Final Report

Orangutan

Population and Habitat Viability Assessment

23-27 May, 2016

Bogor, Indonesia

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A contribution of the IUCN SSC Conservation Breeding Specialist Group

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Population and Habitat Viability Assessment

23-27 May, 2016

Bogor Indonesia

The Directorate General of Natural Resources and Ecosystem Conservation, Ministry of Environment and Forestry of Indonesia

In collaboration with:

Forum Orangutan Indonesia – FORINA

Orangutan Foundation-United Kingdom

IUCN SSC Primate Specialist Group

IUCN SSC Conservation Breeding Specialist Group

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Content

Acronyms and abbreviations

AAC	Annual Allowable Cut
BKSDA	Nature Conservation Agency; Indonesia (Balai Konservasi Sumber Daya Alam)
BMP	Best Management Practices
BNF	Borneo Nature Foundation
BOSF	The Borneo Orangutan Survival Foundation
BPN	National Land Agency
BTNK	Balai Taman Nasional Kutai
BTNS	Balai Taman Nasional Sebangau
BTNTP	Balai Taman Nasional Tanjung Puting
CBSG	Conservation Breeding Specialist Group (of the IUCN SSC)
COP	Centre for Orangutan Protection
ERC	Ecosystem Restoration Concession
FFI	Fauna and Flora International
FMU	Forest Management Unit (general)
FORINA	Forum Orangutan Indonesia
FR	Forest Range
GCN	Global Conservation Network
GD	Gene diversity
HCV	High Conservation Values
IUCN	International Union for the Conservation of Nature
LPF	Low pole forest
K	Carrying capacity
KHDTK	Special Purpose Forest Conservation District
KPH	Forest Management Unit (Indonesia)
MSF	Mixed-swamp Forest
N	Population size
NR	Nature reserve (CA)
NP	National Park
OFI	Orangutan Foundation International
OF-UK	Orangutan Foundation UK
OU	Orangutan
OUSAP	Orangutan Strategic Action Plan (for the Trans-boundary Biodiversity Conservation Area in Sarawak)
PE	Probability of extinction
PF	Protection forest (HL)
PHVA	Population and Habitat Viability Assessment
PVA	Population Viability Analysis
RMU	Rimba Makmur Utama
RRC	Rimba Raya Conservation
Satgas PMH	Mafia Eradication Task Force
SSC	Species Survival Commission (of the IUCN)
SVLK	Timber legality certificate
TNC	The Nature Conservancy
UNAS	Universitas Nasional
UNFCCC	United Nations Framework Convention on Climate Change
WCS	Wildlife Conservation Society
WR	Wildlife reserve (SM)
WWF	World Wide Fund for Nature
YIARI	Yayasan IAR Indonesia (NGO, orangutan rescue and rehabilitation)

Executive summary

Orangutans occur on the islands of Sumatra and Borneo (see Figure 1.). These iconic Indonesian species are the only great apes living in Asia. Both Sumatran and Bornean orangutans are classified as Critically Endangered by IUCN (IUCN 2016) and are protected by Indonesian and Malaysian law. However, the development of forest resources, which assists Indonesia and Malaysia to achieve economic development, has resulted in the loss and degradation of forests over the last 25 years, threatening the habitat of orangutans. This threat, in concert with others, such as the pressure of increasing human population, forest fires, oil palm plantations, mining, poor enforcement of wildlife law, illegal hunting/trade, and inconsistent policies on the management and functions of forested areas, threatens the very existence of these species in the immediate future.

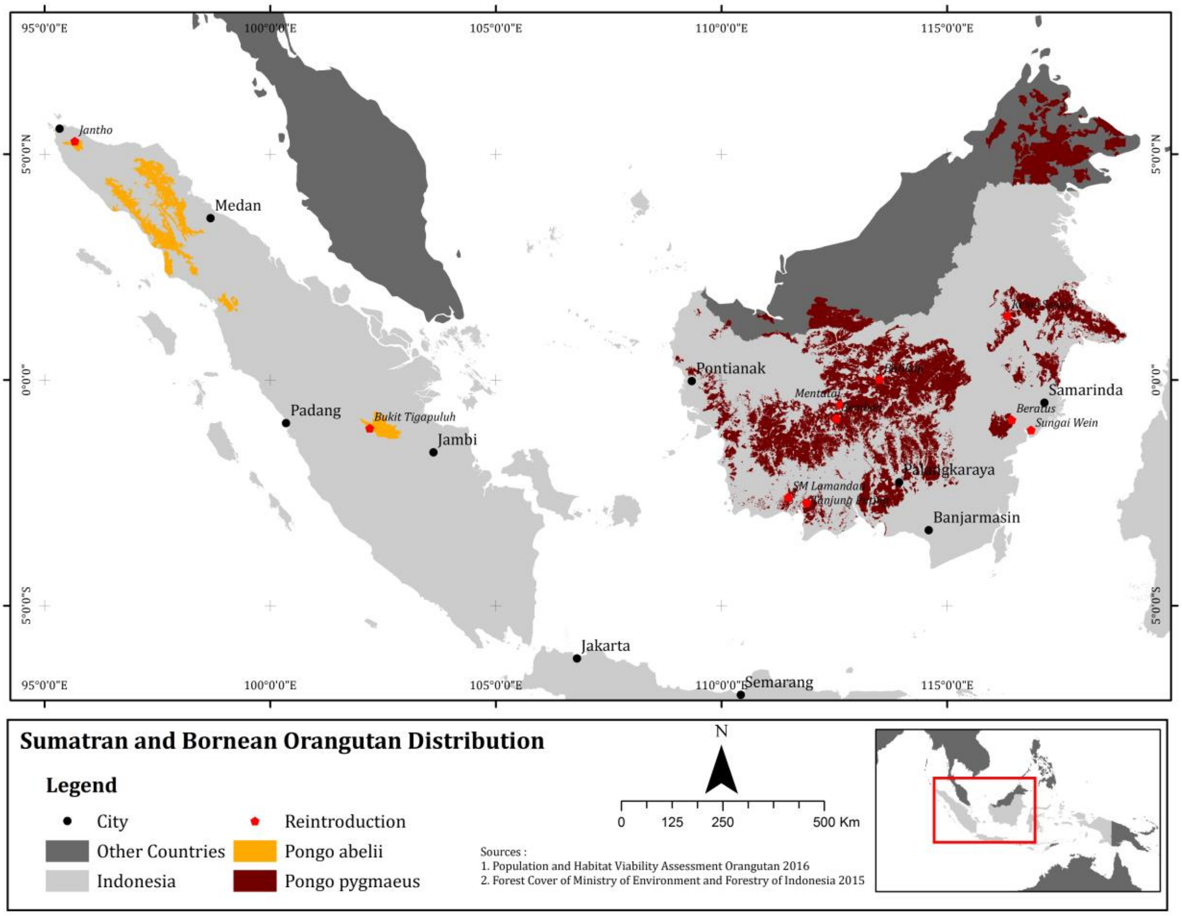

Figure 1. The distribution of Sumatran and Bornean orangutans based on Wich et al., 2016 (Sumatra) and on deliberations at the 2016 Orangutan PHVA (Borneo).

Wild populations of orangutans are in steady decline. This situation has long attracted attention from stakeholders, and in 1993 orangutan scientists and conservationists conducted the first Orangutan Population and Habitat Viability Assessment (PHVA), facilitated by the Conservation Breeding Specialist Group (CBSG) of the IUCN SSC. These assessments were updated and expanded at a second PHVA held in 2004 that integrated estimates of human-based threats, such as current and projected land-use patterns and illegal removals, into viability projections. Computer models were used to evaluate current and future risks of population decline or extinction under current and alternative management scenarios.

The results of the 2004 PHVA have provided important input for government policies, such as the Conservation Strategy and Action Plan for Indonesian Orangutans 2007-2017, the Sabah Orangutan Action Plan 2012-2016 and the Orangutan Strategic Action Plan (OUSAP) for the Trans-boundary Biodiversity Conservation Area in Sarawak. In Indonesia, the official launch of the policy, in December 2007 by the President of the Republic of Indonesia in Nusa Dua, Bali, in a parallel workshop of the Conference of Parties (COP) XIII–United Nations Framework Convention on Climate Change (UNFCCC), was a real political commitment by the government of the Republic of Indonesia to conserve orangutans. The policy, which was established by the Ministry of Forestry Regulation Number P.53 Menhut-IV/2007, also encourages coordination of orangutan conservation. Forum Orangutan Indonesia (FORINA), a central coordinating body for orangutan conservation established on 25 February 2009 with orangutan conservation communities, has regularly evaluated the implementation of the action plan, including in 2009, 2010, 2011, and 2013. Meanwhile, WWF-Malaysia has become the key implementing partner of the Sabah Orangutan Action Plan 2012-2016, and WCS Malaysia has become the key implementing partner of the Sarawak Orangutan Strategic Action Plan (OUSAP) for the Trans-boundary Biodiversity Conservation Area.

In 2016, after more than 10 years since the last PHVA, the Directorate General of Natural Resources and Ecosystem Conservation, in partnership with Forum Orangutan Indonesia (FORINA), the IUCN SSC Primate Specialist Group and the Orangutan Foundation-United Kingdom (OF-UK), conducted the third PHVA for orangutans. The IUCN SSC Conservation Breeding Specialist Group provided neutral facilitation and population viability analyses, and the workshop was made possible by a grant from Arcus Foundation. The resulting assessment, which is documented in this report, will provide important input for the revision of the national conservation strategy and action plan, the planning period for which ends in 2017.

The 2016 PHVA workshop

From 24-27 May 2016, 84 experts from 50 organisations gathered in Bogor, Indonesia, to share information on orangutan distribution, abundance, threats and conservation activities. On Day 1, the opening address was given by Ir. Bambang Dahono Adjie, MM, MSi (Director of Biodiversity Conservation of the Ministry of Environment and Forestry), setting the scene for workshop discussions. A series of brief presentations aimed to bring participants to a common understanding of the current situation for orangutans, the challenges ahead, and to some of the tools available to help plan conservation action for the species.

List of presentations:

- Introduction to IUCN SSC CBSG workshop processes (CBSG, Caroline Lees)
- Status review: a summary of the range-wide status of orangutans (FORINA-UNAS, Sri Suci Utami Atmoko)
- Progress report on the implementation of the Indonesian Orangutan Conservation Strategies and Action Plan 2007-2017 (Ministry of Environment and Forestry representative, Puja Utama.)
- Mixed survey analysis revealed declines in abundance of Bornean orangutans (*Pongo pygmaeus*) (Queensland University, Truly Santika)
- Modeling the density distribution of Bornean orangutans (Max Planck Institute, Maria Voigt)
- Overview of past and current orangutan *VORTEX* models (IUCN SSC CBSG, Kathy Traylor-Holzer)

Following the presentations, participants began work to:

- Update the collective estimate of the distribution and status of orangutans.
- Review and revise what is known about the issues threatening orangutans.
- Review and revise recommendations for priority conservation strategies for the four taxa.

Working groups were formed around each of the four taxa. Orangutans are currently distributed across a large geographic area. Within this area there is considerable variation in orangutan numbers, densities, degree of population fragmentation, and nature and severity of human-mediated risks. To explore species viability across this varied landscape it was first necessary to divide it into smaller population units, using the maps and information available. Each working group began by breaking down the geographic range of their taxon into a number of discrete, area-based population units, using the following hierarchy:

- **Regional units:** large, relatively well-defined regions within the range of each taxon.
- **Meta-population units:** areas within regional units bounded by rivers, roads and industry or other significant barriers to orangutan movement.
- **Habitat blocks:** areas of roughly contiguous habitat within meta-population units.
- **Sub-blocks:** specific sites of interest or within habitat blocks, such as national parks.

Once units were agreed upon, population size estimates and trends for each unit were discussed and estimated. For many sites, groups were able to use Geographic Information System (GIS) models to estimate current population sizes, site carrying capacity, and future rates of habitat loss. For other populations these estimates were based on survey data and the results of within-group discussion. Details of these estimations are provided in this report.

On Day 2, work began to clarify in detail the direct threats to orangutans, the obstacles to their effective conservation, and the relationships between these factors. The key points of these initial discussions are illustrated in Figure 2. New working groups were formed around the main categories of threat: habitat loss and degradation; hunting, poaching and conflict; and fire. An additional group was formed to consider challenges related to the management of small, fragmented populations and reintroduction. Groups worked to understand how each identified threat operates to reduce orangutan breeding and survival rates, and also to understand the drivers and root causes of these threats. For each threat, potential mitigating strategies were identified.

Taxon-based working groups reformed on Day 3 to consider which threats are either currently or potentially impacting each identified population, to what extent, and over what time frame. Each was asked to identify the: 1) main or most pressing threat for that taxon; 2) priority sites for action; and 3) most important or most urgent conservation strategies for those priority sites. Table 5 provides a summary of these recommended priorities.

GIS and PVA models

Preliminary GIS models were built for Sumatran and Bornean orangutans prior to the workshop and were refined during the PHVA. For sites where sufficient data exist, modellers were able to relate forest characteristics and patterns of human-use to observed orangutan density. These general rules were applied to areas for which survey data are absent or highly uncertain, to create systematic estimates of range-wide orangutan distribution and abundance.

Throughout the workshop and in the months following, population viability analysis (PVA) models were developed by revising previous PVA models based on information provided by the working groups. The models were built to consider the specific circumstances of individual populations and the expected impact of these circumstances on future viability. Wherever possible, to provide transparency and consistency, GIS-derived estimates were used in the PVA models for starting population size, site carry capacity, and expected future rates of habitat loss to orangutans. This was not always possible. At some smaller sites, survey data were considered more reliable than GIS estimates and in others it was not possible, in the time available, to align the GIS spatial designations with the complex site boundaries defined by working groups. This is an area for future work.

Results

In total, the working groups identified 55 population and metapopulation units for PVA analysis across Sumatra and Borneo, with population size estimates ranging from as few as 15 to as many as ~12,500 individuals. As far as possible, threats to orangutans at each site were identified, the estimated impact quantified, and these effects included in the models. A breakdown of the main findings is provided below, by taxon.

Pongo abelii

The designation of Sumatra orangutan (*P. abelii*) meta-populations follows Wich *et al*., 2016. Current population size and carrying capacity estimates are derived from GIS models, except in the case of the two release sites (Bukit Tiga Puluh and Jantho Landscape). **There are currently an estimated 14,613 Sumatran orangutans living in eight wild populations and a further 182 in two reintroduced populations.** Model results suggest that none of the eight extant wild populations of Sumatran orangutans are viable in the long term (500 years) under the projected rate and duration of habitat loss and harvest (removal of orangutans from the wild). Population fragmentation (e.g., due to road construction) is likely to increase the rate of decline and risk of extinction. The prognosis changes and viability becomes high in models where habitat loss and harvest are halted immediately. *The future of Sumatran orangutan populations will depend to a great extent upon the future rates of habitat loss, fragmentation, and harvest, and how long these threats continue before they are reduced or eliminated.*

Table 1. Summary of population viability analyses for *Pongo abelii* showing projected extinction risk at 100 and 500 years, for orangutans at each site, given the population and threat characteristics estimated by participants at the 2016 PHVA workshop, with **Initial N** from Wich et al., 2016.

Population	Initial N	Projected viability	Extinction risk at 100 years	Extinction risk at 500 years
West Leuser	5922	Poor	0.008	1
Sikulaping	261	Poor	0.15	1
East Leuser	5779	Poor	0.004	1
Tripa Swamp	212	Very poor	1	1
Trumon-Singkil	1269	Poor	0.000	1
Siranggas/Batu Ardan	87	Very poor	0.996	1
West Batang Toru	605	Moderate to poor	0.008	0.41
East Batang Toru	162	Poor	0.312	1
Bukit Tiga Puluh*	120	Good	0.000	0.016
Jantho landscape*	62	Good	0.000	0.000
TOTAL	14479[1]			

* Released populations – projections assume continued releases for 10 years

Pongo pygmaeus morio

Participants estimated that there are ≈ 9,791 – 22,221 *P.p. morio* in ~17 extant wild and released populations on Borneo. Data gaps and the difficulty of reconciling differences between GIS and site-based survey data did not allow for the development of individual site-based models for this taxon in the time available. However, the PVA results for Bornean populations in general as well as those for *P.p. pygmaeus*, provide a useful guide to the range of viability of *P.p. morio* populations under various conditions. A summary of these general viability assessments is given in Table 2.

Based on the available information, there are 6 large meta-populations, mainly in protected areas in Sabah, that are likely to show long-term viability as long as any loss of habitat or orangutans remains low and/or short term (Kutai NP, Tabin, Central Forest, Lower Kinabatangan, North Kinabatangan, Ulu Kalumpang). Trus Madi and Belayan-Senyiur landscapes represents a moderate-sized meta-population that may be vulnerable depending upon the level of habitat loss and removals that impact it. There are 7 meta-populations of ~150-300 orangutans each; populations of this size may be viable in the absence

[1] This figure excludes an estimated 317 individuals living in various small forest fragments, which were not included in the PVA analysis.

of threats but are vulnerable to loss of habitat and individuals. Three meta-populations are small (under 50 individuals) and subject to extinction risk even in the absence of threats.

These viability assessments for P.p. morio populations are meant to serve as a guide only. As more information becomes available on the size, available habitat, fragmentation and threats, the viability estimates for this taxon can be revised.

Table 2. Mean estimate of current population size, and likely trend, for 17 meta-populations of *P.p. morio*, as collated by participants at the 2016 PHVA workshop (see Appendix III for details), with relative viability estimates inferred from general PVA models. Viability decreases from green (high or good) to yellow (moderate) to orange (poor). GIS estimates of population size, where available, are shown in parentheses.

Meta-population	Mean est. of N (GIS)	Population trend	Viability w/ no habitat loss or removal	Relative viability with habitat loss	Relative viability with removals
Beratus Landscape*	35[#]	Declining	Poor viability without releases	Poor; cannot withstand loss of K	Poor; cannot withstand harvest
Sungai Wain Landscape*	20	Declining	Poor viability without releases	Poor; cannot withstand loss of K	Poor; cannot withstand harvest
Kutai NP-Bontang Landscape	1,700	Variable to declining	High viability (if not fragmented)	Good viability if K remains >500	Good viability if annual removal <1%
Belayan –Senyiur Landscape	224	Declining	Moderate viability (if not fragmented)	Moderate if K remains >200	Low viability if harvested
Wehea-Lesan PF Landscape*	623 (1909+2094)	Mostly declining	Good viability (if not fragmented)	Good viability if K remains >500	Good if annual removal <0.5%
Sangkulirang Landscape	311 (775)	Declining	Moderate viability (if not fragmented)	Moderate if K remains >200	Moderate if annual removal <0.5%
Tabin Range Landscape	1,255 (2,207)	Stable	High viability (if not fragmented)	Good viability if K remains >500	Good viability if annual removal <1%
Central Forest Range Landscape	5,325 (4,765)	Stable to declining	High viability (if not fragmented)	Good viability if K remains >500	Good viability if annual removal <1%
Lower Kinabatangan Range Landscape	1,243 (1,082)	Stable to declining	High viability (if not fragmented)	Good viability if K remains >500	Good viability if annual removal <1%
North Kinabatangan Range Landscape	1,900 (979)	Stable	High viability (if not fragmented)	Good viability if K remains >500	Good viability if annual removal <1%
Ulu Kalumpang Range Landscape	375 (226)	Declining	Good viability (if not fragmented)	Moderate if K remains >200	Good if annual removal <0.5%
Crocker Range Landscape	181 (106)	Stable	Moderate viability (if not fragmented)	Moderate if K remains >200	May reduce viability until N nears K
Lingkabau Landscape	150 (107)	Stable	Moderate viability (if not fragmented)	Moderate if K remains >200	May reduce viability until N nears K
Bonggaya Landscape	190 (104)	Stable	Moderate viability (if not fragmented)	Moderate if K remains >200	May reduce viability until N nears K
Ulu Tungud Landscape	29 (285)	Declining	Poor viability without releases	Poor; cannot withstand loss of K	Poor; cannot withstand harvest
Trus madi Landscape	282 (111)	Declining	Moderate viability (if not fragmented)	Moderate if K remains >200	May reduce viability until N nears K
Sepilok Landscape	200	Stable	Moderate viability (if not fragmented)	Moderate if K remains >200	Moderate if annual removal <0.5%

*Release populations (and part of Wehea landscape in Kehje Sewen forest)

[#]Based on survey in 1/5 total area

Pongo pygmaeus pygmaeus

Total population size for *P.p. pygmaeus* was estimated to be ≈5,725. Two large *P.p. pygmaeus* meta-populations (Betung Kerihun NP and Protection Forest, and Batang Ai-Lanjak-Entimau Landscape) have high viability under the conditions modelled and are projected to maintain about 5000 orangutans combined. Provided habitat loss ceases as projected, the smaller population at Danau Sentarum is projected to stabilize at 500-600 orangutans. *Protection of these large populations and their habitat will be critical for the persistence of this taxon on Borneo*.

None of the five remaining small fragments meets the viability criterion if they remain isolated, even if all threats are removed and the three smallest fragments are not viable under current projected high rates of habitat loss and/or harvest. The viability of small fragments can be greatly increased with the periodic release of translocated or rehabilitated orangutans.

Table 3. Summary of population viability analyses for *Pongo p. pygmaeus* showing projected extinction risk at 100 and 500 years, for orangutans at each site, given the population and threat characteristics estimated by participants at the 2016 PHVA workshop.

Habitat Management Unit	Estimated pop size	Projected viability	Extinction risk at 100 years	Extinct ion risk at 500 years
Betung Kerihun NP and Protection Forest**	2990	High	0.000	0.000
Batang Ai-Lanjak-Entimau Landscape	1808	High	0.000	0.000
Danau Sentarum NP and Corridor**	679	Good	0.000	0.002
Klingkang Range NP and Sintang Utara	80	Moderate to poor	0.001	0.272
Bungoh NP-Gunung Nyiut NR and Penrisen PF	94	Moderate to poor	0.000	0.191
Pygmaeus fragmented North	29	Poor	1.000	1.000
Pygmaeus fragmented South	15	Poor	1.000	1.000
Ulu Sebuyau-Sedilu Landscape	30	Poor	1.000	1.000
TOTAL	5725			

Pongo pygmaeus wurmbii

It is estimated that there are between 31,436 and 44,995 individuals of *P.p. wurmbii* remaining in West and Central Kalimantan (with a few individuals in South Kalimantan province). These occur in 10,170,196 ha of potentially suitable habitat, although they are absent (except for four recently reintroduced populations) from habitat units totalling 3,639,949 ha, resulting in an effective 2016 range of 6,530,247 ha. Five regional units were defined comprising 17 forest landscapes or 'meta-populations'.

Data availability for *P.p. wurmbii* was intermediate between that available for *P.p. pygmaeus* and for *P.p.morio*, with general estimates available for population size and threats. Table 4 provides the population estimates and relative viability assessment for each meta-population (excluding one landscape believed to be devoid of orangutans).

The long-term viability of most *P.p. wurmbii* meta-populations is moderate to poor under current estimated rates of habitat loss and removals. While most have no risk of extinction within 100 years, these meta-populations are projected to decline by 60-90%, reducing their size such that they may become vulnerable to stochastic threats and at risk. Only the three large meta-populations (Tanjung Putting NP, Sabangau NP, Arabela Schwaner) remain large after 100 years given projected threat levels. *Almost all populations (except for those few under 300 orangutans) may be viable if habitat loss and removal of orangutans were halted.*

Table 4. Current population estimates, trends and relative viability estimates over 100 years for 17 meta-populations of *P. p. wurmbii*.

Meta-population	Est. N (lower-upper)	Population trend	Relative viability w/ est. threats (for 100 yrs)	Relative viability w/ no threats (for 100 yrs)
Kubu Raya	798-1684	Declining	~86% decline; PE_{100}=0 N_{100}=111-235	Good viability Stable near K
Gunung Palung NP-Sg Putri	2620-3945	Stable/ declining	~86% decline; PE_{100}=0 N_{100}=375-562	High viability Stable near K
Pematang Gadung	499-775	Declining	~86% decline; PE_{100}=0 N_{100}=68-107	Good viability Stable near K
Sungai Tengar	101-211	Declining	~88% decline; $PE_{100}\leq$0.026 N_{100}=11-27; GD_{100}=0.88-0.94	Moderate viability Stable near K
Kendawangan-Jelai	31-66	Declining	$\geq$90% decline; PE_{100}=0.3-0.86 N_{100}=1-7; GD_{100}=0.68-0.81	Poor viability; decline, some extinction risk
Lamandau WR-Sukamara	516-752	Stable	~86% decline; PE_{100}=0 N_{100}=73-106	Good viability Stable near K
Kotawaringin Lama	437-850	Declining	~86% decline; PE_{100}=0 N_{100}=60-119	Good viability Stable near K
Tanjung Puting NP	3713-4655	Stable	~61% decline; PE_{100}=0 N_{100}=1441-1800	High viability Stable near K
Seruyan-Sampit	79-167	Declining	~88% decline; PE100$\leq$0.06 N_{100}=9-22; GD_{100}=0.85-0.93	Poor to moderate viability; small decline
Katingan	3334-4709	Declining	~86% decline; PE_{100}=0 N_{100}=472-663	High viability Stable near K
Sabangau NP	5943-6222	Stable	~61% decline; PE_{100}=0 N_{100}=2272-2417	High viability Stable near K
Rungan River Landscape	1724-2794	Declining	~86% decline; PE_{100}=0 N_{100}=247-401	High viability Stable near K
Kahayan-Kapuas	1065-2300	Declining	~86% decline; PE_{100}=0 N_{100}=151-331	High viability Stable near K
Kapuas-Barito (Mawas)	2000-3096	Declining	~86% decline; PE_{100}=0 N_{100}=281-434	High viability Stable near K
Barito Timur	144-307	Declining	~87% decline; PE_{100}=0-0.008 N_{100}=18-41; GD_{100}=0.92-0.96	Moderate viability Stable near K
Siawan-Belida	0	--	Not assessed	Not assessed
Arabela Schwaner	8432-12462	Stable	~59% decline; PE_{100}=0 N_{100}=3479-5133	High viability Stable near K
TOTAL	31,436 – 44,995			

Additional analyses

In addition to questions about the viability of individual populations, workshop participants posed additional questions for the PVA models, the answers to which can be summarised as follows:

What is the projected impact on orangutans of the construction of roads through orangutan habitat (e.g., in West and East Leuser, in West and East Batang Toru)?

PVA results for road fragmentation scenarios in this report are conservative, as they do not consider potential impacts of roads such as additional mortality or increased accessibility. Fragmentation alone did not greatly impact viability for large populations with no threat of habitat loss or removals. In the presence of such threats, fragmentation due to roads hastens decline and time to extinction and in most scenarios led to eventual extinction under current projected threats.

What is the smallest population size that can meet the agreed standards for a Minimum Viable Population (MVP)? How does this size change with different conditions or threat levels?

For this purpose, workshop participants defined a viable population as one with < 1% probability of extinction in 100 years and < 10% probability of extinction in 500 years. Given this definition, the MVP fis 150 for Sumatran orangutans and 100 for Bornean orangutans. However, populations of 100-150 demonstrate a slow declining trend and reduced gene diversity (i.e., inbreeding accumulation). A minimum population of 200 orangutans is needed for both species to retain 90% GD for 500 years, and at least 500 orangutans are needed to stabilize population size and avoid decline. All of these thresholds are higher if the initial animals are related or subject to increased threats.

What is the smallest current population that could meet the MVP standard if allowed space to grow larger (e.g., reintroductions into a new area, additional habitat added to an existing area)?

Populations of at least 50 orangutans are able to meet the MVP standard if they have sufficient space to grow, provided they are not under threat of habitat loss, fragmentation or harvest. These results are based on the current PVA model, which incorporates density-dependent reproduction and thus allows populations to grow at a faster rate at low density.

What level of periodic supplementation would be needed to maintain the viability of small populations below the MVP?

The supplementation rate required will depend upon the population size and threat levels. PVA results suggest that the addition of one young adult female every ~35 years can provide viability to a population of 50, while a population of 20 may need supplementation with one adult female every 13 years. Very small fragments may be at risk of losing their only breeding male and may require addition of an adult male in some cases.

What is the viability of populations established using a specified reintroduction scheme?

Release strategies may vary the age, sex and number of orangutans released as well as the length and schedule of release. A thorough assessment of reintroduction schemes is beyond the scope of this PVA. However, a specific scheme was modelled that involved four consecutive years of a large number of releases into a large area of unoccupied habitat. Releases were of sub-adult and young adults and were female biased. The combination of a young, female-biased population at low density promotes faster growth and overall population viability.

Full details of the PVA analyses are provided in this report.

Recommendations and next steps

On the basis of workshop deliberations, participants identified key threats, priority sites and priority strategies for each taxon, summarized below in Table 5.

Table 5. Summary of recommended priorities for orangutan conservation

Taxon	Main threats to the taxon	Priority populations	Recommended priority strategies
Pongo abelii	Habitat conversion & fragmentation, especially oil palm expansion, non-road infrastructure, and roads.	All orangutan populations, both wild and reintroduced.	• Moratorium on palm oil development • Closure of illegal roads • Law enforcement • Better spatial planning • Better forest management

Taxon	Main threats to the taxon	Priority populations	Recommended priority strategies
Pongo p. morio	Habitat conversion for industrial agriculture	Danum Valley, USM, Forest Foundation FC; Wehea Landscape (incl. Kehje Sewen); Kutai NP.	• Moratorium on palm oil development • Law enforcement • Better spatial planning
Pongo p. pygmaeus	Habitat conversion for industrial agriculture	Betung Kerihun NP and BALE landscape & Danau Sentarum NP.	• Moratorium: no new permits, no clearing forest within concessions.
Pongo p. wurmbii	Fires and habitat conversion for industrial agriculture	Arabela Schwaner; Tanjung Puting NP; Sabangau NP; Mawas; Rungan River; Gn Palung NP-Sungai Putri	• Law enforcement • Policy change: moratorium on peat land and natural forest conversion to other purposes. • Harmonise of regulations (MoEF, MoEMR, MoAgr, MoASP[2])

The next steps in pursuing these identified priorities are as follows:

- Developing a new National Orangutan Strategy and Action Plan for 2017-2027, including key elements such as law enforcement;
- Revising island, provincial, and district level spatial planning to mainstream orangutan conservation and synchronize policy and regulation among ministries;
- Responding to the recent change in conservation status of Bornean orangutans, released by the IUCN in 2016; and
- Using the orangutan as a benchmark for the monitoring and evaluation of 25 species conservation priorities in Indonesia.

[2]Ministry of Environment and Forestry (MoEF), Ministry of Energy and Mineral Resources (MoEMR, Ministry of Agriculture (MoAgr), Ministry of Agrarian and Spatial Planning (MoASP)

Threats to the conservation of orangutans

Threats to orangutan viability and conservation across the range were discussed by workshop participants, and the outputs are illustrated in Figure 2. To assist discussions, the threats described were grouped as follows: 1) Habitat loss and degradation; 2) Hunting, illegal capture and conflict; and 3) Fire. Working groups were formed around each of these categories. For the threats assigned, each group discussed and developed: a description of the threat or threats; their regional specificity and primary causes or drivers; specifically, how the threats affect orangutans; what is known about the threats, what is assumed, and what are the key data gaps in regard to achieving effective conservation; and what are the options for mitigation. A fourth group was formed to consider issues related to small population size, orangutan reintroduction projects, and disease. This group followed a different format than that of other groups as its deliberations were designed to be informed by population viability analysis models.

Habitat loss and degradation

Encroachment

In both Sumatra and Borneo, a lack of enforcement allows forest encroachment by local communities. Two types of effect were described:

1. Small scale agriculture

Limited and temporary but illegal clearance of forests by local communities reduces habitat for orangutans (by 100% in the area cleared), and may increase mortality through a small increase in human-orangutan conflict. This activity may lead to more extensive small-scale agriculture (see below).

2. Extensive small scale agriculture

Extensive and long-term or permanent illegal clearance of forest by local communities leads to orangutan population fragmentation in addition to habitat loss and increased mortality from conflict events.

Forest conversion

1. Industrial agriculture

In both Sumatra and Borneo, market demand, speculation, corruption, and the potential for government income and employment are drivers of large-scale forest clearance for palm oil, rubber and other industrial-scale crops. Benefits are mostly accrued by big corporations and local elites. It results in direct habitat loss (in which 100% of the area is lost to orangutans), habitat fragmentation, greater access and, as a result, more incidences of conflict and associated mortality. In peat areas, laying canals removes all available habitat for orangutans in the immediate area reduces the carrying capacity of surrounding areas.

2. Mining

This occurs in Sumatra and in Borneo outside Sabah. Forest clearance for mining is mostly conducted by big corporations but also includes illegal mining by local communities. Mining increases forest access and encroachment of settlements, which leads to habitat loss, increasing fragmentation and a small increase in mortality through human-orangutan conflict. Drivers for this are economic gain and market demand.

3. Infrastructure

In both Sumatra and Borneo, legal and illegal forest clearance for infrastructure, including geothermal, electricity, hydroelectric, and military infrastructure occurs. This may be initiated by government or the private sector as part of development programmes and is driven by poor governance, inappropriate government policy, lack of law enforcement, poor spatial planning, and the priorities of local elite. In areas where it occurs 100% of habitat is lost to orangutans and incidences of conflict increase.

Road construction

In both Sumatra and Borneo, road construction fragments orangutan populations, increases forest access and leads to encroachment and settlement expansion. Where habitat loss occurs it reduces carrying capacity by 100%. Drivers of this are government policy, poor spatial planning, corruption, economic development, the needs of the local elite, and the drive for better human access to areas, particularly where there are industrial concessions and for tourism.

Settlement

In Sumatra, and in Borneo outside Sabah and Sarawak, legal and illegal forest clearance for housing and agriculture occur to fulfil the demands of expanding local human populations, which include relocated disaster victims and those moved as a result of the government's transmigration program. Impacts on orangutans include reduced habitat and increased conflict leading to mortality. Drivers of these impacts are poor governance, inappropriate government policy, human conflict and natural disasters occurring in other areas, and poor law enforcement.

Logging

Logging can be carried out in a variety of ways and these can differ in their impact on orangutans.

Illegal logging

In both Sumatra and Borneo, illegal timber extraction within forest cover can temporarily reduce carrying capacity for orangutans and increase mortality due to orangutan–human conflict. Drivers or causes are considered to be poor governance and inappropriate government policy, lack of law enforcement, local timber demand, and the opportunities created through greater access for agriculture.

Low impact logging

In Borneo, logging activity that follows a "reduced-impact logging method" either fully or partially, does not reduce the carrying capacity of the affected habitat.

High impact logging

Also in both Sumatra and Borneo, logging activity that does not follow a "reduced-impact logging method" can significantly reduce carrying capacity for orangutans and increase human-orangutan conflict. The incidence of high impact logging is increased by poor controls and weak forest governance.

Timber plantation

In Sumatra and in Borneo outside Sabah and Sarawak, forest clearance for industrial timber crops, mostly carried out by big corporations and local elites, increases forest fragmentation and access, resulting in the loss of these areas to orangutans and increasing mortality considerably. Drivers are market demand, speculation, corruption, and the potential for government income and employment.

Absence of forest management units

In Sumatra and in Borneo (excluding Aceh, Central Kalimantan, Sabah and Sarawak), insufficient budget resources and coordination among related parties result in the absence of forest management units (KPH) to enforce regulation and protection, which leads to open access to forest resources and results in loss, fragmentation, further settlement and degradation.

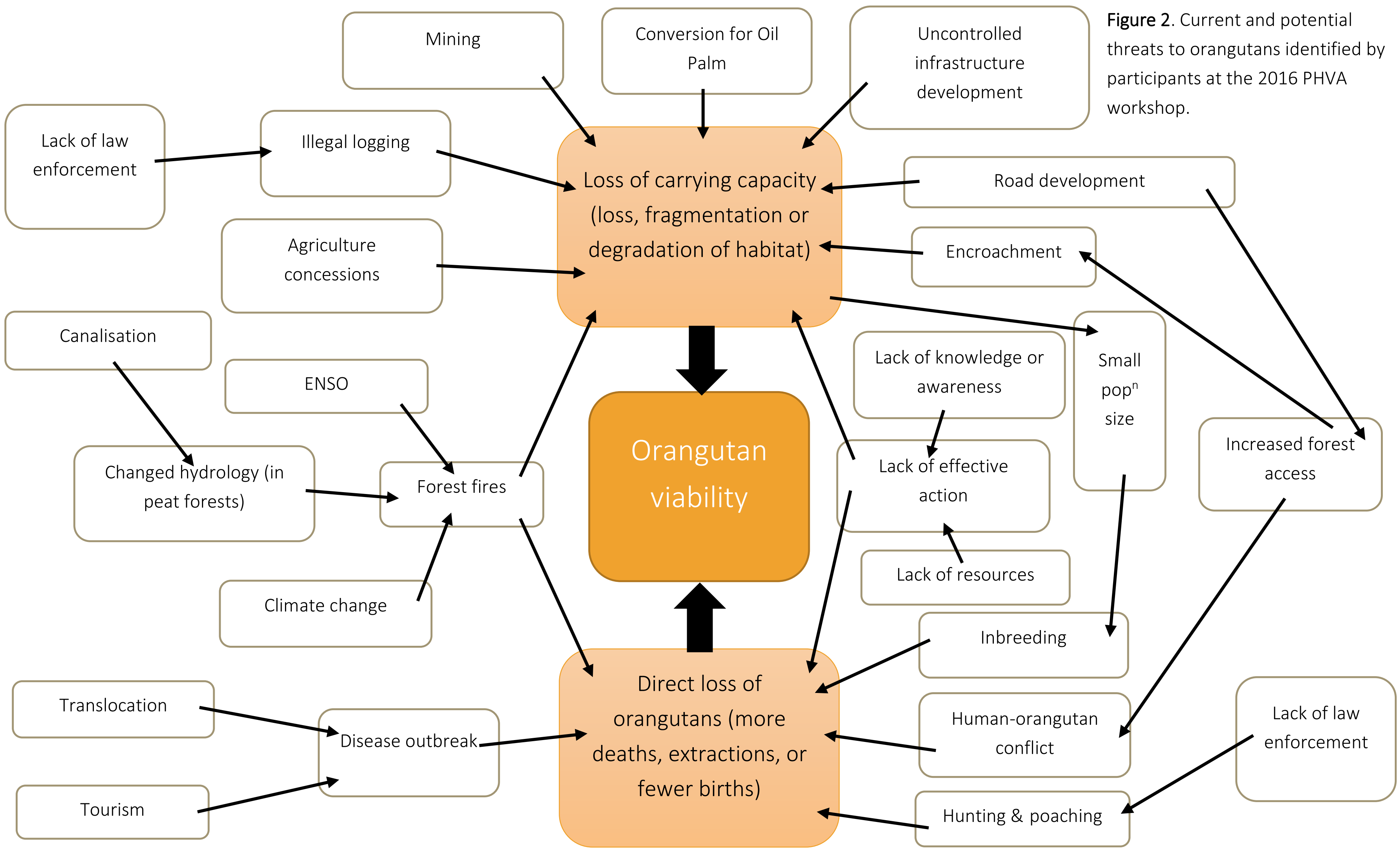

Figure 2. Current and potential threats to orangutans identified by participants at the 2016 PHVA workshop.

Hunting, illegal capture and conflict

This category included those threats that are expected to result directly in orangutan deaths or extraction (other than fire, which was dealt with separately).

Poaching (illegal capture)

In both Sumatra and Borneo, poaching or illegally capturing orangutans for domestication or trade could reduce the viability of wild populations directly. Where individuals are re-released there could be disease implications. In addition to the conservation implications there are negative welfare consequences for the animals taken. This activity is driven by lack of law enforcement, demand from the pet trade, lack of awareness of the law and misperceptions about orangutans, low income and the resulting incentive of potential economic gain, and opportunities created by increased forest access.

Hunting

Orangutans are killed as a source of food for subsistence; often this killing is opportunistic but not always. This occurs throughout the range but is more prevalent in Borneo. This additional mortality may increase the risk of local extinctions. It is thought that hunting played a role in some of the areas where orangutans do not occur anymore. Also it may have reduced overall density in many areas. Causes are low income and the opportunities created by increased forest access due to agricultural expansion and habitat alteration, hunting traditions in local culture and lack of Law enforcement.

Human-orangutan conflict

In cases of human-orangutan conflict, both parties may be impacted negatively and orangutans are often killed. Two main areas where conflict occurs were identified as:

1. Crop raiding

Orangutans that raid crops may be killed or wounded either as retribution for losses or defensively, out of fear.

2. Opportunistic hunting

Orangutans encountered opportunistically in the forests by hunters may be killed for food or poached for trade.

Agriculture expansion, habitat loss, and increased forest access increase the rate of human-orangutan encounters. Lack of knowledge of the protected status of orangutans, lack of awareness of the nature of orangutans, fear of economic loss, and poor law enforcement may all contribute to negative outcomes from these interactions.

In Sumatra there are more instances of small holder-based conflict. In Borneo the conflict is more often related to activities by timber and oil palm companies.

Fire

Impact on orangutan viability

There are a number of potential mechanisms through which fire events can impact orangutan population viability, such as direct killing, destroying and fragmenting the habitat, and reducing the carrying capacity (i.e., reduction of population size).

1. Habitat loss and fragmentation

Loss and fragmentation of habitat reduces the ability of orangutans to travel between trees and make nests. Access to food is reduced and vulnerability increases. Population density in remaining habitat increased, which may trigger conflict between orangutans, increasing mortality and facilitating disease outbreak. These conditions can also lead to reduced reproduction. The increased isolation of remaining fragments may in the long-term increase the likelihood of inbreeding.

2. Direct mortality and injury
Fire can kill orangutans directly, or indirectly as a result of haze. Others can be left with debilitating injuries.

3. Regional specificity
Peat swamp forest is particularly vulnerable to forest fires. The dried-out peat ignites easily and also burns underground, travelling unseen beneath the surface to break out in unexpected locations. Fire susceptibility in these areas is exacerbated by drainage and irrigation canals that alter the hydrology. Lowland *Dipterocarp* and heath forest are also at risk. All Kalimantan is dry, especially in the centre.

Causes

1. Climate Change
Forest fires occur during dry season and worsen during El Niño events. Climate change is expected to increase the frequency and severity.

2. Land use conversion
Uncontrolled fires set as part of land clearing strategies have increased the incidence of large fires. In some peat land areas, canalization due to drainage of the land has also affected the water table and make the peat land more vulnerable to fire.

Small population size, reintroduction and disease
The threats described above lead directly or indirectly to orangutan population declines. As populations decline to small numbers their dynamics are increasingly influenced by chance or "stochastic" effects. These effects are typically characterised as: environmental (random, unpredictable variation in factors such as temperature or food supply); demographic (chance-driven fluctuations in birth or death rates or sex ratio); catastrophic (extreme natural or human-caused events such as fire or environmental disasters); and genetic (the negative effects of inbreeding accumulation and gene diversity loss on population fitness and adaptive potential) (Shaffer 1987). Where populations remain small, these effects can be sufficient to drive populations to extinction even after the threats that caused the initial declines have been removed (Gilpin and Soulé 1986). These effects are relevant to orangutans in the following contexts.

Population fragments
A number of the orangutan populations considered at the 2016 PHVA workshop have been driven to small numbers as a result of habitat loss, fragmentation and extraction, resulting from the threatening process described in this report. Understanding which population fragments are likely to be experiencing the negative effects of small size can be helpful in considering where supportive management might be needed.

Reintroduction
The reintroduction of orangutans into areas where they do not currently exist involves an initial phase where the population is small in size and as a result disproportionately impacted by random events. Planning reintroduction programs can benefit from an understanding of what combinations of founder number, age, sex ratio, and ongoing supplementation rate might be expected to lead to successful establishment of orangutans at a given site.

Disease
Disease may contribute to fluctuating size in large populations but is rarely cited as a primary agent of extinction at the species level (Callum, 2012; McPhee & Greenwood, 2012). Though not expected to be a risk at the species level, for orangutans, disease may pose a risk at the individual population level, and this risk may be increased where populations are small and isolated, where there is overcrowding (e.g. after fires), where inbreeding has accumulated and general fitness levels are already compromised, or

where regular disturbance from human-mediated activity (e.g. tourism, orangutan reintroduction or translocation) may increases exposure to potential disease agents.

Potential mitigation strategies

For the threats described, working groups identified a list of potential mitigating strategies outlined in Table 6 below.

Table 6. Threats to orangutans and associated threat mitigation strategies as identified by participants at the 2016 PHVA workshop.

	Encroachment		Conversion					Logging									
Threats → / Potential mitigating strategies ↓	Small-scale agriculture	Small- scale extensive agriculture	Industrial agriculture	Mining	Infrastructure	Road construction	Settlement	Illegal logging	Low impact logging	High impact logging	Timber plantation	Absence of FMU	Illegal capture & hunting	Human-OU conflict	Fire	Small population risks	Disease risks
Enforce laws	X	X		X	X		X	X	X	X							
Improve law enforcement capacity within local and central government		X									X						
Prosecute law-breaking companies			X						X	X							
Close illegal roads						X											
Prevent new and re-locate existing, illegal settlements							X										
Strengthen monitoring, patrolling and enforcement capacity, and informant networks								X		X			X				
Operate patrols (Satgas PMH) in concessions			X								X						
Strengthen regulation, participation and reward and punishment in relation to protecting orangutans and biodiversity from fires																	
Implement SCS SVLK timber legality verification									X	X	X						
Educate and train law enforcers on the rules and regulations around forestry, biodiversity and the environment															X		
Impose a moratorium on Izin Pinjam Pakai Kawasan (legal land-use permit) for mining in orangutan habitat				X													
Impose a moratorium on agriculture expansion in orangutan habitat													X				
Impose a moratorium on new permits and on clearing forest within concessions			X		X						X						
Educate, socialise and raise awareness – promote a sense of ownership & responsibility for orangutans	X		X				X	X	X	X	X		X	X			
Promote alternative economic livelihoods	X					X		X	X	X			X	X			
Evaluate cost-benefit of long-term palm oil and timber plantations (with transparent, publicly available results)			X								X						
Promote supply chain transparency			X								X						
Encourage and incentivise sound spatial planning (provincial or district/city) and make the planning process and relevant information publicly accessible and transparent															X		
Improve spatial planning for orangutans (to include protection of critical conservation areas, reduced fragmentation from roads, effective corridors, settlements with reduced chance of human-orangutan conflict)					X	X	X				X		X	X		X	

	Encroachment		Conversion					Logging									
Threats → Potential mitigating strategies ↓	Small-scale agriculture	Small- scale extensive agriculture	Industrial agriculture	Mining	Infrastructure	Road construction	Settlement	Illegal lgging	Low impact logging	High impact logging	Timber plantation	Absence of FMU	Illegal capture & hunting	Human-OU conflict	Fire	Small population risks	Disease risks
Harmonise needs of land set-aside for conservation with plantation concessions & land resource (BPN) regulations			X														
Identify and manage HCV areas effectively									X	X						X	
Build corridors to connect HCV areas within concessions to neighbouring viable forest patches			X								X					X	
Implement Better Management Practices (BMP)			X	X					X	X	X						
Implement elevated roads to minimise impact						X											
Encourage effective replanting policies, reclamation and reforestation	X	X	X	X	X						X						
Encourage local community planting schemes on their lands, for community/personal use (e.g. house refurbishment)								X									
Strengthen multi-stakeholder partnerships around key issues such as law enforcement and fire (local, national, international)								X		X			X	X			
Equip companies with the knowledge to reduce human-orangutan conflict										X							
Build community capacity to respond to and mitigate human-orangutan conflict														X			
Set up conflict response units														X			
Encourage effective FMUs to support orangutan habitat in every region (population monitoring, conflict response, ecosystem restoration etc)												X					
Educate and train local community representatives and concession holders (e.g. mining, plantation and logging personnel) on the importance of a) early-warning systems and Standard Operating Procedures (SOPs) for alerting fire fighters, and b) fire management															X		
Awareness campaigns for preventing fire (warning signs, etc)															X		
Restore soil, plant, and hydrology (through canal blocking and habitat restoration, etc)															X		
Strengthen infrastructure and ensure the presence of a skilled fire management unit in every site or village community (wells, personal safety provisions, SOPs for fire-fighting, etc)															X		
Strengthen networking among stakeholders (regional, national, and international forest and land fire agencies)															X		
Increase research on fire risk management and its impacts on orangutan habitats and populations															X		
Strict tourism regulation																	X
Implement disease risk assessment and management in rehabilitation centres																	X
Raise awareness about disease risks in target audiences																	X
Include disease surveillance in post release monitoring and evaluation																	X
Develop a disease communication strategy (OVAG)																	X

	Encroachment		Conversion					Logging									
Threats → Potential mitigating strategies ↓	Small-scale agriculture	Small- scale extensive agriculture	Industrial agriculture	Mining	Infrastructure	Road construction	Settlement	Illegal lgging	Low impact logging	High impact logging	Timber plantation	Absence of FMU	Illegal capture & hunting	Human-OU conflict	Fire	Small population risks	Disease risks

Working group:
Pongo abelii

Working group members:

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Introduction

Pongo abelii is endemic to Sumatra, Indonesia. It is restricted to the north of the island. It was once far more widespread, occurring as far south as Jambi and West Sumatra provinces until at least the mid-1800s (see Rijksen, 1978; Rijksen & Meijaard, 1999). There were in fact reports of Sumatran orangutans in some parts of West Sumatra Province as recently as the 1960s, but many surveys found no evidence of their continuing survival south of the Batang Toru forest block area. There are only approximately 14,479 wild orangutans of this taxon left, inaddition to two reintroduction populations that at present number <150 individuals each (Wich *et al.,* 2016).. The taxon is categorized as Critically Endangered by IUCN (Singleton *et al.*, 2016).

The core populations are centered in Leuser Ecosystem, including Leuser National Park, Tripa Swamp, and Trumon-Singkil Swamp, as well as Siranggas/ Batu Ardan Forest and Sikulaping in Pakpak Bharat, North Sumatra. The other highly populated area is in Batang Toru forest block in North Sumatra. The Batang Toru population, estimated to be <800 individuals (Wich et al. 2016), is completely disjunct from the northern Sumatran orangutan populations and is now known to be genetically unique (Nater *et al*., 2015). In addition to the wild populations, two entirely new Sumatran orangutan populations are gradually being established through the reintroduction of confiscated illegal pets: one in and around Bukit Tigapuluh National Park (Jambi and Riau provinces), and one in and around the Jantho Pine Forest Nature Reserve in the far north of Aceh. All populations, including the two reintroduced ones, are shown in Figure 3. All current populations, both wild and reintroduced, are identified as a priority for *P. abelii* conservation, because the associated habitats have high potential to support viable populations and require intense protection.

Habitat conversion and fragmentation, due to agricultural expansion (e.g., oil palm, rubber, etc.), non-road infrastructure development (e.g., geothermal and hydroelectric plants), and road development, remain the major threats to orangutan survival over most of the range occupied by *P. abelii* (Wich *et al*., 2011). Habitat conversion is a direct threat to orangutan mortality, in some cases orangutans may be directly killed during the process of conversion, but often orangutans die due to lack of suitable habitat/resources, starvation, and malnutrition. Surviving infants are taken for illegal wildlife trade. All of *P. abelii* habitat in Aceh, both East and West Leuser, Tripa Swamp, and Trumon-Singkil Swamp face the problems associated with palm oil plantation expansion. Road construction also threatens sustainability of this taxon in West Leuser, East Leuser and Trumon-Singkil swamp. Non-road infrastructure (e.g., geothermal, hydroelectric, and mining operations) threaten core areas in East and West Leuser and West Batang Toru. The main strategies proposed for tackling and mitigating these threats are listed in Table 7.

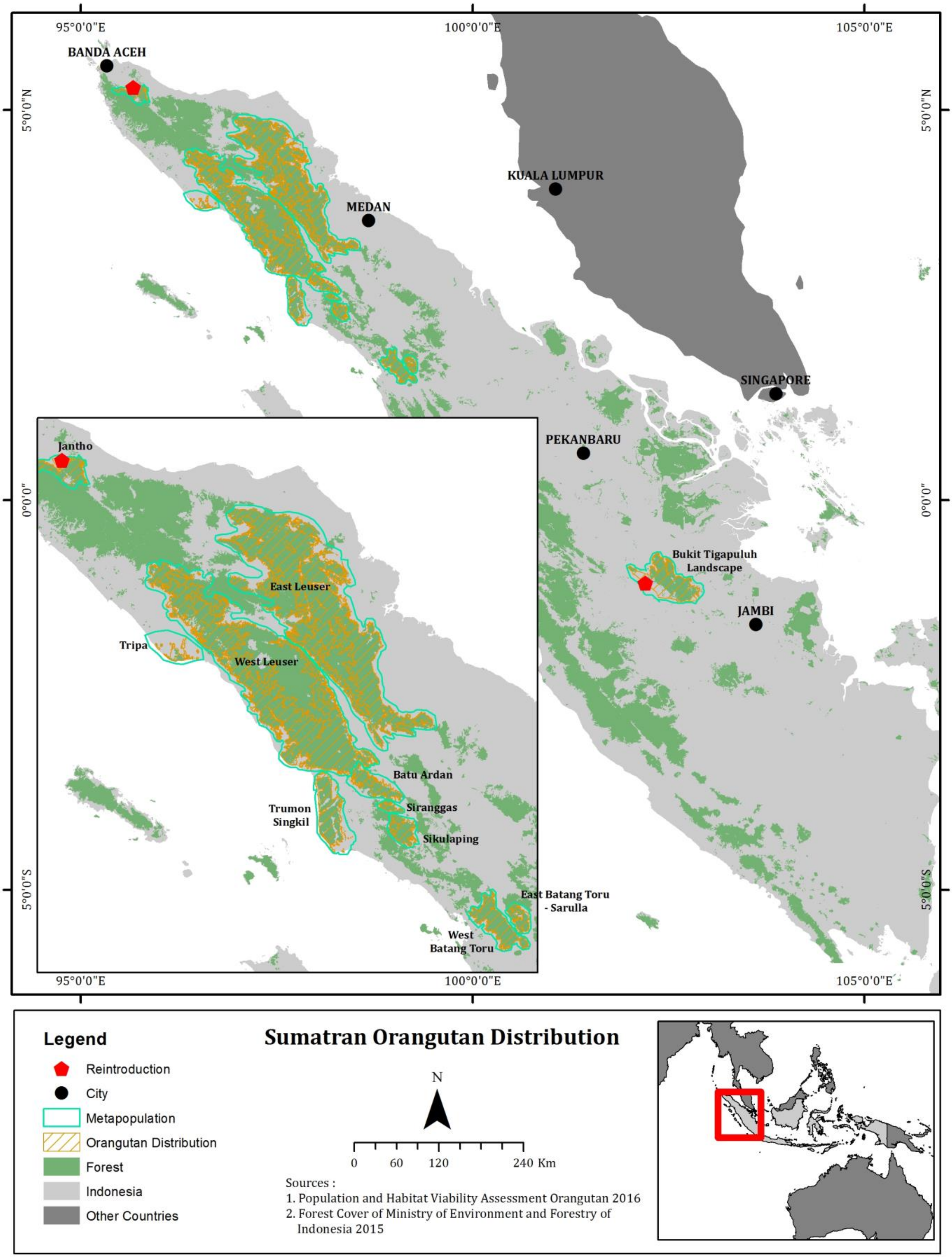

Figure 3. Map of Sumatra showing meta-population delineations for *P. abelii.*

Table 7. Summary of the main threats and recommended mitigation strategies, for *P. abelii*.

Threats	Mitigation Strategy
Agricultural conversion • Oil palm • Rubber	Better spatial planning
	Implementation of a moratorium on palm oil development
	Improved forest management
	Patrol and law enforcement operations
	Alternative livelihood promotion
Road construction	Better spatial planning
	Closure of illegal roads
	Improved forest management
	Patrol and law enforcement operations
	Alternative livelihood promotion
Non-road Infrastructure • Geothermal • Hydroelectric • Mining	Better spatial planning
	Improved forest management
	Stakeholder engagement
Agriculture encroachment	Patrol and law enforcement operations
	Improved forest management
	Stakeholder engagement
	Social forestry in target areas
	Alternative livelihood promotion

Pongo p. morio

Working group members:

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Introduction

Pongo pygmaeus morio is one of the three currently recognized subspecies of the Bornean orangutan (Goossens *et al.* 2009). This subspecies is found in the State of Sabah (Malaysia) and the Province of East Kalimantan (Indonesia). It is assumed that it no longer persists in the Province of North Kalimantan. There are 11 landscapes in Sabah recognized as this taxon's major habitat, with a total population size of 6,958-18,629 orangutans. Overall, *P.p. morio*'s populations in Sabah are in a stable situation because most of the habitats are in the protected forest. It is estimated that 4 of the 11 landscape habitats host more than 1,000 orangutans each, i.e: Tabin Range landscape (889 to 1,765 orangutans), Central Forest Range landscape (3,704 to 8,536 orangutans), Lower Kinabatangan Range landscape (822 to 2,169 orangutans) and North Kinabatangan range (1,016 to 3,043 orangutans). The three population units within the Central Forest Range Landscape, i.e: Danum Valley, USM, Forest Foundation FC, were also identified as priority populations in Sabah. Meanwhile in Kalimantan, most populations of *P.p. morio* are found outside protected areas in forests that are earmarked for conversion to other land uses. There are 6 landscapes in Kalimantan recognized as major habitat with a total population of between 2,833 and 3,592 orangutans. The core population of *P.p. morio* in Kalimantan is centered in Kutai National Park-Bontang landscape, which is estimated to support more than 1,000 orangutans (1,622 to 2,259 orangutans).

Some populations in Kalimantan are reintroduced: Beratus in Landscape Beratus, Sungai Wain in Landscape Sungai Wain and Kehje Sewen in Landscape Wehea-Lesan. The number of orangutans in Beratus landscape is estimated to be 30-40 (in 40,000 ha), from a total of 349 orangutans released between 1997 and 2002. The total area of Beratus landscape exceeds 200,000 ha and consists of Beratus Protected Forest, PT. ITCI and PT. BFI logging concessions. A through survey over a larger area is needed to provide better information about orangutans. The Sungai Wain landscape is in a critical situation since the Sungai Wain protected forest was reduced as a result of forest fire, encroachment, road construction (highway) in some locations, as well as Balikpapan botanical garden. A study on Sungai Wain is urgently needed to update information about the area and to identify appropriate next steps for supporting the remaining orangutans. It is estimated that the Kehje Sewen forest can support around 150 orangutans. The number in the rehabilitation center exceeds 200 and additional forest will be needed to house these animals.

Two priorities for conserving *P.p. morio* were identified as: Kutai National Park-Bontang Landscape and the forested area in Wehea-Lesan PF Landscape, which part of it located inside the concessions, and the customary forest of Wehea. The distribution of *P.p. morio* is shown in Figure 4 with agreed meta-population boundaries indicated.

The main threat to *P. p morio* populations in Kalimantan is habitat conversion for industrial agriculture, such as palm oil development and also timber plantation. Encroachment for small scale agriculture and illegal logging was also considered a serious threat for *P.p. morio* sustainability. The priority strategies for mitigating threats to *P.p. morio* are: improving law enforcement and establishing better spatial planning. Other recommended strategies are listed in Table 8.

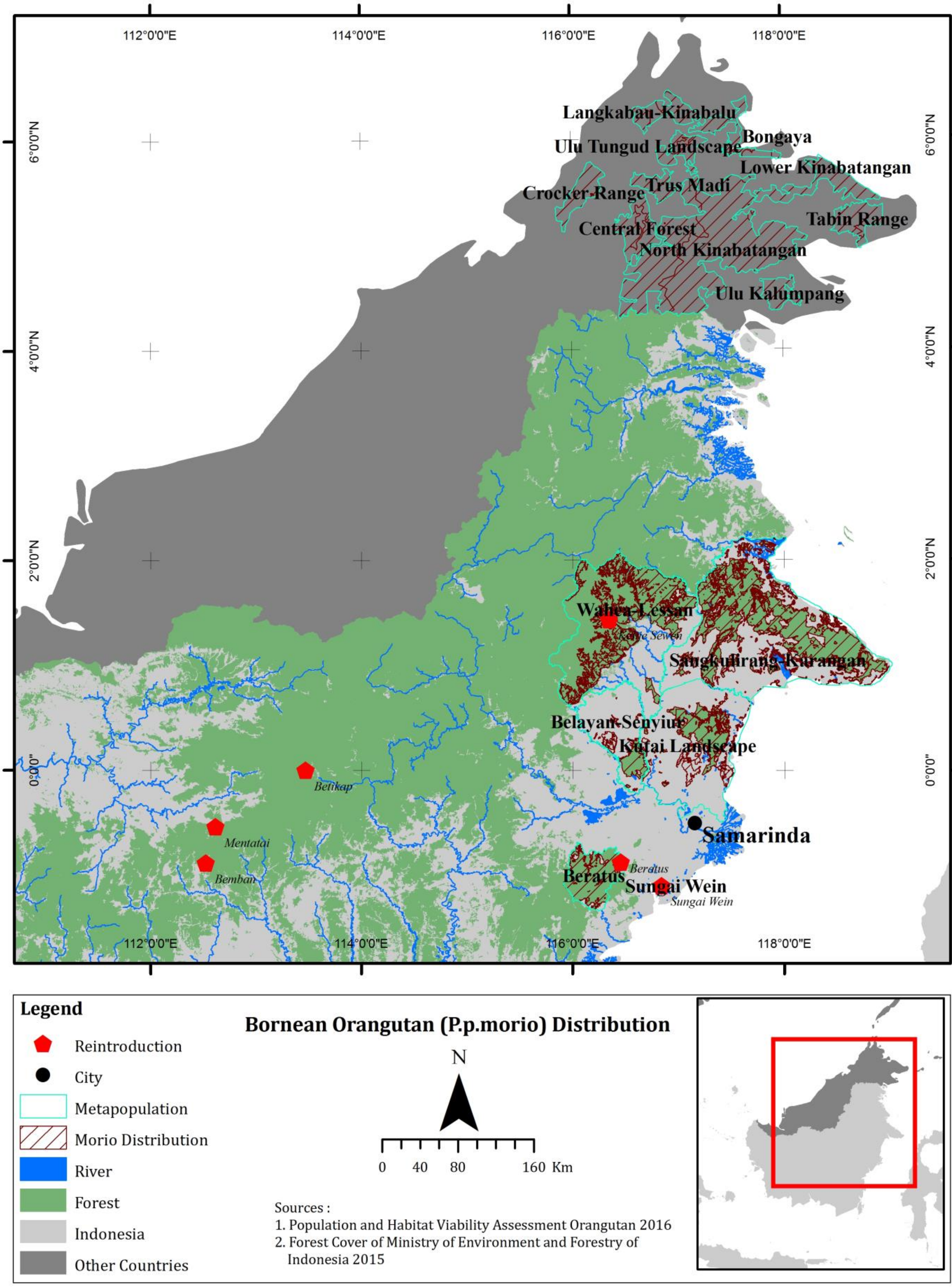

Figure 4. Map of Borneo showing meta-population designations for *Pongo p. morio*.

Table 8. Summary of the main threats and recommended mitigation strategies, for *P.p. morio*

Threats	Priority strategies
Encroachment: small scale agriculture	Law enforcement.
	Developing sustainable alternative livelihoods for local communities.
	Strengthening monitoring and patrolling capacity.
	Improving the capacity of forest management units.
	Intensive education and awareness programs.
	Strengthening multi-stakeholder partnerships (local, national and international).
Illegal logging	Law enforcement.
	Encouraging local communities to plant local timber species on their land/garden, for their own use or to meet local demand (i.e. housing).
	Strengthening monitoring and patrolling capacity/informant networks.
	Intensive education and awareness programs.
	Strengthening multi-stakeholder partnerships (local, national and international).
Conversion for industrial agriculture	Law enforcement.
	Moratorium (no new permits and no clearing of forest within concessions).
	Building corridors connecting High Conservation Values (HCV) areas within concessions to viable forest patches/landscapes. Where not possible and where this threatens the orangutan population of orangutan, the last resort is to relocate to a suitable area with full responsibility taken by the company (i.e. budget, location and other resources).
	Strengthening monitoring and patrolling capacity.
Road construction	Revising spatial planning to reduce fragmentation of orangutan habitat from road development.
Poaching/Hunting	Law enforcement.
	Promoting better spatial planning.
	Intensive education and awareness program.
	Developing sustainable alternative livelihood for local communities.
	Strengthen multi-stakeholder partnerships (local, national and international; including private sector and local community).

Pongo p. pygmaeus

Working group members:

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Introduction

Pongo pygmaeus pygmaeus is one of the three currently recognized subspecies of Bornean orangutan (Goossens *et al.* 2009) and is categorized as Critically Endangered by IUCN (IUCN, 2016). This taxon is found in West Kalimantan (Indonesia) from north of the Kapuas River to the eastern part of Sarawak (Malaysia). It has the smallest range of the three Bornean orangutan subspecies, with only approximately 3,887 individuals remaining in West Kalimantan and 1,838 individuals in Sarawak. The core populations are centered in a trans-boundary conservation area that covers Betung Kerihun National Park in West Kalimantan and Batang Ai National Park/Lanjak Entimau Wildlife Sanctuary complex in Sarawak, also known as **Betung Kerihun NP and BALE landscape**. These protected areas are together the largest contiguous orangutan habitat for *P.p. pygmaeus*, for which there are limited research publications. This area would probably have the best chance of supporting a viable population and currently is the most secure area for orangutans because the land use status is national park, wildlife sanctuary and/ or district strategic zone (Kawasan Strategis Kabupaten), which means that most of this area is already protected.

Another highly populated area is in Danau Sentarum NP and its buffer zone in West Kalimantan. This habitat is also a priority site because it is the second largest orangutan habitat with half of the forested area protected as a national park and is proposed for connection to Betung Kerihun NP landscape by the Labian-Leboyan wildlife corridor. Small populations can still be found in Ulu Sebuyau National Park and Sedilu National Park in Sarawak, as well as some fragmented areas in coastal West Kalimantan, both in the northern and southern parts. Meanwhile, two trans-boundary areas: Klingkang Range National Park in Sarawak and Sintang Utara Protection Forest in West Kalimantan; and Bungoh National Park in Serawak and Gunung Nyiut Nature Reserve-Penrisen Protection Forest in West Kalimantan, are also suspected to still support small populations of orangutans.

Poaching remains the major threat to orangutan survival over most of the range occupied by *P.p. pygmaeus,* although two major populations and some other smaller ones reside in protected areas. In addition, large numbers that existed on the western side of West Kalimantan have been lost due to recent forest conversion for industrial agriculture, such as palm oil and timber plantation. The remaining forested areas in this location are under very high pressure from habitat loss, conflict killing and hunting. The other priority threat affecting orangutan sustainability is road construction along the border in Kalimantan. The border road project will construct 171 km of road in West Kalimantan and 78 km in North Kalimantan. This project will potentially fragment orangutan populations, increase forest access and lead to encroachment and settlement expansion in orangutan habitat, such as Sintang Utara Protection Forest, Gunung Nyiut Nature Reserve, Penrisen Protection Forest, and Betung Kerihun National Park. Fire is not considered an important threat in *P.p. pygmaeus* areas, even in Danau Sentarum NP which is commonly burned by the local community (fishermen) during the dry season, but the burning does not take place in orangutan habitat. The main strategy proposed for mitigating threats is a moratorium on habitat conversion. This moratorium must include no new permits that could potentially convert orangutan habitat, and no clearing of remaining forest within concessions. There is also a need to increase intensive study of the behaviour and ecology of *P.p. pygmaeus*. Other recommended strategies for threat mitigation are listed in Table 9. The distribution of *P.p. pygmaeus* is shown in Figure 5 along with the meta-population boundaries agreed at the PHVA workshop.

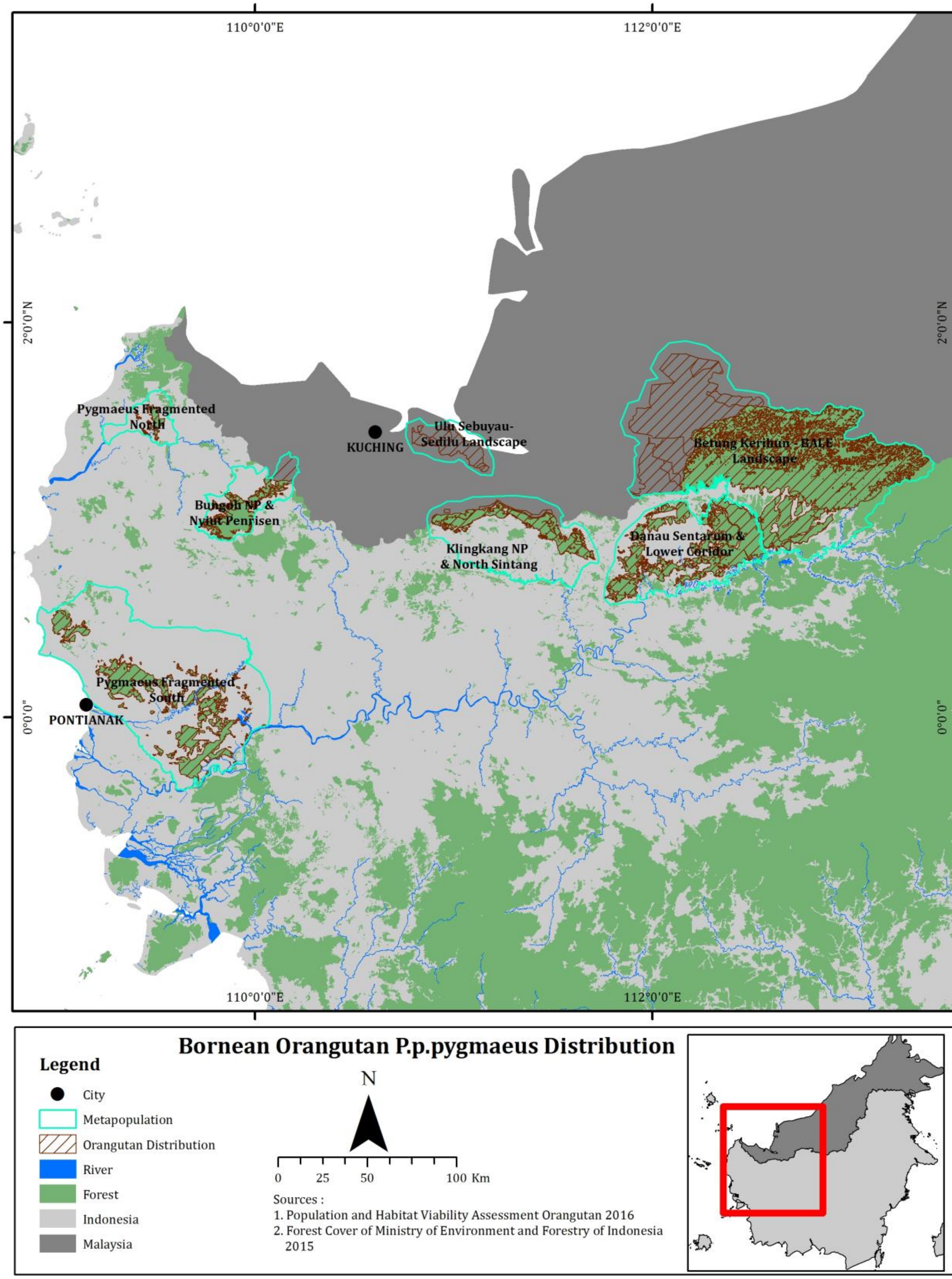

Figure 5. Map showing designated meta-population polygons for *Pongo p. pygmaeus*

Summary of priorities

Priority sites for *Pongo pygmaeus pygmaeus*:

- **Betung Kerihun NP and BALE landscape:** together represent the largest contiguous area of orangutan habitat for *P. p. pygmaeus*, with much of the area already under protection. This was considered by the group to offer the best chance of supporting a long-term viable population of orangutans.
- **Danau Sentarum NP**: prioritised as the second largest area of orangutan habitat, with half of the forested area protected as a national park and because of its potential connection to Betung Kerihun landscape by the Labian-Leboyan wildlife corridor.

The main threat to *P.p. pygmaeus* is conversion for industrial agriculture and the highest priority mitigation strategy is moratorium (no new permits and no clearing forest within concessions).

Table 9. Summary of the main threats and recommended mitigation strategies for *Pongo pygmaeus pygmaeus.*

Threats	*Strategy*
Human orang-utan conflict and poaching	Law enforcement.
	Promote better spatial planning.
	Intensive education and awareness programs.
	Develop sustainable alternative livelihoods for local communities.
	Strengthen multi-stakeholder partnerships (local, national and international; including private sector and local community).
Fire	Law enforcement. Strengthen monitoring and patrolling capacity. Promote better spatial planning. Intensive education and awareness programs. Strengthen multi-stakeholder partnership (local, national and international; including private sector and local community).
Illegal logging	Law enforcement.
	Encourage local community to plant local timber species in their land/garden for their own use or for local demand (i.e. housing).
	Strengthen monitoring and patrolling capacity/informant network.
	Intensive education and awareness programs.
	Strengthen multi-stakeholder partnerships (local, national and international).
Conversion to industrial agriculture	law enforcement.
	Moratorium (no new permit and no clearing forest within concession).
	Building a corridor connecting HCV area within concession to viable forest patch/landscape, if not possible and the population of orangutans is threatened, the last resort is to relocated them to a suitable area with full responsibility taken by the company (i.e. budget, location and other resources).
	Strengthen monitoring and patrolling capacity.
Encroachment: small scale agriculture	Law enforcement.
	Developing sustainable alternative livelihood for local communities.

Threats	*Strategy*
	Strengthen monitoring and patrolling capacity.
	Improve capacity of forest management unit.
	Intensive education and awareness program.
	Strengthen multi-stakeholder partnerships (local, national and international).
Road construction	Revise spatial planning to reduce fragmentation of orangutan habitat caused by road development.

Pongo p. wurmbii

Working group members:

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Analysis editors: Simon Husson, Sri Suci Utami-Atmoko, Gail Campbell-Smith and Bernat Ripoll Capilla

Introduction

Pongo pygmaeus wurmbii is one of the three currently recognized subspecies of Bornean Orangutan (Goossens *et al.* 2009) and is categorized as Critically Endangered by IUCN (IUCN, 2016). This taxon is found in West Kalimantan (Indonesia) from the south part of the Kapuas River to the eastern Barito River in Central Kalimantan (with a few individuals in South Kalimantan province). This taxon has the largest range of the three Bornean Orangutan subspecies, with 31,436-44,995 individuals remaining. These occur in 10,170,196 hectares of potentially suitable habitat, although they are absent (except for four recently reintroduced populations) from habitat units totaling 3,639,949 ha, resulting in an effective 2016 range of 6,530,247 ha. The core populations are centered in Western Schwanner (Arabela, Rongga-Perai, Seruyan Hulu: 7,735-11,178 individuals), Sabangau National Park + surrounds (5,683-5,826 individuals) and Tanjung Puting National Park + Rimba Raya (3,698-4,623 individuals). The other 6 habitats of this taxon combined, support more than 1,000 individuals, i.e: Katingan (3,160-4,343 individuals), Gn.Palung National Park-Gn. Tarak PF (1,727-2,576 individuals), Mawas (1,514-2,070 individuals) and Rungan Timur (Mungku Baru: 1,364-2,034 individuals).

Comparison of *P.p.wurmbii* numbers from the 2004 (Wich *et al*. 2008) and 2016 PHVA workshops. If we compare just those populations which were included in both the 2004 PHVA and 2016 PHVA, we have a 2016 figure of 25,447 – 34,962 (*in prep.*). This therefore represents a decline in this subset of the *P.p.wurmbii* population of 26%, when considering the lower 2016 estimate, to no decline at all at the upper estimate. Eight of the eighteen *P. p wurmbii* populations identified were assessed to be declining (Gunung Palung National Park, Bukit Baka National Park, Tanjung Puting National Park, Sabangau National Park, Arut-Belantikan, Eastern Schwaner (Bukit Raya, Kahayan-Sambah, Sambah-Katingan), Sabangau-Kahayan and Tanjung Kaluang. As this decline is not uniform and indeed several areas have higher estimated populations in 2016, such as Rongga-Perai, Rungan Timur, Katingan and Seruyan Hulu. In other areas where they were thought present in 2004, they are now thought to have been absent for a long period of time. Additionally, 19-22% of the current orangutan population lives in habitat units which were not included in the 2004 PHVA. Therefore, more than anything else, is that we are still refining our knowledge of the distribution and density of orangutan populations throughout their range. Periodic assessments such as this one act as a catalyst for more fieldwork.

We estimate that 32-38% (11,891-14,399 individuals) of the current *P.p.wurmbii* population occur in major protected areas, i.e.: Sabangau National Park, Tanjung Puting National Park, Gunung Palung National Park, and Lamandau Wildlife Reserve. Populations in these areas were considered to be stable. Two locations support reintroduced or translocated populations, i.e.: Batikap Nature Reserve in Murung Raya and Bukit Baka-Bukit Raya National Park.

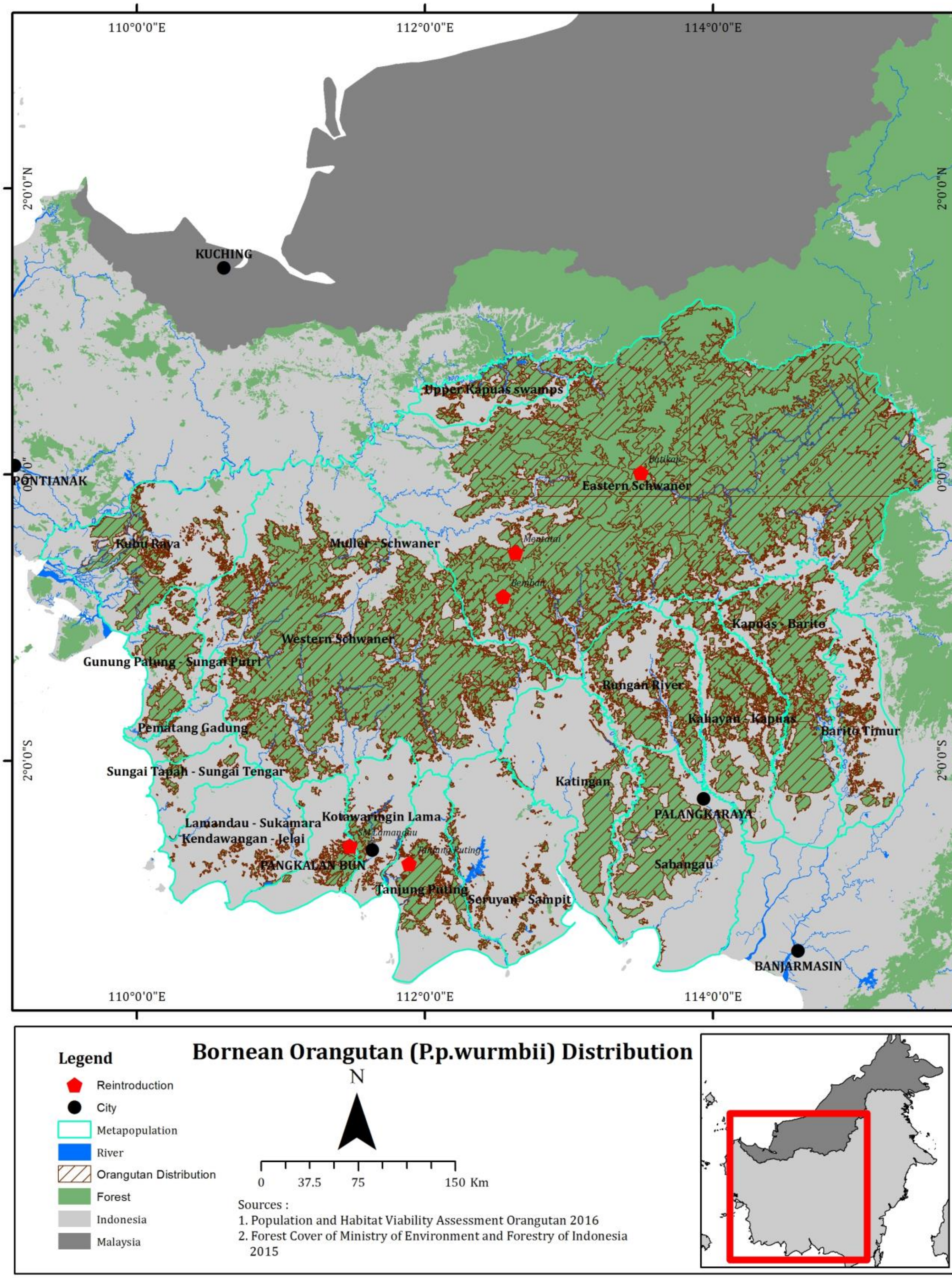


Figure 6. Map showing designated meta-population polygons for *Pongo p. wurmbii*

Forest fires and habitat conversion remain the major threats to orangutan survival over most of the range occupied by *P. p. wurmbii*. In 2015, forest fires in Kubu Raya, West Kalimantan, and Palangkaraya, Central Kalimantan, destroyed significant areas of orangutan habitat. Over half of the population of this sub-species, 57-60% (18,858-25,549 individuals) are found in areas that are predominantly peat-swamp forest habitat and at elevated risk of fire (*in prep.*). Forest conversion for agricultural purposes is also considered a serious threat to orangutan habitat and can be a trigger for human - orangutan conflict. Priority strategies for mitigating the threats to *P. p. wurmbii* are: enforcing the law, a moratorium on the conversion of peat land and natural forest to other purposes, and harmonizing regulations among ministries regarding forest fires and conversion.

Table 10. Summary of the main threats and recommended mitigation strategies for *Pongo pygmaeus wurmbii.*

Threat	Strategies
Encroachment: small scale agriculture	- law enforcement - socialization/awareness - alternative economic livelihoods
Encroachment: small scale extensive agriculture	- law enforcement and improved capacity of local and central government
Conversion: for industrial agriculture	- moratorium (no new permits, no clearing forest within concessions); - evaluate cost and benefit of long-term palm oil plantation with transparent and publicly accessible results; - good governance; - promote transparency of supply chains; - law enforcement through prosecution of law-breaking companies; - promote "responsibility for the threatened orangutan"; - harmonise the needs of land set-aside for conservation with plantation concessions and land resources (BPN) regulations - promote a landscape approach; building corridors connecting HCV areas within their concession into neighbouring viable forest patches; - operate patrols (SATGAS) in concessions; - encourage effective replanting policies
Road construction	- closure of illegal roads - revise spatial planning to reduce fragmentation of orangutan habitat from road development - patrol and law enforcement operation - alternative economic livelihoods
Settlement	- socialization/awareness efforts
Logging: illegal	- law enforcement - socialization/awareness - alternative economic livelihoods - encourage local community replanting schemes on their lands for community/personal use (i.e. house refurbishment)

	- strengthen monitoring and patrolling capacity/informant networks (community patrol teams for example) - strengthen multi-stakeholder partnership (local, national and international)
Logging: low impact	- law enforcement - socialization/awareness - alternative economic livelihoods
Logging: high impact	- law enforcement - socialization/awareness - alternative economic livelihoods - strengthen monitoring and patrolling capacity/informant networks (community patrol teams) - strengthen multi-stakeholder partnership (local, national and international)
Timber plantation	- moratorium (no new permits, no clearing forest within concessions); - evaluate cost and benefit of long-term timber (all types) with transparent and publicly accessible results; - good governance; - promote transparency of supply chains; - law enforcement through prosecution of law-breaking companies; - promote "responsibility for the threatened orangutan"; - promote a landscape approach; building corridors connecting HCV areas within their concession into neighbouring viable forest patches - operate patrols (SATGAS) in concessions - encourage effective replanting policies
Absence of forest management unit	- West Kalimantan

Orangutan Population Viability Analysis Modelling Report

Modeler: Kathy Traylor-Holzer, IUCN SSC CBSG

Introduction

The purpose of this Population Viability Analysis (PVA) is to provide an assessment of the relative viability of wild orangutan populations living on Sumatra and Borneo through the development of a population simulation model based on the best available information. This assessment identifies those factors that most influence orangutan population viability and explores the impacts of increases or reduction of threats. This PVA provides an update to previous orangutan PVAs conducted by CBSG in 1993, 2004 and 2005 in connection with orangutan conservation planning efforts (Tilson *et al*. 1993; Singleton *et al*. 2004; Ellis *et al*. 2006), and is designed to inform the next Orangutan Conservation Strategy and Action Plan.

PVA objectives

Participants at the 2016 PHVA workshop identified the following questions to be addressed by this PVA:

1. What is the projected viability of current orangutan populations given the best estimates of population size, threats and management?
2. What is the projected impact on orangutans of the construction of roads through orangutan habitat (e.g., in West and East Leuser, in West and East Batang Toru)?
3. What is the smallest population size that can meet the agreed standards for a Minimum Viable Population (MVP)? How does this size change with different conditions or threat levels?
4. What is the smallest current population that could meet the MVP standard if allowed space to grow larger (e.g., reintroductions into a new area, additional habitat added to an existing area)?
5. What level of periodic supplementation would be needed to maintain the viability of small populations below the MVP?
6. What is the viability of populations established using a specified reintroduction scheme?

For the purposes of this PVA, the participants agreed to the following definition of a 'viable population':

A viable population is one with less than 1% probability of extinction in 100 years ($PE_{100y} < 1\%$) and less than 10% risk of extinction in 500 years ($PE_{500y} < 10\%$).

Additional measures such as population trend and genetic diversity also are pertinent to assessing viability. Due to the long generation time (~30 years) of this species, it is appropriate to consider population status over multiple generations to detect impacts of threats and stochastic processes on long-term viability.

Introduction to PVA and *Vortex*

Computer modelling is a valuable and versatile tool for quantitatively assessing risk of decline and extinction of wildlife populations, both free ranging and managed. Complex and interacting factors that influence population persistence and health can be explored, including natural and anthropogenic causes. Models can also be used to evaluate the effects of alternative management strategies to identify the most effective conservation actions for a population or species and to identify research needs. Such an evaluation of population persistence under current and varying conditions is commonly referred to as a population viability analysis (PVA).

The simulation software program *Vortex* (v10.2.6) (Lacy and Pollak 2017) was used to examine the viability of orangutan populations on Sumatra and Borneo based on previous PVA models and using updated population and threat information. *Vortex* is a Monte Carlo simulation of the effects of deterministic forces as well as demographic, environmental, and genetic stochastic events on wild populations. *Vortex* models population dynamics as discrete sequential events that occur according to defined probabilities. The program begins by creating individuals to form the starting population and then steps through life cycle events (e.g., births, deaths, dispersal, catastrophic events), typically on an annual basis. Events such as breeding success, sex at birth, and survival are determined based upon designated probabilities. Consequently, each run (iteration) of the model gives a different result. By running the model hundreds of times, it is possible to examine the probable outcome and range of possibilities. For a more detailed explanation of *Vortex* and its use in population viability analysis, see Lacy (2000) and Lacy *et al*. (2017).

Model development and data sources

A *Vortex* population model for orangutans was developed at the 2004 Orangutan PHVA and modified to reflect differences in orangutan life history in Sumatra and Borneo (Singleton *et al*. 2004). Data for age- and sex-specific mortality rates, reproductive lifespan, and inter-birth interval for Sumatran orangutans were taken from 30+ years of data from a study site at Ketambe (Wich *et al.* 2004). This Sumatran orangutan model was revised at the 2005 Sumatran Orangutan Conservation Action Plan Workshop to provide updated future projections of population viability for Sumatran orangutans based upon revised estimates of habitat loss or alteration and the subsequent effects on orangutans (Ellis *et al.* 2006).

This existing *Vortex* orangutan model served as the basis for this current PVA. Input values on life history parameters were reviewed by the 2016 PHVA participants and revised as appropriate. Updated estimates on current population size and structure, available habitat (carrying capacity), projected future habitat loss, and projected removal rates were provided by PHVA working groups to inform new viability projections (also see working group reports in this report).

Model parameters and input values

The input values used for this model are described below – also see Singleton *et al*. 2004 and Ellis *et al*. 2006 for details. The base model was developed for Sumatran orangutans, with minor life history adjustments made for Bornean populations as noted.

Reproductive rates

Mating system: Orangutans have a promiscuous breeding system. Both sexes may have multiple mates, although animals may breed with the same mate(s) for several years. Short-term polygyny was used in the model, with adult males limited to a maximum of five female mates per year. New mates are selected each year. All adult males were considered to be in the breeding pool (i.e., potential breeders) in the model.

Reproduction lifespan: Reproduction was modelled as beginning at age 15 for females and age 20 for males, and indicates the *mean* age at which first offspring are *born*, not conceived (mating). Information from Ketambe at the 2006 PHVA reported the age of first reproduction typically to be 15 years for females and 25 years for males; this was revised to age 20 for males by 2016 PHVA participants. One female at Ketambe produced offspring at about 50 years of age; this was accepted as a plausible maximum age of successful reproduction for females. Males were assumed to be reproductive their entire lives. Maximum age for both sexes was set at 60 years. Age of first reproduction was set at age 18 for males and maximum age (for both sexes) at 55 years in the Bornean model.

Reproductive rate: Density-dependent reproduction was modelled by a functional relationship between population density and percent of females producing offspring, as shown in Figure 7. For the Sumatran model, this relationship represents 15.4% of adult females reproducing at low density (interbirth interval IBI = 6.5 years), declining to 11.1% at carrying capacity (IBI = 9 years). An Allee effect was added to depress breeding at very low density. This function was modified for different population sizes to produce a curve that peaks at 15.4%. Average IBI for wild orangutans in Ketambe is 8.7 years and under 8 at Suaq Balimbing, which translates to populations at 90-97% capacity on this functional curve. Test runs of this model (N=K=1500) result in the population stabilizing at ~ 90% K (IBI = ~8 years on the curve).

Bornean orangutans have a slightly shorter lifespan and faster reproduction; breeding rates were set at 16.7% (IBI = 6) at low density and 11.8% (IBI = 8.5) years at capacity. In addition, the shape of the function was modified to produce a longer range of peak reproduction. Observed IBI for wild Bornean populations are range from 7.1 to 7.8 years, which would translate to populations at 90-96% capacity on this functional curve. Test runs of this model (N=K=1500) result in the population stabilizing at ~93% K (IBI = 7.43 on the curve).

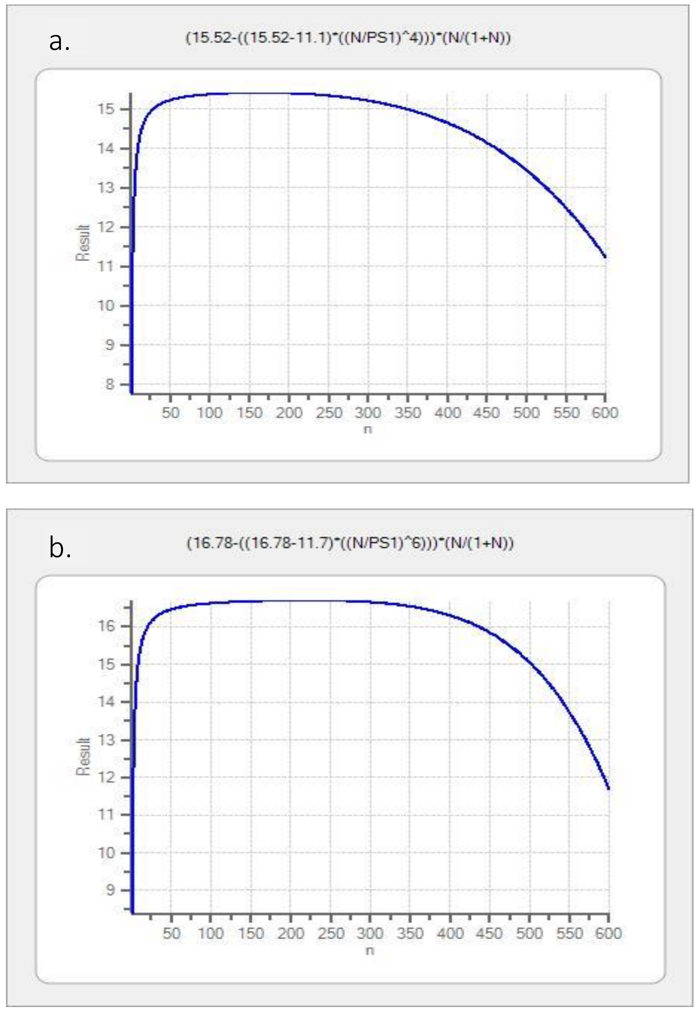


Figure 7. Percent adult females breeding with density (for population of 600) for a) Sumatran and b) Bornean models.

Environmental variation (EV) was set at 5.5% (approximately 33-50% of the mean). Given the lifespan of this species, year-to-year fluctuations in demographic rates tend to average out; therefore this value probably has little effect on population projections.

Only a single offspring were modelled (no twins); in rare instances of the observed birth of twins in the wild, at least one does not survive. Sex ratio at birth was modelled as 55% male. Data from a number of field sites suggest a male bias in births.

Mortality rates

Age- and sex-specific mortality: The long lifespan and slow reproductive rate of this species suggest low rates of natural mortality. Mortality rates were extrapolated from over 30 years of field data from Ketambe for the 2004 PVA model; these rates were reduced for this PVA based on the latest data from Ketambe and Suaq. Mortality was increased in the upper age classes for Bornean so that ~5% of the individuals reach maximum age. Juvenile males are thought to experience higher mortality than females. Adult mortality is believed to be low. Environmental variation (EV) around mortality rates was set at 50% of the mean. EV for survival and for reproduction were correlated in the model.

Table 11. Model age- and sex-specific annual mortality rates.

	Sumatran		Bornean	
Age class (annual %)	Females (% mort.)	Males (% mort.)	Females (% mort.)	Males (% mort.)
0 - 2	3	3	3	3
2 – 8	1	3	1	3
8 – 11	2	3	2	3
11 – 15	1	1	1	1
15 – 20	1.5	1	1.5	1
20 - 41	1.5	1.2	1.5	1.2
41 - 46	5	5	5	5
46 - 51	10	15	15	15
51 - 56	15	20	25	25
56 - 60	20	25	-	-

Inbreeding depression: Inbreeding is thought to have major effects on reproduction and survival of species, especially in small populations, and so was included in the model (as reduced survival of inbred offspring through their first year). The impact of inbreeding was modelled as 6.29 lethal equivalents as a conservative estimate based upon a review of inbreeding effects in wild mammalian and avian populations (O'Grady *et al.* 2006), with 50% of the effect of inbreeding due to recessive lethal alleles (100% for populations >5000).

Catastrophes: Disease and fire are among those catastrophes thought to impact wild orangutan populations. In the absence of sufficient data for specific catastrophes, a collective 'generic' catastrophe was modelled based upon a review of severe catastrophes in 88 vertebrate species by Reed *et al.* 2003. This was modelled as a 14% risk per generation of a 50% reduction in the population, which translates to an annual risk of 0.46% annual risk (severe catastrophe hitting approximately once every 215 years).

Population inputs

Initial population size (N) and carrying capacity (K): Scenarios for sensitivity testing (ST) and exploration of MVP under various conditions were initiated with populations at carrying capacity, with individuals distributed across age-sex classes according to a stable age distribution that is characteristic of the mortality and reproductive rates in the model. Initial individuals were assumed to be unrelated unless otherwise noted. Populations were modelled as isolated populations, with no migrants and no augmentation (translocations or releases) unless otherwise noted. Scenarios for specific existing orangutan populations were parameterized based on inputs from the PHVA working groups (see *Population-Specific Models*).

Habitat loss and fragmentation: Carrying capacity was assumed to be constant for sensitivity testing and MVP exploration unless otherwise noted. In MVP scenarios modelling habitat loss, rates were applied to the remaining habitat each year, such that the actual amount of habitat loss is not linear but diminishes over time; this was done to match the method chosen to model habitat loss in actual orangutan populations. Habitat changes were modelled as a permanent reduction in carrying capacity for orangutans, which not only reduces K but also removes individuals from the population when N>K proportionately across all age-sex classes. Habitat loss rates for actual orangutan populations were estimated by the PHVA working groups.

Direct loss of orangutans: No additional loss of orangutans due to anthropogenic causes (e.g., poaching, illegal trade) was included in the ST or MVP scenarios unless otherwise noted. Additional losses for actual orangutan populations were estimated by the PHVA working groups.

Model runs and timeline

Due to the long-lived and slowly reproducing nature of this species, orangutan populations were modelled for 500 years (~16 generations) so that long-term population trends could be observed and results compared to population viability goals. Results are presented for both 100 years and 500 years. Note that uncertainty in projection results increases over time due to stochastic processes. In addition, it is unlikely that conditions are adequately understood or will remain constant to allow us to accurately predict population status so far into the future. All scenarios were run for a minimum of 500 iterations.

Deterministic results

The baseline model for orangutans describes a population that shows positive deterministic growth (r = 0.014 for Sumatran, r = 0.016 for Bornean) in low density conditions. This is the average population growth expected based on mean fecundity and mortality rates in the absence of inbreeding, human-related mortality, and stochastic processes (e.g., shortage of mates, skewed sex ratio). This is a plausible growth rate for a large, long-lived and slowly reproducing species such as the orangutan. Population growth is reduced under crowded conditions where resources are limited and the carrying capacity of the habitat is reached. In these conditions, the percent of breeding females drops to 11.1% (Sumatran) or 11.8% (Bornean), resulting in almost zero growth rate ($r_{Sumatran}$ = 0.002; $r_{Bornean}$ = 0.004). Thus in the model, populations living in saturated conditions regulate their population size by breeding just enough to balance the population around the habitat's carrying capacity. This negates the need for the model to artificially truncate populations that exceed K except in instances of habitat loss.

Sensitivity testing

Recognizing that there is some uncertainty around model input parameters, sensitivity testing (ST) was conducted by varying a single parameter at a time to assess the sensitivity of the model results to different input values. All ST scenarios were run for 500 years with 500 iterations with an initial population of 500 Sumatran orangutans at capacity (K=500) with no future reduction in K. While stochastic r is often used to assess ST results, this metric is of less value here given that these populations are near K and r is small; thus other metrics such as mean final population size and probability of extinction (PE) were used. Detailed results can be found at the end of this section.

Demographic Sensitivity

Mortality: Juvenile, sub-adult and adult mortality rates were varied independent by ±10% and ±20%, for males and females. Male mortality rates and female juvenile mortality have little impact on model results. As might be expected in a long-lived, slow reproducing polygynous species, adult female mortality (and, to a lesser extent, female sub-adult mortality) does affect population growth and the ability of the population to recover from stochastic declines, resulting in a slow decline in mean population size over time (Figures 8 & 9). Overall viability remains high, with high gene diversity and almost no risk of extinction. Final mean population sizes range from 442 (20% lower mortality) to 394 (20% higher mortality).

As might be expected in a long-lived, slow reproducing polygynous species, adult female mortality (and, to a lesser extent, female sub-adult mortality) does affect population growth and the ability of the population to recover from stochastic declines, resulting in a slow decline in mean population size over time (Figures 8 & 9). Overall viability remains high, with high gene diversity and almost no risk of extinction. Final mean population sizes range from 442 (20% lower mortality) to 394 (20% higher mortality).

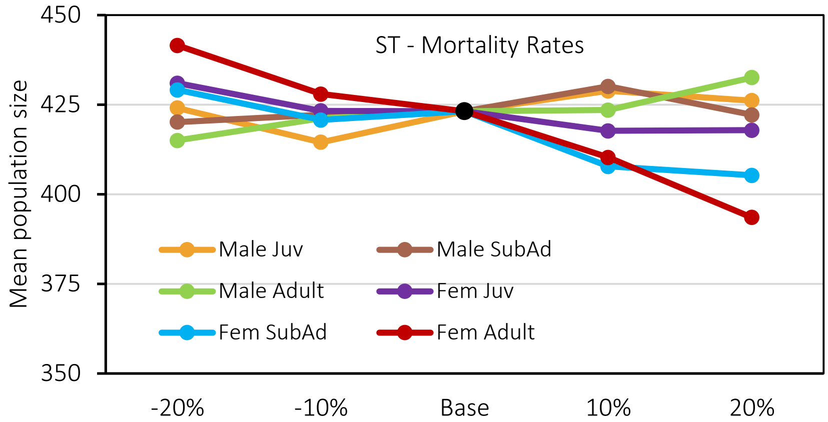


Figure 8. Mean population size at Y500 for mortality rates tested (K = 500). Black dot = base model value.

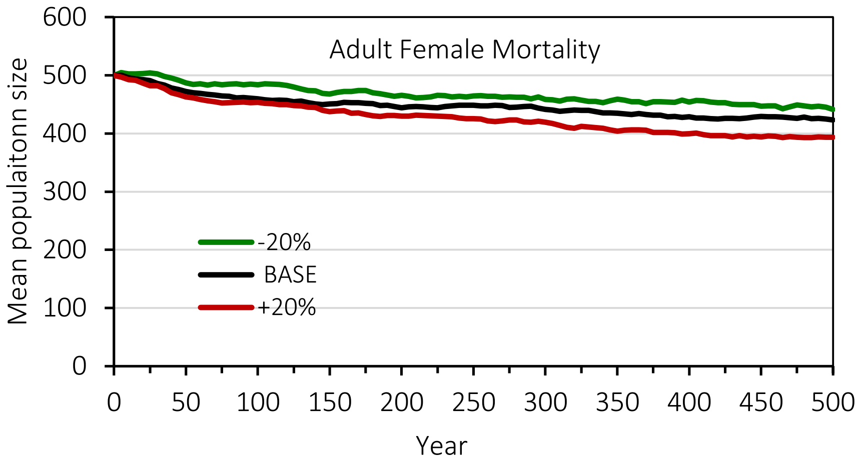


Figure 9. Mean population size over time with adult base mortality rates (black line), and ± 20% of base rates.

Reproduction: Varying the age of first reproduction from 14 to 16 years (base model value = 15) has an almost identical effect on model results as changes in adult female mortality of ±20%. Reducing maximum age from 60 to 55 or 50 has little effect but does negatively impact the population at Max Age = 45 years. Survival rates used in the model result in about 44% of females living to age 45; thus, reducing maximum age to 45 years can have a significant impact on the reproductive potential of the population.

Changing the interbirth interval at low density (6 to 7 years) and at high density (8 to 9 years) each also have a similar impact on final population size. IBI at low density affects the ability of the population to grow following decline, while IBI at K impacts the population's ability to maintain its size in saturated habitat.

Changes in birth sex ratio have an even larger impact over the range of values tested (male:female = 50:50; 55:45, 60:40). Male-biased sex ratios lead to relatively fewer breeding females, which limits population growth in polygynous species. A 60% male bias results in a final mean N_{500} = 330.

Demographic impacts: The general conclusion of demographic sensitivity testing is that population size (and growth) is *impacted by the number of breeding females, their reproductive lifespan, and their productivity* (IBI). Large populations (e.g., N ≥ 500) are viable over the range of values tested (PE_{500} ≤ 0.004) and on average maintain N at 66-95% of K with high gene diversity (≥ 95%). Of course, higher rates of 'mortality' (whether it be deaths or other sources of loss of female orangutans from the population) will have greater negative impacts. While some of these demographic traits cannot be easily influenced, model results suggest that the *loss of breeding females can be especially harmful to wild orangutan populations*. Management actions that minimize loss of adult females (e.g., poaching) and disturbance to breeding behavior should promote population sustainability.

Genetic sensitivity

Genetic load: In the absence of species- or population-specific inbreeding depression data, the recommended conservative value of 6.29 lethal equivalents (LEs) is a 'rule of thumb' estimate for incorporating inbreeding impacts into the PVA. This is implemented as reduced first-year survival of inbred infants and becomes more severe as inbreeding levels rise. Sensitivity analysis explored halving and doubling this value (to 3.145 and 12.58 LEs, respectively) as well as removing all inbreeding effects. Genetic load (as LEs) affected the model results in a manner and magnitude similar as the above demographic effects, with some impact on mean population size but little effect on gene diversity or extinction risk.

Since the base model assumes that all orangutans in the initial population are unrelated, inbreeding levels build slowly in a population of 500 individuals and only reach mean coefficient of inbreeding (F) = 0.0286 at Year 500. Inbreeding will accumulate faster in small populations; for example, a population of 150 orangutans reaches mean F = 0.1592 in 500 years, which is well above the genetic kinship between half siblings (0.1250). As a general rule, inbreeding effects often are seen in populations with inbreeding $\geq$ 0.10, which corresponds to ~90% gene diversity. Thus, smaller populations are likely to be more vulnerable to inbreeding impacts and genetic load.

Initial kinships: In order to separate inbreeding effects from other stochastic processes affecting small populations, a set of scenarios were run by varying levels of kinship among the founding individuals (initial kinships = 0, 0.0156, 0.03125, 0.0625, 0.1250) for a population of 500 individuals. Figure 10. demonstrates the interaction between the severity of inbreeding depression measured by LE and the level of inbreeding in the starting population. If the population is genetically diverse, the genetic load has relatively small impact. With increasing relatedness in the population, increased LE can lead to significant population decline. While extinction risk is low (< 5% over 500 years) for all scenarios except one (LE=12.58, Kin=0.1250), inbred populations show decline and reduced gene diversity. Populations modelled under the default LE value are vulnerable to inbreeding. *As orangutan populations become increasingly fragmented and isolated from other habitat fragments, inbreeding may impact long-term viability without* genetic *augmentation*.

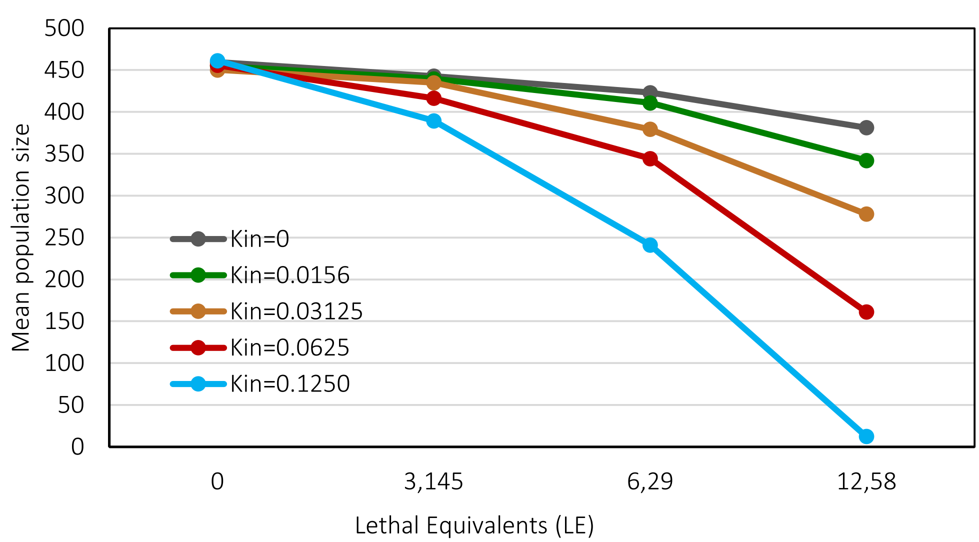


Figure 10. Mean population size at Y500 varied across genetic load (LE) and initial kinships (relatedness) in the population.

Impacts of population size: defining minimum viable population size

Small populations are vulnerable to decline and extinction due to demographic and genetic stochastic processes, including demography stochasticity, environmental variation, catastrophic events, genetic drift, and inbreeding (Shaffer 1987). Inbreeding accumulates faster in small populations, reducing survival and reproduction that, in turn, leads to further decline. This feedback loop has been termed the "extinction vortex" (Gilpin and Soulé 1986) and may drive a small population to extinction in the absence of anthropogenic threats such as poaching. Minimum viable population (MVP) is the term historically used to denote the population size below which extinction risks are unacceptably high. Shaffer initially defined MVP as the smallest isolated population having a 99% chance of remaining extant for 1000 years. However, risk tolerance is a societal construct, and stakeholders vary in their definition of unacceptable risk. Thus MVP will vary depending upon each group's definition of 'viable'.

Participants at the 2016 Orangutan PHVA defined a minimum viable population for orangutans as one with less than 1% risk of extinction in 100 years ($PE_{100} < 1\%$) and less than 10% risk of extinction in 500 years ($PE_{500} < 10\%$). Additional measures such as population trend and genetic diversity also are pertinent to assessing viability. To avoid inbreeding depression and to retain genetic adaptive potential, a common genetic target is to retain at least 90% gene diversity – suggested by Soule et al. 1986 as a reasonable zone between potentially damaging loss and tolerable loss of genetic diversity. Due to the long generation time (~30 years) of this species, it is appropriate to consider population status over multiple (perhaps at least 10) generations to detect impacts of threats and stochastic processes on long-term viability.

Scenarios were run for both Sumatran and Bornean orangutan populations ranging from 5 to 1500 individuals (N_0=K). Initial founders were assumed to be unrelated; as demonstrated earlier, viability will decline more quickly if the initial animals are related or are genetically impoverished. Model results at 100 years and at 500 years (probability of extinction PE, mean population size N, and gene diversity GD) can be seen in Table 17.

To meet the MVP definition based on PE in 100 and 500 years as proposed by the PHVA participants, a *population of 150 is needed for Sumatran orangutans and 100 for Bornean orangutans* (Table 12). Figure 11 illustrates the significant improvement in PE at N$\geq$150 for Sumatran orangutans. While populations of 100-150 may meet these PE criteria, they still demonstrate a slow declining trend and reduced gene diversity (i.e., inbreeding accumulation). *A minimum population of 200 is needed for both species to retain 90% GD* for 500 years. *At least 500 orangutans are needed to stabilize population size* (~85% K) and avoid decline (Fig. 12). These thresholds would need to be higher if the initial animals are related or with increased threats.

Table 12. Model results (at Years 100 and 500) for Sumatran and Bornean populations of varying size.

	Sumatran						Bornean					
Pop Size	PE_{100}	PE_{500}	N_{100}	N_{500}	GD_{100}	GD_{500}	PE_{100}	PE_{500}	N_{100}	N_{500}	GD_{100}	GD_{500}
5	0.948	1.000	0	0	0.576	--	0.931	1.000	0	0	0.566	--
10	0.539	1.000	3	0	0.686	--	0.532	1.000	3	0	0.681	--
25	0.060	0.997	17	0	0.854	0.338	0.045	0.980	18	10	0.858	0.482
50	0.007	0.758	40	4	0.927	0.637	0.007	0.599	42	23	0.929	0.654
75	0.002	0.376	64	20	0.953	0.751	0.001	0.244	66	41	0.965	0.759
100	0.000	0.209	86	41	0.964	0.800	0.000	0.096	90	66	0.965	0.822
150	0.001	0.051	131	90	0.976	0.873	0.000	0.034	137	115	0.977	0.887
200	0.000	0.024	178	139	0.982	0.909	0.000	0.008	185	161	0.983	0.917
250	0.000	0.004	225	183	0.986	0.927	0.000	0.006	237	213	0.986	0.935

500	0.000	0.001	460	423	0.993	0.967	0.000	0.000	475	455	0.993	0.969
750	0.000	0.001	687	645	0.995	0.978	0.000	0.000	716	671	0.995	0.979
1000	0.000	0.000	928	900	0.997	0.984	0.000	0.000	952	924	0.997	0.984
1250	0.000	0.000	1152	1116	0.997	0.987	0.000	0.000	1193	1173	0.997	0.987
1500	0.000	0.000	1410	1329	0.998	0.989	0.000	0.000	1426	1410	0.998	0.990

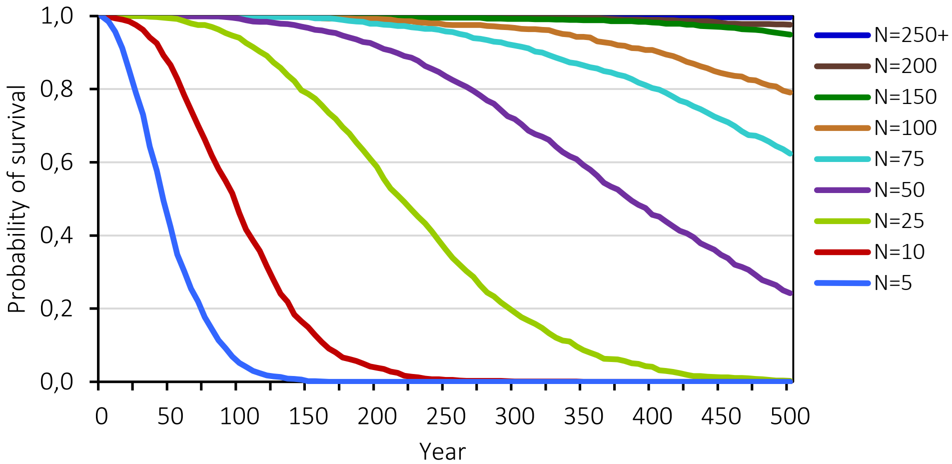


Figure 11. Probability of survival over time for Sumatran orangutan population, varied by size.

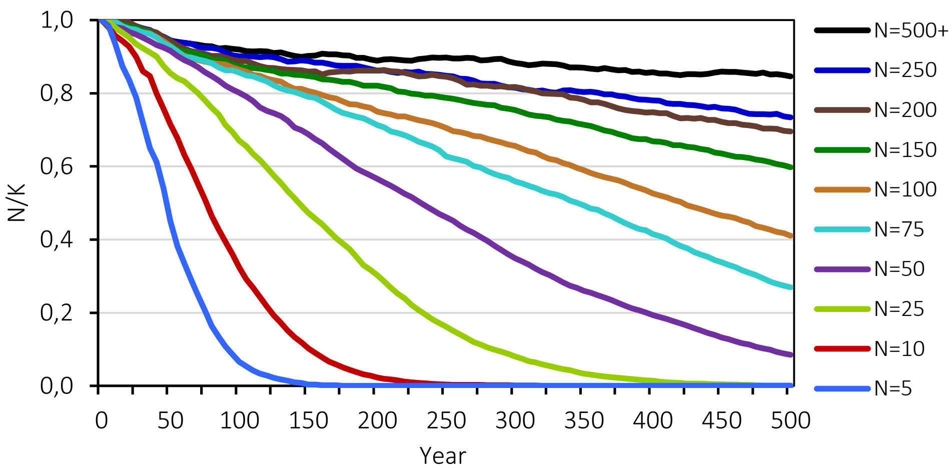


Figure 12. Density (N/K) over time for Sumatran orangutan population, varied by size.

MVP under alternative conditions

Initial relatedness

Populations with diminished genetic variation may have lower demographic rates due to inbreeding depression, which can reduce viability. If these populations are small, further inbreeding will accumulate faster. Thus, small inbred populations have a higher extinction risk than small genetically diverse populations. The result is that MVP may be higher for inbred populations. A set of models was run for populations of different sizes (N=K from 5 to 1500) and at different starting levels of kinship between orangutans. Results in Table 18 illustrate that MVP (based on PE as defined by the PHVA participants) increases to 200 for Sumatran orangutans and 150 for Bornean orangutans for moderately inbred populations. Larger populations are needed to maintain at least 90% gene diversity and relatively stable population size over time. As with the MVP results presented above for unrelated populations, these results assume no additional loss of orangutans due to removals (e.g., poaching) or habitat loss.

Loss of orangutans

Populations under threat that result in the additional loss of orangutans beyond 'normal' mortality have reduced viability. Such losses could be the result of poaching for trade, conflict killing for crop raiding, death or removal due to habitat loss, or any other threat that results in the animal no longer being in the population. Referring back to the model input values, the maximum deterministic growth rate (at relatively low density with abundant resources) is 1.4% per year for Sumatran and 1.6% for Bornean orangutans, with slower growth rates for populations near K. Observed growth will be slower yet due to the effects of stochastic processes not included in the deterministic rate. Therefore, *it is not possible for orangutan populations to reproduce fast enough to overcome additional annual loss of much more than 1%.*

A set of models was run for populations of different sizes (N=K from 5 to 1500) and at different rates of annual loss of orangutans (across all age and sex classes) of 0.5%, 0.75% and 1%. Results in Table 13 illustrate that MVP (based on PE as defined by the PHVA participants) increases significantly with continued additional loss, for example, to 750 for Sumatran orangutans and 400 for Bornean orangutans. While these MVPs meet the PE criteria, they result in an average population size in 500 years of 192 (26% of K) and 155 (39% of K), respectively. It is indicative of these populations' inability to fully recover from stochastic declines. These model results assume initial unrelated populations; the viability of inbred populations under continuous threat may be lower.

Table 13. MVP based on various criteria for Sumatran and Bornean populations varied by initial kinships and by rate of loss (annual loss across all age and sex classes). *indicates the %K of an initial population of 1500 after 500 years.

	Sumatran					Bornean				
Minimum N for:	PE_{100} < 1%	PE_{500} < 10%	GD_{100} ≥ 0.90	GD_{500} ≥ 0.90	N/K_{500} ≥ 0.8	PE_{100} < 1%	PE_{500} < 10%	GD_{100} ≥ 0.90	GD_{500} ≥ 0.90	N/K_{500} ≥ 0.8
Initial kinship:										
0	50	**150**	50	200	350	50	**100**	35	200	200
0.0156	50	**150**	50	250	500	50	**150**	50	250	250
0.03125	75	**200**	75	300	600	50	**150**	75	250	300
0.0625	75	**200**	100	500	1500	50	**150**	100	450	450
Rate of loss:										
None	50	**150**	50	200	350	50	**100**	35	200	200
0.5%	75	**300**	75	300	--[70%*]	50	**200**	35	250	850
0.75%	75	**400**	75	350	--[55%*]	75	**250**	50	300	--[74%*]
1.0%	100	**750**	75	600	--[36%*]	75	**400**	50	350	--[60%*]

Habitat expansion

Populations under 150 Sumatran or 100 Bornean orangutans do not meet the viability criteria set by the PHVA participants. Model scenarios were run to investigate whether smaller populations might meet these criteria if provided with additional habitat in which to expand (e.g., new adjacent habitat, release of orangutans into new habitat, etc.). Initial unrelated populations of 10, 25, 50 and 75 orangutans were modelled in a habitat with K≥100 (Bornean) or K≥150 (Sumatran). Because the initial populations were at relatively low densities they exhibited faster growth rates than populations near K due to density dependent reproduction incorporated into the model. No additional threats (losses) were included in these models, and no additional orangutans were supplemented to the populations.

Table 14 shows the required K for these small populations to meet the criteria of PE_{100} < 0.01 and PE_{500} < 0.10. *Populations of 50+ orangutans or have the ability to meet the viability criteria if given habitat to expand*. Smaller populations have more difficulty growing quickly enough to overcome the demographic and genetic stochastic effects of small size. Some iterations show growth to near K while other runs remain small and may eventually go extinct. Expanding K≥100 for these populations can be beneficial (e.g., decreasing PE_{500} from 0.980 to ≤ 0.20

for N_0=25); however, PE_{500} <0.10 is not achievable. *For populations under 50, periodic supplementation through releases may be needed*, alone or in combination with increased habitat, to meet the defined viability criteria.

Table 14. Carrying capacity (K_{viable}) needed to meet PE criteria for viable with initial population sizes of 10 to 100 orangutans. N_{500} and GD_{500} denote the mean N ($\pm$SD) and mean GD at K_{viable}.

	Sumatran			Bornean		
Pop size (N_0)	K_{viable}	N_{500}	GD_{500}	K_{viable}	N_{500}	GD_{500}
10	--	--	--	--	--	--
25	--	--	--	--	--	--
50	150	83$\pm$50	0.848	125	83$\pm$41	0.844
75	150	88$\pm$47	0.863	100	59$\pm$33	0.818
100	150	89$\pm$46	0.873	100	59$\pm$33	0.822

Supplementation

Periodic supplementation (release of animals into the population) can help to offset both demographic and genetic instability in a small population. Ideally, small populations would be carefully monitored and supplemented only when needed (i.e., few breeding age adults, very low numbers, poorly balanced sex ratio). This may not always be practical, however, and a more regular supplementation schedule may be more feasible. In either case, care should be taken to avoid releases into populations already at capacity of the available habitat.

A set of models were developed to explore the minimum level of supplementation needed to promote viable small populations (N = 10 to 50 Bornean orangutans). These models assume that the initial small population is unrelated, which may be a reasonable assumption if isolation has occurred recently. In the model, new supplements (i.e., released animals) are unrelated to the receiving population and have the same age- and sex-specific survival and reproductive rates as the resident orangutans. Models also assume constant K (no habitat loss or expansion). Models were constructed to evaluate two supplementation strategies, in which one young adult female was added to the population either: 1) at set intervals (e.g., every 20 years); or 2) in any year in which the number of adult females in the population fell below a minimum count. Releases began in Year 5 and did not occur in the last year of the simulation.

Table 15 shows the rate of supplementation needed to produce a viable population (using the PHVA PE criteria) under both strategies. Careful monitoring of populations and conducting releases based on the results can substantially reduce the frequency of supplementation needed to keep PE low. However, a regular and more frequent supplementation schedule leads to a larger population size and higher gene diversity (i.e., healthier population), and also has the advantage of predictability and no dependence upon monitoring. *Adding one young adult female every 10 to 35 years (depending upon population size) can greatly improve the viability of small Bornean orangutan populations*. Slightly higher rates would be recommended for small Sumatran populations.

Very small populations of 10 orangutans present a special case. These small populations are at risk of losing all adult males from the population by chance (demographic stochasticity) and hence stopping reproduction, temporarily or even permanently. This risk is large enough such that no schedule of female-only supplementation meets the PE criteria for viability. Therefore, scenarios for 10 orangutans included the provision to supplement an adult male IF none is present in the population at the time releases are considered (evaluated annually for 'monitored' populations and at the release interval for scheduled releases). Results in Table 20 indicate that strategic releases needed to maintain a very small viable (monitored) population are likely to be less intense than scheduled releases not tied to population status. Raising the minimum criterion from < 2 adult females to <3 adult females leads to a slightly larger and more genetically diverse population (which is true for larger populations as well).

Table 15. Supplementation rate needed to meet PE criteria for viability with population sizes of 10 to 50 Bornean orangutans. Scheduled releases occur at set intervals while releases based on monitoring occur on all years that meet the criterion listed. Releases = one adult female (*and/or one adult male if none are in the population).

		Scheduled releases				Releases based on monitoring				
Pop size (N=K)	Release	Interval	Total released	N_{500}	GD_{500}	Criterion	Approx. interval	Total released	N_{500}	GD_{500}
50	1 adult F	35 yr	16	30.7	0.819	<3 AF	~131.5	3.8	22.1	0.763
40	1 adult F	25 yr	20	34.9	0.889	<3 AF	~89.3	5.6	18.6	0.743
30	1 adult F	20 yr	25	22.2	0.846	<4 AF	~46.9	10.7	20.6	0.787
20	1 adult F	13 yr	38	17.2	0.875	<5 AF	~18.4	~27	18.0	0.845
10	1 adult F *1 adult M	10 yr	50F ~3M	10.2	0.872	<2 AF *<1 AM	~27.8	~14F ~4M	8.7	0.789
						<3 AF *<1 AM	~16.7	~25F ~4M	9.9	0.830

Reintroduction schemes

The establishment of a new orangutan population through multi-year releases into unoccupied habitat is a potential strategy to increase wild orangutan populations. Many different release strategies can be used and may vary by the age, sex and number of orangutans released as well as the length and schedule of release. A thorough assessment of reintroduction schemes is beyond the scope of this PVA. However, a specific scheme was requested to be modelled as an example.

The following reintroduction scheme was modelled using the Bornean orangutan model:

-Year 1: 20 releases (13 females, 7 males)
-Year 2: 50 releases (34 females, 16 males)
-Year 3: 50 releases (34 females, 16 males)
-Year 4: 50 releases (34 females, 16 males)
-No further releases after Year 4

Released orangutans were 8-15 years old (except for two 18-year-old males in Year 1 to provide a breeding age male in the population). Mortality was 13-18% during the first year of release, 3-6% during the second year, and then was the same as wild orangutans. Releases were made into unoccupied habitat with a carrying capacity of 350. No habitat loss or losses (e.g., poaching) were included.

Model results suggest that this scheme leads to a viable population (PE_{500}=0.001; N_{500}=309; GD_{500}=0.951) and are similar to those for a starting population of 350. Although mortality is substantially higher during the first two years after release, reproduction is higher at the initial low densities based on the density-dependent reproduction incorporated into the model. The young age of the population combined with a female-biased sex ratio also promote rapid growth (high reproduction and low mortality), allowing the population to reach K in approximately 35 years.

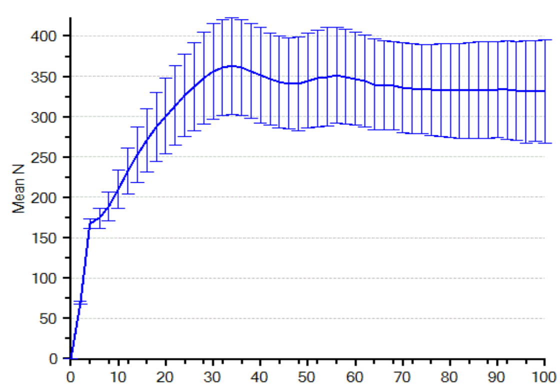


Figure 13. Mean population size over first 100 years of sample reintroduced Bornean population (K=350). Bars indicate SD.

Figure 13 shows the rapid growth during years 1-4 (releases) and shortly thereafter due to reproduction for ~30 years. As the population ages and approaches K, the population levels off, with slight oscillations as the sex and age structure adjust to reach a more stable balance.

Viability of Sumatran orangutan populations

PVA *Vortex* models for Sumatran orangutan populations were developed in collaboration with participants at the 2004 PHVA and 2005 Action Plan workshops using the most current field data and other expertise and resources available at that time (Singleton *et al*. 2004; Ellis *et al*. 2006). These models served as a basis for this PVA, with revisions to the population-specific model inputs provided by 2016 PHVA participants as outlined below (Table 16).

Population-Specific Inputs

Initial population size (N) and carrying capacity (K): Populations were defined by the PHVA working groups based on GIS habitat data and other information and were delineated to represent populations or population fragments whose members interbreed and undergo similar threats. Habitat modelling was used to estimate current carrying capacity of spatially defined populations. Populations were assumed to be at carrying capacity (except for reintroduced populations, as noted) and were distributed across age-sex classes according to a stable age distribution that is characteristic of the mortality and reproductive rates described for the model. Initial individuals were assumed to be unrelated; this is a reasonable assumption for large populations but may underestimate current inbreeding levels in small isolated populations if isolation is not recent.

Habitat loss and fragmentation: Habitat loss or alteration is a primary threat to orangutans on both Sumatra and Borneo. Future rates of habitat loss were estimated based on past trends and anticipated future conditions. These rates were applied to the remaining habitat each year, such that the actual area of habitat lost each year is not linear but diminishes over time. Habitat changes were modelled as a permanent reduction in carrying capacity for orangutans, which not only reduces K but also removes individuals from the population when N>K by imposing additional probabilistic mortality across all age-sex classes. Habitat loss was applied each year for the first 100 years of the simulation only.

Direct loss of orangutans: Orangutans are also hunted or otherwise removed illegally from the wild. Some of this loss is in association with logging or habitat conversion and is already incorporated into the model as immediate reduction in K and associated removal of orangutans. The PHVA working groups estimated the annual loss of orangutans from each population based upon historical information. Losses accounted for by the estimated reduction in K were calculated, and any additional losses above that were incorporated into the model as direct harvest.

New migrants or releases: Most populations were assumed to be isolated in the model and receive no new individuals. A few Sumatran populations were estimated to receive one migrant every 10 or 20 years, modelled as an adult male. For the two reintroduced populations, future releases were modelled as specified by the PHVA working groups (see Table 16).

Table 16. Population-specific model inputs (initial N, initial K, % loss in K, removals, additions) and resulting K and % lost over 100 years for eight wild and two reintroduced* Sumatran orangutan populations.

Population	Initial N	Initial K	% loss in K (annual)	K_{Y100}	K lost in 100 yrs	Total removals, all causes (annual)	Additions
West Leuser	5922	5299	0.29	4429	25%	10M / 18F / 7inf	1M/10 yrs
Sikulaping	261	261	0.01	258	1%	0.5M / 1F / 0.5inf	1M/10 yrs
East Leuser	5779	5779	0.33	4152	28%	11M / 20F / 9inf	1M/10 yrs
Tripa Swamp	212	212	11.48	0	100%	1M / 2F / 1inf	1M/10 yrs
Trumon-Singkil	1269	1269	0.43	825	35%	2M / 3.5F / 1.5inf	1M/10 yrs
Siranggas/BatuArdan	87	87	0.10	79	10%	0.5M / 1F / 0.5inf	1M/20 yrs

West Batang Toru	605	605	0.03	587	3%	2.45M / 0.95F / 0.5inf	--
East Batang Toru	162	162	0.03	157	3%	1.25M / 0.75F / 0.5inf	--
Bukit Tiga Puluh*	120	1560	1.92	224	86%	--	8/yr
Jantho landscape*	62	400	0.001	400	0%	--	20/yr
TOTAL	14479[3]	15634		11111	68%	~29M / ~47F / ~20inf	

Population Scenarios

Five scenarios were run for each of the eight extant orangutan populations:

Best Estimate: projected habitat loss and/or removals (habitat loss for 100 yrs; harvest for 500 yrs)
HarvOnly: Additional removals only (i.e., those *not* due to habitat loss), for 500 yrs; no habitat loss
HarvOnly100Y: Additional removals only, for 100 yrs and then stopped; no habitat loss
HabitatLossOnly: Habitat loss (i.e., loss of K) for 100 yrs; no additional removals
NoLoss: No projected loss of habitat (K) and no removals (e.g., hunting)

Comparison of these scenarios provides insight into the relative impacts of habitat loss and direct removals as well as the ability of the population to recover and persist if these threats were to be removed. Graphs are presented with results of mean population size over time for all five scenarios. Variation around these means is quite large, but these mean trends are informative in determining the drivers of population size and persistence under the rates tested.

For the two reintroduced populations (Bukit Tiga Puluh and Jantho landscape), these populations were supplemented with 8 (5 female, 3 male) or 20 (13 female, 7 male) orangutans, respectively, per year (Table 16). Animals were 9-15 years old at time of release, and had higher mortality rates during the first year (13-18%) and second year (3-6%) after release, then assumed 'normal' mortality risk. These ages and mortality rates were based upon those from the Reintroduction Scheme discussed above. Releases started in Year 2 of the model and were tested for 10, 20 or 50 years of releases.

West Leuser

Projected viability: Poor *PE_{100}=0.008; PE_{500}=1; N_{500}=0; GD_{500}=0*

At projected rates of habitat loss and removals, the West Leuser population is projected to decline to extinction, with median time to extinction = 235 years. Much of this decline is driven by the estimated harvest. If harvest is stopped, the population is able to recover as long as it is not fragmented. If habitat loss is not too severe or does not cause fragmentation, the population may stabilize around the new K. Eliminating all habitat loss and other removals immediately results in a large, genetically diversity population with no risk of extinction in 500 years (*PE_{100}=0; PE_{500}=0; N_{500}=5420; GD_{500}=0.997*).

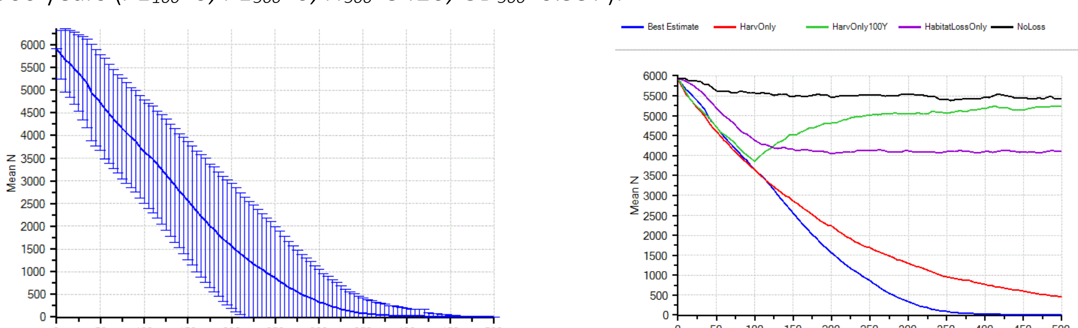


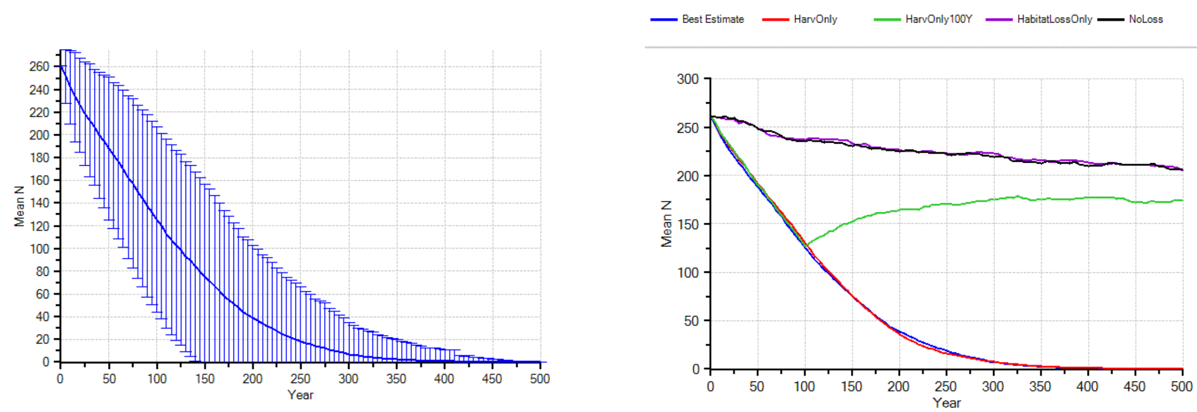
Figure 14. Mean population size over 500 years for West Leuser, under projected best estimated future conditions (left, with SD bars) and under all five estimated and alternate future situations (right).

[3] This figure excludes an estimated 317 individuals living in small forest fragments not included in the PVA analysis.

Sikulaping

Projected viability: Poor PE_{100}=0.15; PE_{500}=1; N_{500}=0; GD_{500}=0

At projected rates of habitat loss and removals, the Sikulaping population is projected to decline to extinction, with median time to extinction = 168 years. This decline is driven entirely by the estimated harvest. If harvest is stopped, the population is able to recover to some extent, depending upon how quickly harvest is reduced or eliminated given the relatively small size of this population and habitat. Habitat loss is estimated to be minimal for this area. Eliminating all habitat loss and other removals results in a small, genetically diversity population with very little risk of extinction in 500 years (*PE_{100}=0; PE_{500}=0.004; N_{500}=206; GD_{500}=0.954*).



East

Figure 15. Mean population size over 500 years for Sikulaping, under projected best estimated future conditions (left, with SD bars) and under all five estimated and alternate future situations (right).

Leuser

Projected viability: Poor PE_{100}=0.004; PE_{500}=1; N_{500}=0; GD_{500}=0

At projected rates of habitat loss and removals, the East Leuser population is projected to decline to extinction, with median time to extinction = 202 years. Similar to West Leuser, much of this decline is driven by the estimated harvest. If harvest is stopped, the population is able to recover as long as it is not fragmented. If habitat loss is not too severe or does not cause fragmentation, the population may stabilize around the new K. Eliminating all habitat loss and other removals results in a large, genetically diversity population with no risk of extinction in 500 years (*PE_{100}=0; PE_{500}=0; N_{500}=5364; GD_{500}=0.997*).

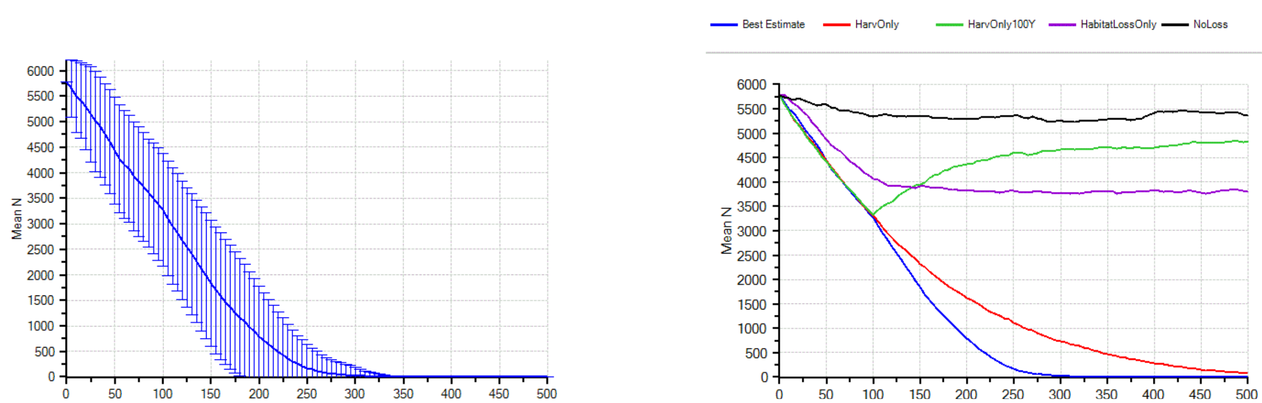
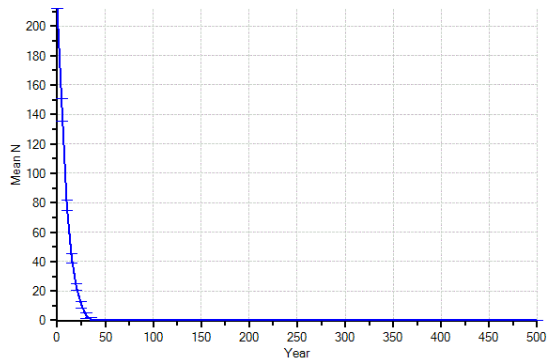


Figure 16. Mean population size over 500 years for East Leuser, under projected best estimated future conditions (left, with SD bars) and under all five estimated and alternate future situations (right).

Tripa Swamp

Projected viability: Very poor $PE_{100}=1; PE_{500}=1; N_{500}=0; GD_{500}=0$

The Tripa Swamp population is projected to decline rapidly to extinction (median time to extinction = 27 years) due to projected high rates of habitat loss and harvest. Both habitat loss and harvest are strong drivers of decline, with habitat loss being more significant given projected rates. In the absence of habitat loss, direct harvest at the projected levels may also drive the population to extinction (median time to extinction = 58 years, vs 37 years for habitat loss only). Eliminating all habitat loss and other removals results in a small viable population with little risk of extinction in 500 years ($PE_{100}=0; PE_{500}=0.002; N_{500}=164; GD_{500}=0.947$).



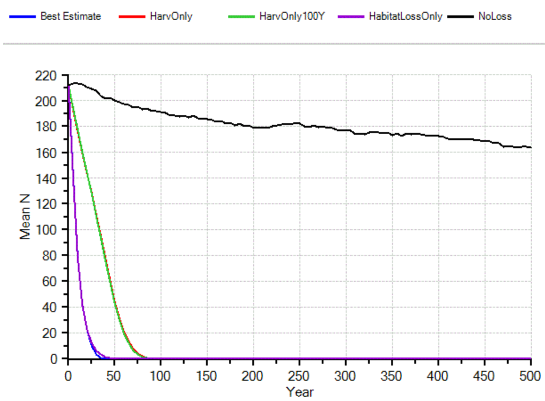
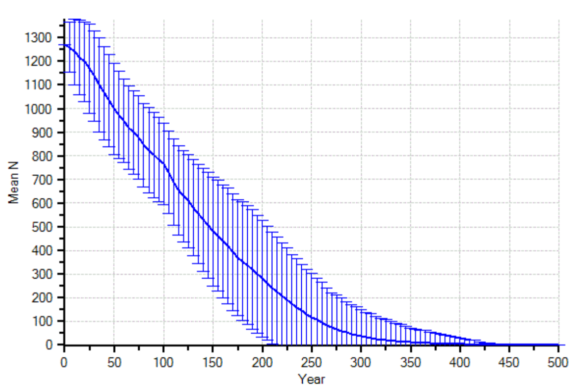


Figure 17. Mean population size over 500 years for Tripa Swamp, under projected best estimated future conditions (left, with SD bars) and under all five estimated and alternate future situations (right).

Trumon-Singkil

Projected viability: Poor $PE_{100}=0; PE_{500}=1; N_{500}=0; GD_{500}=0$

At projected rates of habitat loss and removals, the Trumon-Singkil population is projected to decline to extinction, with median time to extinction = 237 years. This decline is driven by harvest and habitat loss. If harvest is stopped, the population is able to recover as long as it is not fragmented. If habitat loss is not too severe or does not cause fragmentation, the population may stabilize around the new K. Eliminating all habitat loss and other removals results in a large, genetically diversity population with no risk of extinction in 500 years ($PE_{100}=0; PE_{500}=0; N_{500}=1110; GD_{500}=0.988$).



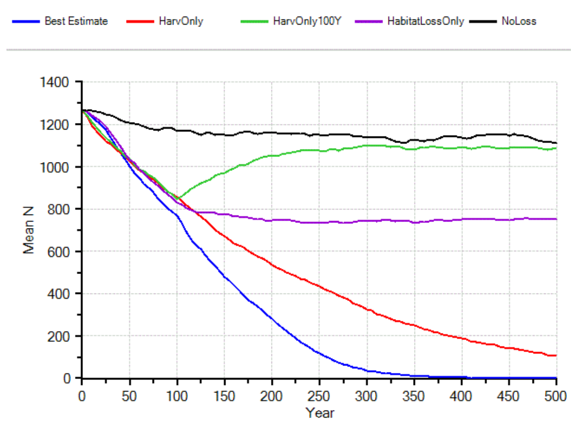


Figure 18. Mean population size over 500 years for Trumon-Singkil, under projected best estimated future conditions (left, with SD bars) and under all five estimated and alternate future situations (right).

Siranggas/Batu Ardan

Projected viability: Very poor $PE_{100}=0.996$; $PE_{500}=1$; $N_{500}=0$; $GD_{500}=0$

At projected rates of habitat loss and removals, the Siranggas/Batu Ardan population is projected to decline rapidly to extinction, with median time to extinction = 49 years. Most of this decline is driven by the estimated harvest. If harvest is stopped immediately, the population still slowly declines with loss of habitat, making this small population even more vulnerable. Eliminating all habitat loss and other removals results in a small, slightly inbred population with some long-term risk of extinction if there is no supplementation ($PE_{100}=0$; $PE_{500}=0.086$; $N_{500}=50$; $GD_{500}=0.881$).

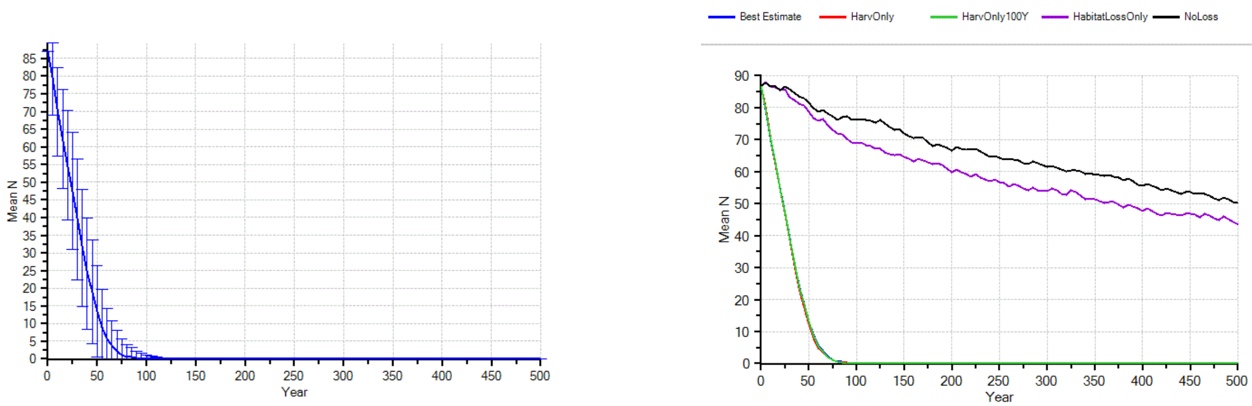


Figure 19. Mean population size over 500 years for Siranggas/Batu Ardan, under projected best estimated future conditions (left, with SD bars) and under all five estimated and alternate future situations (right).

West Batang Toru

Projected viability: Moderate to poor $PE_{100}=0.008$; $PE_{500}=0.41$; $N_{500}=225$; $GD_{500}=0.964$

At projected rates of habitat loss and removals, the West Batang Toru population is projected to decline slowly over time and has a significant risk of extinction, with mean time to extinction = 310 years. This decline is driven entirely by the estimated harvest. If harvest is stopped, the population is able to recover as long as it is not fragmented. Habitat loss is estimated to be minimal for this area. Eliminating all habitat loss and other removals results in a moderate size, genetically diversity population with very little risk of extinction in 500 years ($PE_{100}=0$; $PE_{500}=0.002$; $N_{500}=512$; $GD_{500}=0.973$).

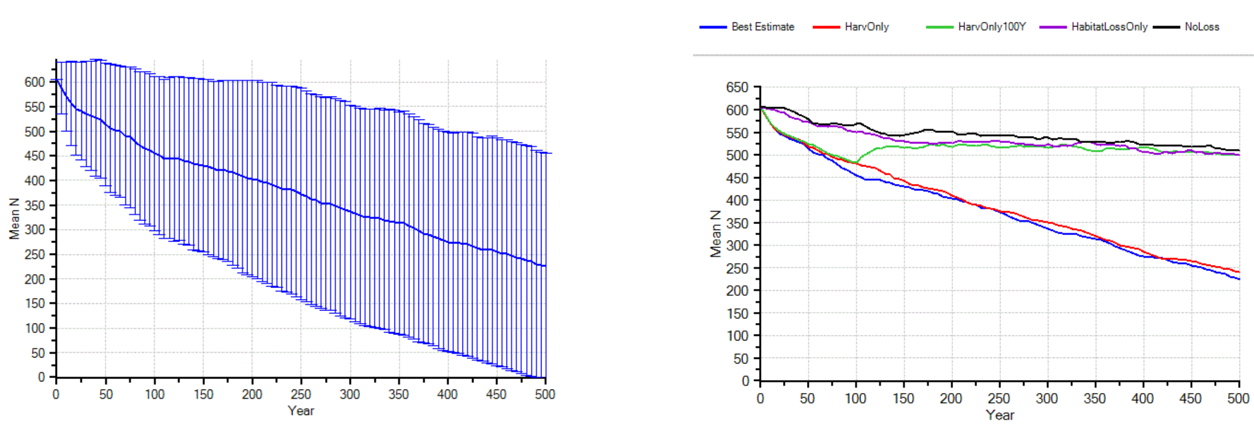


Figure 20. Mean population size over 500 years for West Batang Toru, under projected best estimated future conditions (left, with SD bars) and under all five estimated and alternate future situations (right).

East Batang Toru

Projected viability: Poor *PE_{100}=0.312; PE_{500}=1; N_{500}=0; GD_{500}=0*

At projected rates of habitat loss and removals, the East Batang Toru population is projected to decline to extinction, with mean time to extinction = 124 years. This decline is driven entirely by the estimated harvest. This population is currently at ~MVP and so harvest must be reduced or stopped quickly to maintain viability without the need for supplementation. Habitat loss is estimated to be minimal for this area. Eliminating all habitat loss and other removals results in a small, slightly inbred viable population with little risk of extinction in 500 years (*PE_{100}=0; PE_{500}=0.014; N_{500}=102; GD_{500}=0.882*).

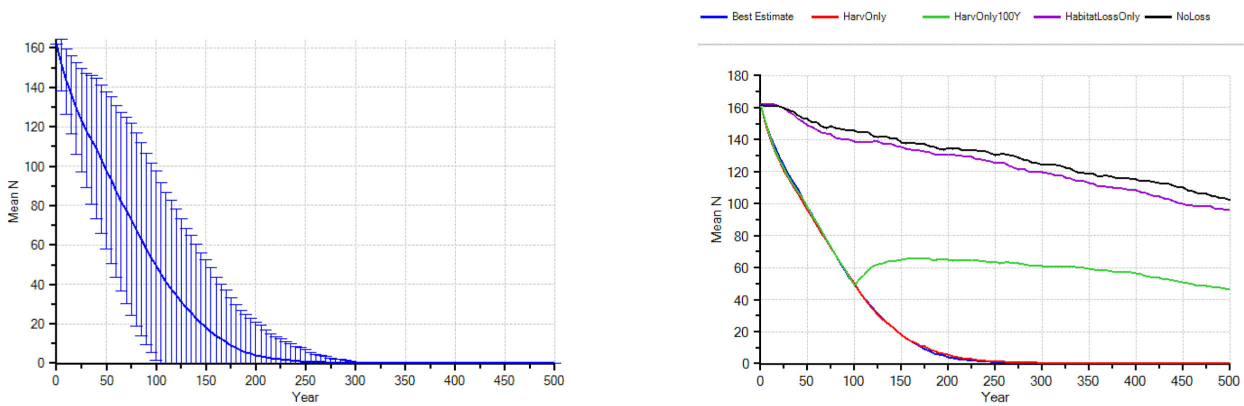


Figure 21. Mean population size over 500 years for East Batang Toru, under projected best estimated future conditions (left, with SD bars) and under all five estimated and alternate future situations (right).

Bukit Tiga Puluh: reintroduced population

Projected viability: Good *PE_{100}=0; PE_{500}=0.016; N_{500}=162; GD_{500}=0.924 (releases for 10 years)*

The Bukit Tiga Puluh population is projected to increase for about 50 years under all three release schemes, assuming no additional harvests and using the age, sex ratio and survival of released animals modelled. Additional years of release lead to faster growth to K, but only 10 years of releases result in a viable population. After about 50 years the population fills the available K and is driven to decline due to continuing habitat loss, stabilizing once habitat loss stops. Population size and viability will depend upon the control of habitat loss and other removals. If no habitat loss occurs, the population grows to K and is a large, genetically diverse population (*PE_{100}=0; PE_{500}=0.002; N_{500}=1394; GD_{500}=0.981*).

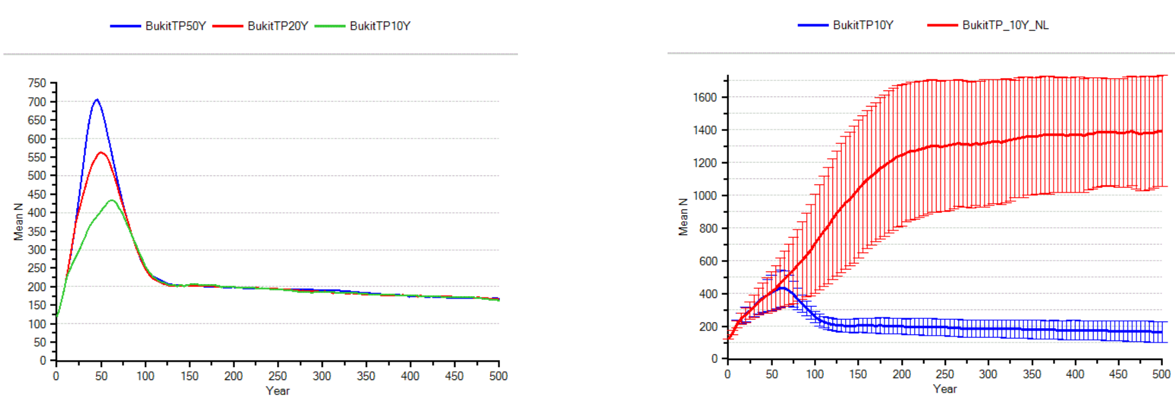


Figure 22. Mean population size over 500 years for Bukit Tiga Puluh, under projected rates of habitat loss at different lengths of annual releases (10, 20, 50 yrs) (left), and with no habitat loss and releases for 10 years (right, with SD bars).

Jantho Landscape: reintroduced population

Projected viability: Good *PE_{100}=0; PE_{500}=0; N_{500}=323; GD_{500}=0.956 (releases for 10 years)*

The Jantho population is projected to increase quickly and then level off close to K under all three release schemes, assuming no habitat loss or additional harvests and using the age, sex ratio and survival of released animals modelled. Additional years of release lead to slightly faster growth, but only 10 years of releases result in a viable population. Population size and viability will depend upon the control of habitat loss and other removals.

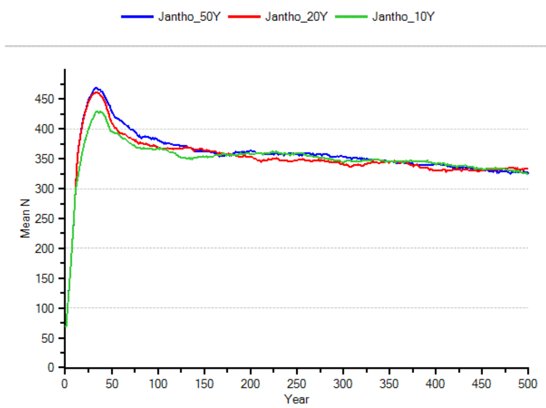


Figure 23. Mean population size over 500 years for Jantho, at different lengths of annual releases (10, 20, 50 yrs) and assuming no habitat loss or other harvest.

Forest fragmentation and loss scenarios

Alternative scenarios were modelled for West Leuser, East Leuser, and Batang Toru to investigate the potential impact of forest loss and road construction. The only impact modelled here was population fragmentation. Other potential impacts of roads such as additional mortality were not included in these models. Habitat loss and removal rates from the default scenarios were proportionally distributed across fragments. Table 17 lists the scenario inputs (number and size of fragments) along with model results.

Under the projected rates of habitat loss and other loss, none of these populations or fragments meets the criteria for viability. *In most cases, fragmentation hastens the decline and time to extinction*. All scenarios for West Leuser and East Leuser project complete extinction within 500 years (mean times to extinction of 156-259 years). Scenarios for Batang Toru with 6 fragments also project certain extinction. When modelled as 1-3 fragments, only West Batang Toru is large and has some probability of long-term survival (43-54%) as a reduced and declining population. If all habitat loss and harvest are removed from these populations, most fragments are viable. Fragments under 100 animals are not viable (WL1, EL5, Sibual-buali area of BT, and West BT 1, 2 and 4), and fragments between 100-200 animals met viability criteria but are in decline (EL1, EL3, East BT, and West BT 3).

Table 17. Population size, carrying capacity, and results for road fragmentation scenarios.

Population	Initial N=K	K_{Y100}	PE_{100}	PE_{500}	N_{100}	N_{500}	GD_{100}	GD_{500}
West Leuser – 1 pop*	5922	4429	0.008	1	3641	--	0.999	--
West Leuser – 2 pops	5922	4429	0.014	0.994	3181	--	0.999	--
WL1	35	26	0.258	1	13	--	0.865	--
WL2	250	187	0.038	0.998	130	--	0.979	--
WL3	1065	797	0.044	1	567	--	0.995	--
WL4	4020	3006	0.028	0.996	2177	--	0.999	--

WL5	522	413	0.046	1	293	--	0.991	--
East Leuser – 1 pop*	5779	4152	0.004	1	3276	--	0.999	--
East Leuser – 2 pops	5779	4152	0.024	1	2655	--	0.999	--
EL1	174	125	0.078	1	80	--	0.969	--
EL2	1771	1273	0.044	1	819	--	0.997	--
EL3	141	101	0.126	1	60	--	0.973	--
EL4	562	404	0.070	1	256	--	0.990	--
EL5	76	55	0.138	1	31	--	0.930	--
EL6	3055	2194	0.042	1	1410	--	0.998	--
Batang Toru – 1 pop	767	744	0.034	0.714	515	124	0.993	0.966
Batang Toru – 2 pops*	767	744	0.006	0.458	511	194	0.993	0.962
East BT	162	157	0.302	1	48	--	0.950	--
West BT	605	587	0.006	0.458	463	194	0.993	0.962
Batang Toru – 3 pops	726	704	0.014	0.566	450	141	0.991	0.956
East BT	162	157	0.336	1	42	--	0.945	--
Sibual-buali area	31	30	0.104	1	18	--	0.863	--
West BT (- PLTA&HPH)	533	517	0.020	0.566	391	141	0.956	0.956
Batang Toru – 6 pops	492	477	0.028	0.992	205	--	0.977	--
East BT	140	136	0.492	1	22	--	0.928	--
Sibual-buali area	31	30	0.346	1	12	--	0.852	--
West BT1 (- PLTA&HPH)	61	59	0.174	1	30	--	0.916	--
West BT2 (- PLTA&HPH)	47	46	0.246	1	21	--	0.892	--
West BT3 (- PLTA&HPH)	157	152	0.090	0.992	92	--	0.962	--
West BT4 (- PLTA&HPH)	56	54	0.174	1	29	--	0.912	--

Summary of Sumatran orangutan PVA results

Model results suggest that none of the eight extant wild populations of Sumatran orangutans are viable in the long term under the projected rates and periods of habitat loss and harvest (Figure 24). Population fragmentation (e.g., due to road construction) is likely to increase the rate of decline and risk of extinction. Alternatively, if all habitat loss and harvest is immediately eliminated, then population viability is high with good retention of genetic diversity (Figure 25). Similarly, the two reintroduced populations may be viable if the populations are built up by additional releases and are not subject to harvest or substantial habitat loss.

Lower rates and shorter periods of habitat loss and/or harvest will lead to intermediate levels of viability between these two extremes. *The actual future of Sumatran orangutan populations will depend to a great extent upon the future rates of habitat loss, fragmentation and harvest, and how long these threats continue before they are reduced or eliminated.*

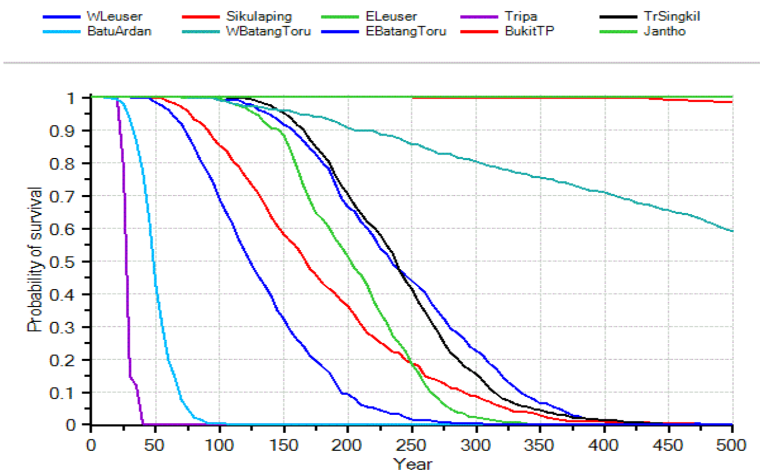


Figure 24. Probability of survival (PS) over time for each of the 10 Sumatran sub-populations. Only West Batang Toru and the two reintroduced populations show PS > 0 in 500 years.

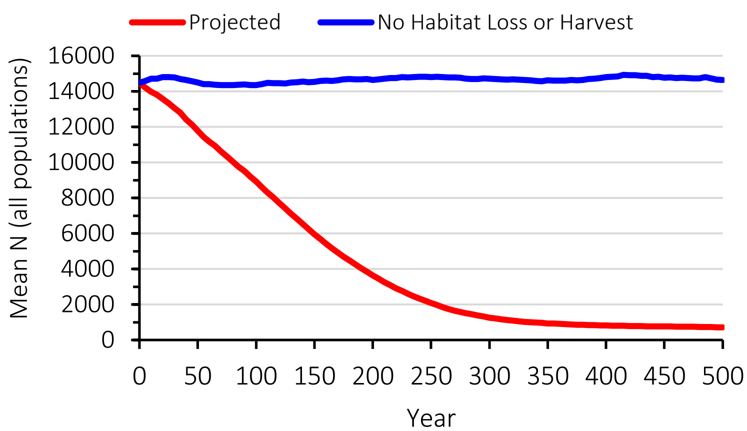


Figure 25. Mean population size of Sumatran meta-population with projected rates of habitat loss and harvest (red) and with no future habitat loss or harvest (blue).

Viability of Bornean orangutan populations

The *Vortex* model modified for Bornean orangutans was used as a basis to assess the viability of the three Bornean taxa: *P.p. pygmaeus*, *P.p. morio* and *P.p wurmbii*.

Pongo pygmaeus pygmaeus Populations

Detailed population-specific model inputs were provided by 2016 PHVA participants for this taxon as outlined below in Table 18. This includes an estimate of fragments within each habitat management unit, estimated current population size and carrying capacity, and projected future habitat loss and removal rate for each habitat management unit. Five of these populations represent fewer than 100 individuals and are below the MVP identified even the absence of threats.

Table 18. Population-specific model inputs for eight Bornean orangutan meta-populations (*P.p. pygmaeus*).

Habitat Management Unit	Within MP units	Estimated pop size	Estimated carrying capacity	Habitat loss (% loss per year)	Removal rate (number removed annually)
Betung Kerihun NP and Protection Forest**	3	2990	3557	0.38% annual loss for 10 years (reduction of K to 3421)	1 adult per year
Batang Ai-Lanjak-Entimau Landscape	1	1808	2010	0.2% annual loss for 10 years (reduction of K to 1970)	2 adults per 5 years
Danau Sentarum NP and Corridor**	2	679	679	0.68% annual loss for 10 years (reduction of K to 633)	1-2 adults and 1 infant per year
Klingkang Range NP and Sintang Utara	2	80	80	1% annual loss for 10 years (reduction of K to 72)	1 adult per year for 2 years
Bungoh NP-Gunung Nyiut NR and Penrisen HL	2	94	94	1% annual loss for 10 years (reduction of K to 85)	1 adult per year for 2 years
Pygmaeus fragmented North	1	29	29	10% annual loss for 10 yrs (100% loss of habitat; K=0)	2-3 adults per year
Pygmaeus fragmented South	1	15	15	10% annual loss for 10 yrs (100% loss of habitat; K=0)	2-3 adults per year
Ulu Sebuyau-Sedilu Landscape	1	30	30	None at present	1 adult per year

**Discrepancies in the numbers provided led to the adoption in the models of the most conservative values.

Discrepancy 1. Estimates for K for Betung Kerihun NP and Protected Forest were based on estimates for three areas (BKNP, Hutan Lindung, Corridor), with the mid-point used for the estimated K of the corridor.

Discrepancy 2. K for Danau Sentarum NP & Corridor is given as 679 in the site characteristics table and as 890 in the threats table. 679 is adopted as the conservative estimate.

Betung Kerihun NP and Protection Forest

Projected viability: High *PE_{100}=0; PE_{500}=0; N_{500}=3222; GD_{500}=0.995*

This large population is projected to undergo a relatively small rate of habitat loss for 10 years only, leaving sufficient habitat for a large population. Projected harvest rate is small and sustainable. Given these conditions, this population is projected to remain large and genetically diverse. Immediate cessation of habitat loss and harvest results in a slightly larger population due to higher K. The viability of this population may be threatened under higher rates of habitat loss and harvest.

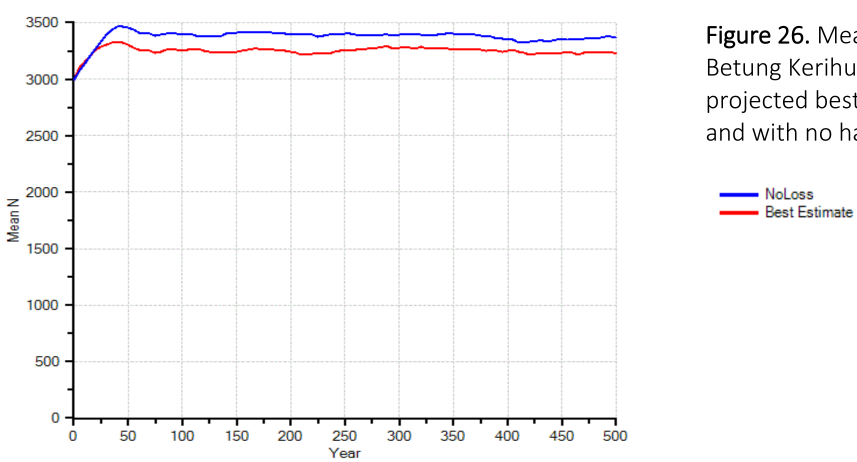


Figure 26. Mean population size over 500 years for Betung Kerihun NP and Protection Forest, under projected best estimated future conditions (red) and with no habitat loss or harvest (blue).

Batang Ai-Lanjak-Entimau Landscape

Projected viability: High *$PE_{100}=0$; $PE_{500}=0$; $N_{500}=1841$; $GD_{500}=0.992$*

Like Betung Kerihun, this large population is projected to undergo a relatively small rate of habitat loss for 10 years only, leaving sufficient habitat for a large population. Projected harvest rate is small and sustainable. Given these conditions, this population is projected to remain large and genetically diverse. Immediate cessation of habitat loss and harvest results in a slightly larger population due to slightly higher K. The viability of this population may be threatened under higher rates of habitat loss and harvest.

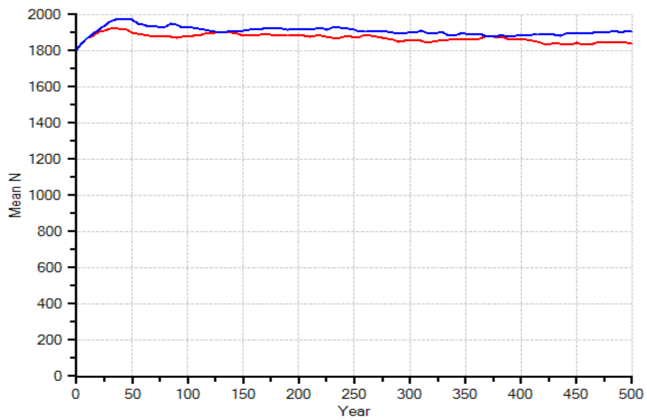


Figure 27. Mean population size over 500 years for Batang Ai-Lanjak-Entimau landscape, under projected best estimated future conditions (red) and with no habitat loss or harvest (blue).

Danau Sentarum NP and Corridor

Projected viability: High *$PE_{100}=0$; $PE_{500}=0.002$; $N_{500}=580$; $GD_{500}=0.974$*

This moderate sized population is projected to decline in the short term under projected rates of habitat loss and harvest that combine to remove animals at an unsustainable rate. If habitat loss is stopped while the population is large it is eventually able to recover and stabilize even under a low level of harvest. Immediate cessation of habitat loss and harvest results in a larger population ($N_{500}=624$) due to higher K. The viability of this population may be threatened under longer periods or higher rates of habitat loss and harvest or this population becomes fragmented.

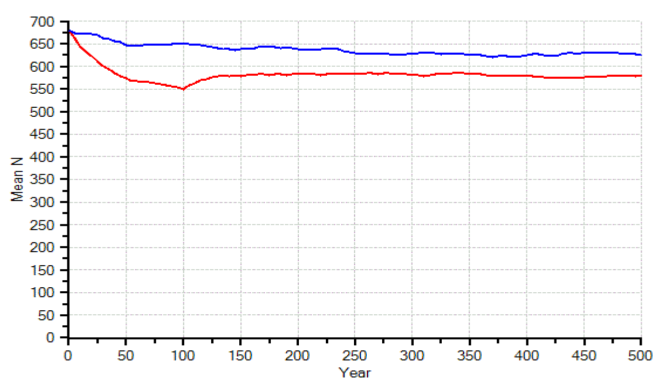


Figure 28. Mean population size over 500 years for Danau Sentarum and Corridor, under projected best estimated future conditions (red) and with no habitat loss or harvest (blue).

Klingkang Range NP and Sintang Utara

Projected viability: Moderate to poor PE_{100}*=0.001;* PE_{500}*=0.272;* N_{500}*=28;* GD_{500}*=0.746*

While this population is projected to persist in the short term (under essentially no harvest), its small size makes it vulnerable to stochastic processes, resulting in smaller size, reduced gene diversity, and moderate risk of extinction. Projections are slightly better with no habitat loss or removals, but do not meet viability criteria if isolated from other orangutan populations (PE_{100}=0; PE_{500}=0.176; N_{500}=37; GD_{500}=0.774). Periodic supplementation has the potential to substantially increase viability (e.g., PE_{100}=0; PE_{500}=0.005; N_{500}=65; GD_{500}=0.886, with 1 adult female added every 20 years) (Figure 29).

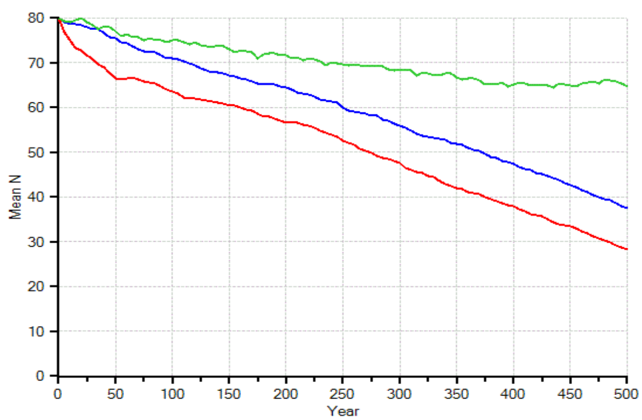


Figure 29. Mean population size over 500 years for Klingkang Range NP and Sintang Utara, under projected best estimated future conditions (red), with no habitat loss or harvest (blue), and with no losses plus supplementation of one adult female every 20 years (green).

Bungoh NP-Gunung Nyiut NR and Penrisen HL

Projected viability: Moderate to poor PE_{100}*=0;* PE_{500}*=0.191;* N_{500}*=40;* GD_{500}*=0.783*

Similar to the Klingkang/Sintang Utara population, this population is projected to persist in the short term (with essentially no harvest) but at reduced size and gene diversity and with moderate risk of extinction. Projections with no habitat loss or removals do not meet viability criteria if isolated from other orangutan populations (PE_{100}=0; PE_{500}=0.116; N_{500}=52; GD_{500}=0.807). Periodic supplementation has the potential to substantially increase viability (e.g., PE_{100}=0; PE_{500}=0.005; N_{500}=77; GD_{500}=0.895, with 1 adult female added every 20 years) (Figure 30).

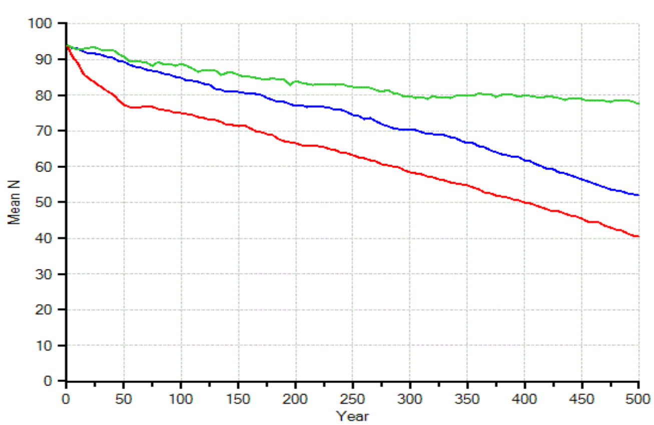


Figure 30. Mean population size over 500 years for Bungoh NP-Gunung Nyiut NR/Penrisen HL, under projected best estimated future conditions (red), with no habitat loss or harvest (blue), and with no losses plus supplementation of one adult female every 20 years (green).

Fragmented North Population

Projected viability: Moderate to poor PE_{100}=1; PE_{500}=1; N_{500}=0; GD_{500}=0

This very small population is projected to undergo heavy harvest and total habitat loss in 10 years. Even if harvest and habitat loss were eliminated, its small size leaves it highly vulnerable to stochastic processes, both demographic and genetic (PE_{100}=0.043; PE_{500}=0.955; N_{500}=0.5; GD_{500}=0.5). Periodic supplementation has the potential to maintain this population provided habitat loss and harvest could be eliminated (e.g., PE_{100}=0.006; PE_{500}=0.109; N_{500}=20; GD_{500}=0.837, with 1 adult female added every 20 years) (Figure 31).

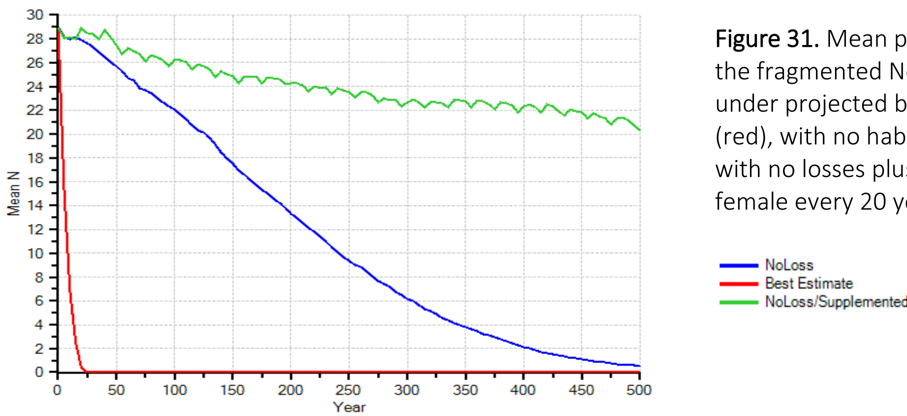
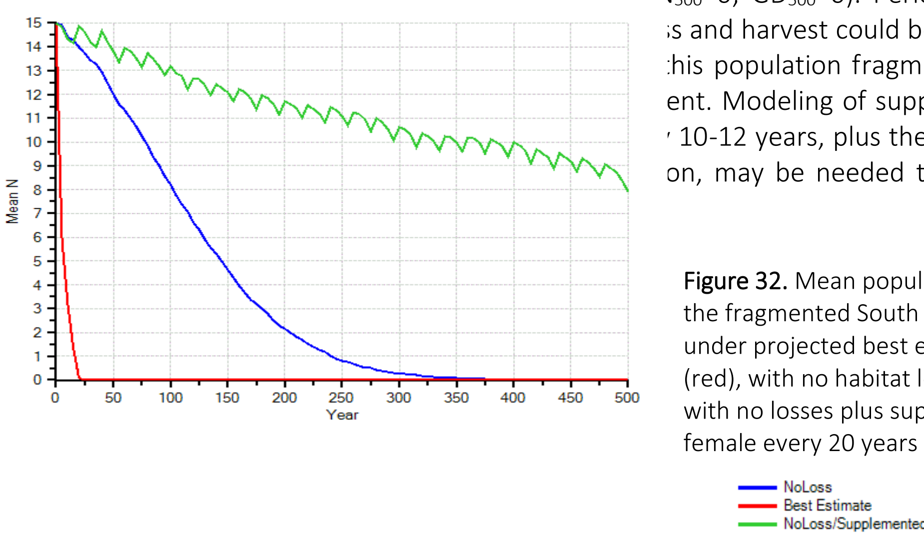


Figure 31. Mean population size over 500 years for the fragmented North *pygmaeus* population, under projected best estimated future conditions (red), with no habitat loss or harvest (blue), and with no losses plus supplementation of one adult female every 20 years (green).

Fragmented South Population

Projected viability: Moderate to poor PE_{100}=1; PE_{500}=1; N_{500}=0; GD_{500}=0

This extremely small population is projected to undergo heavy harvest and total habitat loss in 10 years. Even if harvest and habitat loss were eliminated, its very small size leaves it highly vulnerable to stochastic processes, both demographic and genetic (PE_{100}=0.219; PE_{500}=1; N_{500}=0; GD_{500}=0). Periodic supplementation has the



s and harvest could be eliminated. For example, the
his population fragment (PE_{100}=0.045; PE_{500}=0.369;
ent. Modeling of supplementation rates in this PVA
10-12 years, plus the potential addition of an adult
on, may be needed to produce a long-term viable

Figure 32. Mean population size over 500 years for the fragmented South *pygmaeus* population, under projected best estimated future conditions (red), with no habitat loss or harvest (blue), and with no losses plus supplementation of one adult female every 20 years (green).

Ulu Sebuyau-Sedilu Landscape

Projected viability: Moderate to poor PE_{100}=1; PE_{500}=1; N_{500}=0; GD_{500}=0

While no habitat loss is projected at this time for this very small population, the harvest of one adult per year (>3%) is unsustainable. Even if harvest were eliminated, its small size leaves it highly vulnerable to stochastic processes, both demographic and genetic (PE_{100}=0.021; PE_{500}=0.955; N_{500}=0.5; GD_{500}=0.48). Periodic supplementation has the potential to maintain this population provided harvest and habitat loss are eliminated (e.g., PE_{100}=0.003; PE_{500}=0.078; N_{500}=22; GD_{500}=0.836, with 1 adult female added every 20 years) (Figure 33).

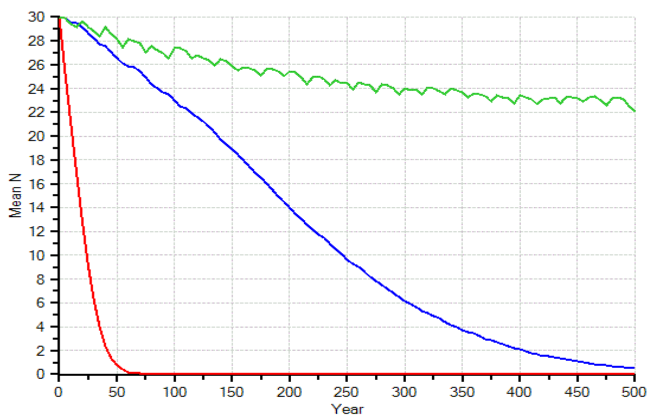


Figure 33. Mean population size over 500 years for the Ulu Sebuyau-Sedilu landscape population, under projected best estimated future conditions (red), with no habitat loss or harvest (blue), and with no losses plus supplementation of one adult female every 20 years (green).

Summary of *P.p. pygmaeus* Population Viability

Two large *P.p. pygmaeus* meta-populations (Betung Kerihun NP and Protection Forest, and Batang Ai-Lanjak-Entimau Landscape) are projected to undergo small amounts of short-term habitat loss and relatively low levels of harvest. These two meta-population have high viability under the conditions modelled and are projected to maintain about 5000 orangutans combined. The smaller population at Danau Sentarum NP is projected to have higher rates of short-term habitat loss and higher relative harvest rates, but if habitat loss ceases as projected this population may stabilize at 500-600 orangutans. *Protection of these large populations and their habitat will be critical for the persistence of this taxon on Borneo*.

None of the five remaining small fragments meets the viability criterion if they remain isolated, even if all threats are removed. Periodic supplementation through natural or managed translocations or releases will be necessary to maintain long-term viability of these fragments. The required rate of releases will vary with population size, threats, and stochastic events, but in most cases should be relatively infrequent. The three smallest fragments are not viable under current projected high rates of habitat loss and/or harvest; these threats would need to be addressed in these small populations in addition to periodic supplementation if they are to persist.

P.p. morio Populations

Data estimates compiled by the 2016 PHVA workshop participants for *P.p. morio* populations were substantially less complete than for *P.p. pygmaeus*. There are many data gaps with respect to estimated carrying capacity and threats. In addition, population size estimates derived from GIS analysis do not correspond well with those estimated from survey data. For some of the specified sites we were unable to locate the equivalent GIS polygon and so comparisons could not be made. These data gaps meant that population-specific PVA models could not be developed for *P.p. morio*.

However, the PVA results for Bornean populations in general as well as those for *P.p. pygmaeus* provide a useful guide to the range of viability of *P.p. morio* populations under various conditions. Table 24. outlines the

20 identified meta-populations for this taxon along with estimates of current population size (from the PHVA and from GIS), carrying capacity, population trend, and relative intensity of habitat loss and removals, all based on the working group's report. The PVA results from other Bornean orangutan models outlined in this report were used to develop some general viability assessments for these meta-populations under various scenarios (no future threats, with habitat loss, with removals). High to good long-term viability is colored in green, moderate viability in yellow, and low to poor viability in orange.

Summary of *P.p. morio* Population Viability

Specific population viability estimates cannot be developed for *P.p.morio*, as detailed estimates of threats (habitat loss and fragmentation, removal of orangutans) are not available. Based on the available information, there are 6 large meta-populations that are likely to show long-term viability as long as any loss of habitat or orangutans remains low and/or short term (Kutai, Tabin, Central Forest, Lower Kinabatangan, North Kinabatangan, Ulu Kalumpang). These meta-populations, many of which are in Sabah in protected areas, represent the core populations for this taxon and could potentially combine to total ~16,000 orangutans (estimated range 9,791 – 22,221, see Appendix III for details). Wehea landscape represents a moderate-sized meta-population that may be vulnerable depending upon the level of habitat loss and removals that impact it.

There are 6 meta-populations of ~300 orangutans each; populations of this size may be viable in the absence of threats but are vulnerable to loss of habitat and individuals. Four of these (Crocker Range, Lingkabau, Bonggaya, Sepilok) appear to be stable and not under threat, possibly representing another ~1000 orangutans. Trus Madi landscape may be at risk depending upon the level of habitat conversion, while Sangkulirang appears to be at risk due to both habitat loss and harvest.

Seven meta-populations are small (most under 100 individuals) and subject to some extinction risk even in the absence of threats. All of these populations appear to be under risk of continued threat, resulting in poor long-term viability. Depending upon their specific situation, these small populations may be able to maintain good viability with periodic supplementation *if* current threats can be significantly reduced or eliminated.

These viability assessments for P.p. morio populations are meant to serve as a guide only. As more information becomes available on the size, available habitat, fragmentation and threats of *P.p. morio* populations, the viability estimates for this taxon can be revised.

Table 19. Estimates of current N, K, population trend, threats, and relative viability for 17 Bornean orangutan meta-populations (*P.p. morio*).

Meta-population	#MP units	Est. N Wksp (GIS)	Est. K Wksp	GIS ID	Population trend	Habitat loss intensity	Removal intensity	Viability w/ no habitat loss or removal	Relative viability with habitat loss	Relative viability with removals
Beratus Landscape	1	35	-	Not found	Declining	High	Medium	Poor viability without releases	Poor; cannot withstand loss of K	Poor; cannot withstand harvest
Sungai Wain Landscape	1	20	20*	Not found	Declining	High	--	Poor viability without releases	Poor; cannot withstand loss of K	Poor; cannot withstand harvest
Kutai NP-Bontang Landscape	7	1700	1696	Not found	Variable to declining	High	Low to medium	High viability (if not fragmented)	Good viability if K remains >500	Good viability if annual removal <1%
Belayan-Senyiur Landscape	3	224	224	Not found	Declining	Medium	Medium	Moderate viability (if not fragmented)	Moderate if K remains >200	Low viability if harvested
Wehea-Lessan PF Landscape	4	623 (1909+2094)	669	KAL 14, 15 and 16	Mostly declining	Medium	Low	Good viability (if not fragmented)	Good viability if K remains >500	Good if annual removal <0.5%
Sangkulirang Landscape	4	311 (775)	311	KAL 2	Declining	High	Variable	Moderate viability (if not fragmented)	Moderate if K remains >200	Moderate if annual removal <0.5%
Tabin Range Landscape	2	1255 (2207)	2150	SAB 6	Stable	--	--	High viability (if not fragmented)	Good viability if K remains >500	Good viability if annual removal <1%
Central Forest Range Landscape	3	5325 (4765)	6900	SAB 7	Stable to declining	High in areas	--	High viability (if not fragmented)	Good viability if K remains >500	Good viability if annual removal <1%
Lower Kinabatangan Range Landscape	2	1243 (1082)	1500	SAB 5	Stable to declining	High in areas	--	High viability (if not fragmented)	Good viability if K remains >500	Good viability if annual removal <1%
North Kinabatangan Range Landscape	1	1900 (979)	3000	SAB 4	Stable	Medium	--	High viability (if not fragmented)	Good viability if K remains >500	Good viability if annual removal <1%
Ulu Kalumpang Range Landscape	1	375 (226)	800	SAB 8	Declining	High	--	Good viability (if not fragmented)	Good viability if K remains >500	Good if annual removal <0.5%
Crocker Range Landscape	1	181 (106)	300	SAB 2	Stable	--	--	Moderate viability (if not fragmented)	Moderate if K remains >200	May reduce viability until N nears K
Lingkabau Landscape	2	150 (107)	300	SAB 1	Stable	--	--	Moderate viability (if not fragmented)	Moderate if K remains >200	May reduce viability until N nears K
Bonggaya Landscape	2	190 (104)	300	SAB 9	Stable	--	--	Moderate viability (if not fragmented)	Moderate if K remains >200	May reduce viability until N nears K
Ulu Tungud Landscape	1	29 (285)	80	SAB 10	Declining	High	--	Low viability without releases	Poor; cannot withstand loss of K	Poor; cannot withstand harvest
Trus madi Landscape	1	282 (111)	350	SAB 11	Declining	High	--	Moderate viability (if not fragmented)	Moderate if K remains >200	May reduce viability until N nears K
Sepilok Landscape	1	200	300	Not found	Stable	--	--	Moderate viability (if not fragmented)	Moderate if K remains >200	Moderate if annual removal <0.5%

P.p. wurmbii Population Viability

Sixteen primary meta-populations were identified for this taxon based on data compiled by the 2016 PHVA workshop participants at or subsequent to the workshop (*see P.p. wurmbii* working group report). Data availability was intermediate between that available for *P.p. pygmaeus* and for *P.p.morio*, with general estimates provided for population size and threats. The data provided in Table 20 were used to develop a general PVA model for each meta-population to provide a relative viability assessment for each. This information is subject to revisions that may alter these viability assessments; thus, they should be used only as guides for relative viability comparisons.

The following assumptions were made for these models, based on those used in other PVA models in this report: 1) each meta-population was modelled as a single population with complete connectivity among sub-populations and fragments within the meta-population; 2) meta-populations are at carrying capacity for their current habitat; 3) % habitat loss was applied to the K current in that year, meaning that the actual area lost diminishes each year over time; and 4) removals are applied as the % of adults removed each year, proportional across sex. Estimates that include < or > were increased or decreased by 0.1% (e.g., < 2% = 1.9%; > 2% = 2.1%). Four scenarios were run for each meta-population, using lower or upper population estimates, and with or without threats (habitat loss and removals). All scenarios were run for 100 years only

The results follow a similar pattern for each of the 16 meta-populations, as illustrated by Figure 34. for the Kubu Raya meta-population. In the absence of further habitat loss or removals, all meta-populations (except for those few ≤ 300 orangutans) are viable and stable, with high genetic diversity and no risk of extinction within 100 years (Table 20). In contrast, the long-term viability of most meta-populations is moderate to poor under current estimated rates of habitat loss and removals. While most have no risk of extinction within 100 years, these meta-populations are projected to decline by 60-90%, reducing their size such that they may become vulnerable to stochastic threats and at risk. Only the three large meta-populations (Tanjung Puting, Sebangau, Arabela Schwaner) remain large after 100 years given projected threat levels.

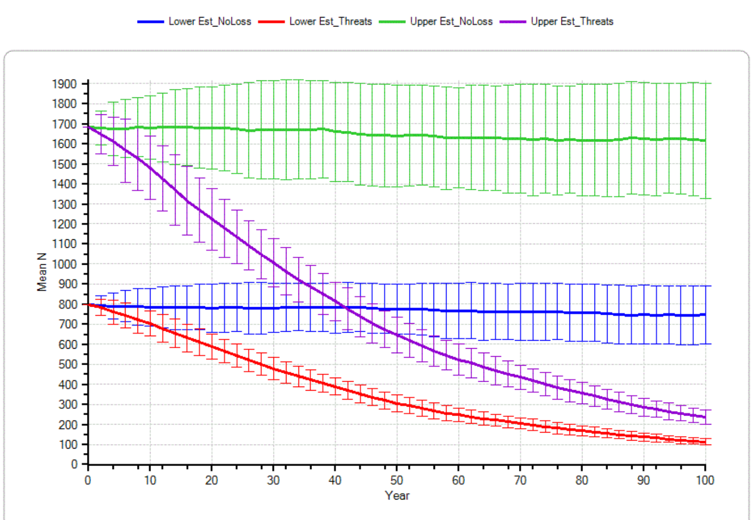


Figure 34. Mean population size over 100 years for the Kubu Raya meta-population, under estimated threat conditions (red for lower estimated N, purple for upper estimated N), and with no habitat loss or harvest (blue for lower estimated N, green for upper estimated N). Bars indicate ± 1 SD.

Note that projected rate of decline tapers over time, as habitat loss and removals are modelled as being proportional to density. If the area of habitat lost and/or the number of orangutans removed remains constant each year, these meta-populations (and the taxon) will decline to extinction within 100 years

Table 20. Estimates of current N, population trend, threats, and relative viability for 16 Bornean orangutan meta-populations (*P.p. wurmbii*) over 100 years.

Meta-population	**Within MP units**	**Lower Est. N**	**Upper Est. N**	**Population trend**	**Habitat loss intensity**	**Removal intensity**	**Viability with est. threats (100 yrs)**	**Viability with no threats (100 yrs)**
Kubu Raya	3 +fragments	798	1684	Declining	High (2%)	Medium (1-2%)	~86% decline; PE_{100}=0 N_{100} = 111-235	Good viability Stable near K
Gunung Palung -Sg Putri	3 +fragments	2620	3945	Stable/ declining	Medium to high (2%)	Medium to low (~1%)	~86% decline; PE_{100}=0 N_{100} = 375-562	High viability Stable near K
Pematang Gadung	4 +fragments	499	775	Declining	High (2%)	Medium (2%)	~86% decline; PE_{100}=0 N_{100} = 68-107	Good viability Stable near K
Sungai Tengar	3 +fragments	101	211	Declining	High (2%)	High (>2%)	~88% decline; PE_{100} =0.002-0.026 N_{100} = 11-27; G_{100} = 0.88-0.94	Moderate viability Stable near K
Kendawangan-Jelai	3 +fragments	31	66	Declining	High (2%)	High (>2%)	$\geq$90% decline; PE_{100} =0.30-0.86 N_{100} = 1-7; G_{100} = 0.68-0.81	Poor viability Slow decline; $PE_{100} \leq$ 0.038
Lamandau-Sukumara	2 +fragments	516	752	Stable	High (2%)	Low (<1%)	~86% decline; PE_{100}=0 N_{100} = 73-106	Good viability Stable near K
Kotawaringin Lama	4 +fragments	437	850	Declining	High (2%)	Low (<1%)	~86% decline; PE_{100}=0 N_{100} = 60-119	Good viability Stable near K
Tanjung Putin	1 +fragments	3713	4655	Stable	Variable (1%)	--	~61% decline; PE_{100}=0 N_{100} = 1441-1800	High viability Stable near K
Seruyan-Sampit	Fragments	79	167	Declining	High (2%)	Medium (1-2%)	~88% decline; PE_{100} =0.004-0.06 N_{100} = 9-22; G_{100} = 0.85-0.93	Poor to moderate viability Small decline; $PE_{100} \leq$ 0.006
Katingan	3 +fragments	3334	4709	Declining	High (2%)	--	~86% decline; PE_{100}=0 N_{100} = 472-663	High viability Stable near K
Sebangau	2 +fragments	5943	6222	Stable	Variable (1%)	--	~61% decline; PE_{100}=0 N_{100} = 2272-2417	High viability Stable near K
Rungan River Landscape	2 +fragments	1724	2794	Declining	Variable (2%)	--	~86% decline; PE_{100}=0 N_{100} = 247-401	High viability Stable near K
Kahayan-Kapuas	6 +fragments	1065	2300	Declining	Variable (2%)	--	~86% decline; PE_{100}=0 N_{100} = 151-331	High viability Stable near K
Kapuas-Barito (Mawas)	3 +fragments	2000	3096	Declining	High (2%)	Medium (1-2%)	~86% decline; PE_{100}=0 N_{100} = 2281-434	High viability Stable near K
Barito Timur	3	144	307	Declining	High (2%)	Medium (1-2%)	~87% decline; PE_{100}=0 to 0.008 N_{100} = 18-41; GD_{100} = 0.92-0.96	Moderate viability Stable near K
Siawan-Belida	0	0		0	--	--	Not assessed (no orangutans present)	--
Arabela Schwaner	6 +fragments	8432	12462	Stable	Medium to low (<2%)	Low (<1%)	~59% decline; PE_{100}=0 N_{100} = 3479-5133	High viability Stable near K

Summary of *P.p. wurmbii* Population Viability

The three large, stable meta-populations (Tanjung Puting, Sebangau, Arabela Schwaner) are likely to be viable over time, provided that habitat loss does not significantly reduce K or fragment the population and that removals are low. These meta-populations could total ~17,000 to 22,000 orangutans if carrying capacity (habitat) is not lost and orangutans are not extracted or killed. Estimated current habitat loss and removal rates for these meta-populations, while low, would result in ~60% reduction in orangutan numbers in these areas over 100 years. Several moderately large populations have combined threat levels that lead to severe decline (~86%) if allowed to continue; while declining, these populations may exhibit good viability IF habitat loss and removals can be slowed or halted while the populations are still large and not fragmented. *Almost all meta-populations may be viable if habitat loss and removal of orangutans were halted immediately.*

Summary of PVA modelling results

This PVA was developed in concert with the 2016 PHVA workshop for orangutans and is based upon the best available information at that time. The following questions were addressed by this PVA; brief conclusions are given below.

What is the projected viability of current orangutan populations given the best estimates of population size, threats and management?

None of the eight extant wild populations of Sumatran orangutans are projected to be viable in the long term under the projected rates and periods of habitat loss and harvest. The two reintroduced populations may be viable with additional releases provided they are not subject to harvest or substantial habitat loss. If all habitat loss and harvest were to be immediately eliminated, then population viability would be high for Sumatran orangutans. Lower rates and shorter periods of habitat loss and/or harvest will lead to intermediate levels of viability between these two extremes.

Bornean populations are divided into three taxa; all three have large, potentially viable meta-populations, moderate-sized meta-populations at various degrees of risk, and small populations under threat with low viability without threat abatement and/or periodic supplementation. The least numerous of the three is *P.p. pygmaeus*, with two large meta-populations totalling ~5000 orangutans that have good long-term viability under projected conditions, while other meta-populations are at risk due to threats and/or small population size. *P.p. morio* has six large meta-populations totaling ~16,000 orangutans that have good viability provided habitat loss and removals remain low and/or are eliminated. Several moderate-size meta-populations also may be viable if losses remain negligible, while small populations under threat are at risk of extinction. The three large *P.p. wurmbii* meta-populations totaling ~20,000 orangutans, plus several moderate-size meta-populations, have good viability if habitat loss can be controlled. Several smaller meta-populations are at risk due to high removal rates as well as habitat loss and small size.

What is the projected impact on orangutans of the construction of roads through orangutan habitat (e.g., in West and East Leuser, in West and East Batang Toru)?

PVA results for road fragmentation scenarios are conservative estimates of road impacts, as they do not consider additional mortality or increased accessibility. Fragmentation hastens decline and time to extinction and in most scenarios led to eventual extinction under current projected threats. In the absence of habitat loss, removals or additional mortality, fragmentation alone did not greatly impact viability.

What is the smallest population size that can meet the agreed standards for a Minimum Viable Population (MVP)? How does this size change with different conditions or threat levels?

The PHVA participants defined a viable population as one with < 1% probability of extinction in 100 years and < 10% risk of extinction in 500 years. Using this definition, the MVP for Sumatran orangutans is 150 and MVP=100 for Bornean orangutans. Although defined as 'viable', these populations of 100-150 demonstrate a slow declining trend and reduced gene diversity (i.e., inbreeding accumulation). A minimum population of 200 orangutans is needed for both species to retain 90% GD for 500 years, and at least 500 orangutans are needed to stabilize population size and avoid decline. All of these thresholds are higher if the initial animals are related or subject to increased threats.

What is the smallest current population that could meet the MVP standard if allowed space to grow larger (e.g., reintroductions into a new area, additional habitat added to an existing area)?

Populations of at least 50 orangutans are able to meet the MVP standard if they have sufficient space to grow, provided they are not under threat of habitat loss, fragmentation or harvest. These results are based on the current PVA model, which incorporates density-dependent reproduction and thus allows populations to grow at a faster rate at low density.

What level of periodic supplementation would be needed to maintain the viability of small populations below the MVP?

Orangutan populations of 50 or fewer animals can be maintained through periodic supplementation. The required supplementation rate will depend upon the population size and potentially other factors such as threat levels. PVA results suggest that the addition of one young adult female every ~35 years can provide viability to a population of 50, while a population of 20 may need supplementation with one adult female every 13 years. Very small fragments may be at risk of losing their sole breeding male and may require addition of an adult male in some cases.

What is the viability of populations established using a specified reintroduction scheme?

Release strategies may vary by the age, sex and number of orangutans released as well as the length and schedule of release. A thorough assessment of reintroduction schemes is beyond the scope of this PVA. However, a specific scheme was modelled that involved four consecutive years of a large number of releases into a large area of unoccupied habitat. Releases were of sub-adult and young adults and were female biased. The combination of a young, female-biased population at low density promotes faster growth and overall population viability.

Summary

This PVA was developed to provide guidance on those factors most affecting wild orangutan population viability, regardless of the exact definition of viability used. This long-lived, slow reproducing species is vulnerable to factors affecting female reproduction and survival and to the stochastic effects of small population size. Threats that reduce population size and/or remove adult females from the population, such as habitat loss and fragmentation as well as direct killing or removal of orangutans from the wild, can greatly impact viability. The slow intrinsic rate of growth for this species means that relatively small rates of continual loss (<1%) may be unsustainable. On the other hand, low rates of periodic supplementation, especially of females, can lead to substantial increases in viability. These conclusions may serve as a guide when considering management and conservation strategies for this species.

Orangutan GIS models

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Introduction

In past PHVAs the PVA models relied on expert opinion for orangutan population and threat estimates, derived from local surveys. The results, however, are often biased towards survey areas and are not methodologically consistent. Using a combination of surveys across the known orangutan range and information about the habitat and anthropogenic threats, spatial models can produce density maps that allow to fill the spatio-temporal gaps in survey-coverage and to have a consistent estimate across the whole range.

Approach

The models for Sumatra are based on nest-survey data that was collected across the species' range. A generalized linear modelling approach was used to analyse the combined influence of different habitat predictors (elevation, carbon content, forest-cover, rainfall, rainfall-variability, temperature and temperature range) and to build a predictive density distribution model for the Sumatran orangutan geographic range. Details are provided in Wich *et al*., (2016).

The model for Borneo is based on several types of data: (a) nest count data obtained from line transect (ground and aerial) surveys, (b) presence-absence data from line transect and reconnaissance walk surveys (mainly nests), and (c) presence-absence data of orangutan sightings from interviews. It is a hierarchical model that separates between the latent orangutan population status and the observed data to predict the density of orangutan on Borneo. The model estimated the orangutan survival rates and colonization rates, and they were parameterized based on site-specific information such as altitude, monthly rainfall during the dry and wet season, proportion of Muslims, forest extent, distance to recently converted forest to industrial agriculture and distance to protected areas. The model also takes into account large rivers as barrier to orangutan dispersal.

Because the reliability of model results decreases with the distance to areas that were sampled, areas with known orangutan populations were delimited by experts and the model results limited to these areas. For the orangutan populations in Sumatra, this was done in the publication by Wich *et al.*, 2016 and for Borneo, this was done at the PHVA 2016.

Current orangutan numbers for Borneo

The estimated change in orangutan abundance in three time periods between 1997 and 2015 are shown in table below.

Table 21. Estimated number of individuals by region.

Region	Estimated number of individuals per time period						Overall
	1997-2002		2003-2008		2009-2014		%
	Individuals	% †	Individuals	% †	Individuals	% †	
Sabah	14,354	14.1%	12,638	14.9%	10,691	15.1%	14.7%
Sarawak	2,268	2.2%	1,800	2.1%	1,664	2.4%	2.2%
West Kalimantan	27,291	26.9%	22,103	26.0%	17,663	25.0%	26.0%
Central Kalimantan	49,467	48.7%	41,542	49.0%	34,673	49.0%	48.9%
East Kalimantan	7,294	7.2%	6,023	7.1%	5,335	7.5%	7.3%
North Kalimantan	815	0.8%	746	0.9%	665	0.9%	0.9%
Total	**101,489**	100.0%	**84,852**	100.0%	**70,691**	100.0%	100.0%

† Over total number of individuals per period (in bold).

Insights

Orangutan populations on Borneo have declined at a rate of >25% over the last 10 years. Pressure on orangutan populations in the same period of time varied substantially among regions, with the populations in Sabah, Sarawak, East and North Kalimantan experiencing a relatively moderate pressure, as opposed to high pressure in West and Central Kalimantan. The occurrence of orangutan populations in areas most suitable for human activities has led to an enhanced risk of human-wildlife conflicts. Unless threats from climate change, land use change and other anthropogenic pressure are abated, we predict that most remaining populations of the Bornean orangutan will be severely impacted by human activities.

Poor connectivity among orangutan habitats within the boundaries of PAs is currently the predominant threat to orangutan populations in Sabah. In Sarawak, East and North Kalimantan, habitat loss from forest conversion to industrial agriculture and human-orangutan conflicts are the main threats. Orangutan populations in West and Central Kalimantan, are mainly endangered by habitat loss from continuing forest conversion to industrial agriculture, human-orangutan conflicts, and anthropogenic activities.

As the populations in different regions face different threats, specific abatement plans should be implemented to ensure the long-term persistence of the species. This includes (1) maintaining high forest cover in orangutan habitats and improving the connectivity among the remaining habitat patches through better spatial planning for all regions of Borneo, (2) close cooperation with plantation companies, smallholder farmers and wider communities in managing conflicts with orangutans in Kalimantan, and specifically in West and Central Kalimantan. This includes (3) improving the effectiveness of anti-hunting efforts and education and (4) developing a better understanding of the underlying socio-economic motivations of hunting.

Estimated yearly deforestation rates for use as threat estimates for the PVA models:

The forest area available for each population in the year 2000 was extracted from a land cover layer (Miettinen *et al*., 2012), using the expert-delineated population polygons and a 2 km buffer around them. From the land cover-classes only mangrove forest, peat swamp forest, lowland forest and lower montane forest were considered suitable orangutan habitat. The yearly deforestation in 2000 until 2014 was obtained from the tree-loss layer by Hansen *et al.,* 2013. The deforestation that occurred outside of primary forest was excluded and for each year the amount of remaining forest was used to calculate the percent of habitat available lost annually, for each population.

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Appendix II. Data for *Pongo abelii*

The following data were collated by the *Pongo abelii* working group during the 2016 PHVA workshop. Estimates for current population size and carrying capacity (K) were derived from GIS models, except for the two reintroduction sites, Bukit Tiga Puluh and Jantho. Habitat loss rates are derived from GIS models for all sites.

Definitions:

Poaching as trade. Deliberate killing/removal of orangutans to obtain infants (still live) for pets
Conflict killing. Killing of orangutans in conflict situations, sometimes leading to surviving infants becoming pets
Hunting/food. Deliberate hunting and killing of orangutans for food
Reintroduction. Introduction of new animals into the population
Palm oil plantations. Large scale plantations usually with permits
Timber/pulp & paper plantations. Large scale concessions usually with permits
Road construction. Legal & illegal, outside concessions
Illegal logging. Random small scale illegal logging. In some cases, followed by small and medium scale agricultural encroachment
Mining: Normally legal if large scale but also sometimes smaller scale and illegal.
Energy projects. Predominantly legal hydro-electric and geothermal.
Settlement. Both legal settlement expansion and establishment of illegal new settlements.
Agricultural encroachment (medium scale). Intended to include illegal medium sized plantations and encroachment of dozens up to hundreds or even thousands of hectares.
Agric. encroachment (small scale). Much smaller illegal encroachment of a few or a few tens of hectares.
Fires/burning forest. Intended to represent fires outside of areas being converted for agriculture and plantation conversion.

Table 22. *Pongo abelii* site designations (Population/area), estimated current orangutan population size (Pop. est.) and carrying capacity (Est. K), and estimated rates of loss resulting from direct removal of orangutans or as a result of habitat loss.

				REMOVAL or LOSS of orangutans from the population			HABITAT LOSS			
Population / area	Pop. est.	Est. K	Pop. trend	Cause	Intensity (H/M/L)	Rate	Cause	Intensity (H/M/L)	Rate	Impact
West Leuser	5,922	5,922	Declining	Poaching as trade	L	7 adult females and 7 infants per year	Total forest loss	-	0.29%	100% reduction of K in converted area
				Conflict killing	L	21 per year?	Palm oil plantations	M	0.0276	
				Hunting/food	L	0	Timber/pulp & paper plantations	L	0.0138	
							Road construction	H	0.0414	
							Illegal logging	M	0.0276	
							Mining	M	0.0276	
							Energy projects	H	0.0414	
							Settlement	L	0.0138	
							Agricultural encroachment (medium scale))	M	0.0276	
							Agric. Encroachment (small scale)	M	0.0276	
							Fires/burning forest	L	0.0414	
Sikulaping (Pakpak Bharat)	261	261	Declining	Poaching as trade	L	0.5 adult female and 0.5 infants per year	Total forest loss	-	0.01%	100% reduction of K in converted area
				Conflict killing	L	1 per year	Palm oil plantations	L	0.0005	
				Hunting/food	-	-	Timber/pulp & paper plantations	L	0.0005	
							Road construction	L	0.0005	
							Illegal logging	M	0.0010	
							Mining	L	0.0005	
							Energy projects	L	0.0005	
							Settlement	L	0.0005	
							Agricultural encroachment (medium scale))	L	0.0005	
							Agric. Encroachment (small scale)	M	0.0010	
							Fires/burning forest	L	0.0005	

				REMOVAL or LOSS of orangutans from the population			HABITAT LOSS			
Population / area	Pop. est.	Est. K	Pop. trend	Cause	Intensity (H/M/L)	Rate	Cause	Intensity (H/M/L)	Rate	Impact
East Leuser	5,779	5,779	Declining	Poaching as trade	L	9 adult females and 9 infants per year	Total forest loss	-	0.33%	100% reduction of K in converted area
				Conflict killing	L	18 per year	Palm oil plantations	H	0.0471	
				Hunting/food	L	0	Timber/pulp & paper plantations	L	0.0157	
				Wounding (for crop guarding and scare)	-	4 per year	Road construction	H	0.0471	
							Illegal logging	M	0.0314	
							Mining	M	0.0314	
							Energy projects	H	0.0471	
							Settlement	M	0.0314	
							Agricultural encroachment (medium scale))	H	0.0471	
							Agric. Encroachment (small scale)	M	0.0314	
							Fires/burning forest	L	0.0471	
Tripa Swamp	212	212	Declining	Poaching as trade	L	1 adult female and 1 infant per year	Total forest loss	-	11.48%	100% reduction of K in converted area
				Conflict killing	L	1 per year	Palm oil plantations	H	1.6400	
				Hunting/food	L	0	Timber/pulp & paper plantations	L	0.5467	
				Fire (Medium)	-	1 per year	Road construction	H	1.6400	
							Illegal logging	H	1.6400	
							Mining	L	0.5467	
							Energy projects	L	0.5467	
							Settlement	L	0.5467	
							Agricultural encroachment (medium scale))	H	1.6400	
							Agric. Encroachment (small scale)	H	1.6400	
							Fires/burning forest	H	1.6400	
Trumon-Singkil	1,269	1,269	Declining	Poaching as trade	L	1.5 adult female and 1.5 infant per year	Total forest loss	-	0.43%	100% reduction of K in converted area
				Conflict killing	L	3 per year	Palm oil plantations	M	0.0410	

				REMOVAL or LOSS of orangutans from the population			HABITAT LOSS			
Population / area	Pop. est.	Est. K	Pop. trend	Cause	Intensity (H/M/L)	Rate	Cause	Intensity (H/M/L)	Rate	Impact
				Hunting/food	L	0	Timber/pulp & paper plantations	L	0.0614	
				Wounding (for crop guarding and scare)	-	1 per year	Road construction	H	0.0614	
				Fire (low)	-	-	Illegal logging	H	0.0614	
							Mining	L	0.0205	
							Energy projects	L	0.0205	
							Settlement	M	0.0410	
							Agricultural encroachment (medium scale))	H	0.0614	
							Agric. Encroachment (small scale)	H	0.0614	
							Fires/burning forest	H	0.0614	
Siranggas/ Batu Ardan	87	87	Declining	Poaching as trade	L	0.5 adult female and 0.5 infant per year	Total forest loss	-	0.10%	100% reduction of K in converted area
				Conflict killing	L	1 per year	Palm oil plantations	L	0.0048	
				Hunting/food	-	-	Timber/pulp & paper plantations	L	0.0048	
							Road construction	L	0.0048	
							Illegal logging	H	0.0143	
							Mining	H	0.0143	
							Energy projects	L	0.0143	
							Settlement	M	0.0095	
							Agricultural encroachment (medium scale))	M	0.0095	
							Agric. Encroachment (small scale)	H	0.0143	
							Fires/burning forest	L	0.0048	
West Batang Toru	604	604	Declining	Poaching as trade	L	0.5 adult female and 0.5 infant per year	Total forest loss	-	0.03%	100% reduction of K in converted area
				Conflict killing	L	1.99 adult male per year	Palm oil plantations	M	0.0029	

				REMOVAL or LOSS of orangutans from the population			HABITAT LOSS			
Population / area	Pop. est.	Est. K	Pop. trend	Cause	Intensity (H/M/L)	Rate	Cause	Intensity (H/M/L)	Rate	Impact
				Hunting/food	L	0.89 per year	Timber/pulp & paper plantations	L	0.0043	
							Road construction	H	0.0043	
							Illegal logging	M	0.0029	
							Mining	M	0.0029	
							Energy projects	H	0.0043	
							Settlement	M	0.0029	
							Agricultural encroachment (medium scale))	M	0.0029	
							Agric. Encroachment (small scale)	H	0.0043	
							Fires/burning forest	L	0.0014	
East Batang Toru (Sarulla)	162	162	Declining	Poaching as trade	L	0.5 adult female and 0.5 infant per year	Total forest loss	-	0.03% per year	100% reduction of K in converted area
				Conflict killing	L	0.99 adult male per year	Palm oil plantations	M	0.0029	
				Hunting/food	-	0.45 per year	Timber/pulp & paper plantations	L	0.0014	
							Road construction	H	0.0043	
							Illegal logging	M	0.0029	
							Mining	M	0.0029	
							Energy projects	H	0.0043	
							Settlement	M	0.0029	
							Agricultural encroachment (medium scale)	M	0.0029	
							Agric. Encroachment (small scale)	H	0.0043	
							Fires/burning forest	L	0.0014	
Bukit Tiga Puluh Landscape							Total forest loss	-	1.89%	100% reduction of K in converted area
No. in original table	137	1,560	Increasing	Re-introduction	-	+8 per year	Palm oil plantations	-	-	
No. released	171			Conflict killing	-		Timber/pulp & paper plantations	-	-	
No. released x 70% survival	120			Hunting/food	-		Road construction	-	-	
							Illegal logging	-	-	

				REMOVAL or LOSS of orangutans from the population			HABITAT LOSS			
Population / area	Pop. est.	Est. K	Pop. trend	Cause	Intensity (H/M/L)	Rate	Cause	Intensity (H/M/L)	Rate	Impact
							Mining	-	-	
							Energy projects	-	-	
							Settlement	-	-	
							Agricultural encroachment (medium scale))	-	-	
							Agric. Encroachment (small scale)	-	-	
							Fires/burning forest	-	-	
Jantho landscape							Total forest loss	-	0.001%	100% reduction of K in converted area
No. in original table	62	400	Increasing	Re-introduction	-	+20 per year	Palm oil plantations	L	0.00005	
No. released	99			Conflict killing	-	0	Timber/pulp & paper plantations	L	0.00005	
No. released x 70% survival	69			Hunting/food	-	0	Road construction	M	0.00010	
							Illegal logging	M	0.00010	
							Mining	L	0.00005	
							Energy projects	L	0.00005	
							Settlement	L	0.00005	
							Agricultural encroachment (medium scale))	L	0.00005	
							Agric. Encroachment (small scale)	L	0.00005	
							Fires/burning forest	H	0.00014	

Appendix III. Data for *Pongo p. morio*

This appendix provides details of the information collated or estimated by the *P. p. morio* working group.

Table 23. *Pongo pygmaeus morio:* designated populations and their characteristics

No	Habitat Management Unit	Meta-population	Within MP units	Number of fragments	Total Habitat Area km2	Estimated number of orangutans	Estimation method (survey/density from elsewhere/guess)	Estimated Carrying capacity
1	Beratus Landscape	1	Camp Beratus	1	2,000 km2	349 OU released in 1997-2002 Estimated 30-40 OU in the 400 km2 survey area	# released/ nest census YR Survey by Rayadin and team (2007)	NA
2	Sungai Wain Landscape	1	-	1	40 km2 (protected forest and connected forest/ agroforestry surrounding)	Minimum 20 OU (97 OU released in 1992-1997, but some OU moved to Meratus)	1998 nest census and birth record	NA
3	Kutai NP-Bonrang Landscape	1	CA Muara Kaman	1	650 km2 (only 10 km2 suitable)	Minimum 2 OU (base on nest characteristic)	8 nests found in 10 km2 and 3 km transect by Rayadin and team (2016)	5 OU (10 km2)
			Kutai NP	1	1,920 km2 (only 1,300 km2 suitable)	1,500 OU (BTNK) Minimum 2,097 OU (Rayadin)	Nest Survey by Kutai National Park Authority (BTNK) (2015) Nest survey by Rayadin & team 2010, TNK Main Zone and Bufferzone	1,511 OU
			Bontang PF	1	150 km2	Minimum 11 OU	Camera traps and survey by Rayadin & Team (2013)	11 OU
			Timber Estate -SRH -SHJ	9	2,000 km2 (1,400 km2 in SRH and 600 km2 in SHJ)	80 to 120 OU	Nest survey and camera trap by Rayadin Y, Spehar S and Team (2012-2016)	-
			Coal Mining concessionaire	12	Total concession	Minimum 29 OU	Nest survey and camera trap by Rayadin Y, and Team (2012-2016)	11 OU

No	Habitat Management Unit	Meta-population	Within MP units	Number of fragments	Total Habitat Area km2	Estimated number of orangutans	Estimation method (survey/density from elsewhere/guess)	Estimated Carrying capacity
			(KPC: 3 sites, Indominco: 5 sites JMB Group: 3 sites)		aire 2,500 km2			
			Hutan Kota PKT	1	3 km2	3 OU	Direct sighting by BTNK (2014)	3 OU
			Palm Oil concessionaire	15	500 km2	30 to 80 OU	Nest survey and camera trap by Rayadin and Team (2012-2016)	NA
4	Belayan-Senyiur Landscape		PT REA Kaltim	8	49.75 km2 (HCV Forest)	29 OU	Line transect method by UNAS team (2011)	NA
			PT KMS	5	18.79 km2	35 OU	Line transect method by UNAS team (2014)	NA
			Senyiur Natural Forest	1	2,000 km2	> 160 OU	Nest survey and camera trap by Rayadin and Team (2015)	160 OU
5	Wehea-Lesan Landscape	1	Kehje Sewen	1	864.5 km2 (suitable only 220 km2)	38 OU (40 OU released with 3 OU dead and 1 OU born)	Data from BOSF	150 OU
			Gunung Gajah	1	20 km2	99 OU	Survey by TNC (2012)	99 OU
			PT Narkata Rimba, GG Abadi, Karya Lestari, Hutan Adat Wehea, DSN (oil palm), AAU (Timber estate), NAS (oil Palm) dan GPM	6	2,638.3 km2 (include customary forest, PT. NAS and PT. GPM)	409 to 424 OU	Nest Survey by TNC (2002 to 2015) and Line transect method by BOSF (2016)	350 OU
		1	Lesan PF	1	100 km2	> 70 OU	Nest survey and camera trap by Rayadin and Team (2013)	70 OU

No	Habitat Management Unit	Meta-population	Within MP units	Number of fragments	Total Habitat Area km2	Estimated number of orangutans	Estimation method (survey/density from elsewhere/guess)	Estimated Carrying capacity
6	Sangkulirang Landscape	1	Karst Pangadan Bayanak Sei Bulan Karangan	3	> 600 km2	30 to 40 OU	Nest survey and camera trap by Rayadin and Team (2012-2016)	NA
			PT Anugerah Energitama (Palma Serasih Group)	NA	400 km2	10 to 15 OU	Line transect method by BOSF (2016)	-
			Timber Plantation Concessionaire	2	600 km2 (90% natural forest)	> 240 OU	Nest survey and camera trap by Rayadin and Team (2012-2016))	-
			Sawit Gunta Samba, Telen	4	400 km2	8 OU (COP) > 40 OU (YR)	Direct sighting report by COP Nest survey and camera trap by Rayadin and Team (2012-2016)	8 OU 40 OU
7	Tabin Range Landscape	1	Tabin FR	1	1,200 km2	1,197 OU (868 to 1,606 OU)	Nest census by Alfred et al. (2010)	2,000 OU
			Silabukan	1	100 km2	58 OU (21 to 159 OU)	Nest census by Ancrenaz et al. (2005)	150 OU
8	Central Forest Range Landscape	1	Danum Valley	-	480 km2	425 OU (309 to 570 OU)	Nest census by Alfred et al. (2010)	900 OU
			USM	1	1,611 km2	2,600-3,000 OU (1,295 to 5,866 OU)	Nest census by Ancrenaz et al. (2005, 2010); and Alfred et al. (2010)	4,000 OU
			Sabah Foundation Forest Concession Area	1	4,294 km2	2,100 OU	Nest census by Ancrenaz et al., (2005, 2010); and Alfred et al. (2010)	2,000 OU
9	Lower Kinabatangan Range Landscape	1	Lower Kinabatangan Floodplain	1	517.2 km2	700-825 OU (546 to 955 OU)	Nest census by Ancrenaz et al., (2005), and Alfred et al. (2010)	900 OU
			Kulamba FR	1	210 km2	480 OU (276 to 1,214 OU)	Nest census by Ancrenaz et al., (2005), Alfred et al. (2010)	600 OU
10	North Kinabatangan Range Landscape	1	Deramkot FR, Tangkulap FR, Segaliud Lokan FR	1	ca 1,400 km2	1,700-2,100 OU (1,016 to 3,043 OU)	Nest census by Ancrenaz et al., (2005), Alfred et al. (2010)	3,000 OU
11	Ulu Kalumpang Range Landscape	1	Ulu Kalumpang, Tawau Hills	1	700 km2	144 OU (54 to 408 OU) to 605 (487 to 783 OU)	Nest census by Ancrenaz et al., (2005), Alfred et al. (2010)	800 OU

No	Habitat Management Unit	Meta-population	Within MP units	Number of fragments	Total Habitat Area km2	Estimated number of orangutans	Estimation method (survey/density from elsewhere/guess)	Estimated Carrying capacity
			Park, Mt Wullersdorf					
12	Crocker Range Landscape	1	-	1	900 km2	181 OU (62 to 528 OU)	Nest census by Ancrenaz et al. (2005)	300 OU
13	Lingkabau Landscape	1	Lingkabau FR	1	300 km2	100 OU (75 to 150 OU)	Nest census by Payne (1987)	150 OU
			Kinabalu Park	1	200 km2	50 OU (25 to 75 OU)	Nest census by Ancrenaz et al. (2005)	150 OU
14	Bonggaya Landscape	1	Bonggaya FR	1	600 km2	111 OU (38 to 324 OU)	Nest census by Ancrenaz et al. (2005)	150 OU
			Trusan Sugut FR	1	38.44 km2	79 OU (38 to 121 OU)	WWF Report (2014)	150 OU
15	Ulu Tungud Landscape	1	Ulu Tungud FR	1	720 km2	29 OU (9 to 99 OU)	Nest census by Ancrenaz et al., (2005)	80 OU
16	Trus madi Landscape	1	Trus Madi FR	1	680 km2	282 OU (126 to 736 OU)	Nest census by Ancrenaz et al., (2005)	350 OU
17	Sepilok Landscape	1	Sepilok FR	1	40 km2	200 OU (100 to 300 OU)	Nest census by Payne (1987)	300 OU

Table 24. *Pongo pygmaeus morio:* threats and their estimated impacts on designated populations (K=carrying capacity).

					REMOVAL or LOSS of orangutans from the population			HABITAT LOSS			
Meta population	Population / area	Current population estimate	Est. K	Pop. trend	Cause	Intensity (H/M/L)	Rate	Cause	Intensity (H/M/L)	Rate	Impact
Beratus Landscape	Beratus Protected Forest	349 OU released in 1997-2002 Estimated 30-40 OU in the 400 km2 survey area	NA	Declining	Human-orangutan conflict	Medium	No info	Illegal logging local settling Forest fire	High - Medium	BOSF survey, 2005 illegal loggers cleared about 3.975-4.24 Ha per day Yaya Rayadin: PT ITCI logging concession in Beratus landscape: 200,000 Ha	Wide ranging disturbance of orangutans

					REMOVAL or LOSS of orangutans from the population			HABITAT LOSS			
Meta population	Population / area	Current population estimate	Est. K	Pop. trend	Cause	Intensity (H/M/L)	Rate	Cause	Intensity (H/M/L)	Rate	Impact
Sungai Wain Landscape	Sungai Wain Protected Forest CA Muara Kaman	Minimum 20 OU (97 OU released in 1992-1997, but some OU moved to Meratus) Minimum 2 OU (base on nest characteristic)	NA 5 OU	Declining Declining	- -	- -	- -	Encroachment Road construction Forest fire Illegal logging Road Construction Forest fire	Medium High High	No info 2% per year High	Reduction of K 100% reduction of K for orangutans
Kutai NP-Bontang Landscape	Kutai NP	1,500 OU (BTNK) Minimum 2,097 OU (Rayadin)	1,511 OU	Variable	Killing Conflict	Low to Medium	1 mati 2016	Habitat Conversion - mining Illegal logging Forest fire Encroachment	High	Conversion area in 2015: 78.16 km2 Encroachment area in 2011-2016: 24.69 km2	In total 3.9% habitat reduction from 1995 condition
	Bontang PF	Minimum 11 OU	11 OU	Declining	Conflict	High	??	Habitat Conversion - 60% Coal mining, other land use & settlement Encroachment Road Construction Settlement Increase of human population	High	Rate 2 km2/year	80% reduction of K for orangutans
	Timber Estate: SRH & SHJ	80 to 120 OU	NA	Declining	Conflict	High	20 OU relocated (2012-2015)	Land clearing (timber estate)	High	High	40% reduction of K in conservation area
	Coal Mining: KPC, Indomincodan JMB Group	Min. 29 OU	11 OU	Variable	-	-	-	Land clearing (mining)	High	5 km2/ year since 1980's	60% reduction of K in all of concession
	Hutan Kota PKT	3 OU	3 OU	Declining	Conflict	Low	3 OU killed by forest fire in 2016 in local community land	-	-	-	-
	Sawit	30 to 80 OU	NA	Declining	Conflict	-	-	Conversion to palm oil Encroachment in conservation area	High	High	-

					REMOVAL or LOSS of orangutans from the population			HABITAT LOSS			
Meta population	Population / area	Current population estimate	Est. K	Pop. trend	Cause	Intensity (H/M/L)	Rate	Cause	Intensity (H/M/L)	Rate	Impact
								inside the concessionaire			
Belayan-Senyiur Landscape	PT REA Kaltim	29 OU	NA	Declining	-	-	-	Road construction (public)	-	-	-
	PT KMS	35 OU	NA	Stable	-	-	-	Illegal logging (iron wood)	-	-	-
	Senyiur Natural Forest	> 160 OU	160 OU	Declining	Conflict	Medium	No info	Forest fire Habitat conversion (oil palm, timber estate, mining)	Medium	10 km2/ year	60% decline in K
Wehea – Lesan Landscape	Kehje Sewen	38 OU (40 OU released with 3 OU dead and 1 OU born)	150 OU	Increase	Illness	Low	1 OU in 2 years	-	-	-	-
	Gunung Gajah	99 OU	150 OU	Declining	Conflict	Low	No info	Legal logging concession	Medium	10 km2 AAC	Decline in K
	PT Narkata Rimba, GG Abadi, Karya Lestari, Hutan Adat Wehea, DSN (oil palm), AAU (Timber estate), NAS (oil Palm) dan GPM	409 to 424 OU	350 OU	Declining	Conflict	Low	No info	Land clearing for palm oil and timber plantation	Medium	10 km2 Annual Allowable Cut (AAC)	
	Lesan Protected Forest	> 70 OU	70 OU	Declining	-	-	-	Forest fire Illegal logging Encroachment	Medium	2 km2/ year	40% decline in K
Sangkuliran g Landscape	Karst Pangadan Bayanak Sei Bulan Karangan	30 to 40 OU	NA	Stable	No	-	-	-	-	-	Stable
	PT Anugerah Energitama (Palma Serasih Group)	10 to 15 OU	NA	-	-	-	-	-	-	-	-
	Timber estate	> 240 OU	NA	Declining	Conflict	Low	No info	Land clearing (timber estate)	Medium	3,0 km2/ year	70% decline in K

					REMOVAL or LOSS of orangutans from the population			HABITAT LOSS			
Meta population	Population / area	Current population estimate	Est. K	Pop. trend	Cause	Intensity (H/M/L)	Rate	Cause	Intensity (H/M/L)	Rate	Impact
	PT. Gunta Samba (oil palm), telen	8 OU (COP) > 40 OU (YR)	NA	Declining	Conflict	High	20 OU was relocated in 2011-2015	Land clearing (oil palm)	High	No info	90% decline in K
Tabin Range Landscape	Tabin FR	1,197 OU (868 to 1,606 OU)	2,000 OU	Stable	-	-	0	Fires (20 yrs ago, no recent fires)	-	-	No recent impact
	Silabukan	58 OU (21 to 159 OU)	150 OU	Stable	-	-	0	Fires (20 yrs ago, no recent fires)	-	-	No recent impact
Central Forest Range Landscape	Danum Valley	425 OU (309 to 570 OU)	900 OU	Stable	-	-	0	-	-	-	No recent impact
	USM	2,600-3,000 OU (1,295 to 5,866 OU)	4,000 OU	Stable	-	-	-	Fires (20 yrs ago, no recent fires)	-	-	No recent impact
	Sabah Foundation Forest Concession Area	2,100 OU	2,000 OU	Declining	-	-	-	Conversion to mosaic plantation	High	-	40% decline in K
Lower Kinabatangan Range Landscape	Lower Kinabatangan Floodplain	700-825 OU (546 to 955 OU)	900 OU	Declining	-	-	-	fragmentation	High	-	10% decline in K
	Kulamba FR	480 OU (276 to 1,214 OU)	600 OU	Stable	-	-	-	-	-	-	-
North Kinabatangan Range Landscape	Deramkot FR, Tangkulap FR, Segaliud Lokan FR	1,700-2,100 OU (1,016 to 3,043 OU)	3,000 OU	Stable	-	-	-	Sustainable logging	Medium	-	NA
Ulu Kalumpang Range Landscape	Ulu Kalumpang, Tawau Hills Park, Mt Wullersdorf	144 OU (54 to 408 OU) to 605 (487 to 783 OU)	800 OU	Declining	-	-	-	Geothermal	High	-	10% decline in K
Crocker Range Landscape	Crocker Range	181 OU (62 to 528 OU)	300 OU	Stable	-	-	-	-	-	-	None
Lingkabau Landscape	Lingkabau FR	100 OU (75 to 150 OU)	150 OU	Stable	-	-	-	-	-	-	None
	Kinabalu Park	50 OU (25 to 75 OU)	150 OU	Stable	-	-	-	-	-	-	None
Bonggaya Landscape	Bonggaya FR	111 OU (38 to 324 OU)	150 OU	Stable	-	-	-	-	-	-	None
	Trusan Sugut FR	79 OU	150 OU	Stable	-	-	-	-	-	-	None

					REMOVAL or LOSS of orangutans from the population			HABITAT LOSS			
Meta population	Population / area	Current population estimate	Est. K	Pop. trend	Cause	Intensity (H/M/L)	Rate	Cause	Intensity (H/M/L)	Rate	Impact
		(38 to 121 OU)									
Ulu Tungud Landscape	Ulu Tungud FR	29 OU (9 to 99 OU)	80 OU	Declining	-	-	-	Conversion for mosaic plantation	High	-	10% decrease in K
Trus madi Landscape	Trus Madi FR	282 OU (126 to 736 OU)	350 OU	Declining	-	-	-	Encroachment	High	-	10% decrease in K
Sepilok Landscape	Sepilok FR	200 OU (100 to 300 OU)	300 OU	Stable	-	-	-	-	-	-	None

Appendix IV. Data for *P. p. pygmaeus*

Table 25. *Pongo pygmaeus pygmaeus:* designated populations and their characteristics. Bold indicates the best population estimate for PVA models

No	Habitat Management Unit	Meta-population	Within MP units	Number of fragments	Total Habitat Area km2	Estimated number of orangutans (OU) and density	Estimation method (survey/density from elsewhere/ guess)	Estimated Carrying capacity (K)	Sources and Years
1A	Betung Kerihun National Park/BKNP and Protection Forest Surrounding National Park (Embaloh Watershed and Sibau Watershed, Upstream of Labian-Leboyan Corridor)	1	3	2	4,851.00	BKNP - 2.990 individual OU with density 0.58-1.01 OU/km^2 (2005) - **2,233 OU with density 0.56–0.67 OU/km^2 (2011)** Upstream of Labian-Leboyan Corridor - 585 OU with density 0.69–5.84 OU/km^2 include lower corridor (2011) - **419 OU with density 0.948 OU/km^2 (2016)** Protected Forest - **338 OU** (based on estimation population with in protected forest based of PHVA orangutan 2016 modeling result)	Line transect survey	4,029 OU Note: National Park at K Corridor 60-70% of K (1,120 OU) Protected Forest 50% of K (676 OU)	Report WWF Indonesia (2005, 2011) Report FORINA (2016)
1B	Batang Ai-Lanjak-Entimau Landscape (Lanjak - entimau WS, Ulu Sungai Menyang, Batang Ai NP, Engkari-Telaus, Lanjak-Entimau WS extension areas, Batang Ai NP Extension areas, Ulu Pasin proposed extension)		1	7	260.84	1808 OU (average prediction from estimates of different location)	Line-transect surveys for nest for Batang Ai and Lanjak-Entimau Marked Sign Count for fresh nest for Batang Ai and Lanjak-Entimau (Distance) Marked Sign Counts for fresh next using Bayes analysis	2,010 OU Note: Has reached 90% of K	Report (1992) Report WCS (2007, 2016)
2	Danau Sentarum National Park/DSNP and Downstream of Labian-Leboyan Corridor	1	2	2	1,821.6	**679 individual OU, consist of 434 OU with in DSNP and 245 OU in Downstream of Labian-Leboyan Corridor** (2016) Estimation population based on Survey in 2009: 771– 1,006 OU with density 0.38–4.08 OU/km2 Survey in lower corridor 2014-2016: Density 0.278-0.421 OU/km2	Line transect survey	at K	Report WWF Indonesia (2009) Report FORINA (2016)

No	Habitat Management Unit	Meta-population	Within MP units	Number of fragments	Total Habitat Area km2	Estimated number of orangutans (OU) and density	Estimation method (survey/density from elsewhere/ guess)	Estimated Carrying capacity (K)	Sources and Years
3	Klingkang Range National Park and Sintang Utara	1	2	2	729.75	80 OU Prediction using minimum density number of GIS modelling result (0.11 OU/km2)	-	at K	Information from local people
4	Bungoh National Park-Gunung Nyiut NR and Penrisen HL	1	2	1	860.96	94 OU Prediction using minimum density number of GIS modelling result (0.11 OU/km2)	-	at K	Based on nest sighting 2014 in Bungo NP
5	Pygmaeus fragmented North	1	1	4	209.48	29 OU Prediction using density number of GIS modelling result (0.14 OU/km2)	Confirmed presence	at K	HL Senujuh (2014) based from confiscated
6	Pygmaeus fragmented South	1	1	3	50	15 OU Prediction using density number of GIS modelling result (0.3 OU/km2)	Line transect survey	at K	WWF Report 2012
7	Ulu Sebuyau-Sedilu Landscape	1	1	6	275	30 OU Prediction using minimum density number of GIS modelling result (0.11 OU/km2)	Confirmed presence	at K	Report WCS (2007) Report SFC (2015) Report WCS (in prep. 2016)

Table 26. *Pongo pygmaeus pygmaeus*: threats and their estimated impacts on designated populations.

				REMOVAL or LOSS of orangutans from the population			HABITAT LOSS			
Population / area	Current population estimate	Est. carrying capacity	Population trend	Cause	Intensity (H/M/L)	Rate	Cause	Intensity (H/M/L)	Rate	Impact
Betung Kerihun	2,990	4,029	NP & Corridor: Most stable Hutan Lindung: decline	Poaching/ Hunting	Low	1 adult per year (Since 2-3 years ago no single case documented)	NP: no significance Corridor: encroachment: small scale agriculture Hutan Lindung: illegal logging, settlement	NP: low Corridor: low	NP: lost 0% for 10 years Corridor: 0.5% per year for 10 years HL: 2% per year for 10 years	HL: Reduction 20% of K in total area
Batang Ai-Lanjak-Entimau Landscape	1,808	2,010	Stable	Hunting for food HOC (Human orangutan conflict)	Low Low	1 animal recorded in past 5 years 1 animal recorded in the past 5 years	Illegal logging Conversion for industrial agriculture	Medium Medium	Estimated at <1% per year for 10 years Estimated at <1% per year for 10 years	<1% reduction in K for orangutans in total area <1% reduction in K for orangutans in total area
Danau Sentarum and Corridor Labian	679	890	Declining	Poaching/ Hunting	Moderate	1-2 adult and 1 infant per year	Encroachment: small scale agriculture Conversion for industrial agriculture	NP: Medium Koridor: High	NP: 1 % for 10 years Surrounding NP: 10% for 10 years	NP: 5% reduction in K for orangutans in total area

				REMOVAL or LOSS of orangutans from the population			HABITAT LOSS			
Population / area	Current population estimate	Est. carrying capacity	Population trend	Cause	Intensity (H/M/L)	Rate	Cause	Intensity (H/M/L)	Rate	Impact
Laboyan Downstream (Bawah)							Road Construction			Corridor: 10% reduction in K for orangutans in total area
Klingkang Range National Park and Sintang Utara	80	80	N/A	N/A	Low	1 adult for 2 years	N/A (Malaysia) Conversion for mining Road construction	Medium	1% per year for 10 years	Uncertain
Bungoh National Park-Gunung Nyiut NR + Penrisen HL	94	94	Declining	N/A (Malaysia) Poaching (Indonesia)	Low	1 adult for 2 year	N/A (Malaysia) Encroachment: small scale agriculture Road construction (Indonesia)	N/A (Malaysia) High (Indonesia)	1% per year for 10 years	Uncertain
Pygmaeus fragmented North	29	29	Declining	Poaching	High	2 – 3 adults per year	Conversion for industrial agriculture -Fire -Fragmentation	High	Loss 10% of existing area for 10 yrs (total loss: 100%)	Non Viable Area
Pygmaeus fragmented South	15	15	Declining	Poaching	High	2 – 3 adults per year	Conversion for industrial agriculture -Fire -Fragmentation	High	Loss 10% of existing area for 10 yrs (total loss: 100%)	Non Viable Area
Ulu Sebuyau-Sedilu Landscape	30	30	-	Poaching/ Hunting	Medium	1 adult per year	Conversion for industrial agriculture	Stopped for the moment	Zero for the moment	Uncertain

Appendix V: Data for *P. p. wurmbii*

Table 27. *Pongo pygmaeus wurmbii:* designated populations and their characteristics

Regional Unit	Forest Landscape	Habitat Unit	Population Estimate (workshop) & Survey Details	Habitat Area (Ha) (GIS)	Lower Density estimate	Upper Density estimate	CONFIDENCE	Lower Population estimate	Upper Population estimate
Pongo pygmaeus wurmbii									
West Kalimantan Coastal Lowlands								**4049**	**6681**
	Kubu Raya			**284,482**				**798**	**1684**
		Kubu Raya Coastal	unsurveyed	70,743	0.9	1.9	25%	159	336
		Sanggau	(1) >150 in 20,000 ha in and around PT. ATP (oil palm) (1.54 ind/km2, YIARI/BNF 2015) (2) northern block unsurveyed	30,664	0.9	1.9	50%	138	291
		Mendawak	unsurveyed, presence confirmed	93,313	0.9	1.9	50%	420	886
		Fragmented landscape		*89,762*	*0.9*	*1.9*	*10%*	*81*	*171*
	Gunung Palung-Sg Putri			**198,769**				**2620**	**3945**
		Gunung Palung NP-Gunung Tarak HL	(1) 2500 in GPNP, 90,000 ha (Johnson et al., 2004); 1302-1939 in GPNP (YIARI, 2016) (2) 326-482 in HL Gunung Tarak, 24,000 ha (2.01 ind/km2, YIARI/BNF 2013) (3) 49 in PT. Kayung Agro Lestari (PT. KAL, oil palm) North region, 820 ha (6.99 ind/km2, YIARI/BNF 2015) (4) 108 in Kuala Satong (PT KAL) East region (4.35 ind/km2, FFI 2010)	109.424 (including TNGP 79,000 & HLGT 24,000)			100%	1727	2576

Regional Unit	Forest Landscape	Habitat Unit	Population Estimate (workshop) & Survey Details	Habitat Area (Ha) (GIS)	Lower Density estimate	Upper Density estimate	CONFIDENCE	Lower Population estimate	Upper Population estimate
		Sungai Putri-Sungai Tolak	(1) 900-1250 in Sg.Putri-Sg.Tolak, 55,000 ha (1.52-2.27 ind/km2, YIARI/BNF 2012) (2) 189 in PT. KAL south region, 5,000 ha (4.50 ind/km2, YIARI/BNF 2015)	54,997	1.52	2.27	100%	836	1248
		Sg. Pawan Hilir (North)	30-50 in PT Sinar Karya Mandiri (PT. SKM, oil palm) (best guess from patrol sightings)	4,509	0.9	1.9	75%	30	64
		Fragmented landscape		*29,839*	*0.9*	*1.9*	*10%*	*27*	*57*
	Pematang Gadung			**35,000**				**499**	**775**
		Sg. Pawan Hilir (South)	(1) 30-50 estimated in PT. Artu (oil palm) - unsurveyed (2) 30 in PT. Limpah Sejahtera (PT.LS, oil palm), company data	3,111	0.9	1.9	75%	21	44
		Pematang Gadung	548-808 in 21,000 ha (two blocks) (survey estimate 2.61-3.85 ind/km2, YIARI/BNF 2012)	16,720	2.61	3.85	100%	436	644
		Pesaguan	unsurveyed	4,997	0.9	1.9	50%	22	47
		Batu Menangis	unsurveyed	7,365	0.9	1.9	25%	17	35
		Fragmented landscape		*2,807*	*0.9*	*1.9*	*10%*	*3*	*5*
	Sungai Tengar			**28,649**				**101**	**211**
		Sungai Tengar	0.46 ind/km2 (brief survey YIARI/BNF 2014)	7,274	0.9	1.9	50%	33	69
		Sungai Tapah	unsurveyed	11,023	0.9	1.9	50%	50	105
		Gunung Raya	unsurveyed	6,161	0.9	1.9	25%	14	29
		Fragmented landscape		*4,191*	*0.9*	*1.9*	*10%*	*4*	*8*
	Kendawangan-Jelai			**34,460**				**31**	**66**

Regional Unit	Forest Landscape	Habitat Unit	Population Estimate (workshop) & Survey Details	Habitat Area (Ha) (GIS)	Lower Density estimate	Upper Density estimate	CONFIDENCE	Lower Population estimate	Upper Population estimate
		Kendawangan landscape	heavily fragmented, unsurveyed	4,181	0.9	1.9	10%	4	8
		Sungai Mading landscape	heavily fragmented, unsurveyed	16,679	0.9	1.9	10%	15	32
		Air Hitam landscape	heavily fragmented, surveys by FFI, Andi Erman, 2006 (RESULTS??)	6,423	0.9	1.9	10%	6	12
		Fragmented landscape		*7,177*	*0.9*	*1.9*	*10%*	*6*	*14*
Southwest Central Kalimantan								**4745**	**6424**
	Lamandau-Sukamara			**68,049**				**516**	**752**
		Sukamara	unsurveyed	2,479	0.9	1.9	25%	6	12
		SM Lamandau	(i) 144 (BKSDA, monitoring 2015) (ii) 960 (FORINA survey 2010) (iii) 431-618 within reserve at mean D 0.97-1.45 ind/km2 including ca. 160 reintroduced individuals (OFUK/BNF survey 2016)	56,962 (including SM Lamandau 49,600)	0.97	1.45	100%	502	724
		Fragmented landscape		*8,608*	*0.9*	*1.9*	*10%*	*8*	*16*
	Kotawaringin Lama			**69,703**				**437**	**850**
		Kotawaringin Lama Block Barat	(1) Large forest block, unsurveyed (2) 10-30 in PT. Kalimantan Sawit Abadi (PT. KSA, oil palm), 3,000 ha (1.1-1.4 ind/km2, BOSF 2015)	33,863	0.9	1.9	75%	229	483
		Kotawaringin Lama Block Timur	unknown	7,637	0.9	1.9	50%	34	73
		Kotawaringin Lama Utara	71-77 in PT Korintiga Hutani (PT. KTH, pulpwood), 10,040 ha fragmented (0.88-4.5 ind/km2, BOSF 2014)	912	0.9	4.5	100%	71	77

Regional Unit	Forest Landscape	Habitat Unit	Population Estimate (workshop) & Survey Details	Habitat Area (Ha) (GIS)	Lower Density estimate	Upper Density estimate	CONFIDENCE	Lower Population estimate	Upper Population estimate
		Rawa Kuno landscape	150 in 5,000 ha, fragmented (KPHP/OFI). Includes Tanjung Keluang region	13,308	0.9	1.9	75%	90	190
		Fragmented landscape		*13,983*	*0.9*	*1.9*	*10%*	*13*	*27*
	Tanjung Puting			**205,694**				**3713**	**4655**
		Tanjung Puting NP - Rimba Raya ERC	(1) Tanjung Puting NP : 6000 pre-fire in 415,040 ha (park area, not forest area) (current BTNTP estimate); density estimates 1.96 - 2.90 ind/km2, mean 2.45 ind/km2, OFI survey 2004 (2) PT. Andalas Sukses Makmur (PT. ASMR, oil palm), 1,000 ha on Sekonyer river before park boundary; estimate 10 orangutans (BOSF Survey 2013; density 0.8-1.47) (3) Rimba Raya; no wild orangutan data; 100 ex-captive (OFI / RRC), 65,000 ha (~25,000 forested)	188,680 (including 159,364 TNTP & 22,909 RR)	1.96	2.45	100%	3698	4623
		Fragmented landscape		*17,014*	*0.9*	*1.9*	*10%*	*15*	*32*
	Seruyan-Sampit			**87,714**				**79**	**167**
		Fragmented landscape	(1) Makin Group (oil palm) : 44 individuals (2) Tehang Group (oil palm) : density estimate of 0.002 ind/km2 in 130 ha = <1 OU (BKSDA) (3) PT. KIU (oil palm) : density estimate of 1.0 ind/km2 in 145 ha = 1 OU (BKSDA) (4) PT. SSIK (oil palm): density estimate of 0.3 ind/km2 in 40 ha = <1 OU	87,714	*0.9*	*1.9*	*10%*	*79*	*167*

Regional Unit	Forest Landscape	Habitat Unit	Population Estimate (workshop) & Survey Details	Habitat Area (Ha) (GIS)	Lower Density estimate	Upper Density estimate	CONFIDENCE	Lower Population estimate	Upper Population estimate
			(BKSDA) (5) Keruing : density estimate of 0.1 ind/km2 in 10 ha = <1OU (BKSDA)						
Katingan-Barito lowlands								**14210**	**19428**
	Katingan			**254,915**				**3334**	**4709**
		Katingan	3,012-4,139 in 192,300 ha (size of ERC) pre-fire (mean 2.3 +/-0.6 ind/km2 mixed swamp forest; 0.76 ind/km2 low pole forest RMU / BNF surveys 2010/2013)	201,759 (including 192,300 ERC)			100%	3160	4343
		Kelaru	no recent surveys, presence confirmed at normal psf densities in 2003 (BNF)	16,311	0.9	1.9	75%	110	232
		Kalanaman River	(1) unsurveyed block (2) 6 in (PT. NKU, oil palm) (1.40 ind/km2, BOSF 2014)	8,442	0.9	1.9	50%	38	80
		Fragmented landscape		*28,403*	*0.9*	*1.9*	*10%*	*26*	*54*
	Sebangau			**514,548**				**5943**	**6222**
		Sebangau NP + surrounds	(i) ca. 5,800 individuals pre-fire in 495,000 ha (BNF, extrapolation from monitoring surveys in the LLG, 2015) (ii) 5826 individuals pre-fire in 568,700 ha (National Park size, not forest area); (WWF-BTNS survey, July 2015)	485,017 (including 426,850 TNS)			100%	5683	5826

Regional Unit	Forest Landscape	Habitat Unit	Population Estimate (workshop) & Survey Details	Habitat Area (Ha) (GIS)	Lower Density estimate	Upper Density estimate	CONFIDENCE	Lower Population estimate	Upper Population estimate
		Kalampangan + Block C	300-400 (BNF surveys 2009, 2.48-3.66 ind/km2, Cattau et al. 2014) – formerly home to 1,500 individuals. Forest now burnt but many orangutans now living outside forest area in shrubland	9,778	2.48	3.66	100%	242	358
		Fragmented landscape		*19,753*	*0.9*	*1.9*	*10%*	*18*	*38*
	Rungan River Landscape			**372,256**				**1724**	**2794**
		Rungan Barat	unsurveyed	122,288	0.9	1.9	25%	275	581
		Rungan Timur (Mungku Baru)	(1) 2.93 ind/km2 Mungku Baru Ulin Forest (BNF, 2010) (2) 2.61 ind/km2 Mungku Baru KHDTK good kerangas forest (BNF, KHDTK 2016) (3) 3.94 ind/km2 Kanarakan dipterocarp forest (BOSF/Russon, 2005)	155,834	1.75	2.61	50%	1364	2034
		Fragmented landscape		*94,134*	*0.9*	*1.9*	*10%*	*85*	*179*
	Kahayan-Kapuas			**399,630**				**1065**	**2300**
		Mangkutup West	unsurveyed, confirmed present 2001	51,664	0.9	1.9	75%	349	736
		Mangkutup East (Sg Lading)	unsurveyed, confirmed present	24,335	0.9	1.9	75%	164	347
		Murui - Timpah	unsurveyed	11,829	0.9	1.9	50%	53	112
		Block B (S of Main Canal)	unsurveyed, confirmed present	11,266	0.9	1.9	75%	76	161
		Bawan	2.15 ind/km2 in good habitat; reducing to 0.5 ind/km2 in lower canopy areas (BNF 2010, Bawan research area)	42,142	0.9	2.15	50%	190	453

Regional Unit	Forest Landscape	Habitat Unit	Population Estimate (workshop) & Survey Details	Habitat Area (Ha) (GIS)	Lower Density estimate	Upper Density estimate	CONFIDENCE	Lower Population estimate	Upper Population estimate
		Sungai Murui Hulu	unsurveyed	187,556	0.9	1.9	*10%*	169	356
		Fragmented landscape		*70,838*	*0.9*	*1.9*	*10%*	*64*	*135*
	Kapuas-Barito (Mawas)			**603,779**				**2000**	**3096**
		Mawas (Block E)	2,070 (BOSF/Zurich 2002-03 aerial+ground surveys)	168,203	0.9	1.23	100%	1514	2070
		Mantangai (Block A)	400 (BOSF/Zurich 2002-03 in what was then 40,000 ha), highly fragmented & burnt since	11,555	0.9	1.9	100%	104	220
		Barito Tengah (Timpah- Buntok-Muara Teweh-Purukcahu-Seihanyu)	no info on habitat or status or OU population. Absent or rare in CA Pararawen (probably location of CA Pararaum mispelled in 2004 PHVA)	367,692	0.9	1.9	*10%*	331	699
		Fragmented landscape		*56,329*	*0.9*	*1.9*	*10%*	*51*	*107*
	Barito Timur			**101,255**				**144**	**307**
		Sungai Sirau (Central Kalimantan)	Presence confirmed (FORINA/TNC 2013; BNF/UMP 2016)	14,450	0.9	1.9	75%	98	206
		Hulu Sungai Utara-Tabalong (South Kalimantan)	1.95 ind/km2; 10-15 OU in 600 ha (FORINA, 2016)	4,135	0.9	1.95	100%	37	81
		Buntok	reports of presence, other reports of absence	10,534	0.9	1.9	10%	9	20
		Fragmented landscape	*no information on presence*	*72,136*	*0*	*0*	*10%*	*0*	*0*
Upper Kapuas Swamps								**0**	**0**
	Siawan-Belida			**176,476**				**0**	**0**

Regional Unit	Forest Landscape	Habitat Unit	Population Estimate (workshop) & Survey Details	Habitat Area (Ha) (GIS)	Lower Density estimate	Upper Density estimate	CONFIDENCE	Lower Population estimate	Upper Population estimate
		Siawan Belida	rare-absent (i) 2 nests in 4 km (YIARI/BNF 2012), (ii) absent, FFI (2012) (iii) 25 nests in 2km (Erman, 2003)	69,803	*0*	*0*	*10%*	*0*	*0*
		Danau Tang - Danau Selogan	27 nests in 4.6 km (Erman, 2003)	34,892	*0*	*0*	*10%*	*0*	*0*
		Fragmented landscape		71,781	*0*	*0*	*10%*	*0*	*0*
Muller Schwaner								**8432**	**12462**
	Arabela-Schwaner			**6,734,817**				**8432**	**12462**
		Rongga-Perai	(1) 675 in PT. Suka Jaya Makmur (PT. SJM, timber), 170,500 ha (WWF, 2011-12) (2) 528 in PT. Wanasokan Hasilindo (PT. WH, timber), 46,962 ha (WWF, 2014) (3) 25-30 in PT. Permata Sawit Mandiri (oil palm), 6,500 ha (0.86 ind/km2, YIARI/BNF, 2014) (4) Bukit Rongga - unsurveyed (5) Bukit Perai - 230 in 20,000 ha (1.12 ind/km2, FFI, 2008) (6) Kerabai - Bahana (0.46 ind/km2, BNF 2003) (7) Tanjung Bunga - unsurveyed	870,897	0.75	1.5	25%	2634	3815

Regional Unit	Forest Landscape	Habitat Unit	Population Estimate (workshop) & Survey Details	Habitat Area (Ha) (GIS)	Lower Density estimate	Upper Density estimate	CONFIDENCE	Lower Population estimate	Upper Population estimate
		Arabela (Arut-Belantikan)	(1) recorded present in PT Wana Kayu Batu Putih (PT. WKBP, timber), (FFI, no survey details) (2) 99 in PT Sari Bumi Kusuma - Delang concession (PT. SBK, timber), 60,500 ha (2.18 ind/km2, WWF, 2015) (3) 771 in PT. Amprah Mitra Jaya (PT. AMJ, timber) and PT. Karda Trades (PT. KT, timber), 142,000 ha (1.5 ind/km2, Yayorin/Forina 2015) (4) 23 in PT. Sawit Mandiri Lestrai (PT. SML, oil palm), 10,000 ha (0.23 ind/km2, BOSF, 2014) (5) 5 in PT. Pilar Wana Persada (PT. PW, oil palm), 1,000 ha (BOSF, 2011) (6) 972 in PT. Trisetia Intiga (PT. TSI, timber) 48,750 ha (2.93 ind/km2, BOSF 2014)	483,039	0.75	1.5	50%	2698	3526
		Seruyan Hulu	(1) South-west of Tumbang Manjul - no recent surveys. Previously high densities. (2) mean 1289-1638 in PT Erna Djuliawati (PT. ED, timber), 160,000 ha, [0.63 ind/km2, WWF 2016 (867-1189 individuals), 1.31 ind/km2, BNF 2016 (1711-2088 individuals); mean 0.97 ind/km2] (3) 30 in PT Sari Bumi Kusuma - Nanga Nuak concession (PT. SBK timber), 144,700 ha, (WWF 2013) (4) Seruyan - Sampit - Katingan, unsurveyed	883,002	0.75	1.5	25%	2403	3837

Regional Unit	Forest Landscape	Habitat Unit	Population Estimate (workshop) & Survey Details	Habitat Area (Ha) (GIS)	Lower Density estimate	Upper Density estimate	CONFIDENCE	Lower Population estimate	Upper Population estimate
		Samba - Kahayan hills (Eastern Schwaner)	(1) few Bukit Raya - Bimban region of TNBBBR - (i) 5 nests in 4 km (BOSF 2015); 30+ orangutans reintrouced by BOSF on Sg. Bimban; (ii) Kuluk Sepangi region of TNBBBR - 6 OU (BTNBBBR 2012); Batu Panahan - 2 OU (BTNBBBR 2012) (2) absent PT. Dwima Jaya Utama (PT. DJU, timber) - west of Sg. Samba, ca. 80,000 ha, (0 ind/km2, WWF 2015; 0.08 ind/km2, BNF 2004) (3) 63 OU in PT. Dwima Jaya Utama (PT. DJU) - east of Sg. Samba, ca. 80,000 ha (WWF, 2015); >300 OU (1.18-1.59 ind/km2, BNF 2004) (4) rare in PT Carus Indonesia (PT. CI, timber) - 72,000 ha (3 OU, WWF 2014); 40 nests/ 5 km (BOSF, 2009) (5) Kahayan Hulu (PT. Domas Raya) - unsurveyed (6) Kapuas Murung Hulu - largely unsurveyed; 33 nests in 3.5 km (1.5 ind/km2, Tanjung Niok, BOSF 2009), 27 nests in 4.7 km (Tumbang Beronang, BOSF 2009)	1,034,175	0.5	1	*10%*	517	1034
		Melawi Catchment	(1) rare Bukit Baka - Belaban region of TNBBBR - (i) 7 nests in 8 km (YIARI/BNF 2013), (ii) 7 nests in 5.5 km (UNAS 2012) (iii) 44 nests in 7.5 km (0.60 ind/km2, BNF 2003) (iv) 7-27 OU (BTNBBBR 2012-2016)	680,761	0	0	*0%*	30	50

Regional Unit	Forest Landscape	Habitat Unit	Population Estimate (workshop) & Survey Details	Habitat Area (Ha) (GIS)	Lower Density estimate	Upper Density estimate	CONFIDENCE	Lower Population estimate	Upper Population estimate
			(2) absent Bukit Baka - Rantau Malam region of TNBBBR; 10+ OU reintroduced by YIARI (3) Upper Melawi catchment & southern slopes of Madi Plateau, unsurveyed						
		Murung Raya	(1) HL Bukit Batikap: >160 OU reintroduced since 2012 (BOSF) in 32,000 ha lowland valley (2) Rekut - Sg. Banana: 75 OU reintroduced 2008-2010 (BOSF) (3) Joloi - Busang - Murung - Maruwai - Ratah, essentially absent (average 1.0 nests/km = negligible density, BOSF 2008-2012) but many areas presumed ecologically suitable e.g. Maruwai, Busang Hulu, Sg. Burak, Ratah Hulu (4) CA Sapat Hawung - absent. Population recorded as >500 in 2004 PHVA but this erroneous	2,297,138	0	0	*0%*	150	200
		Kapuas Hulu	largely unsurveyed, presumed absent (ecology/hunting)	485,574	0	0	*0%*	0	0