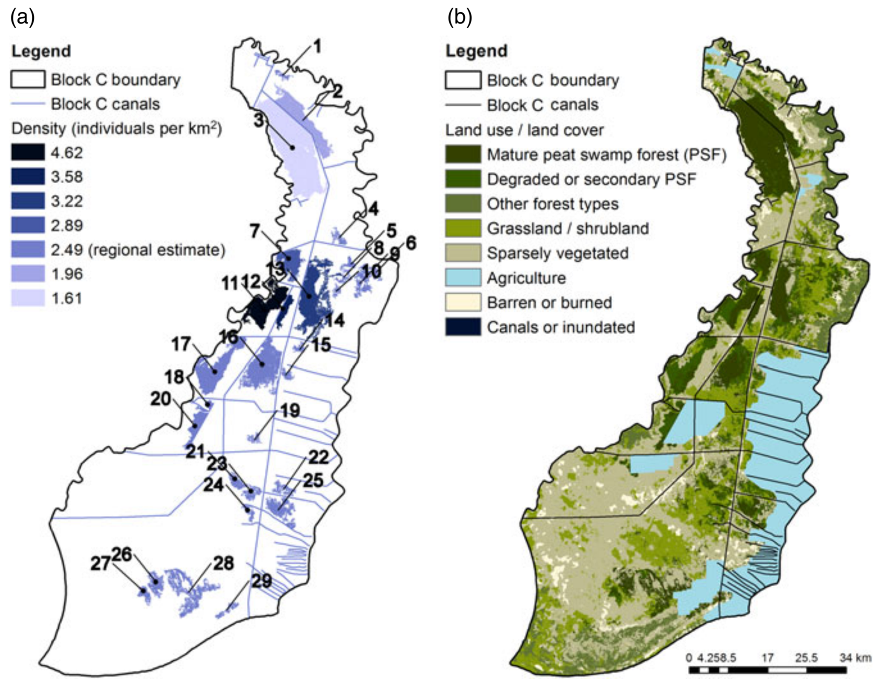

FIG. 2 (a) Land cover/land use in Block C of the former Mega Rice Project in Central Kalimantan, Indonesia. (b) Habitat patches of > 250 hectares and estimated orang-utan population density within Block C.

estimates of nest density based on a survey design in which line transects are surveyed only once, compared with line transects with a repeat survey technique or plots. To avoid overestimation we used our original uncorrected density estimates to calculate orang-utan numbers for each patch and extrapolate a minimum population estimate.

Results

According to the land cover/land use classification (Fig. 2), c. 10% of the area in Block C comprises peat-swamp forest (Table 1). This increases to 17% when degraded or secondary peat-swamp forest is included, which represents an area of 76,755 ha (Table 1), 67,718 ha of which comprises patches > 25 ha. The area of viable habitat (fragments > 250 ha) is 59,948 ha, distributed among 29 patches (Table 2).

The *DISTANCE* analysis indicates an effective strip width of 13.09 m for the survey, and a nest density estimate of 944.77 ± SE 103.07 km^{-2}. Orang-utan density estimates based on the range of published values for the parameters *p*, *r* and *t* in peat-swamp forests in Borneo vary from 2.27 ± SE 0.25 to 2.56 ± SE 0.28 km^{-2} (Table 3). Using the values for *p*, *r* and *t* from Sabangau, the density estimate for Block C is 2.48 ± SE 0.32 individuals km^{-2} and the standardized density estimate is 3.66± ± SE 0.47 km^{-2}. The density of orang-utans in the patches that were surveyed directly ranges from 1.61 ± SE 0.21 to 4.62 ± SE 0.60 km^{-2} (Fig. 2, Table 2). Based on patch-specific density estimates for the patches that were surveyed and the regional density estimate for the patches that were not, the population size over the entire Block C is 1,507 ± SE 195 to 1,700 ± SE 220 (Table 2), using 250 and 25 ha minimum patch size thresholds, respectively. It is thought that 250 individuals are a genetically viable population over the long term (Singleton et al., 2004), and none of the forest fragments support such a population, with the potential exception of patches 3 and 13, with 227 ± SE 29 and 232 ± SE 30 individuals, respectively (Table 2). However, none of these populations should be abandoned, as the larger landscape supports a large population, which highlights the importance of developing a management plan that incorporates orang-utan habitat connectivity in Block C.

TABLE 1 Land use/land cover in Block C of the Mega Rice Project, Central Kalimantan, Indonesia (Fig. 1), with land area and percentage of landscape.

Land use/land cover	Area (ha)	% of landscape
Mature peat-swamp forest	46,557	10.4
Degraded or secondary peat-swamp forest	30,198	6.7
Other forest types	29,823	6.6
Grassland/shrubland	76,489	17.0
Sparsely vegetated	163,665	36.5
Agriculture	78,267	17.4
Barren or burned	20,453	4.6
Canals or inundated	3,471	0.8

Discussion

We identified the density and abundance of Bornean orang-utan subpopulations and quantified the remaining habitat area in Block C of the former Mega Rice Project to

TABLE 2 Patch area, mean orang-utan *Pongo pygmaeus wurmbii* density, and mean number of orang-utans in each patch > 250 ha in Block C of the Mega Rice Project, Central Kalimantan, Indonesia (Fig. 1). The regional density estimate (Block C-wide) is applied to the patches that were not surveyed directly.

Patch	Area (ha)	Mean density ± SE (km^{-2})	Mean number of individuals ± SE
1	276	2.48 ± 0.32	7 ± 1
2	4,394	1.96 ± 0.25	86 ± 11
3	14,117	1.61 ± 0.21	227 ± 29
4	488	2.48 ± 0.32	12 ± 2
5	362	2.48 ± 0.32	9 ± 1
6	317	2.48 ± 0.32	8 ± 1
7	2,392	2.89 ± 0.32	69 ± 9
8	408	2.48 ± 0.32	10 ± 1
9	1,370	2.48 ± 0.32	34 ± 4
10	263	2.48 ± 0.32	7 ± 1
11	4,296	4.62 ± 0.60	199 ± 26
12	978	3.57 ± 0.46	35 ± 5
13	7,213	3.21 ± 0.41	232 ± 30
14	320	2.48 ± 0.32	8 ± 1
15	377	2.48 ± 0.32	9 ± 1
16	5,419	2.48 ± 0.32	135 ± 17
17	4,701	2.48 ± 0.32	117 ± 15
18	400	2.48 ± 0.32	10 ± 1
19	361	2.48 ± 0.32	9 ± 1
20	1,546	2.48 ± 0.32	38 ± 5
21	698	2.48 ± 0.32	17 ± 2
22	693	2.48 ± 0.32	17 ± 2
23	687	2.48 ± 0.32	17 ± 2
24	405	2.48 ± 0.32	10 ± 1
25	1,924	2.48 ± 0.32	48 ± 6
26	1,136	2.48 ± 0.32	28 ± 4
27	577	2.48 ± 0.32	14 ± 2
28	3,375	2.48 ± 0.32	84 ± 11
29	455	2.48 ± 0.32	11 ± 1
Total	59,948		1,507 ± 195

contribute to a more focused conservation effort for this population of c. 1,500–1,700 orang-utans.

Prior to the construction of irrigation canals in 1995–1996, Block C contained 233,275 ha of peat-swamp forest (Boehm & Siegert, 2001). Since then, c. 70% of the forest has been lost as a result of rapid forest fragmentation and subsequent drainage and fire, and the orang-utans have become confined to habitat fragments. The current population density may be temporarily inflated above the carrying capacity of the fragments, and therefore the population may be unable to persist in the long term because of this extinction debt (Tilman et al., 1994), as may also be the case in other areas that have experienced rapid loss of peat forest in recent history. Supporting this, our standardized density estimate of 3.66 ± SE 0.47 individuals km^{-2} for this site is relatively high compared to the adjacent Sabangau area, with a standardized density estimate of 1.12–2.49 individuals km^{-2} (Husson et al., 2009).

Using a density estimate derived from an intact mixed swamp forest area adjacent to the Mega Rice Project (nest density estimate 599 ± SE 78 km^{-2}; Morrogh-Bernard et al., 2003) as a pre-canal baseline, we estimate the original population in Block C to have been 3,676 ± SE 479 orang-utans, c. 55–60% of which have been lost. Unless the area of viable habitat increases, the population density will probably decrease further. If it decreases to 1.58 individuals km^{-2} (derived from an adjacent intact mixed swamp forest area; Morrogh-Bernard et al., 2003) the population on Block C would be reduced to 945 ± SE 123 (minimum patch size 250 ha) to 1,067 ± SE 139 (minimum patch size 25 ha) individuals, assuming no further loss of forest were to occur. This underscores the need to reforest barren areas and to connect existing forest fragments.

The effective conservation of this population will also require information concerning how orang-utan population ecology is affected by changes in habitat extent and spatial configuration. Although the effects of forest disturbance (e.g. logging) on orang-utan density and demography (Felton et al., 2003; Morrogh-Bernard et al., 2003) and behaviour (Hardus et al., 2012) have been documented, little is known about how orang-utans respond to a harsh non-forest matrix (e.g. barren or grassland areas) and how they use these non-forest areas, if at all. It is expected that they rarely disperse between forest fragments (van Schaik et al., 2001). This may not be the case in a multi-functional landscape, such as plantation matrix (Meijaard et al., 2010) or mixed agroforestry systems (Campbell-Smith et al., 2011a,b), but is probably the case in places such as the Mega Rice Project where the matrix is relatively harsh. However, if orang-utans traverse the matrix relatively frequently it is thought that small forest patches supplement the habitat area provided by larger patches. If we categorized all peat-swamp forest areas as habitat, the population estimate for Block C would increase to 1,925 ± SE 249.

We selected a 250 ha threshold for the minimum habitat patch size, based on the range requirements of female orang-utans (Singleton et al., 2009). However, male home ranges are larger (Galdikas, 1988; Nietlisbach et al., 2012) and they are not exclusive or stable (van Schaik & van Hooff, 1996). Thus, the spatial distribution of habitat patches is especially important for dispersal of male orang-utans and the resulting genetic variation in individuals and connectivity between meta-populations across the landscape. More research on the movement patterns of orang-utans in a fragmented landscape is required (see Goossens et al., 2005, for the genetic effects of fragmentation).

The importance of this population to the persistence of the species regionally and globally is an issue of value judgement and prioritization. The population has limited potential to connect to other populations of orang-utans, as it became functionally isolated from populations in the Sabangau Forest with the development of the city of

TABLE 3 Orang-utan density estimates for Block C, based on the range of published values for the parameters *p, r* and *t* for peat-swamp forests in Borneo and the standard error associated with nest density in our dataset (but not our parameter estimates). The best estimates for parameter values for Block C of the Mega Rice Project yield an estimated density of 2.48 ± SE 0.27 individuals per km².

p	*r* (*t* = 365[1,2])		*r* (*t* = 399[3])	
	1.15[4]	1.17[1,5]	1.15[4]	1.17[5]
0.88[4]	2.56 ± SE 0.28	2.51 ± SE 0.27	2.34 ± SE 0.26	2.30 ± SE 0.25
0.89[1,5]	2.53 ± SE 0.28	2.48 ± SE 0.27	2.31 ± SE 0.25	2.27 ± SE 0.25

[1]Best estimates for parameter values for Block C of the Mega Rice Project
[2]Husson (unpubl. data)
[3]Johnson et al. (2005)
[4]van Schaik et al. (2005)
[5]Morrogh-Bernard (unpubl. data)

Palangka Raya. In terms of numbers this population accounts for c. 2–4% of the global total and 4–5% of the subspecies *P. pygmaeus wurmbii* (Wich et al., 2008). However, every viable population contributes to the persistence of the species, and the Indonesian government has made a commitment to stabilize all populations of orang-utans and their habitat (Soehartono et al., 2007). Furthermore, this population is potentially the seventh largest population of *P. pygmaeus wurmbii* (Wich et al., 2008). For this population to persist, direct conservation action in the area will be required, including closing the irrigation canals, reforesting barren areas and fighting fires. Although efforts are being made to restore Block C, they are small-scale, limited and underfunded and this scenario is likely to continue if land is designated for conversion and not conservation.

The loss of peat-swamp forest could potentially be slowed by climate mitigation policies that provide financial incentives for avoiding carbon emissions. Peatlands have a large capacity for below-ground carbon sequestration and storage and, thus, an effect on global carbon cycles and climate change (Sorensen, 1993). The Oslo Pact (Solheim & Natalegawa, 2010) was initiated in 2011, with a 2-year moratorium on new permits for the conversion or logging of carbon-rich deep peatlands (> 50 cm) and of primary forest (Presidential Instruction No. 10/2011). It was extended for an additional 2 years (Presidential Instruction No. 6/2013), which could benefit peat-swamp conservation, particularly in Block C, the majority of which is protected under the moratorium. If the moratorium is properly enforced and continually renewed, it could have a significant effect on the area's capacity to support orang-utans in the long term. To evaluate the agreement's contribution to orang-utan conservation at the national scale it will be critical to determine to what extent the areas protected under the agreement overlap with orang-utan habitat.

In addition to supporting the moratorium we also recommend conserving the marginal, shallower peat zones that fall outside the protection of the moratorium. Management of these shallow areas is required to maintain water tables in the upslope, deep interior peat areas, and these are some of the areas in which orang-utan densities are highest. The highest priorities are to prevent further oxidation of peatlands, increase the quantity and connectivity of the forest for the resident population of orang-utans and decrease the likelihood of the detrimental peatland fires that have been occurring in this region since the 1990s.

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Biographical sketches

Megan Cattau uses remote sensing, geospatial analysis and modelling to research the effects of human alteration of the landscape on ecosystem service provision and on the associated species drivers. She is interested in the patterns and processes of forest community change following habitat alteration in peat-swamp forest. Simon Husson has worked on orang-utan conservation in Kalimantan since 1999, with a special focus on surveying unknown populations throughout the island, protecting populations in peat-swamp forest, and the reintroduction of ex-captive orang-utans to the wild. Susan Cheyne has worked in Indonesia since 2002 and is leading a long-term study of gibbon behaviour and ecology in peat-swamp forest as well as carrying out a detailed study of felid biodiversity and conservation in the area. She has carried out surveys on flying-fox hunting and abundance and is interested in how anthropogenic factors affect biodiversity in peat-swamp forests.