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ORANGUTAN

Population and Habitat Viability Assessment

15-18 January 2004

Jakarta, Indonesia

Gibbon Foundation
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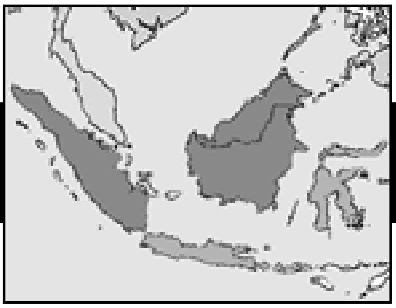

ORANGUTAN

Population and Habitat Viability Assessment

15-18 January 2004
Jakarta, Indonesia

In Collaboration with:
IUCN SSC Conservation Breeding Specialist Group
IUCN SSC Primate Specialist Group

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Singleton, I., S. Wich, S. Husson, S. Stephens, S. Utami Atmoko, M. Leighton, N. Rosen, K. Traylor-Holzer, R. Lacy and O. Byers (eds.). 2004. *Orangutan Population and Habitat Viability Assessment: Final Report*. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN.

Additional copies of *Orangutan Population and Habitat Viability Assessment* can be ordered through the IUCN/SSC Conservation Breeding Specialist Group, 12101 Johnny Cake Ridge Road, Apple Valley, MN 55124, www.cbsg.org.

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Jakarta, Indonesia

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Map Credits

Sumatra
The Sumatra maps were created by Ian Singleton with considerable help from Riswan and Rachmadi A. Dadi of the Leuser Development Programme's GIS Dept. Field data used to compile the orangutan distribution was kindly made available by many sources, including Serge Wich, Carel van Schaik, Suci Utami, Dolly Priatna, Tine Guertz, Herman Rijksen, Erik Meijaard, Idrusman and Ibrahim. Much of the GIS work used in collating, analysing and mapping the data was carried out by Nick Jewel of the Leuser Management Unit.

Borneo
The data behind the Borneo orangutan distribution map comes from two different sources:

1) Ancrenaz, M. and Lackman-Ancrenaz, I. 2004. Orang-utan status in Sabah: distribution and population size;

2) Meijaard, E. and Dennis, R. 2003. Assessment of the extent of remaining habitat for Bornean Orangutan, based on 2002 forest cover data.

At the workshop, the second set of data was edited by a host of people, overseen by cartographer Matt Doughty of UNEP World Conservation Monitoring Centre. Data contributors included: Simon Husson, Erik Meijaard, Andrew Hearn, Joanna Ross (for Bukit Baka); Fransiscus Harsanto (for Seruyan, Arut-Belantikan); Laura D'Arcy, Claire McLardy (for Katingan-Mendawai, Sungai Samba); Helen Morrogh-Bernard (Sebangau, Kahayan-Sebangau); Andrea Johnson (Gunung Palung); Birute Galdikas (Tanjung Puting); Carel van Schaik; Kisar Odom (Mawas); Dr. Kunkun (for Betung Kerihun); Togu Simorenangkir; Stephen Brend (Tanjung Puting); Dr. Akira Suzuki (Kutai); Andy Marshall (G. Palung + Berau).

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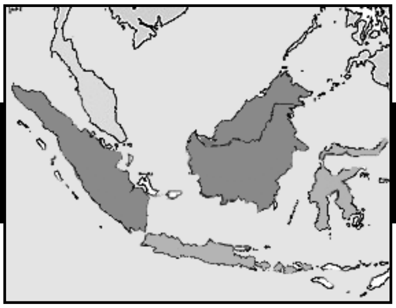

ORANGUTAN

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Section 1

EXECUTIVE SUMMARY

Executive Summary

Introduction

Serious downward trends in the integrity of Indonesia's forest estate occurred throughout the 1990s due to widespread logging and conversion for plantation agriculture. Some protected areas were, in retrospect, left relatively unscathed, while others suffered from devastating fires that resulted from unwise land-use practices. Since the change in government in 1998, however, conservation in Indonesia has seen a virtual collapse, and deforestation has been enormous regardless of the legal status of the land (Holmes 2000; Jepson et al. 2001; Robertson and van Schaik 2001). As a result, wild orangutans are in steady decline due to logging, habitat conversion, fires and poaching.

Leading orangutan experts recognized that, in order to reverse this disaster, it was imperative to ascertain current population status and to develop and implement important conservation strategies. Therefore, the Conservation Breeding Specialist Group (CBSG) was invited to conduct a Population and Habitat Viability Assessment (PHVA) workshop for both Bornean (*Pongo pygmaeus pygmaeus*, *Pongo pygmaeus wurmbii* and *Pongo pygmaeus morio*) and Sumatran (*Pongo abelii*) orangutans to develop a strategic recovery plan for these threatened species and their habitat. The PHVA workshop was held 15-18 January 2004 and generously hosted by BOS Indonesia at the Schmutzer Primate Centre at Ragunan Zoo in Jakarta. Over 80 people participated in the PHVA (participants and invitees are listed in Sections 8 and 9 of this report, respectively).

At the PHVA, orangutan population data were integrated with estimates of human-based threats, such as current and projected land-use patterns. Computer models were used to evaluate current and future risk of population decline or extinction under alternative management scenarios. Participants developed detailed management recommendations based on these and other analyses. The main task of this new PHVA workshop, a follow-up to the 1993 Orangutan PHVA, was to assess the current status of wild orangutan habitats and populations and their future.

The specific objectives of the workshop were to assist Indonesia's wildlife managers, policy makers, and scientists to:

1) formulate priorities for practical scientific management of the wild population;
2) develop a risk analysis and simulation population model for the wild populations;
3) suggest research priorities linked to preservation of the species; and
4) encourage communication and collaboration with government and non-government conservation programs.

A briefing book including taxonomic information, distribution maps, field study synopsis, life history information and relevant, current published and unpublished materials was distributed to participants. This workshop report addresses the objectives listed above and reports all findings and updated information on orangutans of Borneo and Sumatra as well as the pre-PHVA field research.

Pre-workshop Data Collection

To properly prepare for the workshop, a project was proposed and funded by Orangutan Foundation UK to assemble updated information on orangutan distribution and densities. Additional Sumatran surveys were conducted with the support of The Gouden Ark Foundation, The Netherlands. Without new information on orangutan life history parameters, the modeling component of the PHVA workshop would not give us the tools for proper population management given current conditions. Data gaps were identified in all of the previous workshops and the situation concerning orangutan habitat and population trends has changed drastically since 1993. In order to draw the greatest benefit from a gathering of experts, preparatory fieldwork was undertaken, coordinated by Dr. Carel van Schaik. The most urgent need was updated information on the current distribution of wild orangutans and the quality of their remaining habitat.

In order to obtain the necessary data, the distribution maps produced by Rijksen and Meijaard (1999) were reviewed and the information updated through consultation with all relevant field experts. Based on their recommendations, priority survey areas were identified. Visits to these areas were conducted by several teams of Indonesian and international researchers to update distributional information, estimate densities on the ground, and record the nature of habitat disturbance. The findings were presented at the PHVA workshop. The project report, which compiles all the known data on oranguatn distribution, genetics and ecology, can be found in Appendix II of this document.

The PHVA Process

The Conservation Breeding Specialist Group (CBSG) was invited to serve as a neutral workshop facilitator and organizer. CBSG is a member of the Species Survival Commission of the IUCN - World Conservation Union, and for more than a decade has been developing, testing, and applying a series of science-based tools and processes to assist species management decision-making. One tool CBSG employs is use of neutral facilitators to moderate small working group sessions, as the success of the workshop is based on the cooperative process of dialogue, group meetings, and detailed modeling of alternative species and/or habitat management scenarios.

Effective conservation action is best built upon critical examination and use of available biological information, but also very much depends upon the actions of humans living within the range of the threatened species. Motivation for organizing and participating in a PHVA comes from fear of loss as well as a hope for the recovery of a particular species.

At the beginning of each PHVA workshop, there is agreement among the participants that the general desired outcome is to maintain a viable population(s) of the species. By way of introduction, each participant was asked to provide a statement on his or her personal goal for the workshop and what they hoped to contribute to the workshop. Nearly universal among the participants was their interest in protection of remaining wild populations of orangutans and in sharing information relevant to the deliberations to take place over the next 3 1/2 days. Learning and sharing of information is at the heart of the PHVA workshop process which takes an in-depth look at the species' life history, population history, status, and dynamics, and assesses the threats that may put the species at risk.

One crucial by-product of a PHVA workshop is that an enormous amount of information can be gathered and considered that, to date, has not been published. This information can be from many sources; the contributions of <u>all</u> people with a stake in the future of the species are considered.

To obtain the entire picture concerning a species, all of the information that can be gathered is discussed by the workshop participants with the aim of first reaching agreement on the state of current information. These data then are incorporated into computer simulation models to determine: (1) potential for population persistence under current conditions; (2) those factors that make persistence of the species problematic; and (3) which factors, if changed or manipulated, may have the greatest effect on improving the prospects for survival. In essence, these computer-modelling activities provide a neutral way to examine the current situation and what needs to be changed if orangutans are to avoid extinction.

Complementary to the modelling process is a communication process, or deliberation, that takes place during a PHVA. Workshop participants work together to identify the key issues affecting the conservation of the species. During the PHVA process, participant's work in small groups to discuss key identified issues. Each working group produces a report on their topic, which is included in the PHVA document resulting from the meeting. A successful PHVA workshop depends on determining an outcome where all participants, coming to the workshop with different interests and needs, "win" in developing a management strategy for the species in question. Local solutions take priority. Workshop report recommendations are developed by, and are the property of, the local participants.

The workshop began with a series of presentations. The first was on CBSG and the process that had been designed for the Orangutan PHVA Workshop. This was followed by a series of excellent research presentations providing the most accurate and current information on wild populations of orangutans on Sumatra and Borneo. The final presentation focused on the computer modelling tools to be used during the workshop and results of preliminary orangutan projections.

The participants then split up into three working groups. Two were region-based (Borneo and Sumatra) and the third, Conservation Strategies, addressed global and local issues facing orangutan conservation.

Each region-based working group was asked to:
- Review the data and refine the baseline model
- Determine priority sites
- Identify threats to orangutan survival at priority sites
- Propose preliminary management recommendations
- Test effect of preliminary recommendations in population models
- Develop action plans for priority sites

The Conservation Strategies group brainstormed the key issues facing the future of orangutan conservation and then determined the core competencies of the members of the group and how best they could contribute to the survival of the species. The tasks for this group evolved over the course of the workshop and many participants in the region-based groups contributed to the product resulting from the work of the Conservation Strategies working group.

Each group presented the results of their work in daily plenary sessions to make sure that everyone had an opportunity to contribute to the work of the other groups and to assure that issues were carefully reviewed and discussed by all workshop participants. The majority of the recommendations coming from the workshop were accepted by all participants, thus representing a consensus. Those that could not agree with the recommendations and actions of the group were offered the option of writing dissenting opinion pieces. Summaries of the results of each working group reports are below. Detailed reports can be found in Sections 3-5 of this document.

A fourth group was established to address the stated goal of identifying priority sites for conservation action. A small group took time out from their primary working groups to tackle this issue. They reported back in a plenary session where a lively debate took place and the intention of the process and a procedure for prioritizing habitat units were agreed upon. The results of this group's effort are described in Section 2 of this report.

Working Group Results and Recommendations

CONSERVATION STRATEGIES

The goal of this working group was to mobilize the expertise represented at the PHVA workshop and use its results to develop some new strategies to protect orangutans and discuss why old ones have failed. The region-based working groups (see below) identified a set of priority populations and the supporting habitat areas critical to preventing extinction of each orangutan taxa. This working group was charged to develop new ideas about how to protect these priority populations and the other remaining forest fragments containing orangutans.

The working group defined its purpose as: developing a scientifically-based conservation strategy, with the goal of maximizing protection of numbers and sizes of populations, prioritized by the sustainable size of populations within their habitat blocks, and their taxonomic and ecological diversity. The group recognized that any conservation strategies pursuing this goal should be advised by these considerations: a) Avoid creating incentives to devalue small populations; and b) Prioritization of populations needs to forecast long-term sustainability of viable populations and their habitat blocks or fragments.

The group evaluated the need for new institutional arrangements to improve the monitoring and conservation of populations and habitat blocks. While recognizing the value of two important international initiatives that already exist (GrASP - the Great Ape Survival Project and GAWHSP - the Great Ape World Heritage Species Project), the formation of two new institutions was endorsed. These are:

- At the international level, an Orangutan Scientific Commission (OSC), and
- At the national level, an Orangutan Conservation Forum (OCF)

The structure and function of the OSC and the OCF are described in detail in Section 3 of this report. Some of the OSC's primary functions will include:

- Monitor status of populations and habitat units
- Raise awareness: provide an authoritative source of information

- Maintain a website with links to publicize changes in status of populations (perhaps maintained by WCMC – UNEP)
- Prioritize research and funding needs, comment on documents regarding specific populations
- Link information to national and local level through websites and disseminated information
- Assist fundraising by raising awareness among international government and private donors

The OCF will focus on scientific aspects of conservation. Its important functions will include:

- Communication with all levels of stakeholders about PHVA results and their scientific basis
- Liaison with the scientific commission providing data and distributing information to the members of the OCF
- Liaison with local stakeholders working at orangutan field sites regarding conservation status of the population and forest habitat, changes in policies, etc.
- Advising preparation of the GrASP National Great Ape Survival Plan (NGASP)

On the morning these guidelines were outlined to the PHVA participants, NGOs present in the room pledged >$25,000 in funds to support the OCF (Conservation International, Orangutan Foundation UK, BOS Foundation, Ape Alliance, Hutan, Australian Orangutan Project, Sumatran Orangutan Conservation Programme). This show of support provided enormous encouragement and motivation to the initiative.

ORANGUTANS ON SUMATRA

With current estimated rates of logging and the associated removal of orangutans, model results indicate that habitat loss and other factors will cause Sumatran orangutan populations to decline quickly toward extinction. Sensitivity testing of the baseline model suggests that in the absence of logging or hunting, only populations of 250 or more orangutans show long-term viability. Logging decreases viability, and high annual logging rates of 10-20% quickly drive even large populations to extinction.

Of the 13 identified orangutan populations on Sumatra, only 7 are estimated to contain 250 or more individuals. Of these 7 populations, 6 are believed to be subject to 10-15% annual habitat loss due to logging and are expected to decline quickly. This includes the largest Sumatran orangutan populations, which are found in West and East Leuser and in Singkil; these populations are projected to decline dramatically within the next few years due to high rates of illegal logging and are at risk of rapid extinction if habitat loss is not checked. Although the West Batang Toru population is markedly smaller (about 400 individuals), the estimated rate of habitat loss in this area is relatively low (2% annually). It is therefore likely that this population may persist longer than other populations if current conditions continue, but it will also eventually go extinct. The conclusion is bleak – Sumatran orangutan populations may decline by 50% in about a decade, by 97% in 50 years, and will eventually disappear unless continued habitat loss is stopped.

Efforts to reduce fragmentation and link orangutan populations to form meta-populations may contribute to the viability of Sumatran orangutans. Ultimately, however, continued habitat loss and removal of individuals associated with logging will drive this species close to extinction within a few decades. To counteract this threat, efforts need to be made to reduce high levels of logging and ultimately to stop further loss of habitat and carrying capacity through cessation of logging and/or habitat restoration. The urgency for action varies among the habitat units and is dependent upon the current rate of logging and size of the orangutan population; for some habitat units, the need for action is immediate if orangutans are to persist. Fragmentation due to the presence of roads or other factors exacerbates the urgency for such conservation action.

By the conclusion of the workshop, the working group had developed general recommendations for conservation action for the 13 habitat units identified for Sumatra (pages 42-43). Conservation International Indonesia made a commitment to the Sumatran Orangutan Working Group to find funds to bring the group together again, plus additional key people who may not have participated originally, within the year to build upon the work begun at the PHVA combined with the final modeling results and work toward the next level of developing an effective Sumatran orangutan action plan.

ORANGUTANS ON BORNEO

Our initial exploration of some scenarios representing typical populations on Borneo suggests that orangutan populations restricted to habitats capable of supporting only about 50 animals can persist for a considerable number of years, but are unstable and vulnerable to extirpation. Habitats capable of supporting more than 250 orangutans appeared necessary to ensure good demographic and genetic stability.

Low rates of hunting (more than 1% per year) could destabilize and threaten the persistence of even initially large populations in extensive areas of habitat. The impacts are most severe when hunting occurs in lower quality habitat, where the potential population growth rate is low at best, but even in the best habitats, the slow breeding rates of orangutans cannot compensate for hunting at rates of 2% and higher.

Models of populations within specific habitat blocks further reinforced the finding that the smaller populations, if isolated from other populations, would be less stable and eventually decline as they became inbred and lost their genetic diversity. It should be noted that there are many small patches of forest on Borneo that contain very small populations of orangutans. These populations, smaller than any we modeled, would be very vulnerable to extirpation. In addition, some of the forest areas that were considered in our assessments to be single "habitat units" – such as some of the areas in central and west Kalimantan – are partly to severely fragmented. It is not known if orangutans can move among these forest blocks, and the effects of this fragmentation may therefore be to cause the populations in these forest "units" to be much less stable and less secure than appears in our models.

It is also important to recognize that our basic models assume that the habitat units will remain largely unchanged and will not be subjected to stresses larger than (or even, in some cases, as large as) those that they are currently experiencing. *Yet many of these forests will be cleared or badly degraded unless urgent and forceful action is taken soon. Our models should be seen not as a prediction of what will happen, but rather as projections of the expected stability of the existing large populations of orangutans if the habitat units are preserved and other threats such as hunting do not harm the orangutans within the forests.* We ran several simulations to project the declines that will occur if habitat is destroyed (for example, in Mawas and Sebangau). Not surprisingly, the models show that even populations that are currently very large could be driven to extinction within the next 50 years – a shorter time frame than the known potential longevity of single orangutans in the forest. We also tested the effect of hunting in three sample habitat units – and demonstrated again that even low rates of hunting can depress populations in the best habitat and completely eliminate populations in worse habitat. Higher rates of hunting (e.g., 3% per year) are unsustainable anywhere.

The working group identified a set of general recommendations for conservation of the orangutans on Borneo (page 116). Included are recommendations focusing on the areas of: awareness and education, economic development, law enforcement, habitat management, research (long-term) and population monitoring, policy, and wildlife corridors.

Sections three through five of this report contain detailed results from each of the working groups.

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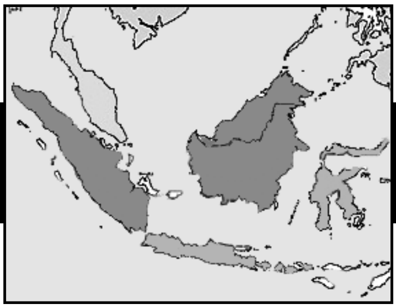

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Section 2

PRIORITIES FOR CONSERVATION

Priorities for Conservation

Goal and significance

The goal is to identify viable orangutan populations that make substantial contributions to orangutan survival. Inclusion on the list implies that a threat to any of these populations must lead to immediate conservation action. Loss of any of these populations would seriously jeopardize the taxon's integrity as an evolutionary unit.

Each orangutan population is worthy of protection. Hence, *absence from this list does not imply absence of priority for conservation*. However, the need to prevent a population's extinction should be correlated with its importance to the overall survival of the taxon. Thus, inclusion on the list recognizes the major contributions that the populations on it make to orangutan conservation. These populations form the insurance policy for the taxon's survival.

We refrain from adding an assessment of the priority for conservation action because our emphasis is on identifying the habitat units currently making the greatest contribution to orangutan survival. The main reason for omitting it is that it is impossible to generalize about the feasibility or cost-effectiveness of conservation measures: Every local situation is unique, and conservationists tend to develop strategies tuned to the local situation. One person's lethal threat is another's unique opportunity.

Procedure

The primary determinant of the contribution to orangutan survival of a population (habitat unit) is its **size** (the habitat unit is the level of analysis relevant here since extinction is at this level). This contribution may be modified by several biological factors:

- *Taxonomic position*: the largest population[s] in each of the four major orangutan taxa deserves special attention.[1]
- *Unusual habitat:* in each taxon, the largest population in habitats that differ strongly from the top-ranked population deserves attention, because of the likelihood of local genetic (morphological) and cultural adaptation to habitat conditions.
- *Peripherality:* in larger regions, habitat units that are far from the predominant one, and therefore likely to differ most from it, deserve special attention.
- *Presence in political unit:* in each major political unit (province in Indonesia; state in Malaysia), the largest population deserves special attention.

This procedure assumes that we can confidently identify habitat units. In one case (Gunung Gajah/Berau/Kutai), habitat units were combined in this analysis because they were probably connected until recently and can be reconnected with limited effort.

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[1] Because the Sumatran population is much smaller than the Bornean, yet recognized as a separate species by the IUCN, *P. abelii* and *P. pygmaeus* must be given equal weighting. As a result, each individual orangutan in Sumatra makes a relatively greater contribution to orangutan diversity, and hence smaller populations in Sumatra warrant inclusion on the list.

Obviously, this assessment reflects the current situation. A habitat unit not currently on the list will be placed on the list if restoring the connection to another habitat unit creates a large enough unit, or if habitat restoration increases the size of the population in it, and thus increases its conservation value. Similarly, habitat units will be removed if their numbers fall dramatically, or if fragmentation breaks them up which indicates then that conservation has failed. Thus, the potential contribution to conservation may differ from the practical contribution at present. We recommend that the International Commission needs to reconsider the inclusion on this list on a regular basis.

Application

The following table lists the habitat units by taxon. The units in large font are those that make essential contributions to the orangutan's survival. Those in smaller font make a major contribution, which is larger than expected on the basis of their size due to the presence of special factors. All other population units with viable populations (not listed here) make important contributions.

Table 2.1

Habitat Unit	Pop Size	Taxon	Unusual habitat	Peripher-ality	Political unit
Sebangau	6300	X (Ppw)			
Tanjung Puting	6000		X		
Belantikan	5000+		X		
Mawas	3500			X	
Gunung Palung	2500			X	X
"Sabah Foundation"	5320	X (Ppm)			
Kinabatangan	4000		X		
Gng. Gajah/ Berau/Kutai	3000 (?)			X	X
West Leuser/Singkil	4000	X (Pa)			
East Leuser	1050		X		X
West Batang Toru	400			X	X
Batang Ai/Lanjak-Entimau/ Betung-Kerihun	>2500 (?)	X (Ppp)			X
Danau Sentarum + surroundings	500				X

Working group members: Stephen Brend, Birute Galdikas, Anne Russon, Ian Singleton, Carel van Schaik

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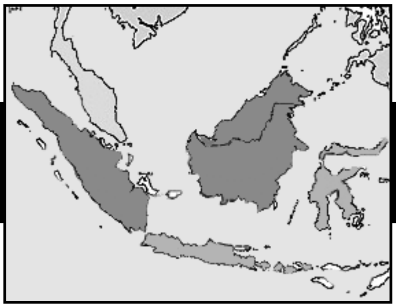

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Section 3

CONSERVATION STRATEGY WORKING GROUP

Conservation Strategy Working Group Report

The goal of this working group was to mobilize the expertise represented at the PHVA workshop, and its results, to develop some new strategies to protect orangutans. The workshop would be identifying a set of priority populations and the supporting habitat areas critical to preventing extinction of each orangutan taxa. In anticipation, this working group was charged to develop new ideas about how to protect these priority populations and the other remaining forest fragments with orangutans.

I. Working Group Objectives and Agenda

The working group defined its purpose as: *Adding value to the workshop by developing a more scientifically-based conservation strategy, and developing follow-up mechanisms and products that help implement this strategy.*

A. We identified this more scientifically-based conservation strategy as the following goal: *To maximize protection of numbers and sizes of populations, prioritized by the sustainable size of populations within their habitat blocks, and their taxonomic and ecological diversity.*

However, any conservation strategies pursuing this goal should be advised by these considerations:

a) Avoid creating incentives to devalue small populations because:

- these have scientific, educational and flagship values;
- small ancillary populations help reduce extinction risk and contribute genetic diversity; and
- some are models of conservation success and effective political will (e.g., Sungai Wain).

b) Prioritization of populations needs to forecast long-term sustainability of viable populations and their habitat blocks or fragments, including:

- projected declines to K in compressed populations;
- ecological threats (fire, global climate change); and
- sociopolitical uncertainties (variation in conservation commitment under decentralized autonomy).

B. To brainstorm about conservation strategies, two tasks were required: *a) defining threats to orangutan conservation, and b) mechanisms to address these threats.*

Therefore, a comprehensive list of threats was compiled from the group discussion. In so doing, it became clear that:

- Threats to orangutan populations vary by country: effective law enforcement, sustainable forestry and lower rural population pressure all reduce field problems of population protection in the Malaysian states of Sabah and Sarawak compared to Indonesia.
- Threats and the effectiveness of potential strategies to counter these threats vary by land use status: Is the orangutan population within a protected area, timber production forest,

or some mixture, and is the habitat block of forest under central government control or decentralized control at the regency level?

The following are the threats to orangutan populations discussed by the working group:

- Hunting
- Disease (more prominent in the future?)
- Illegal logging (and legal, but unsustainable logging)
    - Lack of political will to enforce laws, corruption, poor field monitoring, dysfunctional legal system
- Fire (risk increases with logging, road construction and climate change)
- Human population growth in colonization of forested regions
- Forest conversion (plantations, transmigration, infrastructure)
- Poor land use planning to maximize conservation benefits and avoid fragmentation
- Mining
- Unclear government legal jurisdiction, and dysfunctional legal processes
- Poor capacity of NGOs/govt in conservation-related fields
- Poor conservation models and funding constraints (ICDPs)
- Poor integration and prioritization of conservation efforts:
    - Scientists, NGOs, Govt., International efforts
- Ineffective mechanisms to publicize problems and bring pressure to solve these (media, legal)
- Breakdown of local traditions, increased economic demands
- Low appreciation of environmental benefits, and limited direct economic benefits to local and political stakeholders
- Lack of conservation/environmental awareness:
    - Local communities, general public, district and national governments

After producing this list of threats, discussion focused on developing foci that might best be pursued by the assembled expertise. Because the workshop in general, and this working group in particular, attracted a broad range of scientists, field conservation practitioners--both local and international, and government and NGO policy makers and conservation funders, a diversity of strategies and interventions were brought to the table.

During Day 2, the working group made progress identifying important foci for further deliberations. These were to develop new institutional mechanisms that would enhance the effectiveness of conservation efforts, and examine in more detail the problems of policing and protection, the major threat to orangutan populations in Indonesia. However, a subgroup decided that they wished to focus on local stakeholder issues rather than international and national institutional issues. This defined three different topics meriting further exploration, which were then pursued by separate working committees on Day 3.

These committees focused on:

- Developing new institutional arrangements that better monitor populations, and coordinate conservation policies and actions from international to local levels;
- Evaluating strategies of effective policing and protection to stop habitat loss and orangutan mortality; and
- Evaluating innovative strategies of conservation work in the field.

The results of the deliberations of the first two of these committees are presented below. The third committee did not submit a written summary, in part because critical evaluation of the success of conservation approaches at the local level requires a more in depth treatment than was possible during this workshop. Therefore, the balance of this chapter summarizes the results on the first two topics.

II. Committee Report on New Institutions for Orangutan Conservation

A committee was formed from the Conservation Strategy Working Group to evaluate the need for new institutional arrangements to improve the monitoring of populations and habitat blocks and their conservation.

Two important international initiatives that could importantly use the results of this PHVA Workshop already exist. During brief plenary presentations, workshop participants were informed both about GrASP, the Great Ape Survival Project, and GAWHSP, the Great Ape World Heritage Species Project.

To date, GrASP is promoting great ape conservation primarily by encouraging and funding range states to develop National Great Ape Survival Plans (NGASPS). Clearly the results of the PHVA Workshop can provide the basis for this, as the important populations of different taxa are identified and prioritized for protection. The stakeholders represented at this workshop are the ones that can advise governments on the NGASP, and in fact, Indonesian government conservation authorities attending the workshop were explicit in endorsing this anticipated relationship. GrASP is sponsored by UNESCO and UNEP, and recently held a preliminary intergovernmental meeting to agree to be constituted as a Partnership among range states, NGOs, multilateral environmental agencies (e.g., relevant UN conventions, World Bank, GEF, etc.), and non-range states supportive of great ape protection and conservation. GrASP is still in a process of developing its identity and scope of activities, which should be clarified after the next Partnership meeting in early 2005.

GAWHSP is working with UNESCO's Natural Areas Section of the World Heritage Centre to develop the legal, scientific and philosophical basis for establishing World Heritage Species (WHS) under the various conservation oriented United Nations conventions. A brainstorming meeting on WHS is expected to be hosted by UNESCO in May 2004. It is hoped that the orangutan, and other great ape taxa, might be promoted there as the world's first World Heritage Species. The relationship between WHS and PHVA Workshops sponsored by the CBSG is very direct. An important consequence of WHS status would be the designation of an expanded cluster of populations as WHS sites, to complement those few that are already World Heritage

Sites, for instance. The selection of populations so designated should be based on conserving the full genetic and ecological diversity of the taxa, with attention to cultural and scientific values.

The Committee discussed and endorsed formation of two new institutions. These are:
- At the international level, an Orangutan Scientific Commission (OSC); and
- At the national level, an Orangutan Conservation Forum (OCF).

A. The functions of the Orangutan Scientific Commission

The functions proposed for the OSC were suggested by the problems inherent in the current fragmented efforts on behalf of orangutan conservation, and the need for stronger scientific input into how government agencies and NGOs prioritize and make decisions. There is a critical need, for instance, for monitoring of orangutan populations and their conservation status on an ongoing basis, rather than the sporadic attempts represented by PHVA Workshops or the Great Ape Atlas. This monitoring could be key for international publicity, and provide information to address crises by national stakeholders. Currently, important populations are unstudied and unprotected, and the focus of no conservation action. The OSC could perform the following functions:

- Monitor status of populations and habitat units
- Raise awareness: provide an authoritative source of information
- Maintain a website with links to publicize changes in status of populations (perhaps maintained by WCMC – UNEP)
- Prioritize research and funding needs, comment on documents regarding specific populations
- Issue reviews to standardize methodologies, and hold workshops and symposia
- Link information to national and local level through websites and disseminated information
- Assist fundraising by raising awareness among international government and private donors
- Fundraise for support of commission activities

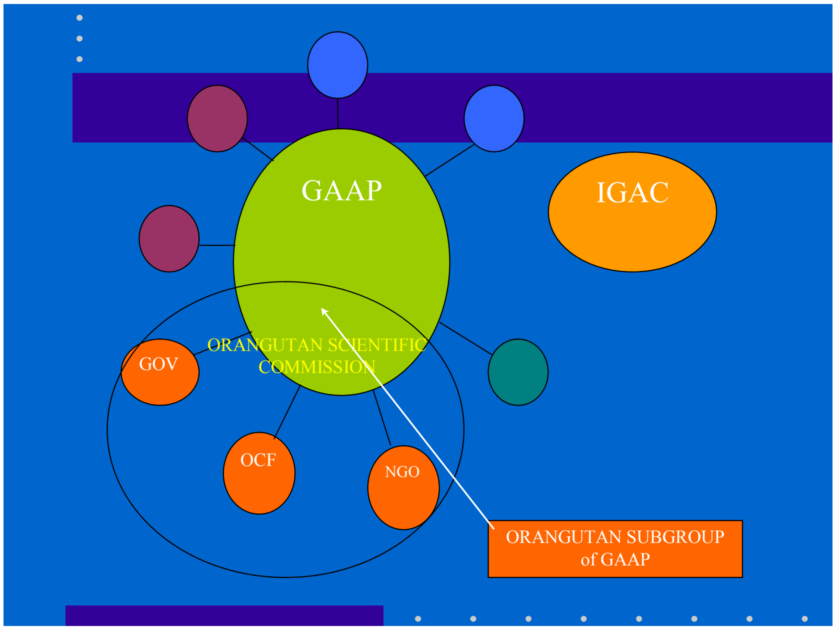
B. Orangutan Scientific Commission Organizational Structure

The working group endorsed the recommendation that the OSC should be embedded within the International Great Ape Commission (IGAC). IGAC is a proposed organization and its structure is to be worked out during this year. There are advantages of cost savings, greater scientific expertise, shared lessons and approaches, and enhanced international effectiveness gained by making the OSC an overlapping subset of IGAC. The figure below clarifies the organizational structure of OSC and IGAC:

IGAC is proposed to have the following organizational structure:
- The core group of IGAC is made up of rotating "commissioners" elected from the Great Ape Advisory Panel (GAAP). GAAP is already established as a subgroup under the Primate Specialist Group (PSG) of the Species Survival Commission (SSC) of the IUCN (or IUCN/SSC/PSG. Several orangutan scientists are already members of GAAP, but GAAP can be further expanded to include others. The broader membership of GAAP then serves a

core advisory function for IGAC. Therefore, the diagram (representing one possible option for the structure of the OSC within IGAC) shows GAAP at the hub of IGAC.

- However, to ensure good communication between scientists, government wildlife and forestry departments, and NGOs, these organizations will also be members of IGAC, as the spokes linked to the hub. This allows some number of NGO and governments to appoint scientists to participate. The empty bubbles in the diagram illustrate that IGAC will include other subsets of specialists and associated partner organizations.



- IGAC has been proposed by the Primate Specialist Group of IUCN and by GAWHSP (the Great Ape World Heritage Species Project) to become an independent organ under GrASP, the Great Ape Survival Project. GrASP is sponsored by UNEP and UNESCO. GrASP's sponsorship of IGAC would not be confirmed until the next intergovernmental meeting, probably in early 2005. However, an "Interim IGAC" will hopefully start functioning during 2004, even if its eventual sponsorship home is uncertain. IGAC may be established independent of GrASP.
- The Orangutan Scientific Commission would thereby be a subset of this GAAP hub and spokes linking Indonesian and Malaysian government agencies, and NGOs active in orangutan conservation.
- It is essential that the OSC is linked to a network based in Indonesia and Malaysia, where information provided by IGAC and information on the status and threats to field populations can be received by IGAC and the OSC. Therefore, note that one of the IGAC spokes is the Orangutan Conservation Forum, linking this international institution directly to locally based stakeholders.

C. Functions of the Orangutan Conservation Forum

Participants attending the Palangkaraya workshop on orangutan rehabilitation in June 2002 informally designated the Orangutan Conservation Forum (OCF). However, this body was never activated in part because organizational structure and commitment was not put into place to activate the institution, it was left in the hands of persons already overly committed, and the necessary key staff were not funded. The committee determined that this remained an essential body to establish, and that these lessons learned should not need repeating.

The OCF will emphasize scientific aspects of conservation. Its important functions would be:

- Communication with all levels of stakeholders about the PHVA results and their scientific basis
- Liaison with the scientific commission (OSC) providing data and distributing information to the members of the OCF
- Liaison with local stakeholders working at orangutan field sites regarding conservation status of the population and forest habitat, changes in policies, etc.
- Advising preparation of the GrASP National Great Ape Survival Plan (NGASP)

D. Organizational Structure of the Orangutan Conservation Forum

The key guidelines agreed upon by the working group were:

- The OCF is a network of concerned NGOs, scientists, and national and local government stakeholders committed to the conservation of orangutans. This group can conduct policy advising, media awareness and networking to improve conservation effectiveness.
- The OCF should establish an independent main office in Jakarta, with branch offices or coordinators in Sabah and Sarawak. Although several conservation NGOs offered to host the office in Jakarta, it was felt important that the office should be perceived as independently representing all stakeholders.
- A full-time Coordinator should be based in Jakarta, with a 1/2-time person in Sabah, and a part-time person in Sarawak. The Coordinator should be Ph.D. level Indonesian. A committee from the Indonesian Primatological Society should forward a short list of candidates to the Orangutan Scientific Commission and NGO stakeholders (Marc Ancrenaz will help designate persons in Sabah and Sarawak with the help of local NGOs and government authorities).
- The Coordinator may need one or more technical staff, especially to run an email listserve linking all members of the Forum together.

Remarkably, and as a hopeful sign, on the morning these guidelines were outlined, NGOs pledged >$25,000 in funds to support the OCF (Conservation International, Orangutan Foundation UK, BOS Foundation, Ape Alliance, Hutan, Australian Orangutan Project, Sumatran Orangutan Conservation Programme). Every NGO member of OCF should be encouraged to contribute, according to its ability.

E. Recommendations & Actions

The following were presented in the final PHVA Workshop plenary session and adopted by the workshop participants.

1. Orangutan Scientific Commission

Recommendation 1: An Orangutan Scientific Commission (OSC) should be established within the International Great Ape Commission (IGAC), following the structure and set of defined functions outlined above.

a) IGAC should be asked to endorse the results of the Orangutan PHVA and assist the Orangutan Scientific Commission to develop materials (brochures, web sites) to publicize the crisis in orangutan conservation.

b) The Orangutan Scientific Commission should develop an integrated ongoing monitoring system using GIS, database and web site tools as one of its first activities.

c) IGAC fundraising should be supported by orangutan conservation to support the costs of these activities.

Action 1a. Coordinate and follow-up with Chair of IUCN/SSC/PSG & GAAP to adopt these recommendations, coordinate OSC within IGAC and communicate with GrASP and other relevant institutions (M. Leighton will begin this process and hopefully complete this within the next several months, in communication with other GAAP members and scientists).

Action 1b. Develop a scientifically accurate and cost-effective GIS set of tools for monitoring habitat loss and degradation (M. Leighton will coordinate with CI, WCMC-UNEP and P.T. SarVision to develop with IGAC & OSC for funding).

2. Orangutan Conservation Forum (OCF)

Recommendation 2: An Orangutan Conservation Forum should be established following the structure and set of defined functions outlined above.

Action 2a. Draft the Terms of Reference for the Coordinator positions, distribute to scientific committee, and advertise positions (Indonesian Primatological Society committee for Indonesia, Jatna chairing; M. Ancrenaz for Sabah and for Sarawak arrangements within 4 weeks).

Action 2b. Follow up on funding pledges and solicitations; establish accounting procedures and budget (OCF development committee, co-chairs Jatna and Jito).

Action 2c. Hire the Coordinators (after review by scientific committee); develop budget, rent office space and equipment, etc. (OCF development committee, co-chairs Jatna S. and Jito S.).

3. World Heritage Species

Recommendation 3: The World Heritage Species concept is endorsed, and the governments of Indonesia, Malaysia, Sabah and Sarawak should be encouraged to promote orangutans as one of the world's first WHS.

> *Action 3.* Inform the WHS informal working group of this recommendation and develop appropriate contacts with relevant government officials (M. Leighton within one week, with continued follow-up to facilitate).

4. BOSF Mawas Project

Although the workshop participants did not systematically review case studies of orangutan conservation, they wished to acknowledge the many excellent elements of the Mawas case study:

Recommendation 4: BOSF is encouraged to continue developing and refining innovative models for the sustainable conservation of the Mawas population.

III. Committee Report on Policing, Law Enforcement and Protection

While it is recognized that legal logging concessions may well have destroyed more orangutan habitat over the last couple of decades than illegal logging, this commmittee was focused on law enforcement. Therefore, the discussion was oriented towards identifying successful methods that have reduced illegal logging in the recent past. Illegal logging is a significant source of habitat destruction and therefore, population decline, for orangutans, but is essentially an Indonesian problem. While both Sabah and Sarawak should be encouraged to maximize the sizes of habitat areas and orangutan populations placed under protected status, wildlife protection authorities function well to prevent illegal poaching and logging in these Malaysian states. Therefore, the following points and recommendations represent Indonesian experiences in the protected forest areas that are besieged by illegal logging and the agricultural conversion and fires that often follow logging. Recommendations are numbered and offset. The actors recommended to implement recommendations are in parentheses (note: Guardians are NGOs working on behalf of conservation at a site).

A. Experience in Indonesia suggests having 'protected area status' helps with all arguments for law enforcement.

- All habitat unit managers, with the help of the Orangutan Conservation Forum, should attempt to secure some legal "protected area" status for each population.
- To ease protection and law enforcement, borders should follow natural features such as rivers, although the goal should be the protection of the maximum amount of habitat as possible.

B. The Wana Laga Military and Special Forces teams deployed in Indonesia in February 2003 were a major success. The large size of these teams size was key.

- This should become some sort of flying team that can be called on by Heads of National Parks if the illegal logging situation becomes critical (the Orangutan Conservation Forum therefore should lobby the government to keep Wana Laga active).
- The team needs to be large and preferably with aerial support.

C. To follow up the success of the Wana Laga team, a local task force needs to be set up to continue anti illegal logging activities. This local task force would consist of National Park rangers, local government Forestry Dept rangers, local police, military and community. (Habitat Unit Managers and Guardians should help facilitate setting up of task force.)
- Local community OPMUs (Orangutan Protection and Monitoring Units) accompanied by a 'jagawana' (ranger) should patrol hunting activities in all habitat units. The team would send reports to the task force to deal with illegal logging. (Habitat Unit Manager/Guardian to facilitate setting up of OPMU & to send reports to OCF)

D. Frequent and comprehensive monitoring of protected areas can lead to immediate responses by governmental authorities (BOS experience with satellite monitoring at Mawas Reserve is good example).
- Encourage aerial patrols, either by helicopter, microlite or small plane, as these seem to deter and frighten loggers.
- Establish regular remote sensing monitoring to track illegal activities and use these to make authorities accountable.

E. Training is needed to increase local government understanding of environmental laws.
- Training for local judges to increase their abilities to convict lawbreakers.
- Training of local National Park officials to Penyidik Pegawai Negeri Sivil) (PPNS) standard so they can build legitimate cases against lawbreakers.

F. Increase effectiveness of environmental lawyers to develop cases and coordinate these.
- Employ an environmental law expert in each of our priority areas to ensure that cases are carried as far as possible in the court cases (Orangutan Conservation Forum to coordinate, possibly seek help from TRAFFIC).
- NGOs should keep a database of all cases at their sites in order to provide specific information to lobby central government and apply pressure to change the current situation.

G. There has been one example where tree spiking has been very successful, Sungai Wain. There it was incorporated as part of an overall campaign that incorporated all levels of society in the discussions to perform tree spiking.
- Tree spiking should be used as a deterrent in an overall campaign to reduce illegal logging, not as a stand-alone solution (Habitat Unit Manager/Guardian to oversee).

H. Blockades of rivers and roads leaving the protected area seem to have been successful in keeping out loggers. It is important to stop the activities taking place, as there has not been an investment in time, money and effort.
- Establish posts at these checkpoints to prevent loggers from entering the park and confiscate logs illegally leaving the park (Habitat Unit Manager/Guardian).

I. Illegal logs and orangutans are marketed through a limited number of ports, and these can be patrolled.

- Ensure that relevant government bodies carry out patrols at ports. (Orangutan Conservation Forum to lobby government for this).

J. Park rangers need to use force to deter loggers and hunters in some cases.

- Non-lethal weapons, such as tear gas, rubber and plastic bullets, permanent ink from paint ball weapons, should be experimented with to determine effectiveness (some of these are being considered at Gunung Palung National Park, success will be reported to OCF).

K. International conventions and other bilateral and multi-lateral agreements can be used to pressure compliance with laws.

- Bring illegal activities to these international agencies to push for the cessation of illegal activities in habitat units (Orangutan Scientific Commission).

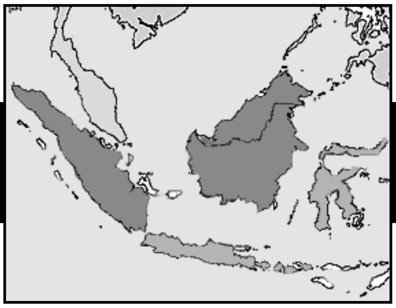
L. Put pressure on donor agencies to consider orangutan conservation issues in all their activities.

- Monitor compliance of Environmental Impact Assessments for both direct & indirect consequences of projects on orangutans & their habitat (Orangutan Scientific Commission).

M. Pressure relevant international authorities to track profits from illegal logging.

- Explore whether international collaboration can exert pressure on the international banking system (Orangutan Scientific Commission/CIFOR).

FINAL REPORT



ORANGUTAN

Population and Habitat Viability Assessment

15-18 January 2004
Jakarta, Indonesia

Section 4

SUMATRAN ORANGUTAN WORKING GROUP

Sumatran Orangutan Working Group Report

Goals and Measures of Success

The working group began by discussing several ways to identify goals and measures of success for conservation of the wild Sumatran orangutan (*Pongo abelii*) population. Members agreed that the overall aim is to conserve as many Sumatran orangutans as possible.

Several pieces of information are needed to develop a strategy for conservation action, which include the need to:

- Determine if the wild Sumatran orangutan population is still viable.
- Determine how many separate populations are viable.
- Identify priority areas for conservation action.

The first two needs were addressed through population modeling using *Vortex*, while identification of priority areas was accomplished through review and discussion of the data by the working group.

Everyone acknowledged that conservation in times of crisis is particularly difficult. This is the current situation in Aceh province in Sumatra due to civil unrest. Here it is extremely difficult to collect information because it is difficult to gain permission to visit Aceh, particularly for foreigners and non-Sumatrans. Even if access is possible, it is a dangerous task. Aceh is where the largest population of Sumatran orangutans exists, and therefore it is only possible to estimate the current status of the population.

The group agreed that we want to maintain viable populations of Sumatran orangutans within their range in perpetuity, although a quantitative definition of "viable" was not developed. After discussion the group agreed that the overarching goal is to *ensure that Sumatran orangutan populations are viable and secure for the next 1000 years. We will accept 0% risk of extinction over 1000 years.*

Measures of success were discussed that would allow us to identify whether or not this goal will be achieved. A number of measures were brainstormed, including:

- Tying measures of success to reproduction rates
- Using generations as a measure rather than years (for the model)
- Tying the measure to the IUCN Red List category of threat. Currently Sumatran orangutans are categorized as "Critically Endangered." The group agreed that population status should improve such that orangutans would minimally be downlisted to "Vulnerable".

Developing the *Vortex* Model for Sumatran Orangutans

The next task was to review the baseline orangutan *Vortex* model (developed at a pre-PHVA data compilation meeting held in Singapore in August 2003) and revise values for Sumatran orangutans as appropriate. The following changes were made based upon the 30+-year dataset from Ketambe and supplementary data from Suaq.

Age at first reproduction for males:
Changed from 20 years to 25 years

Maximum age of successful reproduction:
Initially left at 45 years, but the group agreed to also explore the model using 50, as one female in Ketambe produced offspring at age 50. This offspring is now 2 years old.

Sex ratio at birth:
Initially changed to 57% male based upon data for Ketambe (57%) and Suaq (56%); later changed back to 55% male (see below).

Density dependence/inter-birth interval (IBI):
Under good conditions (i.e., abundant food sources where there is room for the population to expand), the group agreed to an inter-birth interval of 8 years. In situations of limited resources and habitat saturation the inter-birth interval was set to 10 years. These figures were subsequently changed (see below).

Mortality schedule:
The following mortality rates were based upon data from Ketambe and Suaq and used in the initial baseline model (rates for infants and adults were subsequently changed – see below):

Age (years)	*Females*	*Males*
0-1	6%	6%
1-2	6%	5%
2-8	0.5%	3%
8-11	6%	6%
11-15	0.5%	0.5%
15+	2%	1.5%

Catastrophes:
Epidemic disease was left in the baseline model, as there are no data to support or refute this.
Extreme food shortage was thought to be less frequent on Sumatra than on Borneo; initially the probability of occurrence was reduced from 5% to 2%, but this catastrophe was subsequently eliminated from the model.
Fire was thought to be a threat in some areas of Sumatra, but the severity of its effect was estimated to be less. Fire was not included in the baseline model but was added for some individual habitat unit models, with a probability of 0.2% (once every 500 years) and an effect of 10% temporary reduction in carrying capacity.
Landslides were added as a threat for some of the habitat unit models, although they were not included in the baseline model. Landslides were estimated to occur once every 40 years (2.5% probability of occurrence) and to reduce carrying capacity temporarily by 0.75%.

Model Revision
Model results based upon these initial baseline parameters resulted in 100% probability of extinction in every run. The deterministic growth rate for this model based upon fecundity and mortality rates was negative, even in optimal conditions with ample food resources and

minimum inter-birth interval (r_{det} = - 0.005). The working group recognized that this was probably not realistic; as such a population would not have the ability to grow or persist, even with ample resources and no external threats. Although many of the demographic rates are based upon the real data (i.e., from Ketambe/Suaq), this population might be described as a stressed remnant population, and so it was decided to adjust demographic parameters slightly as appropriate to produce a population model that would allow for positive growth under optimal environmental conditions and in the absence of threats. After reviewing the model developed for Bornean orangutans and discussing the available data for Sumatra, the following changes were made to produce the final baseline model.

Maximum age of successful reproduction:
Changed to 50 years, which assumes that a 50-year-old female can live long enough to rear offspring to independence.

Sex ratio at birth:
Changed back to 55% male.

Density dependence/inter-birth interval (IBI):
The minimum inter-birth interval (i.e., under good conditions) was changed from 8 years to 6 years, the shortest IBI observed in Ketambe. Both IBI_{min} and IBI_{max} were then adjusted for females whose offspring do not survive to independence, resulting in adjusted IBI values of 5.5 and 9 years, respectively.

Mortality schedule:
Mortality rates for infants and adults were changed to:

Age (years)	*Females*	*Males*
0-1	From 6% to 5%	From 6% to 5%
15+	From 2% to 1.75%	From 1.5% to 1.25%

The resulting baseline model represented an orangutan population with a deterministic growth rate of 1.5% under good environmental conditions and a negative growth rate of – 0.2% under crowded or stressed conditions. This describes a population in sub-optimal habitat that is slightly oversaturated above the habitat's long-term carrying capacity (see *Modeling of Orangutan Populations on Sumatra Report*). This is a reasonable growth rate for a long-lived and slowly reproducing species such as the orangutan. Preliminary simulation results indicated that a population of 1000 orangutans was viable over 500 years in the absence of logging or hunting.

The primary immediate threat to orangutans in Sumatra is illegal logging. Orangutans are also hunted or otherwise removed illegally from the wild, but working group members believed that this is primarily in association with logged areas. Logging was incorporated into the *Vortex* orangutan model by a permanent reduction in carrying capacity, which removes individuals from the population and reduces the capacity for future growth. This appears to simulate logging effects and therefore no additional hunting was modeled for Sumatran orangutans.

Orangutan Habitat Units

Defining Habitat Units in Sumatra

The group next reviewed the data available on orangutan distribution and habitat for the 11 habitat units designated prior to the PHVA workshop. Ian Singleton and Serge Wich described how these habitat units were derived. The survey team first divided the dryland primary forest into habitat blocks, which were further divided into 100m height intervals. The survey team then defined the habitat units by overlaying contours on to areas of primary forest; secondary forests that were readily distinguishable using satellite imagery were believed to be so badly damaged that they were unlikely to contain significant orangutan populations that would be sustainable over the long term. It was also acknowledged that some of the areas included as primary forest would have already been heavily disturbed (especially since some satellite images dated back to 1998) and are therefore almost certainly not primary forest any longer. For this reasons, the team considered that any error in estimating total orangutan numbers that was due to ignoring some areas of secondary forest in which orangutans might still occur would have been largely offset by including a number of areas of what is today already secondary forest, as primary forest in the analysis. The team then assigned altitude and site-specific density estimates within each habitat unit (see *Status of the Orangutan in Indonesia, 2003 Report and Sumatran Habitat Unit Map*).

During their discussion, working group members decided that the NW Aceh Habitat Unit (HU) represented two separate orangutan populations, and split them into the NW Aceh HU (Blocks 1 & 2) and the NE Aceh HU (Block 7). Similarly, Middle Aceh HU was split into West Middle Aceh HU (Blocks 3 & 9) and East Middle Aceh HU (Block 8). This resulted in the identification of 13 separate orangutan populations and habitat units in Sumatra (Table 4.1). These habitat units differ in area, estimated orangutan population size, susceptibility to fire and landslides, current rate of logging, and threat of fragmentation, e.g. due to existing or proposed roads (see *Modeling of Orangutan Populations on Sumatra Report* and *Sumatran Habitat Unit Map*).

Prioritizing Habitat Units

After revision of the habitat units for Sumatra, the working group then brainstormed to create a list of criteria that might be used to prioritize these areas. Potential criteria were clustered and then pair-ranked to prioritize them, resulting in the following order of descending importance:

- Ability to sustain a viable orangutan population
- Orangutan numbers
- Degree of threat
- Habitat fragmentation/isolation
- Protected versus non-protected status
- Size (area) of unit
- Uniqueness (e.g., habitat types, orangutan culture or other – to be specified)
- Overall biodiversity value
- Political diversity
- Potential for connectivity with other habitat units
- Inclusion of more than one province

Table 4.1. Estimated area and orangutan numbers for 13 habitat units for Sumatra used for modeling.

Habitat Unit	Est. orangutan # (habitat unit)	Habit Block	Primary Forest (km^2)	Orangutan Habitat (km^2)*
NW Aceh	654	1. Ulumasin (Aceh Besar)	2066	847
		2. Tutut (Woyla; NW Aceh)	1918	832
NE Aceh	180	7. Geumpang	2116	282
Seulawah	43	6. Seulawah	103	85
West Middle Aceh	103	3. Beutung (W Aceh)	1297	261
		9. Linge	352	10
East Middle Aceh	337	8. Bandar-Serajadi	2117	555
West Leuser	2508	4. Kluet Highlands (SW Aceh)	1209	934
		5. W Mt. Leuser	1261	594
		5A. Kluet swamp	125	125
		10. E Mt. Leuser/Demiri	358	273
		11. Mamas-Bengkung	1727	621
Sidiangkat	134	12. Puncak Sidiangkat/B. Ardan	303	186
East Leuser	1052	13. Tamiang	1056	375
		14. Kapi and Upper Lesten	592	220
		15. Lawe Sigala-gala	680	198
		16. Sikundur-Langkat	1352	674
Tripa Swamp	280	17. Tripa (Babahrot) swamps	140	140
Trumon-Singkil	1500	18. Trumon-Singkil swamps	725	725
E Singkil Swamps	160	19. East Singkil swamps	80	80
West Batang Toru	400	20. West Batang Toru	600	600
East Sarulla	150	21. East Sarulla	375	375
Total	**7501**		**20552**	**8992**

*This column refers to the area of primary forest within each block considered (due to known altitudinal limits) or known to contain orangutan populations.

Note: The Bornean Working Group included populations of rehabilitant/introduced orangutans but the Sumatran group did not. There is one population of re-introduced orangutans in the Bukit Tigapuluh National Park in Jambi province (currently comprising over 30 individuals). This is an area where orangutans did historically occur and there are reliable reports of orangutans persisting in the area up until around the 1830's, but since the focus of the PHVA meeting was to ensure the survival of truly wild populations no analyses or further examination of this population was carried out.

After intensive discussion of these multiple criteria, the group decided to attempt to evaluate the highest priority habitat units in need of conservation action through general discussion. If there did not prove to be good consensus within the group, we would pair-rank the areas against the top criteria. The rationale for this method was that not everyone in the group had experience or knowledge of all data related to the criteria in all habitat units. Further, group members were confident that there would be agreement in identifying the areas of highest priority. Opinions proved to be consistent among group members and resulted in the following prioritization (habitat units are not prioritized within lists):

First Priority HUs:
West Leuser
East Leuser
Trumon-Singkil
NE Aceh
NW Aceh
East Middle Aceh
West Middle Aceh
West Batang Toru

Second Priority HUs:
Tripa (Babahrot)
East Singkil
Puncak Sidiangkat/Bukit Ardan
East Sarulla (Sipirok)
Seulawah

Habitat units were prioritized without the benefit of results from individual habitat unit *Vortex* models run after completion of the workshop and so should be considered preliminary pending further evaluation in light of model results.

Conservation Actions for Sumatra

Political Situation in Aceh Province

Much of the current wild Sumatran orangutan population lives within Aceh province. As part of the discussion of habitat units in Aceh, group members provided some background on the situation in Aceh.

In December 2002 the Free Aceh Movement (Gerakan Aceh Merdeka, or GAM) and the Indonesian Government signed a cease-fire agreement, or Cessation of Hostilities Agreement - CoHA, widely seen as the best hope for ending the conflict that has claimed 10,000 to 30,000 lives since the late 1980s. Terms of the agreement included: an immediate ceasefire; disarmament of GAM in designated areas; free elections in 2004 to establish an autonomous (but not independent) government; and a revenue-sharing system through which the new provincial government receives 70% of fuel (oil, gas, mineral, forest) revenues. With this deal came significant opportunities to work with the provincial and local governments for long-term conservation and development, and many biologists had great hope that security issues would lessen, allowing field conservation activities in Aceh again.

Unfortunately the ceasefire agreement did not last long. After weeks of uncertainty due to the breakdown of the Cessation of Hostilities Agreement, martial law was declared in Aceh through a presidential decree on 19 May 2003. This decree was effective for 6 months, and has since been renewed for a second 6-month period. This means that the military has total provincial control (over and above the governor). An active serving military general is Aceh's highest command. The last time martial law was declared in Indonesia was in 1999 in East Timor, prior to its secession from Indonesia. Several armed clashes have occurred between the separatist group (GAM) and the Indonesian military.

The above situation has made conservation in the area extremely difficult. This is particularly true for international NGOs, most of which evacuated their staff when a 17 June 2003 declaration barred foreigners from entering Aceh. As of that date, all international NGOs left the area and very few have returned. It is just quite recently that the capital city of Banda Aceh has become relatively safe. Martial law has been extended minimally through 19 May 2004.

Potential Conservation Options

The working group brainstormed to create a list of potential conservation options that might be applicable across the Sumatra habitat units. These included:

- Stop illegal logging
- Stop road plans (most importantly the Ladia Galaska plan)
- Continue funding for existing conservation projects
- Improve patrols and law enforcement
- Gain World Heritage Site status for the Leuser Ecosystem
- Develop education outreach programs
- Continue efforts to connect Trumon-Singkil and West Leuser HUs
- Reconnect West and East Leuser HUs
- Maintain research station at Ketambe
- Maintain concession moratorium indefinitely for legal logging
- Consider helicopter patrols for rapid enforcement
- Encourage local NGOs' participation and collaboration
- Promote forest restoration
- Provide incentives for people to move out of the Leuser Ecosystem
- Work more closely with local government (e.g., land use planning)
- Work closely with *Adat* leaders (traditional community leaders)
- Use local government regulations (*Perda*)
- Develop income-generating activities for local people (e.g., agro-forestry such as coffee, nutmeg)
- Identify and set up new research sites
- Develop innovative ecotourism opportunities (accompanying helicopter patrols, elephants)
- Monitor forest loss (e.g., satellite imagery higher resolution and more frequently)
- Initiate international and national media campaign
- Develop capacity-building

Each of these options was discussed regarding its suitability and effectiveness. Table 4.2 identifies the appropriate potential conservation strategies for each habitat unit on Sumatra. Several of these conservation actions were incorporated into the individual habitat unit *Vortex* models to help evaluate their relative effectiveness as follows (see *Modeling of Orangutan Populations on Sumatra Report*).

Maintain Moratorium on Logging Concessions

Modeled as the current situation (only illegal logging was included in model). Estimates were made for the current rate of logging in each HU, which ranged from 2% to 20% annually.

Improve Patrols and Law Enforcement

Modeled as reduced rates of logging compared to estimated current logging rate. This also includes a reduction in orangutans removed (e.g., by hunting) associated with logging.

Stop Illegal Logging

Modeled as complete and permanent cessation of all logging at various points in the future (i.e., in 20 years, 15 years, 10 years, 5 years, and immediately).

Stop Roads
Modeled by comparing one panmictic population to a meta-population composed of 2-3 fragments due to the presence of roads, either with complete isolation (West Leuser, East Leuser, West Middle Aceh, East Middle Aceh) or with migration of 50% of subadult males between fragments (NW Aceh) with 5% mortality during dispersal.

Reconnect West and East Leuser HUs
Modeled as one panmictic population for the combined HU populations. It was pointed out that this would include relocation of people that are currently living illegally in this area.

Connect West Leuser and Trumon-Singkil HUs
Modeled as two fragments with moderate migration (50% of subadult males age 12-20, with 5% mortality during dispersal). It was suggested that the corridor would be about 8 km wide.

Promote Forest Restoration
Assumes that reforestation efforts begin immediately, but that it will take 10 years for trees to provide additional resources for orangutans, and that these resources will continue to increase for the subsequent 20 years. Modeled as continued logging for 10 years, then cessation of logging and an increase in carrying capacity of 1% annually for 20 years to represent reforestation. Several additional actions were discussed that are believed to promote orangutan conservation but whose effects cannot be directly modeled. Helicopter patrols were felt to be an important and fresh idea for Sumatra, although problems in implementation are anticipated. NGO collaboration on many issues, including illegal logging and relocation of illegal dwellings, was recommended to further conservation action. The suggestion was made to use SAR vision (or a similar technology) that produces high-resolution satellite images to monitor orangutan habitat, especially for Sumatra; perhaps the Sumatran maps could be donated for this purpose. It is also important to follow through on the legal process of prosecution. In most cases people who are caught poaching or logging illegally are released quickly and are not prosecuted.

An important issue that arose during the discussion is that the Indonesian government had an earlier plan to submit a proposal to UNESCO to give World Heritage Site status to the ca 2.5 million hectare Leuser Ecosystem in Sumatra. However, the proposal that was eventually submitted included only the much smaller (approx 830,000 ha) Gunung Leuser National Park (GLNP). PHKA submitted a proposal to UNESCO for a ‘cluster-mountain’ World Heritage site comprising of the Bukit Barisan Selatan, Kerinci Seblat and Gunung Leuser National Parks (of which only the latter contains any orangutans). Cluster Mountain World Heritage Sites are specifically tailored to high mountain ranges, i.e. the kind of designation that would be more appropriately proposed for areas such as the high Himalayas, Andes or Alps, where the focus of conservation is on the high altitude habitats. It is considered wholly inappropriate for Sumatra, where most biodiversity is concentrated in and totally dependent on lowland forests. Working group members are concerned whether the current proposal, focusing just on GLNP (as its only orangutan population), is the most appropriate option, since most Sumatran orangutans are found outside of the National Park itself. In fact, a subsequent analysis using exactly the same data and methods used in the PHVA (i.e. density estimates at 100m altitude intervals) concluded that Leuser Ecosystem contains ca 5,598 orangutans whilst in GLNP there are only ca 2,025, meaning that around 3,573 orangutans exist within Leuser Ecosystem's borders but <u>outside</u> of the

National Park. Therefore, we believe that focusing only on GLNP (and the more southerly Parks) as a World Heritage site will shift attention away from the Leuser Ecosystem as a whole and provide little benefit to North Sumatra and Aceh's orangutans, elephants, and many other species. We believe that there is a need to lobby the Indonesian government and/or UNESCO to utilize the new proposed World Heritage Species for the orangutan, along with the GrASP efforts to designate new World Heritage Sites to safeguard ape species. We believe that it is important to ensure that any designated World Heritage Site in Sumatra is suitably located to benefit large numbers of orangutans, especially including the Singkil swamps (which are currently excluded under the present proposal). A better alternative may be a species-specific designation to declare the orangutan as a World Heritage Species, which would allow the proposal to contain as much prime orangutan habitat as possible.

At the conclusion of the workshop, the working group had developed general recommendations for conservation action for the 13 habitat units identified for Sumatra (Table 4.2). Conservation International Indonesia made a commitment to the Sumatran Orangutan Working Group to find funds to bring the group together again, plus additional key people who may not have participated originally, possibly in the next 6-8 months. The goal of this next workshop will be to build upon the work begun at the PHVA combined with the final modeling results and work toward the next level of developing an effective Sumatran orangutan action plan.

Working Group Members: *Noviar Andayani, Suci Utami Atmoko, Awen, Riswan Bangun, Renie Djojoasmoro, Susie Ellis, Ermayanti, Ivona Foitova, Iman, Abu Hanifah Lubis, Peter-Hinrich Pratje, Dolly Priatna, Christian Nahot Simanjuntak, Ian Singleton, Barita Manullang, Tatang Mitra Setia, Bambang Suyikno, Kathy Traylor-Holzer, Carel van Schaik, Serge Wich, Wira, Lucy Wisdom,*

Table 4.2. Recommended conservation actions for habitat units in Sumatra (boldface indicates actions modeled using *Vortex*).

CONSERVATION OPTIONS	W Leuser	E Leuser	Trumon-Singkil	NW Aceh	W Middle Aceh	Geumpang	E Middle Aceh	W Batang	Tripa	E Singkil	Sidiangkat	E Sarulla (Siporok)	Seulawah
Stop illegal logging	X	X	X	X	X	X	X	X	X	X	X	X	X
Stop roads	X	X	X	X	X	X	X	X	X	X	X	X	X
Continue funding for existing conservation projects	X	X	X		X	X	X		X				X
Improve patrols and law enforcement.	X	X	X	X	X	X	X	X	X	X	X	X	X
World Heritage status for Leuser Ecosystem	X	X	X		X	X	X		X		X		X
Education outreach programs	X	X	X	X	X	X	X	X	X	X	X		
Continue effort to connect Trumon-Singkil & West Leuser	X		X										
Ecotourism (post-war option)	X	X	X	X	X	X	X	X	X	X	X	X	X
Reconnect West and East Leuser	X	X											
Reactivate research station at Ketambe	X												
Maintain concession moratorium indefinitely for legal logging (status quo)	X	X	X		X	X	X		X		X		X
Helicopter patrols for rapid enforcement	X	X	X					X	X			X	
Encourage local NGO collaboration	X	X	X	X	X	X	X	X	X	X	X	X	X
Forest rehabilitation (with halt to illegal logging)	X	X	X	X	X			X	X			X	X
Incentives for people to move out of Leuser Ecosystem	X	X	X		X	X	X						
Work more closely with local government (e.g., land use planning)	X	X	X	X	X	X	X	X	X	X	X	X	X
Work with closely with Adat leaders (traditional community leaders)	X	X	X	X	X	X	X	X	X	X	X	X	X
Local government regulation (PERDA)	X	X	X	X	X	X	X	X	X	X	X	X	X

CONSERVATION OPTIONS	W Leuser	E Leuser	Trumon-Singkil	NW Aceh	W Middle Aceh	Geumpang	E Middle Aceh	W Batang	Tripa	E Singkil	Sidiangkat	E Sarulla (Siporok)	Seulawah
Income generating activities for local people (e.g., agro-forestry such as coffee, nutmeg)	X	X	X	X	X	X	X	X	X	X	X	X	X
Identify and set up new research sites	X	X	X	X	X	X	X	X	X	X	X	X	X
Innovative tourism (helicopter patrols, elephants)	X	X	X	X	X	X	X	X	X	X	X	X	X
Monitoring forest loss (e.g., satellite imagery higher resolution and more frequent).	X	X	X	X	X	X	X	X	X	X	X	X	X
International and national media campaign.	X	X	X	X	X	X	X	X	X	X	X	X	X
Capacity building	X	X	X	X	X	X	X	X	X	X	X	X	X

MODELING OF ORANGUTAN POPULATIONS ON SUMATRA

VORTEX Simulation Model

Computer modeling is a valuable and versatile tool for assessing risk of decline and extinction of wildlife populations. 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. Such an evaluation of population persistence under current and varying conditions is commonly referred to as a population viability analysis (PVA).

To examine the viability of orangutan populations on Sumatra, we used the simulation software program *Vortex* (v9.42). *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 stepping through life cycle events (e.g., births, deaths, dispersal, catastrophic events), typically on an annual basis. Events such as breeding success, litter size, 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 Appendix V as well as Lacy (2000) and Miller and Lacy (2003).

Development of the Baseline Model

The Sumatran Orangutan Working Group began development of an orangutan baseline model for Sumatra by first reviewing the more general orangutan baseline model developed by the small modeling working group in Singapore in August 2003 in preparation for this PHVA workshop. Each model parameter was discussed and values were revised as necessary to reflect Sumatran orangutan populations when such data were available. Density-dependent reproduction was retained in the model. Data for age- and sex-specific mortality rates, reproductive lifespan, and inter-birth interval were taken from 30+ years of data from a study site at Ketambe provided by Serge Wich (Wich et al. submitted). Several life history traits, as well as the type and effect of catastrophes, were believed to differ between the Sumatra and Borneo orangutan populations (see *Sumatran Orangutan Working Group Report*).

The initial model developed by the working group described a declining population, with a deterministic growth rate of $r = -0.005$ as a maximum growth rate under good environmental conditions and in the absence of human-induced mortality. To produce a more biologically realistic model, parameter values were then revisited and revised to allow for positive growth during conditions of low density and good availability of resources. The final values used for the baseline model are presented below. The *Vortex* project files with these input values are available at www.vortex9.org/projects/sum_orangutan.zip.

VORTEX Baseline Model Parameters

The final values used in the baseline model are described below. Initial population size, carrying capacity, types of catastrophes, and logging rate were modified as appropriate for individual orangutan population (habitat unit) models.

Number of iterations: *500*
500 independent iterations (runs) for each scenario.

Number of years: *1000*
Due to the long-lived and slowly reproducing nature of this species, it was decided to model populations for 1000 years so that long-term population trends could be observed. 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; thus both short-term and long-term results are presented.

Extinction definition: *Only one sex remaining*

Inbreeding depression: *Yes*
Inbreeding is thought to have major effects on reproduction and survival, 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 modeled as 4.06 lethal equivalents, estimated from analysis of studbook data for captive orangutans maintained in zoos (from J. Ballou, National Zoological Park, U.S.). In simulations of populations with 1000 or fewer animals, 50% of the effect of inbreeding was modeled as being due to recessive lethal alleles. In populations with more than 1000 animals, the inbreeding effect was specified to be due entirely to recessive lethal alleles (100%). This optimistic assumption was made for the larger populations to allow the *Vortex* simulations to run much more quickly, as this parameter has little effect in large populations (see *Modeling Populations of Orangutans on Borneo Report* for more information).

Concordance between environmental variation in reproduction and survival: *No*
The working group believed that there is little correlation between environmental conditions that affect survival and reproduction and chose to omit it from the model. Large, long-lived species tend to show little correlation between breeding and survival.

Mating system: *Short-term polygyny*
Orangutans have a promiscuous breeding system. Both males and females potentially may have multiple mates, although animals may breed with the same mate(s) for several years. We modeled the populations as having a short-term polygynous mating system, in which animals can select new mates every year.

Age of first reproduction: *15 years (females); 25 years (males)*
Vortex defines reproduction onset as the time at which offspring are born, not simply the age of sexual maturity. The model uses the mean age of first reproduction rather than the earliest recorded age of offspring production. Based on information from Ketambe, the age of first reproduction is typically 15 years for females and 25 years for males.

Maximum age of reproduction: *50 years*
Vortex assumes that animals can reproduce throughout their adult life. One female at Ketambe is known to have produced offspring at about 50 years of age; this was accepted as a plausible maximum age of successful reproduction.

Maximum litter size: *1*
Only a single offspring is raised. In rare instances of the birth of twins, at least one always dies.

Sex ratio at birth: *55% male*
Data from a number of field sites suggest a small male bias in births (in Sumatra, 57% at Ketambe, 56% at Suaq). The working group chose to model 55% of births to be male.

Density-dependent reproduction: *Yes*
Density dependence is defined by specifying parameters of a particular functional shape for the relationship between population density and breeding success. The curve that is often used to represent the functional relationship is: % breeding = $[(P_0-(P_o-P_k)*(N/K)^B)]* (N/(N+A))$. We used the following parameter values for the Sumatran orangutan population (see the *Modeling Populations of Orangutans on Borneo Report* for a more detailed explanation of these parameters):

P_0	Specifies the % of adult females breeding in an average year when population density is very low relative to the food supply and carrying capacity of the habitat. Data from Ketambe suggest an inter-birth interval as short as 6 years; this was adjusted to 5.5 years by correcting for females that re-breed earlier after loss of their infants, or 18.18% of females breeding each year. Given the shape of the curve (which includes an Allee effect depressing breeding at very low density), P_0 was set to the required value needed to obtain a curve that peaks at 18.18.
$P_k=11.1$	Specifies the breeding rate (% females breeding each year) when the population is at its carrying capacity. The maximum inter-birth interval was estimated at 10 years based on Ketambe data. After correcting for females that lose their infants, 9 years was used as the estimated inter-birth interval for populations at high density, or 11.1% of females breeding each year.
$A=1$	Defines the Allee effect (difficulty in finding mates at low densities).
$B=2.0$	Defines the steepness with which breeding decreases as population approaches K.

Environmental variation in breeding rate: *5.5%*
This approximates 50% of the mean percent of females breeding at high densities and 25% of the value used at low densities. 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.

Monopolization of breeding: *50%*
Some males are more likely than others to be successful breeders. The percent of males that were considered to be potential breeders (i.e., available for breeding in a given year) was roughly estimated at 50%. This parameter primarily affects genetics rather than demography and affects

small populations. Sensitivity testing using higher values (75% and 100%) in small populations (N=50) showed no effect on population status, so the value of 50% was retained in the model.

Mortality: *See below*
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 and are given below. Juvenile males are thought to experience higher mortality than females. Mortality rates rise as offspring become independent of their mothers, while adult mortality is believed to be low. Environmental variation around mortality rates was set at 50% of the mean mortality rates.

	Mean annual mortality		Environmental variation	
Age class	Females	Males	Females	Males
0 – 1	5%	5%	2.5%	2.5%
1 – 2	6%	5%	3%	2.5%
2 – 8	0.5%	3%	0.25%	1.5%
8 – 11	6%	6%	3%	3%
11-15	0.5%	0.5%	0.25%	0.25%
15+	1.75%	1.25%	0.875%	0.625%

Catastrophes: *Yes (3)*
Three types of catastrophes were thought to affect some or all orangutan populations on Sumatra. The risk of a disease epidemic was included for all populations; taken from the preliminary model, disease was modeled to occur in 2% of years (about once every 50 years), killing about 20% of the local population but having no effect on reproduction. The effects of fire and landslides were each modeled for some but not all Sumatran populations based upon elevation, habitat and other factors. Both were modeled as a temporary reduction in carrying capacity (and therefore population size). Fire events occur in 0.2% of years (once every 500 years) and reduce the carrying capacity by 10%. Landslides occur in 2.5% of years (once every 40 years) and reduce carrying capacity by 0.75%. Food shortage and general effects of El Niño-related events were not modeled as catastrophic events for Sumatran orangutans.

Initial Population Size (N): *Population specific*
The estimated population size used for each model was developed with respect to a particular population within a specific habitat unit. *Vortex* distributes the specified initial population among age-sex classes according to a stable age distribution that is characteristic of the mortality and reproductive schedule described for the model.

Carrying capacity (K): *See below*
The model assumes that each population is currently at the carrying capacity of its habitat. The same value as the initial population size was used as K in the density-dependent breeding function (see above). Thus, when populations are below K they grow toward the carrying capacity, and when they exceed K, breeding decreases so that the population declines back toward K. In the absence of factors such as inbreeding depression or catastrophes, populations will reach an equilibrium size close to K.

Vortex normally imposes the value entered as carrying capacity by truncating the population (killing animals) if the population size exceeds K. To avoid such a mortality-imposed carrying capacity, the level at which this truncation would occur was set arbitrarily high (at twice the desired K) in the model. The baseline model assumes carrying capacity to be constant, i.e., no change in habitat area or quality. The effects of habitat loss, primarily through logging, were modeled during sensitivity testing and in models for particular orangutan populations and habitat units.

Harvest: *None*
Although the hunting or removal of orangutans occurs in many areas of Sumatra, it is typically in conjunction with logging. Thus harvest was not modeled separately but was taken into account with the reduction of K and N due to habitat loss.

Supplementation: *None*
The addition of individuals to the population from captive or other sources was not modeled.

Parameters Varied During Sensitivity Testing

Many of the demographic parameter values were explored during development of the pre-PHVA baseline model. Field data were used by the working group to refine this model for Sumatra. Further extensive testing of the demographic parameters was not conducted.

Initial population size: 50, 100, 250, 500, 1000, 1500, 2500
Sumatran orangutan populations are estimated to be no larger than about 2500 individuals, and most are smaller than 1000. To explore the stability of populations of various size, models were constructed with initial population size and carrying capacity set at 50, 100, 250, 500, 1000, 1500 and 2500.

Logging rates: 0, 1, 2, 3, 5, 10, 15, 20 (%)
All orangutan habitat units in Sumatra are thought to be currently undergoing logging. Logging (and the often associated removal of orangutans – see above) was modeled as a permanent annual percent reduction in the current carrying capacity. Current annual logging rates are estimated to be 2-20% for the 13 identified populations and habitat units. Sensitivity testing explored annual logging rates of 0%, 1%, 2%, 3%, 5%, 10%, 15% and 20%. Continual logging will eventually drive any orangutan population to extinction as carrying capacity continually decreases, but the time to extinction will vary due to population size and logging rate.

Results of the Baseline Model for Sumatra

The baseline model describes a population that shows positive deterministic growth ($r = 0.015$) in low-density conditions (in which 18.18% of adult females breed). This is the average population growth expected based on mean fecundity and mortality rates in the absence of inbreeding, human-related mortality (e.g., logging, hunting), 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%, resulting in a slightly negative growth rate (r = - 0.002). Thus under the influence of density-dependent reproduction, the model describes a population in sub-optimal habitat that is slightly oversaturated beyond the habitat's long-term carrying capacity. Populations in this model decline to an equilibrium size of about 93-95% of the initial population size in the absence of inbreeding effects and catastrophes.

Effect of Population Size

As populations become smaller, they become more susceptible to the negative effects of inbreeding and stochastic processes. The baseline model was used to assess the relative viability of Sumatran orangutan populations of varying size independent of human threats. Estimated current population sizes range from 43 to 2508 individuals; for this analysis, scenarios were run for population sizes of 50, 100, 250, 500, 1000, 1500 and 2500 individuals.

Table 4.3 gives the probability of extinction, mean population size, and proportion of gene diversity (heterozygosity) obtained from 500 iterations for populations of each tested initial size (and K) after 50, 100 and 1000 years. Density-dependent reproduction and mortality rates in combination with the effects of inbreeding, disease and stochastic events led all populations to decline substantially below carrying capacity (to about 83% of K) in a relatively short period of time (Fig. 4.1). Smaller populations remained more vulnerable to these effects over the long-term.

Although short-term projections (i.e., for 50-100 years) under baseline conditions show almost no probability of extinction, this time period encompasses only 2-3 generations for this long-lived species, making it difficult to observe population trends. Projections for 1000 years allow us to better evaluate these trends and those factors that influence them. Populations of 50 and 100 had a high probability of extinction over 1000 years (Fig. 4.2); those that survived were greatly reduced in size and genetic diversity. Although populations of 250 had a very small probability of extinction, they declined on average to almost one-half of their original size and lost substantial genetic diversity. Populations of 500 or larger were demographically stable and retained over 90% of gene diversity, a common genetic goal for managed populations. This pattern is similar to that observed in the Bornean orangutan model for populations in poor quality habitat (see *Modeling Populations of Orangutans on Borneo Report*).

Table 4.3. Effects of initial population size (N_{init}) on population viability (PE = % probability of extinction; N = mean population size; GD = % of initial gene diversity).

	50 years			100 years			1000 years		
N_{init}	PE	N	GD	PE	N	GD	PE	N	GD
50	0	41	96	1	36	92	99	7	40
100	0	83	98	0	78	96	64	28	59
250	0	210	99	0	203	99	2	142	85
500	0	417	100	0	404	99	0	342	93
1000	0	839	100	0	808	100	0	732	97
1500	0	1269	100	0	1206	100	0	1149	98
2500	0	2085	100	0	2020	100	0	1947	99

Overall, simulation results suggest that orangutan populations of about 250 have a very high probability of survival in the absence of human-related mortality, habitat loss or unforeseen catastrophic events, but will be significantly reduced in size and genetic variation. Populations of 500 are more demographically and genetically stable and may contribute to the long-term conservation of this species. Smaller populations that are linked by occasional exchanges of animals could also contribute to the overall stability of a larger meta-population.

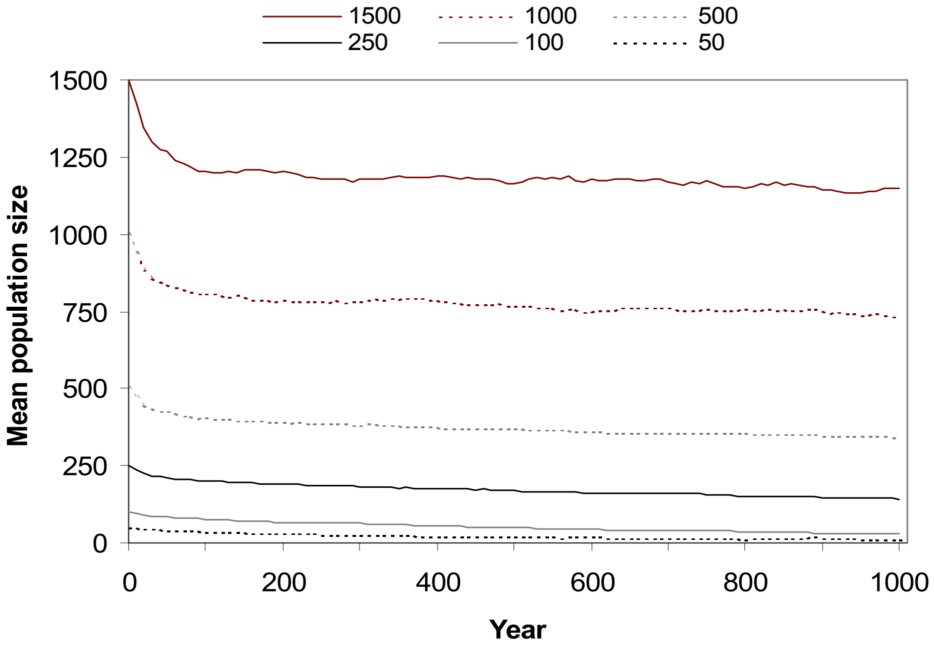


Figure 4.1. Mean population size of surviving orangutan populations with initial N (and K) of 50, 100, 250, 500, 1000, 1500 and 2500. Baseline model assumes no change in carrying capacity.

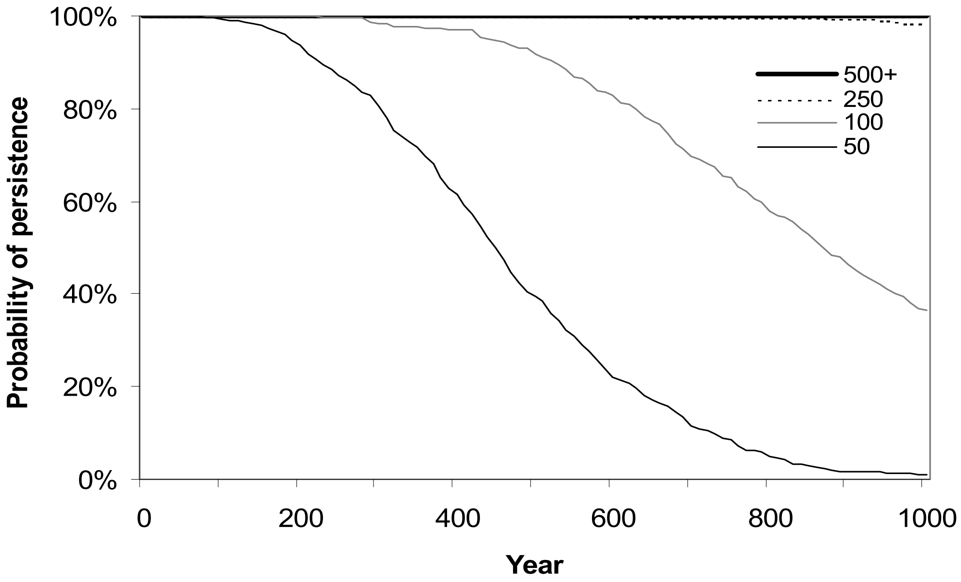


Figure 4.2. Probability of persistence of surviving orangutan populations with initial N (and K) of 50, 100, 250, 500, 1000, 1500 and 2500. Baseline model assumes no change in carrying capacity.

Effects of Logging

Logging and habitat conversion continue to threaten Indonesia's forests, fueled in recent years by political and economic events in this country. Estimates of the rate of deforestation for Sumatra suggest a trend similar to that observed in Kalimantan, where quantitative analyses demonstrate that at least 39% of orangutan habitat has been lost in the past decade (1992-2002) (see *Status of the Orangutan in Indonesia, 2003 Report*). Much of the loss of orangutan habitat in Sumatra has occurred along forest edges and in lowland areas, resulting in population fragmentation and loss of lowland corridors.

The working group believed logging to be widespread throughout much of Sumatra, including all identified orangutan habitat units. Some areas were estimated to be losing orangutan habitat at a rate as high as 20% per year. Unabated deforestation will eventually drive any orangutan population to extinction as populations and habitat resources decline. However, the persistence and viability of populations under such conditions will vary depending upon both the population size and rate of loss. The interaction of these parameters was modeled for orangutan populations from 50 to 1000 individuals to investigate this relationship. Logging was modeled as a permanent and annual reduction in carrying capacity (and resulting truncation of the population). Although annual rate of loss remains constant, the actual amount of habitat lost lessens each year. This simulates logging effects, as the area of habitat lost declines each year as prime lowland forests disappear and logging operations move up forested slopes that are more difficult to log.

Model results are given in Table 4.4. High annual rates of habitat loss (15% and higher) result in certain extinction in all orangutan populations within 50 years. At this rate only about 1-4% of habitat would remain after 20 years. Moderate rates of logging (5-10% annually) drive most populations to extinction with 100 years; although initially large populations (N=1000) persist, they consist of very few individuals at 100 years and are not viable. Low rates of logging can be sustained for 100 years, although all populations eventually go extinct within several hundred years. An annual loss of 1% results in a 63% reduction in carrying capacity over 100 years, while a 3% loss removes over 95% of the habitat in 100 years (Fig. 4.3). Cessation of logging and/or restoration of habitat to counteract habitat loss and maintain carrying capacity will be necessary to maintain viable orangutan populations long-term.

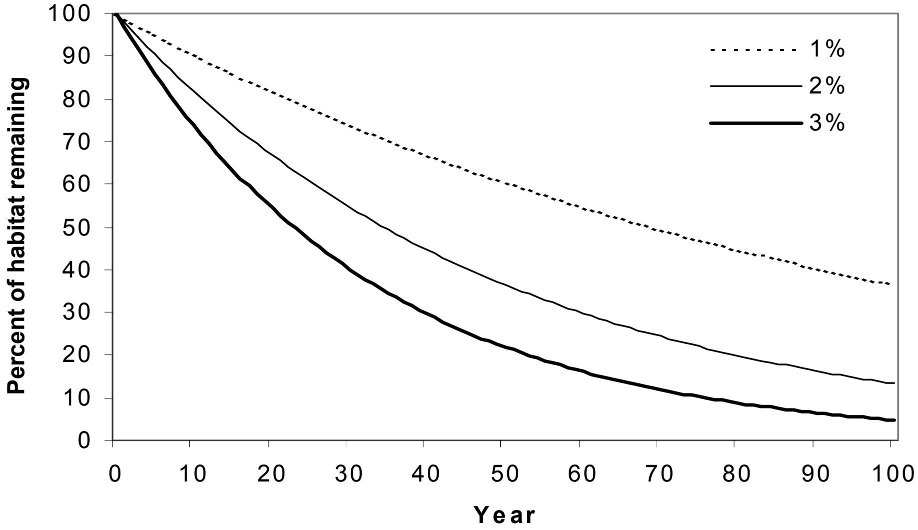


Figure 4.3. Percent of remaining habitat over 100 years with annual logging rates of 1%, 2% and 3%.

Table 4.4. ***Vortex*** **model results for the effect of various logging rates on orangutan population viability (PE = % probability of extinction; N = mean population size; GD = % of initial gene diversity). Shaded cells indicate scenarios in which 100% of simulated populations went extinct.**

Annual Logging Rate	50 Years			100 Years			1000 Years			Yr at PE 5%	Yr at PE 100%
	PE	N	GD	PE	N	GD	PE	N	GD		
N_{init} = 50											
None	0	41	96	1	36	92	99	7	40	188	>1000
1%	0	30	95	1	16	89	100	-	-	121	332
2%	0	20	94	14	7	81	100	-	-	88	186
3%	0	13	93	67	3	72	100	-	-	61	138
5%	27	5	85	100	-	-	100	-	-	45	82
10%	100	-	-	100	-	-	100	-	-	28	44
15%	100	-	-	100	-	-	100	-	-	18	30
20%	100	-	-	100	-	-	100	-	-	13	23
N_{init} = 100											
None	0	83	98	0	78	96	64	28	59	448	>1000
1%	0	62	98	0	35	95	100	-	-	179	371
2%	0	42	97	1	14	91	100	-	-	119	218
3%	0	27	96	18	6	82	100	-	-	85	157
5%	4	9	92	100	-	-	100	-	-	51	97
10%	100	-	-	100	-	-	100	-	-	33	48
15%	100	-	-	100	-	-	100	-	-	22	36
20%	100	-	-	100	-	-	100	-	-	16	26
N_{INIT} = 250											
None	0	210	99	0	203	99	2	142	85	>1000	>1000
1%	0	159	99	0	93	98	100	-	-	273	462
2%	0	109	99	0	38	96	100	-	-	161	259
3%	0	70	99	0	14	93	100	-	-	116	186
5%	0	23	97	77	3	72	100	-	-	57	114
10%	88	2	75	100	-	-	100	-	-	42	56
15%	100	-	-	100	-	-	100	-	-	27	39
20%	100	-	-	100	-	-	100	-	-	21	29
N_{INIT} = 500											
None	0	427	100	0	404	99	0	342	93	>1000	>1000
1%	0	318	100	0	189	99	100	-	-	340	501
2%	0	220	99	0	77	98	100	-	-	200	307
3%	0	141	99	0	31	97	100	-	-	137	210
5%	0	47	99	33	4	82	100	-	-	64	129
10%	55	3	82	100	-	-	100	-	-	46	62
15%	100	-	-	100	-	-	100	-	-	32	44
20%	100	-	-	100	-	-	100	-	-	24	33
N_{INIT} = 1000											
None	0	839	100	0	808	100	0	732	97	>1000	>1000
1%	0	648	100	0	380	99	100	-	-	407	594
2%	0	448	100	0	158	99	100	-	-	234	338
3%	0	284	100	0	63	98	100	-	-	163	230
5%	0	96	99	4	9	90	100	-	-	101	140
10%	19	6	89	100	-	-	100	-	-	49	69
15%	100	-	-	100	-	-	100	-	-	35	47
20%	100	-	-	100	-	-	100	-	-	27	36

ORANGUTAN POPULATION (HABITAT UNIT) ANALYSES

The Sumatran Orangutan Working Group reviewed the data available on orangutan distribution and habitat in Sumatra for the 11 habitat units designated prior to the PHVA workshop (see *Status of the Orangutan in Indonesia, 2003 Report*). Working group members decided that the NW Aceh Habitat Unit (HU) represented two separate orangutan populations, and split them into the NW Aceh HU (Blocks 1 & 2) and the NE Aceh HU (Block 7). Similarly, Middle Aceh HU was split into West Middle Aceh HU (Blocks 3 & 9) and East Middle Aceh HU (Block 8). This assessment resulted in the identification of 13 separate orangutan populations and habitat units in Sumatra. These populations differ in estimated population size, susceptibility to fire and landslides, current rate of logging, and threat of fragmentation (e.g. due to existing or proposed roads), and were modeled separately using the parameters given in Table 4.5. All populations were assumed to be at carrying capacity. Several very small and isolated groups of orangutans are believed to exist in addition to these 13 identified Habitat Unit populations but are not likely to be viable and were not included in these analyses.

The results for each HU model are given in the following sections (in approximate order of north to south Sumatra), and include the probability of extinction, mean population size and mean percent of genetic diversity retained (heterozygosity) at 50, 100 and 1000 years. Also reported is the year at which the probability of population extinction reaches 5% as an additional measure of risk of population extinction. Population projections and probability of extinction are given for current conditions as well as under alternative management actions. Logging is modeled as a direct proportional decrease in carrying capacity, with no adjustment for the possible loss of higher quality habitat or potential fragmentation effects. Scenarios involving the presence of roads consider only the demographic and genetic effects of fragmentation and do not include possible additional logging or orangutan removal due to increased access provided by roads. Therefore, model results may represent conservative estimates of the effects of logging and roads on orangutan populations. Specific HU model results are followed by a general discussion of orangutan populations in Sumatra based upon a compilation of results for the individual HUs.

Table 4.5. Parameter values used in individual habitat unit models for Sumatran orangutans.

Habitat Unit	Block(s)	$N_{init} = K$	Fire	Landslide	Logging	Road
Seulawah	6	43			3%	
NW Aceh	1,2	654		X	10%	X
NE Aceh	7	180			10%	
East Middle Aceh	8	337		X	15%	X
West Middle Aceh	3,9	103		X	10%	X
Tripa	17	280	X		15%	
East Leuser	13,14,15,16	1052		X	15%	X
West Leuser	4,5,5A, 10, 11	2508	X	X	10%	X
Trumon-Singkil	18	1500	X		10%	
Sidiangkat/Ardan	12	134			5%	
East Singkil	19	160			20%	
East Sarulla	21	150			20%	
West Batang Toru	20	400			2%	

Seulawah Habitat Unit

Current Status

Seulawah Habitat Unit is a small area of orangutan habitat in northern Aceh province of Sumatra (Block 6) that falls partially under Taman Hutan Raya Tjut Nya Dhien Conservation Area (see Sumatran Habitat Unit Map). The current orangutan population is estimated at 43 individuals and believed to be at ecological carrying capacity for the area, with no major fragmentation of the population. This is the smallest of the 13 Sumatran orangutan populations analyzed and is isolated from other populations by existing roads. The estimated level of logging in this area is 3% per year of the available orangutan habitat. Potential conservation strategies to improve population viability include prevention of additional logging, reduction or cessation of logging, and reforestation of logged areas to increase habitat. The removal of orangutans (e.g., hunting) is associated with logging and therefore was not modeled directly but in association with logging effects (see Baseline Model discussion).

The baseline model for the Seulawah orangutan population suggests that the population will undergo rapid and steady decline due to habitat and population loss from logging. At an annual loss of 3%, the carrying capacity of the population will decrease by 50% in only 23 years; in 100 years, less than 5% of the habitat will remain. The probability of population extinction in the next 100 years is 68% and is 100% by year 135. Inbreeding depression is likely to be a contributing factor to the viability of this small population.

Table 4.6. ***Vortex*** **model results for the Seulawah orangutan population (PE = % probability of extinction; N = mean population size; GD = % of initial gene diversity).**

	50 Years			100 Years			1000 Years			Year at PE 5%
Logging Management	PE	N	GD	PE	N	GD	PE	N	GD	
Current (annual 3%)	**0**	**13**	**93**	**68**	**3**	**70**	**100**	**-**	**-**	**61**
REDUCE LOGGING										
Reduce to annual 2%	0	21	94	16	7	81	100	-	-	84
Reduce to annual 1%	0	30	95	2	16	88	100	-	-	118
STOP LOGGING										
Stop in 20 yrs	0	23	94	3	18	87	100	-	-	114
Stop in 15 yrs	0	26	94	2	22	88	100	-	-	124
Stop in 10 yrs	0	31	95	1	26	90	100	-	-	154
Stop in 5 yrs	0	34	95	1	30	91	100	-	-	170
Stop immediately	0	40	96	0	37	92	100	-	-	203
REFORESTATION										
Stop in 10yrs, reforest (1%)	0	35	95	1	33	91	100	-	-	167
Stop in 10yrs, reforest (2%)	0	39	95	1	39	92	99	15	46	199
Stop in 10yrs, reforest (3%)	0	43	95	0	46	92	95	15	43	244

Effects of Conservation Action

Table 4.6 presents the model results for reduction or cessation of logging and habitat restoration. Continued logging will ultimately result in population extinction due to continual population reduction and loss of habitat. Slowing the rate of habitat loss (from the current estimated rate of 3% per year) will delay population extinction slightly, but even with an annual logging rate of 1%, the probability of extinction is 100% in about 300 years (Fig. 4.4). Extinction of this small population is inevitable in the face of unsustainable logging with no restoration of habitat.

Complete cessation of logging is slightly more effective in promoting population persistence over the next few hundred years, even if this cannot be accomplished immediately (Fig. 4.5). However, even an immediate and complete logging moratorium will be insufficient to ensure the survival of this small population. Inbreeding depression and stochastic events will ultimately drive the population to extinction within 1000 years without demographic or genetic supplementation or population/habitat expansion.

The current habitat available in Seulawah is insufficient to allow this population to grow large enough to ensure long-term viability. A reforestation scenario was suggested in which restoration efforts would begin immediately, taking 10 years for trees to mature enough to begin producing food resources for orangutans. Under this scenario food resources (i.e., carrying capacity) would increase by 1% annually for 20 years, then remain constant. As part of this management scenario, logging would be stopped in 10 years, resulting in a loss of habitat over 10 years (down to 74% of the original carrying capacity) and then increasing over 20 years to stabilize at 90% of the original K. Although this proposed scenario improves population viability over the next few hundred years, it is insufficient for long-term viability. If reforestation of 3% annually could be accomplished during years 11-30, the resulting carrying capacity would increase to 133% of the original habitat, allowing population expansion to 57 orangutans and improving long-term viability (Fig. 4.6). Ultimately, however, this population is likely to be too small to be viable over 1000 years without interventive management strategies to counteract demographic instability or genetic deterioration.

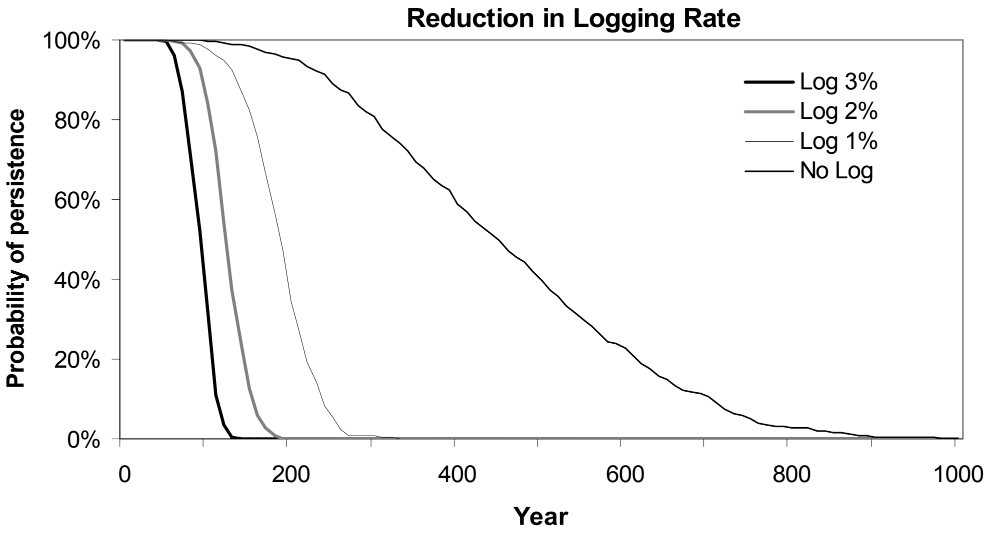


Figure 4.4. Probability of survival for the Seulawah orangutan population with annual logging rates of 3%, 2%, 1% and 0%.

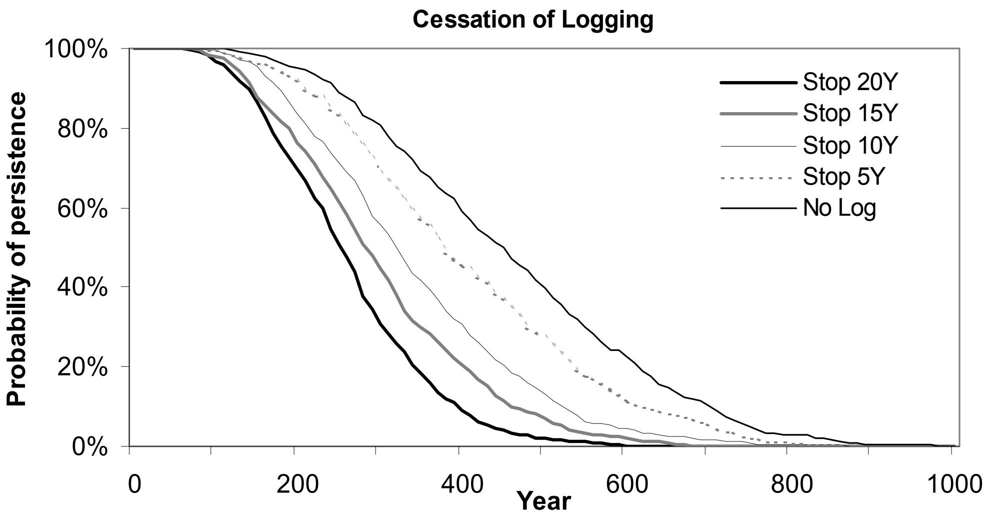


Figure 4.5. Probability of survival for the Seulawah orangutan population with cessation of logging at 20, 15, 10 and 5 years and immediately.

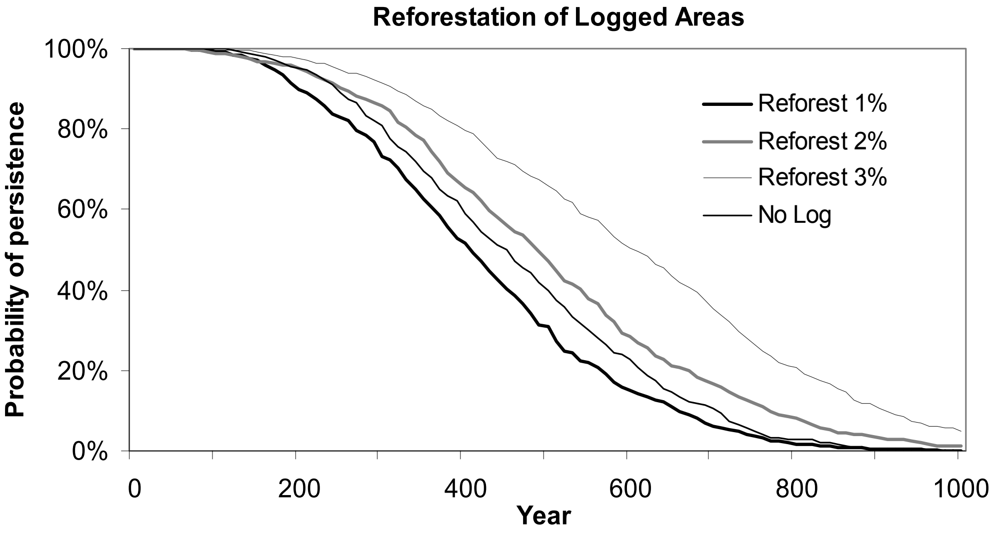


Figure 4.6. Probability of survival for the Seulawah orangutan population with cessation of logging at 10 years and habitat restoration in years 11 – 30, at annual reforestation rates of 1%, 2% and 3% during this 20-year period.

NW Aceh Habitat Unit

Current Status

NW Aceh Habitat Unit encompasses a relatively large, elongated area of orangutan habitat in northern Aceh province (Blocks 1 & 2) bordered on the northeast by existing and proposed stretches of the Ladia Galaska road scheme (see Sumatran Habitat Unit Map). A small portion of this HU falls within Bio-Genetic Reserve and Cagar Alam Pinus Jantho Conservation Areas. The orangutan population was estimated at 654 individuals (340 in the north and 314 in the south) in 1998 (the year of some of the satellite images used for the extreme North of Aceh; see Status of the Orangutan in Indonesia, 2003 Report and the Sumatran Habitat Unit Map). It is uncertain to what extent logging has since occurred in this war-torn region. It was decided to model the population as starting with 654 individuals, but it is recognized that the actual orangutan population may be smaller.

Northern and southern areas of this HU are divided by a road that may limit movement of animals between areas. There is evidence of additional fragmentation of habitat within these two subpopulations (see Sumatran Orangutan Distribution Map). The estimated level of logging in this area is 10% per year of the available orangutan habitat. Potential conservation strategies to improve population viability include prevention of additional logging, reduction or cessation of logging, and reforestation of logged areas to increase habitat. The removal of orangutans (e.g., hunting) is associated with logging and was not modeled directly but in association with logging effects (see Baseline Model discussion).

The baseline model for the NW Aceh orangutan population suggests that the population will undergo rapid and steady decline due to habitat and population loss from logging. At an annual loss of 10%, the carrying capacity of the population will decrease by 50% in the next 6-7 years and essentially all habitat will disappear within about 50 years. If logging has been continuing at this rate since 1998, then the current population may be significantly smaller than estimated.

Table 4.7. *Vortex* model results for the NW Aceh orangutan population (PE = % probability of extinction; N = mean population size; GD = % of initial gene diversity).

Logging Management	50 Years			100 Years			1000 Years			Year at PE 5%
	PE	N	GD	PE	N	GD	PE	N	GD	
Current (annual 10%)	**28**	**5**	**86**	**100**	**--**	**--**	**100**	**--**	**--**	**47**
REDUCE LOGGING										
Reduce to annual 5%	0	64	99	23	5	85	100	--	--	88
Reduce to annual 1%	0	412	100	0	244	99	100	--	--	362
STOP LOGGING										
Stop in 20 yrs	0	49	98	0	52	95	94	16	42	239
Stop in 15 yrs	0	88	99	0	97	97	48	41	66	552
Stop in 10 yrs	0	162	99	0	176	98	3	113	82	>1000
Stop in 5 yrs	0	306	100	0	307	99	0	244	90	>1000
Stop immediately	0	550	100	0	519	99	0	460	95	>1000
REFORESTATION										
Stop in 10 yrs, reforest (1%)	0	197	99	0	212	99	1	156	86	>1000

Effects of Conservation Action

Table 4.7 presents the model results for reduction or cessation of logging and habitat restoration. Continued logging at an annual rate of 10% will quickly result in population extinction due to continual population reduction and loss of habitat. Slowing the rate of habitat loss from 10% to 1% results in a viable population for 100 years, but the probability of eventual extinction is 100% in the face of unsustainable logging with no restoration of habitat (Fig. 4.7).

Complete cessation of logging is more effective in promoting long-term population persistence (Fig. 4.8). Stopping logging in 10 years will likely allow a small and genetically impoverished population to persist. Logging must be stopped within 5 years to maintain a relatively large and genetically healthy population long-term; if logging can be stopped immediately, the resulting population of orangutans will be almost double what it will be if it takes 5 years to accomplish this. Reforestation (in which logging is stopped in 10 years, and habitat is increased at 1% annually during years 11-30) is less effective unless logging can be stopped or reduced earlier. Immediate action is needed to control habitat loss if it is indeed occurring at such a fast rate.

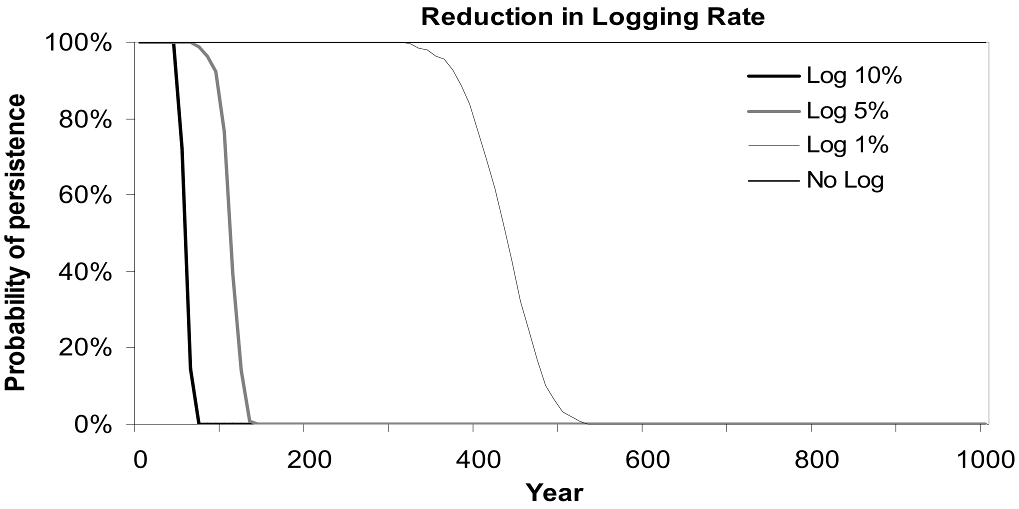


Figure 4.7. Probability of survival for the NW Aceh orangutan population with annual logging rates of 10%, 5%, 1% and 0%.

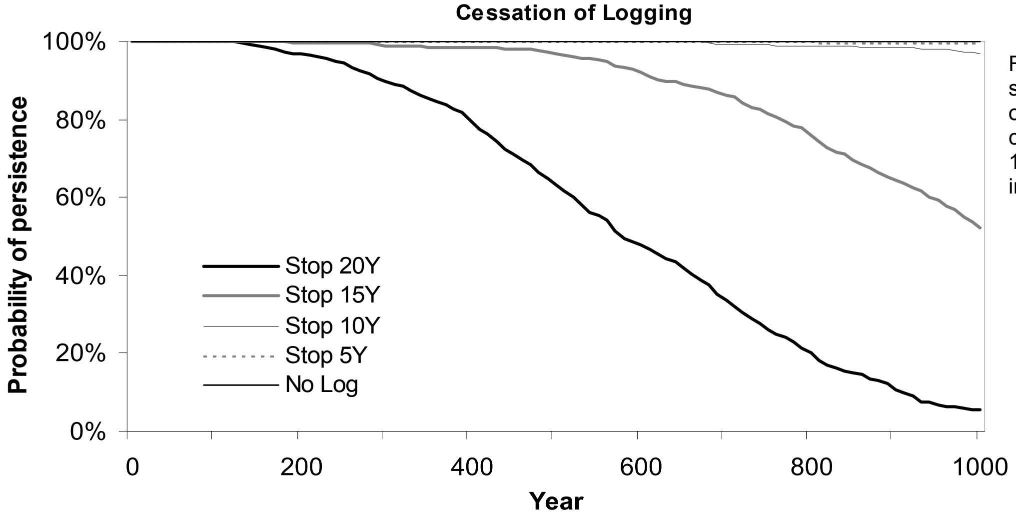


Figure 4.8. Probability of survival for the NW Aceh orangutan population with cessation of logging at 20, 15, 10 and 5 years and immediately.

Effects of Existing Road

The NW Aceh HU is bisected by an existing road, dividing the HU into two large areas (see Sumatran Habitat Unit and Sumatran Orangutan Distribution Maps). A portion of the Ladia Galaska road scheme also isolates a small area of habitat in the northeast portion of Block 1. The extent to which orangutans migrate across these roads is unknown. Therefore, a model was developed that assumed restricted movement between the north and south orangutan populations due to the presence of the existing road (50% of subadult males disperse each year). Model results for each sub-population and the combined meta-population, as well as those for one single panmictic population, are given in Table 4.8.

As expected, the two smaller populations are subject to higher probabilities of extinction with partial isolation; however, the resulting probability of extinction and mean population size of the combined meta-population of both populations does not differ from that of the large panmictic population (Fig. 4.9). The substantial rate of migration between sub-populations used in the model provides sufficient demographic and genetic supplementation to simulate a single population. If the presence of the existing road restricts orangutan movement to a greater extent or isolates the two sub-populations completely, then there may be a greater effect upon the NW Aceh orangutan population. If the increased access provided by roads results in increased logging within this HU, then the orangutan population would be expected to decline more rapidly toward extinction.

Table 4.8. *Vortex* model results for the NW Aceh orangutan population as two populations with restricted migration (due to presence of road) and as one population (PE = % probability of extinction; N = mean population size; GD = % of initial gene diversity).

	50 Years			100 Years			1000 Years			Year at PE 5%
Population	PE	N	GD	PE	N	GD	PE	N	GD	
Restricted Dispersal (Road)										
North population (N=340)	59	3	79	100	--	--	100	--	--	42
South population (N=314)	73	3	78	100	--	--	100	--	--	42
Metapopulation (N=654)	29	3	85	100	--	--	100	--	--	48
No Restriction (N=654)	28	5	86	100	--	--	100	--	--	47

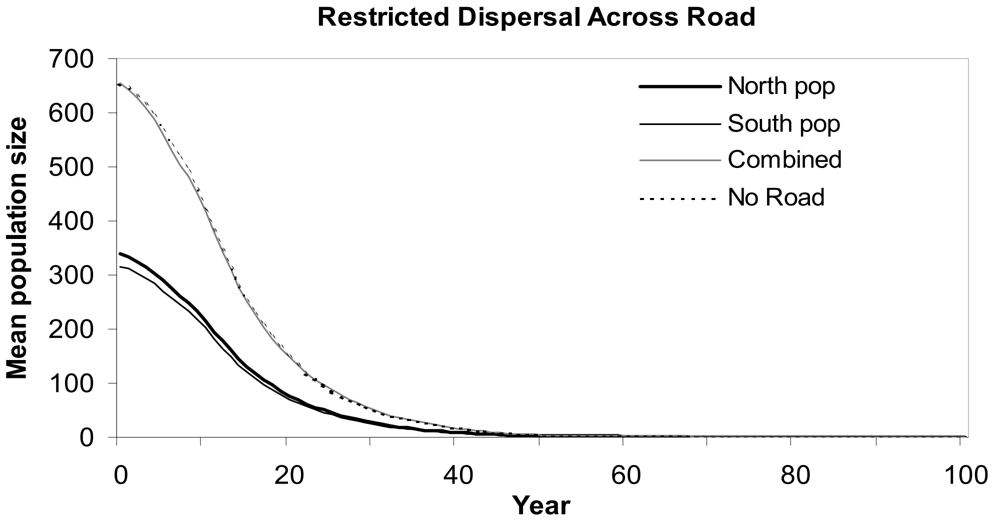


Figure 4.9. Mean population size of surviving orangutan populations in NW Aceh. Results given for north and south populations with restricted migration across road, combined meta-population with road, and one panmictic population with no road effects.

NE Aceh Habitat Unit

Current Status

NE Aceh (Geumpang) Habitat Unit encompasses an area of orangutan habitat in northern Aceh province (Block 7) and is separated from the NW Aceh HU by existing and proposed stretches of the Ladia Galaska road scheme (see Sumatran Habitat Unit Map). Orangutans are believed to occupy only a portion of this area and are spatially disjunct from other orangutan populations (see Sumatran Orangutan Distribution Map). This fragmented orangutan population was estimated at 180 individuals in 1998. It is uncertain to what extent logging has since occurred in this war-torn region. It was decided to model the population as starting with 180 individuals, but it is recognized that the actual orangutan population may be smaller.

The rate of logging in NE Aceh is estimated to be relatively high at about 10% per year. Potential conservation strategies to improve population viability include prevention of additional logging, reduction or cessation of logging, and reforestation of logged areas to increase habitat. The removal of orangutans (e.g., hunting) is associated with logging and therefore was not modeled directly but in association with logging effects (see Baseline Model discussion).

As with the NW Aceh model, the baseline model for the NE Aceh orangutan population suggests that the population will undergo rapid and steady decline due to habitat and population loss from logging. At an annual loss of 10%, the carrying capacity of the population will decrease by 50% in the next 6-7 years and essentially all habitat will disappear within about 50 years. If logging has been continuing at this rate since 1998, then the current population may be significantly smaller than the estimated 180 orangutans.

Table 4.9. *Vortex* model results for the NE Aceh orangutan population (PE = % probability of extinction; N = mean population size; GD = % of initial gene diversity).

	50 Years			100 Years			1000 Years			Year at PE 5%
Logging Management	PE	N	GD	PE	N	GD	PE	N	GD	
Current (annual 10%)	**96**	**2**	**73**	**100**	**--**	**--**	**100**	**--**	**--**	**39**
Reduce Logging										
Reduce to annual 5%	0	16	96	91	2	67	100	--	--	55
Reduce to annual 1%	0	115	99	0	67	97	100	--	--	235
Stop Logging										
Stop in 20 yrs	2	12	92	23	11	81	100	--	--	59
Stop in 15 yrs	0	22	95	2	22	89	100	--	--	123
Stop in 10 yrs	0	42	97	0	44	94	99	9	33	210
Stop in 5 yrs	0	84	98	0	81	97	63	29	58	483
Stop immediately	0	151	99	0	142	98	7	79	76	904
Reforestation										
Stop in 10yrs, reforest (1%)	0	51	98	0	54	95	95	18	53	290

Effects of Conservation Action

Table 4.9 presents the model results for reduction or cessation of logging and habitat restoration. Continued logging at an annual rate of 10% will quickly result in population extinction due to continual population reduction and loss of habitat. Slowing the rate of habitat loss from 10% to 1% results in a viable small population for 100 years, but the probability of eventual extinction is 100% in about 400 years under unsustainable logging with no restoration of habitat (Fig. 4.10).

Complete cessation of logging is more effective in promoting population persistence over the next few hundred years, even if this cannot be accomplished immediately (Fig. 4.11). However, only an immediate and complete logging moratorium will allow the potential long-term persistence of this small population. Reforestation (in which logging is stopped in 10 years, and habitat is increased at 1% annually during years 11-30) may increase short-term population persistence, but is not an effective long-term solution unless logging can be stopped or significantly reduced earlier. Immediate action is needed to control habitat loss if it is indeed occurring at such a fast rate.

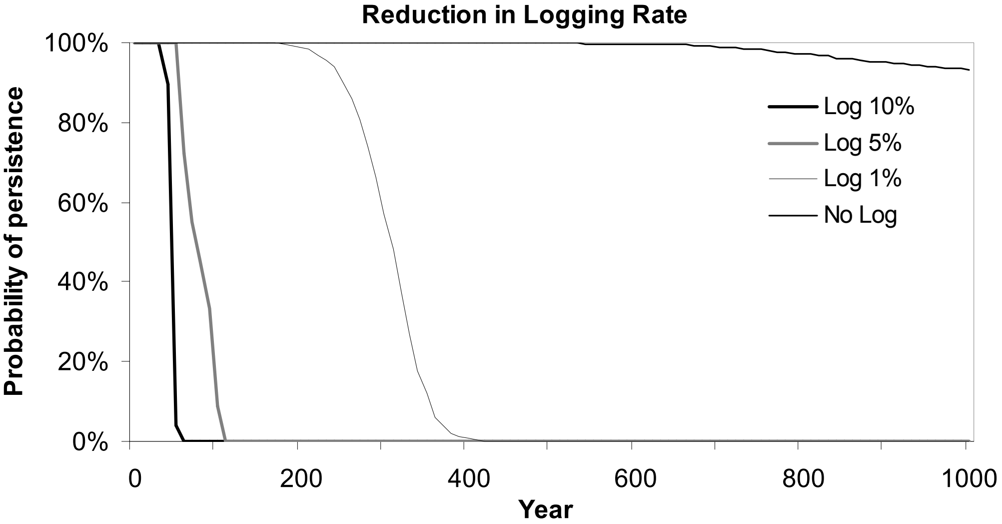


Figure 4.10. Probability of survival for the NE Aceh orangutan population with annual logging rates of 10%, 5%, 1% and 0%.

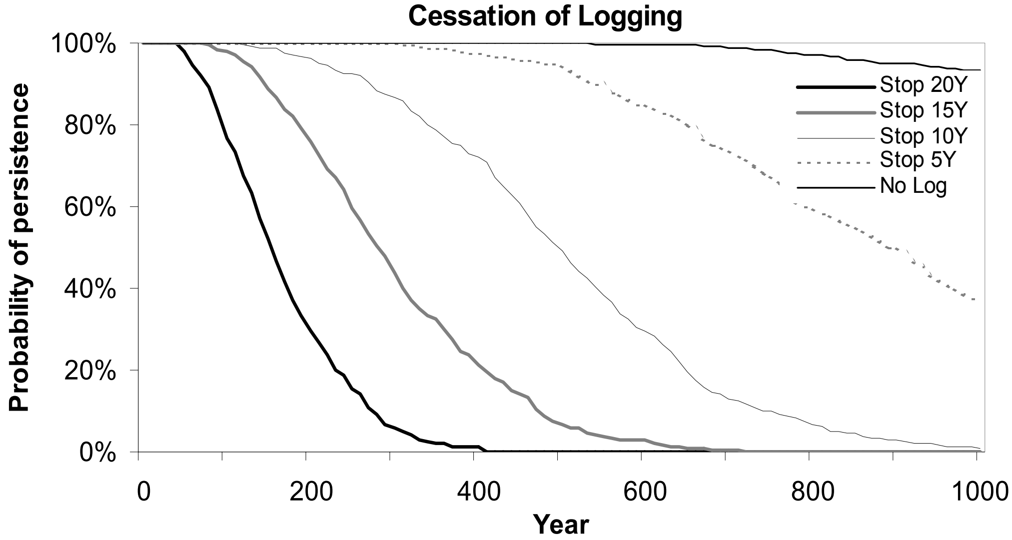


Figure 4.11. Probability of survival for the NE Aceh orangutan population with cessation of logging at 20, 15, 10 and 5 years and immediately.

East Middle Aceh Habitat Unit

Current Status

East Middle Aceh Habitat Unit comprises a relatively large area of orangutan habitat in central Aceh province (Block 8) surrounded by existing roads on the north, west and south (see Sumatran Habitat Unit Map). Almost all of this HU and its orangutan population fall within the Leuser Ecosystem Conservation Area. A small portion of this HU lies within Taman Buru Lingga Isaq Conservation Area (Taman Buru means hunting park - an area designated specifically for hunting), and few orangutans are estimated to live within its boundaries. The current orangutan population is estimated at 337 individuals and is fragmented into several large and small sub-populations within this area. Two proposed sections of the Ladia Galaska road scheme threatened to divide this HU into three sections and may restrict or halt movement of orangutans between these areas (see Sumatran Orangutan Distribution Map).

The estimated level of logging in this area is 15% per year of the available orangutan habitat. Potential conservation strategies to improve population viability include prevention of additional logging, reduction or cessation of logging, and reforestation of logged areas to increase habitat. Prohibition of construction of proposed roads would also help to reduce additional fragmentation of orangutans. The removal of orangutans (e.g., hunting) is associated with logging and was not modeled directly but in association with logging effects (see Baseline Model discussion).

The baseline model for the East Middle Aceh orangutan population suggests that the population will undergo rapid and steady decline due to habitat and population loss from logging. At an annual loss of 15%, the carrying capacity of the population will decrease by 50% within about 4 years and essentially all habitat will disappear within about 25 years.

Table 4.10. ***Vortex*** **model results for the East Middle Aceh orangutan population (PE = % probability of extinction; N = mean population size; GD = % of initial gene diversity).**

	50 Years			100 Years			1000 Years			Year at PE 5%
Logging Management	PE	N	GD	PE	N	GD	PE	N	GD	
Current (annual 15%)	**100**	**--**	**--**	**100**	**--**	**--**	**100**	**--**	**--**	**28**
Reduce Logging										
Reduce to annual 10%	67	3	78	100	--	--	100	--	--	42
Reduce to annual 5%	0	32	98	62	3	77	100	--	--	66
Reduce to annual 1%	0	210	99	0	122	98	100	--	--	299
Stop Logging										
Stop in 20 yrs	19	7	85	63	6	72	100	--	--	43
Stop in 15 yrs	0	16	93	9	17	86	100	--	--	88
Stop in 10 yrs	0	44	97	0	47	94	99	5	50	225
Stop in 5 yrs	0	108	99	0	117	98	18	53	70	640
Stop immediately	0	287	99	0	273	99	0	211	89	>1000
Reforestation										
Stop in 10 yrs, reforest (1%)	0	52	98	0	57	95	94	19	50	296

Effects of Conservation Action

Table 4.10 presents the model results for reduction or cessation of logging and habitat restoration. Continued logging at an annual rate of 15% will quickly result in population extinction in about 25-40 years due to continual population reduction and loss of habitat. Slowing the rate of habitat loss from 15% to 1% allows the population to persist for a few hundred years, but the probability of eventual extinction is 100% in about 480 years with no restoration of habitat (Fig. 4.12).

Complete cessation of logging is more effective in promoting population persistence (Fig. 4.13). Logging must be stopped within 5 years if the population is to survive for longer than a few hundred years. An immediate halt to logging will maintain a relatively large and genetically healthy population with no risk of extinction over 1000 years. Reforestation (in which logging is stopped in 10 years, and habitat is increased at 1% annually during years 11-30) is less effective unless logging can be stopped or reduced earlier. Immediate action is needed to control habitat loss to prevent rapid loss of orangutans in East Middle Aceh.

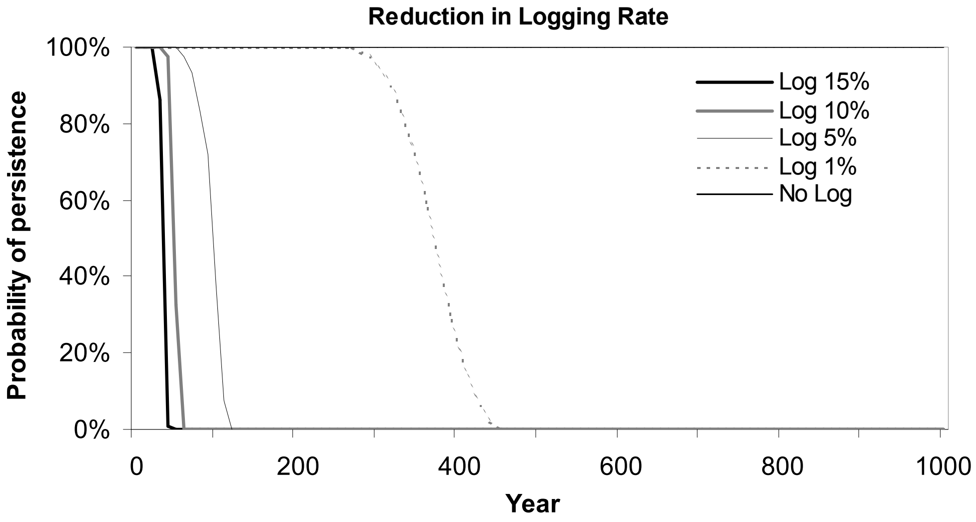


Figure 4.12. Probability of survival for the East Middle Aceh orangutan population with annual logging rates of 15%, 10%, 5%, 1% and 0%.

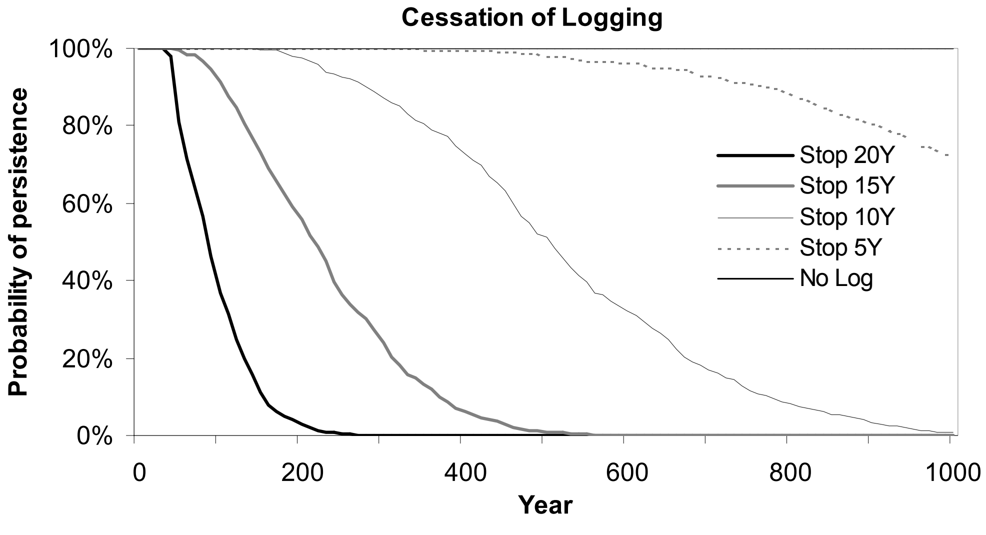


Figure 4.13. Probability of survival for the East Middle Aceh orangutan population with cessation of logging at 20, 15, 10 and 5 years and immediately.

Effects of Proposed Roads

Plans for the further development of the Ladia Galaska road scheme include construction of two roads running west-east through East Middle Aceh HU, dividing the HU into three unequal areas (see Sumatran Habitat Unit and Orangutan Distribution Maps). The extent to which orangutans will migrate across these roads is unknown. Therefore, a model was developed that assumed complete isolation between the north, central and south orangutan populations with construction of these roads, and results were compared to those representing one panmictic population.

The fragmented metapopulation shows the same projected rapid decline and extinction of the orangutan population in this HU as projected for the single large population, with 100% probability of extinction in 37 years (vs 42 years for the single population). Population size and genetic diversity decline in a similar manner in both scenarios (with and without proposed roads). In this situation, the high rate of logging has pervasive effects that swamp the effects of fragmentation. If logging were controlled or stopped, detrimental effects of fragmentation then might be observed, as smaller isolated populations would be more susceptible to inbreeding and stochastic processes. With an immediate cessation of logging, there is a risk of population extinction in 1000 years with fragmentation due to the proposed roads. Likewise, the projected orangutan population for this HU is much smaller and more inbred with the construction of new roads (see Table 4.11 & Fig. 4.14). The current estimated population of 337 orangutans is large enough to be viable in the absence of further logging; the proposed roads may subdivide this population into fragments that are too small for long-term viability and may also dramatically increase logging.

Table 4.11. *Vortex* model results for the East Middle Aceh orangutan population as three populations with no migration (due to presence of roads) and as one population.

	50 Years			100 Years			1000 Years			Year at PE 5%
Logging rate: Fragmentation	PE	N	GD	PE	N	GD	PE	N	GD	
15% logging: One population	100	--	--	100	--	--	100	--	--	28
15% logging: Metapopulation	100	--	--	100	--	--	100	--	--	27
No logging: One population	0	287	99	0	273	99	0	211	89	>1000
No logging: Metapopulation	0	226	99	0	205	99	17	59	70	763

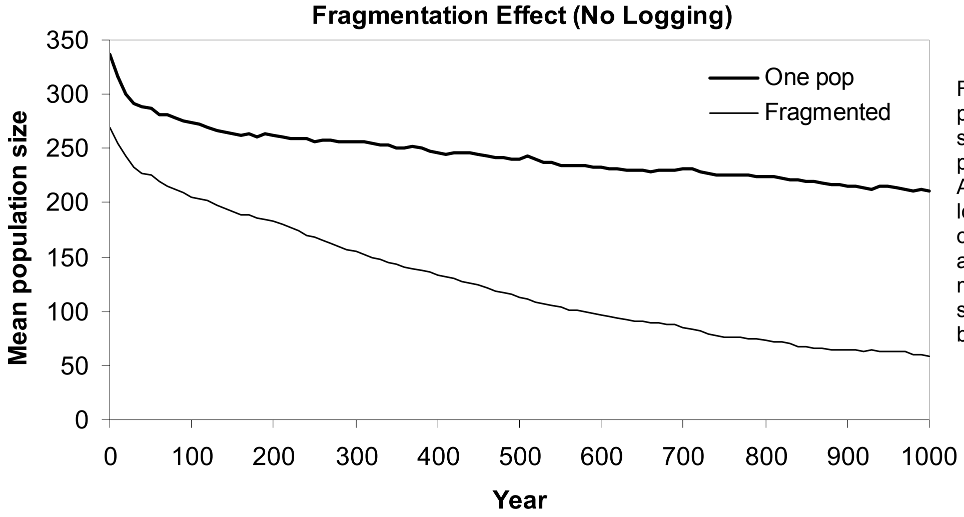


Figure 4.14. Mean population size of surviving orangutan populations in E Middle Aceh in the absence of logging. Results given for one panmictic population and for the combined meta-population of three sub-populations isolated by roads (fragmented).

West Middle Aceh Habitat Unit

Current Status

West Middle Aceh Habitat Unit includes an area of orangutan habitat in central Aceh province (Blocks 3 & 9). Part of this HU lies within the Taman Buru Lingga Isaq Conservation Area, but the majority of the HU and almost all of the orangutan population is contained within the Leuser Ecosystem Conservation Area (see Sumatran Habitat Unit and Sumatran Orangutan Distribution Maps). Three sections of the Ladia Galaska road scheme are proposed that would border this HU to the north, east and south. The current orangutan population is estimated at 103 individuals with some fragmentation. Construction of the proposed roads might isolate a small portion of this population in the south.

The estimated level of logging in this area is 10% per year of the available orangutan habitat. Potential conservation strategies to improve population viability include prevention of additional logging, reduction or cessation of logging, reforestation of logged areas to increase habitat, and possible halt of construction of proposed roads. The removal of orangutans (e.g., hunting) is associated with logging and was not modeled directly but in association with logging effects (see Baseline Model discussion).

The baseline model for the West Middle Aceh orangutan population suggests that the population will undergo rapid and steady decline due to habitat and population loss from logging. At an annual loss of 10%, the carrying capacity of the population will decrease by 50% in the next 6-7 years and essentially all habitat will disappear within about 50 years. Possible fragmentation due to logging could hasten population extinction.

Table 4.12. *Vortex* model results for the West Middle Aceh orangutan population (PE = % probability of extinction; N = mean population size; GD = % of initial gene diversity).

	50 Years			100 Years			1000 Years			Year at PE 5%
Logging Management	PE	N	GD	PE	N	GD	PE	N	GD	
Current (annual 10%)	**100**	**--**	**--**	**100**	**--**	**--**	**100**	**--**	**--**	**32**
Reduce Logging										
Reduce to annual 5%	2	9	92	100	--	--	100	--	--	52
Reduce to annual 1%	0	62	98	0	37	95	100	--	--	185
Stop Logging										
Stop in 20 yrs	14	7	86	59	6	73	100	--	--	43
Stop in 15 yrs	2	13	91	21	12	81	100	--	--	59
Stop in 10 yrs	0	24	95	4	23	89	100	--	--	111
Stop in 5 yrs	0	47	97	0	45	94	99	10	63	243
Stop immediately	0	86	98	0	78	96	66	28	60	439
Reforestation										
Stop in 10yrs, reforest (1%)	0	29	95	1	29	91	100	--	--	155
Stop in 10 yrs, reforest (2%)	0	34	96	1	37	92	100	--	--	209
Stop in 10 yrs, reforest (3%)	0	39	96	0	44	93	99	21	36	176

Effects of Conservation Action
Table 4.12 presents the model results for reduction or cessation of logging and habitat restoration. Continued logging at an annual rate of 10% will quickly result in population extinction due to continual population reduction and loss of habitat. Slowing the rate of habitat loss from 10% to 1% allows a small population for about 200 years, but the probability of eventual extinction is 100% in about 350 years under unsustainable logging with no restoration of habitat (Fig. 4.15).

Complete cessation of logging is more effective in promoting population persistence over the next few hundred years, even if this cannot be accomplished immediately (Fig. 4.16). However, even an immediate and complete logging moratorium will not ensure the long-term persistence of this small population. Reforestation (in which logging is stopped in 10 years, and habitat is increased at 1% annually during years 11-30) may increase short-term population persistence, but is not an effective long-term solution unless logging can be stopped or significantly reduced earlier. Immediate action is needed to control habitat loss in this habitat unit.

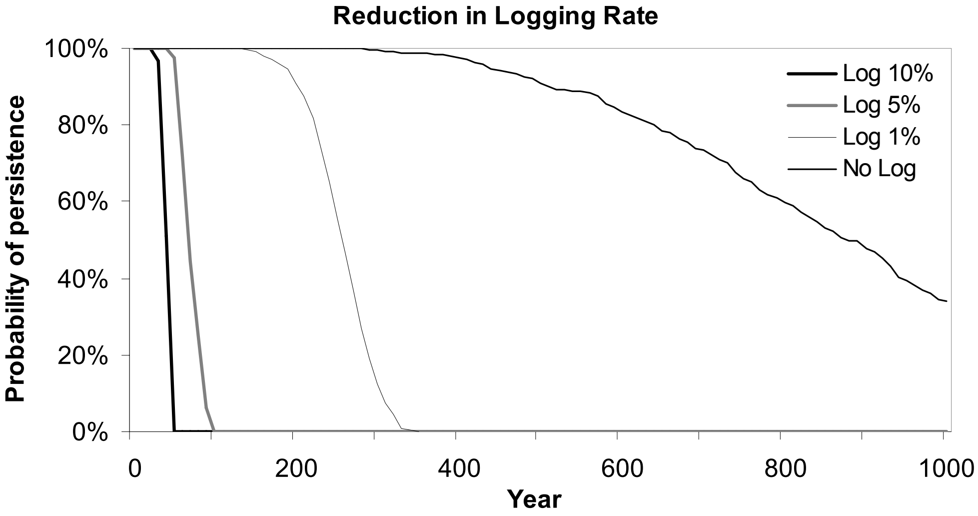


Figure 4.15. Probability of survival for the West Middle Aceh orangutan population with annual logging rates of 10%, 5%, 1% and 0%.

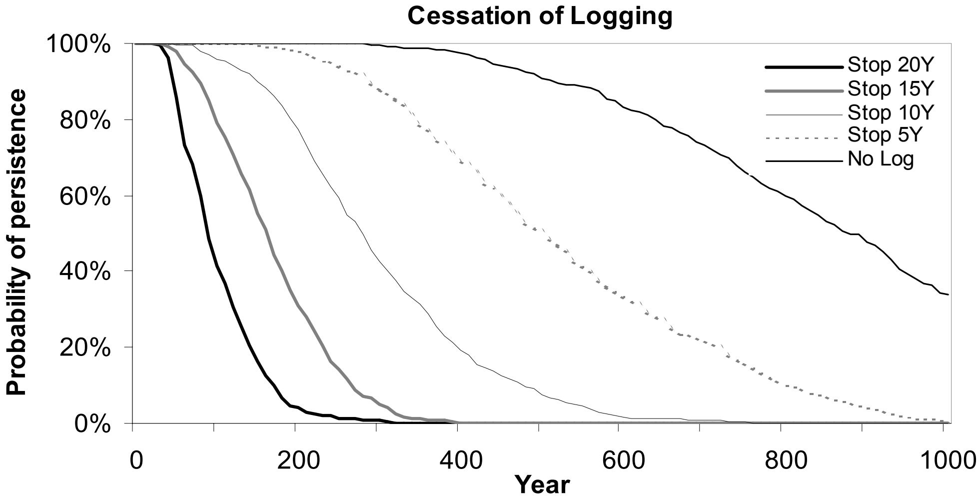


Figure 4.16. Probability of survival for the West Middle Aceh orangutan population with cessation of logging at 20, 15, 10 and 5 years and immediately.

Effects of Proposed Roads

Plans for the further development of the Ladia Galaska road scheme include construction of three roads, two running along the north and south borders respectively of the West Middle Aceh HU, and a third between Blocks 3 and 9. Two of these roads are spatially removed from the primary orangutan population, but the third is likely to isolate a small pocket of orangutans (see Sumatran Habitat Unit and Orangutan Distribution Maps). The extent to which orangutans will migrate across roads is unknown. Therefore, a model was developed that assumed complete isolation between the large and small orangutan populations with construction of these roads, and results were compared to those representing one panmictic population.

The fragmented metapopulation shows the same projected rapid decline and extinction of the orangutan population in this HU as projected above for the single large population, with 100% probability of extinction in 46 years (vs 49 years for the single intact population). Population size and genetic diversity decline in a similar manner in both scenarios (with and without proposed roads). In this situation, the high rate of logging has pervasive effects that swamp the effects of fragmentation. If logging were controlled or stopped, detrimental effects of fragmentation then might be observed, as smaller isolated populations are more susceptible to inbreeding and stochastic processes. As expected, there is a greater risk of population extinction in 1000 years and a smaller resulting population size with less genetic diversity with fragmentation due to the proposed roads (Table 4.13). However, the current estimated population of 103 orangutans is too small to be viable in the long-term even in the absence of further logging and the proposed roads without demographic and genetic supplementation from other orangutan populations and/or dramatic expansion of available habitat and carrying capacity.

Table 4.13. *Vortex* model results for the West Middle Aceh orangutan population as two populations with no migration (due to presence of roads) and as one population (PE = % probability of extinction; N = mean population size; GD = % of initial gene diversity).

	50 Years			100 Years			1000 Years			Year at PE 5%
Logging rate: Fragmentation	PE	N	GD	PE	N	GD	PE	N	GD	
10% logging: One population	100	--	--	100	--	--	100	--	--	32
10% logging: Metapopulation	100	--	--	100	--	--	100	--	--	29
No logging: One population	0	86	98	0	78	96	66	28	60	439
No logging: Metapopulation	0	64	97	0	55	95	99	11	41	284

Tripa Swamp Habitat Unit

Current Status

Tripa (Babahrot) Swamp Habitat Unit is a small area of orangutan habitat along the southern coast of Aceh province in northern Sumatra (Block 17) and falls within the Leuser Ecosystem Conservation Area (see Sumatran Habitat Unit and Sumatran Orangutan Distribution Maps). The current orangutan population is estimated at 280 individuals and believed to be at ecological carrying capacity for the area, with limited fragmentation of the population. The estimated level of logging in this area is 15% per year of the available orangutan habitat. Potential conservation strategies to improve population viability include prevention of additional logging, reduction or cessation of logging, and reforestation of logged areas to increase habitat. The removal of orangutans (e.g., hunting) is associated with logging and therefore was not modeled directly but in association with logging effects (see Baseline Model discussion).

The baseline model for the Tripa orangutan population suggests that the population will undergo rapid and steady decline due to habitat and population loss from logging. At an annual loss of 15%, the carrying capacity of the population will decrease by 50% within about 4 years and essentially all habitat will disappear within about 25 years. Habitat restoration efforts will come too late (only 20% of habitat will remain after 10 years) unless logging can be reduced or stopped.

Table 4.14. *Vortex* model results for the Tripa orangutan population (PE = % probability of extinction; N = mean population size; GD = % of initial gene diversity).

	50 Years			100 Years			1000 Years			Year at PE 5%
Logging Management	PE	N	GD	PE	N	GD	PE	N	GD	
Current (annual 15%)	**100**	**--**	**--**	**100**	**--**	**--**	**100**	**--**	**--**	**28**
Reduce Logging										
Reduce to annual 10%	80	2	76	100	--	--	100	--	--	42
Reduce to annual 5%	0	26	97	72	3	74	100	--	--	58
Reduce to annual 1%	0	176	99	0	103	98	100	--	--	275
Stop Logging										
Stop in 20 yrs	25	5	83	72	6	71	100	--	--	42
Stop in 15 yrs	1	13	92	19	13	83	100	--	--	68
Stop in 10 yrs	0	34	97	0	37	93	>99	10	37	182
Stop in 5 yrs	0	89	99	0	94	97	48	38	64	483
Stop immediately	0	236	99	0	221	99	0	167	86	>1000
Reforestation										
Stop in 10 yrs, reforest (1%)	0	42	97	0	47	94	99	8	46	255

Effects of Conservation Action

Table 4.14 presents the model results for reduction or cessation of logging and habitat restoration. Continued logging at an annual rate of 15% will quickly result in population extinction in about 25-40 years due to continual population reduction and loss of habitat. Slowing the rate of habitat loss from 15% to 5% allows the population to persist a little longer, but even with a logging rate of only 1% the probability of eventual extinction is 100% in 470 years with no restoration of habitat (Fig. 4.17).

Complete cessation of logging is more effective in promoting population persistence (Fig. 4.18). Logging must be stopped within 5 years if the population is to potentially survive for longer than a few hundred years. An immediate halt to logging will maintain a population of modest size and genetic diversity with no risk of extinction over 1000 years. Reforestation (in which logging is stopped in 10 years, and habitat is increased at 1% annually during years 11-30) is not effective for securing long-term viability unless logging can be stopped or reduced earlier. Immediate action is needed to control habitat loss to prevent rapid loss of orangutans in Tripa Swamp HU.

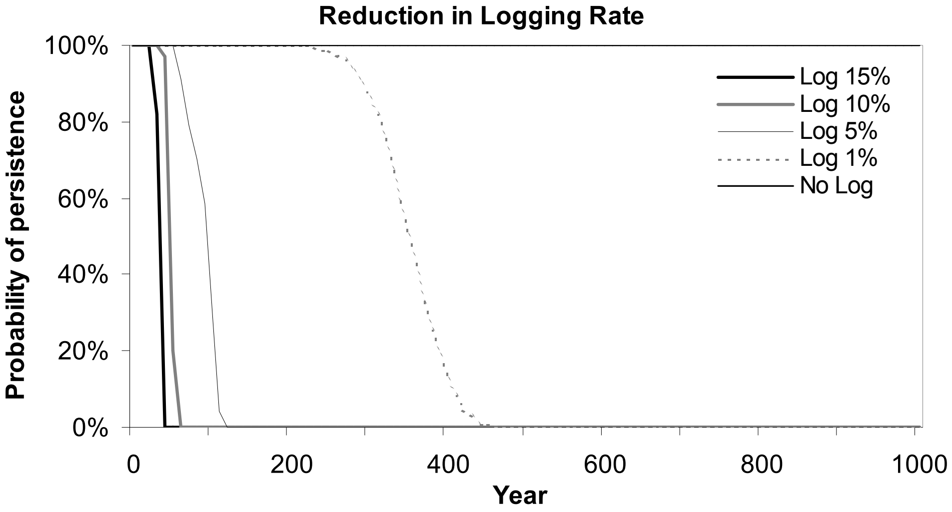


Figure 4.17. Probability of survival for the Tripa orangutan population with annual logging rates of 15%, 10%, 5%, 1% and 0%.

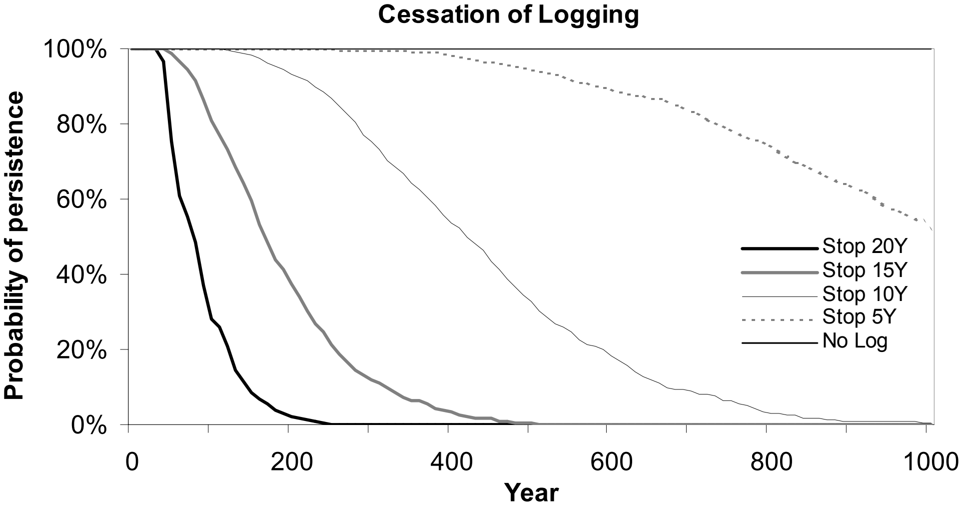


Figure 4.18. Probability of survival for the Tripa orangutan population with cessation of logging at 20, 15, 10 and 5 years and immediately.

East Leuser Habitat Unit

Current Status

East Leuser Habitat Unit encompasses a large area of orangutan habitat (Blocks 13, 14, 15 & 16) that falls across two provinces of Sumatra: southern Aceh province and northern North Sumatra province (see Sumatran Habitat Unit Map). This HU lies within the Leuser Ecosystem Conservation Area and almost entirely within Gunung Leuser National Park. East Leuser is separated from West Leuser by the Ladia Galaska road scheme, which bisects the National Park. The orangutan population is estimated at 1052 individuals, concentrated primarily in a large (but relatively low density) sub-population in the southeast and a smaller sub-population in the northwest (see Sumatran Orangutan Distribution Map). Roads from Berastagi to Bohorok (more precisely Kuta Rakyat to Pama Simalir) and from Bohorok to Kutacane may result in the reduction and division of the orangutan population into three unequal fragments: 700 orangutans in the north, 130 in the central area, and essentially no orangutans in the southeast fragment. The estimated level of logging in this area is 15% per year of the available orangutan habitat. Potential conservation strategies to improve population viability include prevention of additional logging, reduction or cessation of logging, reforestation of logged areas to increase habitat, and halting the construction of roads that fragment populations. An additional strategy would be to connect the East and West Leuser orangutan populations (see following section). The removal of orangutans (e.g., hunting) is associated with logging and was not modeled directly but in association with logging effects (see Baseline Model discussion).

The baseline model for the East Leuser orangutan population suggests that despite the large number of orangutans, the population will undergo rapid and steady decline due to habitat and population loss from logging (Fig. 4.19). At an annual loss of 15%, the carrying capacity of the population will decrease by 50% within about 4 years and essentially all habitat will disappear within about 30 years.

Table 4.15. ***Vortex*** **model results for the East Leuser orangutan population (PE = % probability of extinction; N = mean population size; GD = % of initial gene diversity).**

	50 Years			100 Years			1000 Years			Year at PE 5%
Logging Management	PE	N	GD	PE	N	GD	PE	N	GD	
Current (annual 15%)	**100**	**--**	**--**	**100**	**--**	**--**	**100**	**--**	**--**	**35**
Reduce Logging										
Reduce to annual 10%	9	7	90	100	--	--	100	--	--	49
Reduce to annual 5%	0	102	99	6	8	89	100	--	--	99
Reduce to annual 1%	0	661	100	0	393	99	100	--	--	408
Stop Logging										
Stop in 20 yrs	0	22	95	3	23	89	92	25	29	116
Stop in 15 yrs	0	56	98	0	65	96	33	61	59	331
Stop in 10 yrs	0	139	99	0	154	98	2	148	82	>1000
Stop in 5 yrs	0	343	100	0	369	99	0	336	92	>1000
Stop immediately	0	880	100	0	852	100	0	801	97	>1000
Reforestation										
Stop in 10yrs, reforest (1%)	0	166	99	0	190	99	0	182	85	>1000

Effects of Conservation Action

Table 4.15 presents the model results for reduction or cessation of logging and habitat restoration. Continued logging at an annual rate of 15% will quickly result in population extinction in about 30-40 years due to continual population reduction and loss of habitat. Slowing the rate of habitat loss from 15% to 5% allows the population to persist a little longer, but even with a continued logging rate of only 1% the probability of eventual extinction is 100% in about 600 years with no restoration of habitat (Fig. 4.19).

Complete cessation of logging is much more effective in promoting population persistence (Fig. 4.20). Logging must be stopped within 10 years to achieve a low risk of population extinction. A halt to logging within 5 years may be sufficient to maintain a relatively large and genetically viable population with no risk of extinction over 1000 years; the sooner habitat loss stops, the larger the resulting population. Reforestation (in which logging is stopped in 10 years, and habitat is increased at 1% annually during years 11-30) may contribute to population viability but is not as effective as stopping or reducing logging earlier. Action is needed within the next few years to control habitat loss to prevent rapid loss of orangutans in East Leuser HU.

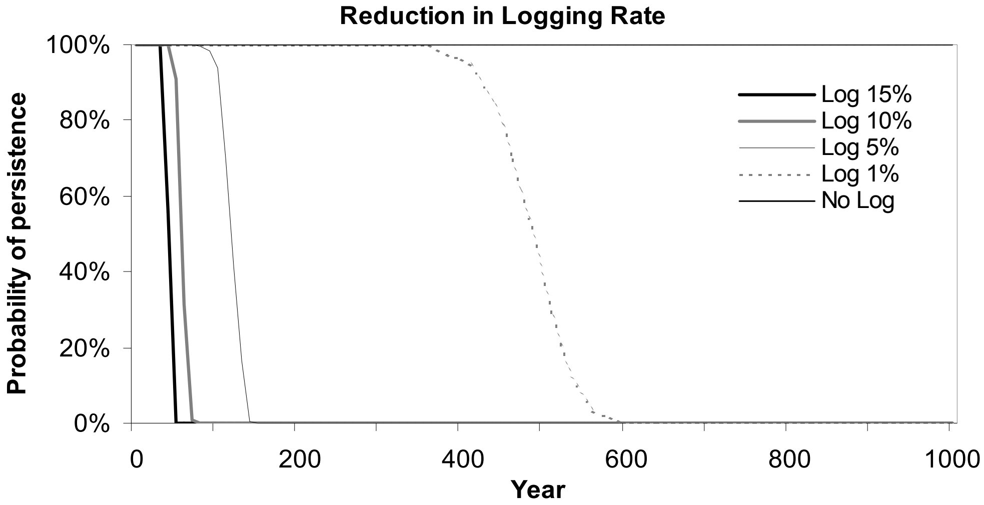


Figure 4.19. Probability of survival for the East Leuser orangutan population with annual logging rates of 15%, 10%, 5%, 1% and 0%.

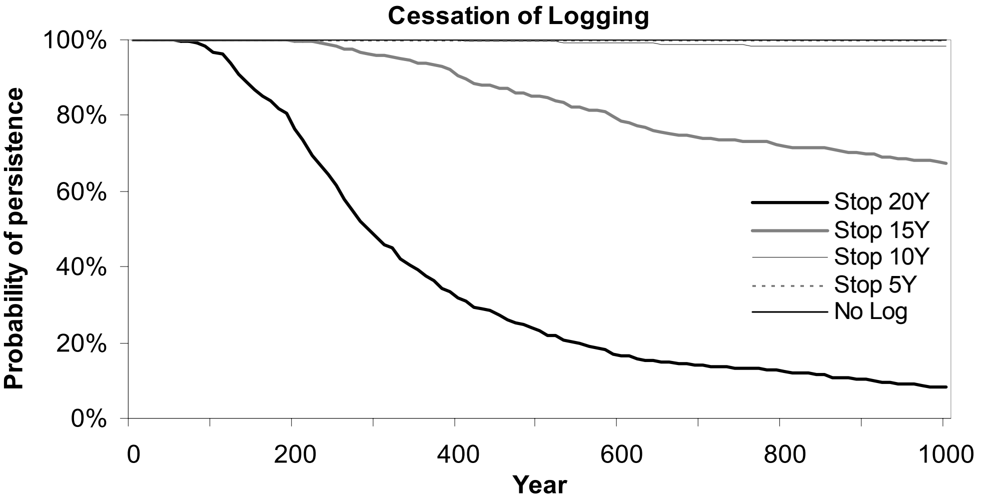


Figure 4.20. Probability of survival for the East Leuser orangutan population with cessation of logging at 20, 15, 10 and 5 years and immediately.

Effects of Roads
Roads from Berastagi to Bohorok (more precisely Kuta Rakyat to Pama Simalir) and from Bohorok to Kutacane in the southern portion of East Leuser threaten to reduce and separate the orangutan population into two smaller isolated populations, with about 700 individuals in the north and 130 in the central area. The smaller population is probably too small to be viable long-term, even if logging were stopped immediately. The larger population is more robust if habitat loss can be controlled. Since, however, the smaller population is likely to be lost, then the resulting orangutan population for East Leuser will be smaller with fragmentation and will be more sensitive to the rate and length of time of habitat loss.

Table 4.16 gives model results for the East Leuser orangutan population as a metapopulation of two smaller isolated fragments and as one panmictic population. The fragmented metapopulation shows the same projected rapid decline and extinction of the orangutan population in this HU as projected above for the single large population, with 100% probability of extinction within 50 years. Population size and genetic diversity decline in a similar manner in both scenarios. In this situation, the high rate of logging has pervasive effects that swamp the effects of fragmentation. If logging were stopped immediately, the current population is large enough in either scenario to be viable over 1000 years; there would just be fewer orangutans with fragmentation.

Fragmentation would have the greatest impact if logging were stopped sometime within the next 10 years. In the absence of road effects, the orangutan population would likely persist for 1000 years if logging were stopped within 10 years, and a moderate large and genetically healthy population could be maintained long-term with a halt to logging within 5 years. Under a road fragmentation scenario, 10 years would be too long to wait to stop logging. Cessation after 5 years will allow the population to persist for 1000 years, but it may not be of sufficient size and genetic diversity for continued viability. A road fragmentation scenario would almost certainly increase the rate of logging over time as well. Isolation due to roads would exacerbate the need to take immediate action to stop or reduce the rate of logging in East Leuser.

Table 4.16. ***Vortex*** **model results for the East Leuser orangutan population as two populations with no migration (due to presence of roads) and as one population (PE = % probability of extinction; N = mean population size; GD = % of initial gene diversity).**

	50 Years			100 Years			1000 Years			Year at PE 5%
Logging rate: Fragmentation	PE	N	GD	PE	N	GD	PE	N	GD	
15% logging: One population	100	--	--	100	--	--	100	--	--	35
15% logging: Metapopulation	100	--	--	100	--	--	100	--	--	34
Stop in 10 yrs: One population	0	139	99	0	154	98	2	148	82	>1000
Stop in 10 yrs: Metapopulation	0	107	99	0	116	98	40	43	67	528
Stop in 5 yrs: One population	0	343	100	0	369	99	0	336	92	>1000
Stop in 5 yrs: Metapopulation	0	273	100	0	288	99	0	182	87	>1000
No logging: One population	0	880	100	0	852	100	0	801	97	>1000
No logging: Metapopulation	0	699	100	0	662	100	0	538	95	>1000

West Leuser Habitat Unit

Current Status

West Leuser Habitat Unit in southern Aceh province represents the largest area of Sumatran orangutan habitat (Blocks 4, 5, 5A, 10 & 11) and lies within the Leuser Ecosystem Conservation Area (see Sumatran Habitat Unit Map). Although most of this HU falls within Gunung Leuser National Park, a significant portion of the orangutan population is outside of the park boundaries. West Leuser is separated from East Leuser by the Ladia Galaska road scheme, which bisects the National Park. The orangutan population is estimated at 2508 individuals, concentrated primarily in the southern part of West Leuser (see Sumatran Orangutan Distribution Map). A proposed section of the Ladia Galaska road scheme would potentially isolate the most southeastern portion of the population. The estimated level of logging in this area is 10% per year of the available orangutan habitat. Potential conservation strategies to improve population viability include prevention of additional logging, reduction or cessation of logging, reforestation of logged areas to increase habitat, and halting construction of the proposed road. An additional strategy would be to connect the West Leuser orangutan population with adjacent populations in East Leuser and/or Trumon-Singkil HU (see following sections). The removal of orangutans (e.g., hunting) is associated with logging and was not modeled directly but in association with logging effects (see Baseline Model discussion).

The baseline model for the West Leuser orangutan population suggests that despite the large number of orangutans, the population will undergo rapid and steady decline due to habitat and population loss from logging. At an annual loss of 10%, the carrying capacity of the population will decrease by 50% in the next 6 -7 years and almost all habitat will disappear within about 50 years, leading to population extinction. This population is projected to disappear in 50-80 years given current estimated rates of logging.

Table 4.17. ***Vortex*** **model results for the West Leuser orangutan population (PE = % probability of extinction; N = mean population size; GD = % of initial gene diversity).**

	50 Years			100 Years			1000 Years			Year at PE 5%
Logging Management	PE	N	GD	PE	N	GD	PE	N	GD	
Current (annual 10%)	**0**	**17**	**96**	**100**	**--**	**--**	**100**	**--**	**--**	**52**
Reduce Logging										
Reduce to annual 5%	0	247	100	0	20	96	**100**	**--**	**--**	113
Reduce to annual 1%	0	1567	100	0	920	100	**100**	**--**	**--**	489
Stop Logging										
Stop in 20 yrs	0	194	99	0	216	99	<1	218	88	>1000
Stop in 15 yrs	0	350	100	0	392	99	0	380	93	>1000
Stop in 10 yrs	0	631	100	0	680	100	0	652	96	>1000
Stop in 5 yrs	0	1189	100	0	1190	100	0	1121	98	>1000
Stop immediately	0	2105	100	0	2026	100	0	1950	99	>1000
Reforestation										
Stop in 10yrs, reforest (1%)	0	738	100	0	836	100	0	799	97	>1000

Effects of Conservation Action

Table 4.17 presents the model results for reduction or cessation of logging and habitat restoration. Continued logging at an annual rate of 10% will result in population extinction in about 50-80 years due to continual population reduction and loss of habitat. Slowing the rate of habitat loss from 10% to 1% allows the population to persist for several hundred years, but with continued logging the probability of eventual extinction is 100% in about 700 years with no restoration of habitat (Fig. 4.21).

Complete cessation of logging is very effective in promoting population persistence. Because the current population is so large, an immediate halt to logging is not necessary to prevent population extinction (Table 4.17), although eventual cessation is necessary. The sooner habitat loss is controlled, the greater the number of orangutans will be that can be maintained. For instance, the long-term orangutan population would be almost twice as large if logging were stopped immediately as opposed to 5 years from now (Fig. 4.22). West Leuser HU currently contains the largest Sumatran orangutan population, representing about one-third of all wild Sumatran orangutans, and quick action to reduce or halt logging could have substantial benefits in terms of the number of Sumatran orangutans that persist.

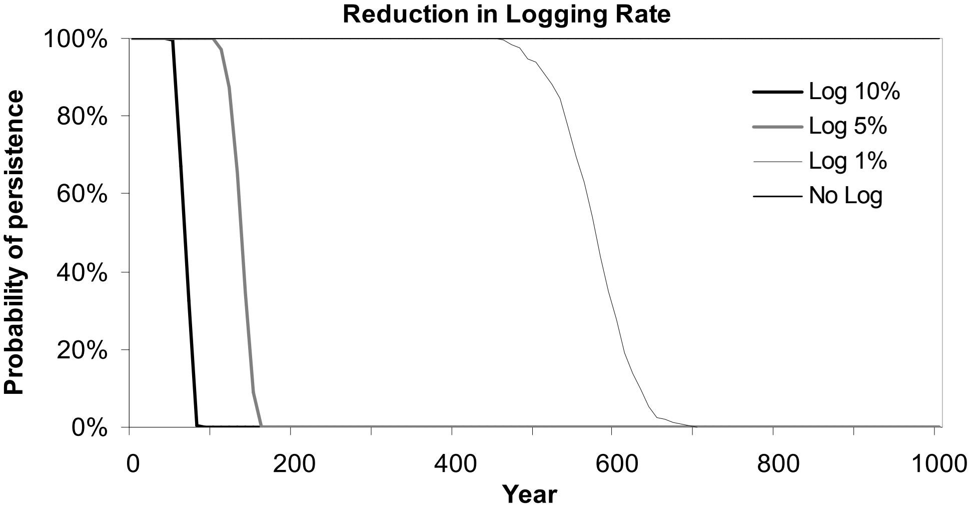


Figure 4.21. Probability of survival for the West Leuser orangutan population with annual logging rates of 10%, 5%, 1% and 0%.

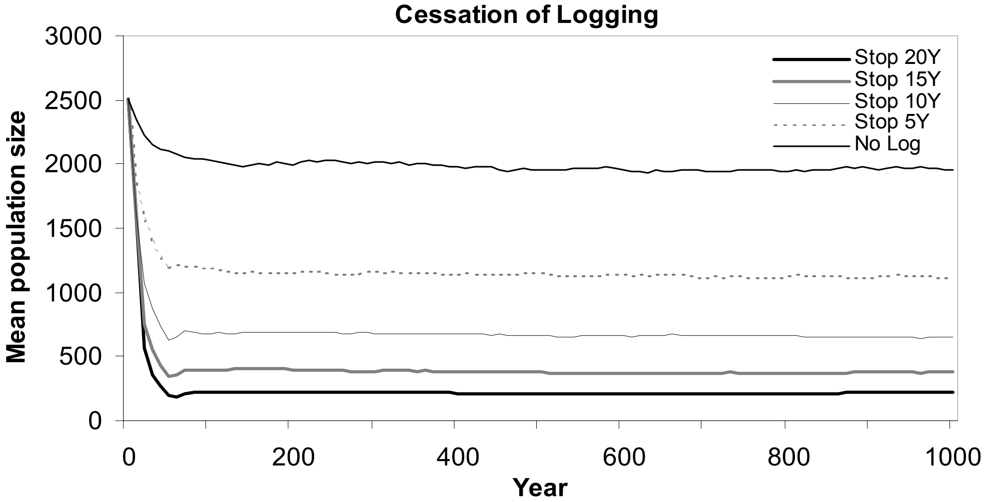


Figure 4.22. Mean population size of surviving West Leuser orangutan populations with cessation of logging at 20, 15, 10 and 5 years and immediately.

Effects of Roads

A proposed section of the Ladia Galaska roads scheme (specifically the ‘Bengkung Road’ linking Muara Situlen and Gelombang) would separate a small pocket of habitat in southeast West Leuser, resulting in a large primary population estimated to contain 1783 individuals and a small population of 400 individuals. This scenario assumes a loss of some orangutan habitat and associated population reduction. Additional fragmentation also might be expected in the smaller habitat area over the next 10 years, which could result in the loss of this fragment.

If logging continues in West Leuser, the orangutan population will not be able to survive for 1000 years, whether or not the population is fragmented. The high rate of logging drastically limits carrying capacity and therefore population size and overshadows the effects of fragmentation. Conversely, if the population is divided into two fragments as suggested above, both populations would be of sufficient size for long-term viability in the absence of further logging or fragmentation. As with the East Leuser population, the survival of the orangutan population in this HU is dependent upon how long logging will continue (as well as the rate of logging). Fragmentation of this population will mean that habitat loss needs to be curtailed sooner in order to maintain viable, genetically healthy orangutan populations. Any additional logging caused by the increased access provided by roads would exacerbate population decline.

Table 4.18 gives model results for the West Leuser orangutan population as two isolated fragments after 1000 years in relation to how quickly habitat loss can be stopped (assuming no additional logging with roads). Fragmentation would have the greatest impact if logging were stopped about 15-20 years from now. In the absence of fragmentation, the orangutan population would likely persist for 1000 years if logging were stopped within 20 years, and a moderate large and genetically healthy population could be maintained long-term with a halt to logging within 15 years. Under a road fragmentation scenario, another 15 years of logging would likely drive the southeast population to extinction and leave a small population in the rest of the HU. Cessation after 5 years will allow likely allow both populations to persist for 1000 years in the absence of no further fragmentation. Isolation due to the construction of new roads would promote the need to take quicker action to stop or reduce the rate of logging in West Leuser.

Table 4.18. ***Vortex*** **model results at 1000 years for the West Leuser orangutan population if separated by roads into two populations with no migration and as one interbreeding population (PE = % probability of extinction; N = mean population size; GD = % of initial gene diversity).**

Logging Management	Large Population			Small Population			Metapopulation			One Population		
	PE	N	GD	PE	N	GD	PE	N	GD	PE	N	GD
Stop in 20 yrs	5	98	80	>99	4	41	5	98	80	<1	218	88
Stop in 15 yrs	0	227	90	92	16	52	0	229	90	0	380	93
Stop in 10 yrs	0	434	94	37	45	67	0	462	95	0	652	96
Stop in 5 yrs	0	770	97	2	124	83	0	891	97	0	1121	98
Stop now	0	1360	98	0	257	91	0	1617	98	0	1950	99

Potential Corridor: West and East Leuser Habitat Units

Reconnecting West and East Leuser

One suggested conservation management strategy is to reconnect the orangutan populations in West and East Leuser Habitat Units to form one interbreeding population. These two populations are currently separated primarily by the existing Ladia Galaska road scheme that bisects both the Gunung Leuser National Park and the Leuser Ecosystem along their central axes. Gunung Leuser National Park. The combined population of West and East Leuser HUs represents about one-half of the remaining wild Sumatran orangutan population.

Table 4.19 gives the model results for current conditions as well as the reduction or cessation of logging and habitat restoration for the combined Leuser HU, and assumes a reduction of logging in East Leuser from 15% to 10%. Continued logging at an annual rate of 10% will result in population extinction in about 50-80 years due to continual population reduction and loss of habitat, and overrides much of the benefit of reconnecting the two populations. Slowing the rate of habitat loss from 10% to 1% allows the population to persist for about 500 years, but with continued logging the probability of eventual extinction is 100% in about 700 years with no restoration of habitat.

Because of the large population inhabiting Leuser, the model suggests that it is not necessary to cease logging immediately to ensure long-term viability of an orangutan population in this HU. Ending logging after 20 years would reduce habitat and carrying capacity by 88% and likely result in the long-term persistence of a genetically healthy population of about 300 orangutans. However, the more quickly logging can be stopped, the larger and more genetically diverse the resulting population will be.

Table 4.19. ***Vortex*** **model results for the combined West and East Leuser orangutan population (PE = % probability of extinction; N = mean population size; GD = % of initial gene diversity).**

Logging Management	50 Years			100 Years			1000 Years			Year at PE 5%
	PE	N	GD	PE	N	GD	PE	N	GD	
Current (annual 10%)	**0**	**24**	**97**	**100**	**--**	**--**	**100**	**--**	**--**	**52**
Reduce Logging										
Reduce to annual 5%	0	352	100	0	29	97	**100**	**--**	**--**	121
Reduce to annual 1%	0	2227	100	0	1325	100	**100**	**--**	**--**	527
Stop Logging										
Stop in 20 yrs	0	275	100	0	309	99	0	313	92	>1000
Stop in 15 yrs	0	491	100	0	549	100	0	542	95	>1000
Stop in 10 yrs	0	886	100	0	965	100	0	935	97	>1000
Stop in 5 yrs	0	1705	100	0	1681	100	0	1631	98	>1000
Stop immediately	0	3016	100	0	2866	100	0	2763	99	>1000
Reforestation										
Stop in 10 yrs, reforest (1%)	0	1079	100	0	1200	100	0	1138	98	>1000

Trumon-Singkil Swamp Habitat Unit

Current Status

Despite its relatively small area compared to many other habitat units, the Trumon-Singkil Swamp Habitat Unit in southern Aceh province (Block 18) contains the second largest Sumatran orangutan population. Bordered by the Indian Ocean to the west and by rivers to the south and east, this coastal swamp lies within the Suaka Marga Satwa Rawa Singkil and Leuser Ecosystem Conservation Areas (see Sumatran Habitat Unit and Sumatran Orangutan Distribution Maps). The orangutan population is estimated about 1500 individuals and inhabits most of the HU with little fragmentation. The estimated level of logging in this area is 10% per year of the available orangutan habitat. Potential conservation strategies to improve population viability include prevention of additional logging, reduction or cessation of logging, and reforestation of logged areas to increase habitat. An additional strategy would be to connect the Trumon-Singkil orangutan population with the West Leuser population to the north (see the following section). The removal of orangutans (e.g., hunting) is associated with logging and was not modeled directly but in association with logging effects (see Baseline Model discussion).

The baseline model for the Trumon-Singkil orangutan population suggests that despite the large number of orangutans, the population will undergo rapid and steady decline due to habitat and population loss from logging. At an annual loss of 10%, the carrying capacity of the population will decrease by 50% in the next 6 -7 years and almost all habitats will disappear within about 50 years, leading to population extinction.

Table 4.20. ***Vortex*** **model results for the Trumon-Singkil orangutan population (PE = % probability of extinction; N = mean population size; GD = % of initial gene diversity).**

	50 Years			100 Years			1000 Years			Year at PE 5%
Logging Management	PE	N	GD	PE	N	GD	PE	N	GD	
Current (annual 10%)	**5**	**8**	**92**	**100**	**--**	**--**	**100**	**--**	**--**	**50**
Reduce Logging										
Reduce to annual 5%	0	146	100	1	13	93	100	--	--	105
Reduce to annual 1%	0	962	100	0	574	100	100	--	--	445
Stop Logging										
Stop in 20 yrs	0	107	99	0	123	98	3	125	79	>1000
Stop in 15 yrs	0	198	99	0	226	99	0	221	88	>1000
Stop in 10 yrs	0	372	100	0	403	99	0	389	93	>1000
Stop in 5 yrs	0	715	100	0	710	100	0	659	96	>1000
Stop immediately	0	1530	100	0	1530	100	0	1483	98	>1000
Reforestation										
Stop in 10 yrs, reforest (1%)	0	445	100	0	490	99	0	476	94	>1000

Effects of Conservation Action

Table 4.20 presents the model results for reduction or cessation of logging and habitat restoration. Continued logging at an annual rate of 10% will result in population extinction in about 50-80 years due to continual population reduction and loss of habitat. Slowing the rate of habitat loss from 10% to 1% allows the population to persist for several hundred years, but with continued logging the probability of eventual extinction is 100% in about 650 years with no restoration of habitat (Fig. 4.23).

Complete cessation of logging is very effective in promoting population persistence. Because the current population is large, an immediate halt to logging is not necessary to prevent population extinction (Table 4.20). However, the sooner habitat loss is controlled, the greater the number of orangutans will be that can be maintained. For instance, the long-term orangutan population would be over twice as large if logging were stopped immediately as opposed to 5 years from now (Fig. 4.24). Trumon-Singkil Swamp HU currently contains the second largest Sumatran orangutan population, and quick action to reduce or halt logging could have substantial benefits in terms of the number of Sumatran orangutans that persist.

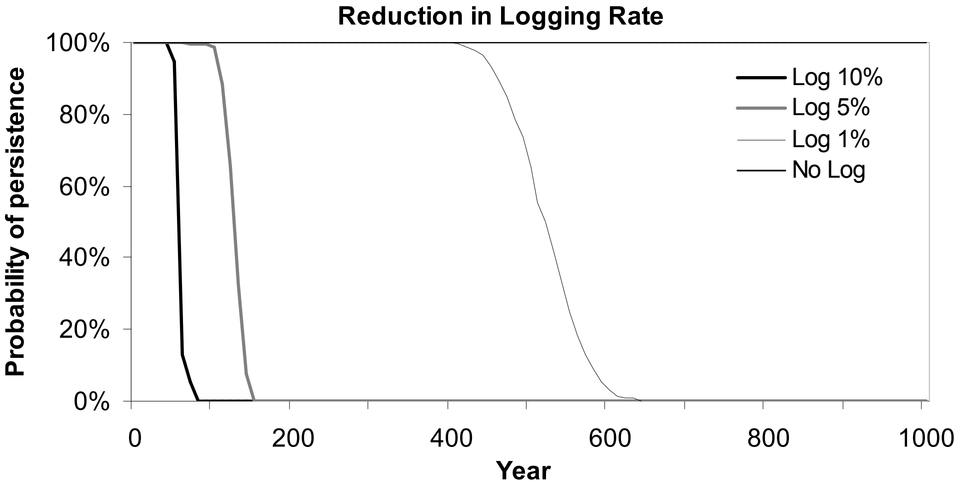


Figure 4.23. Probability of survival for the Trumon-Singkil orangutan population with annual logging rates of 10%, 5%, 1% and 0%.

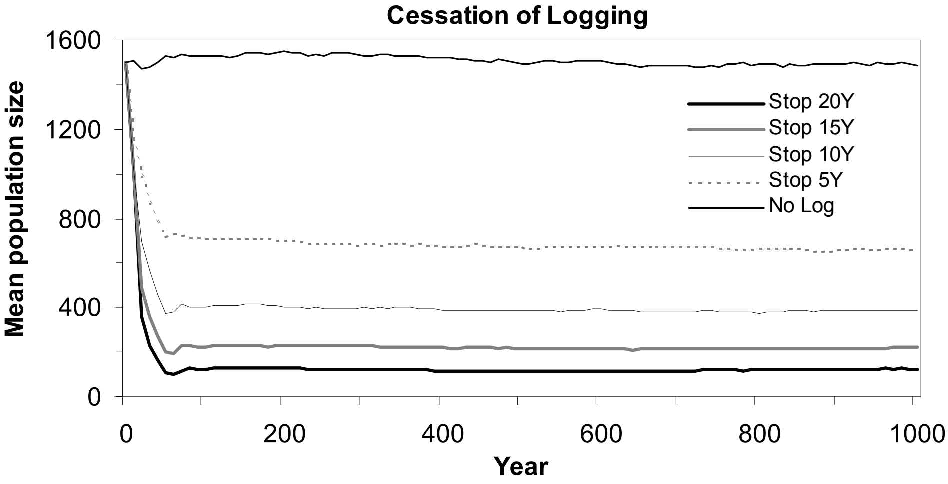


Figure 4.24. Mean population size of surviving Trumon-Singkil orangutan populations with cessation of logging at 20, 15, 10 and 5 years and immediately.

Potential Corridor: Trumon-Singkil and West Leuser Habitat Units

Connecting Trumon-Singkil and West Leuser

One suggested conservation management strategy is to connect the orangutan populations in Trumon-Singkil and West Leuser Habitat Units to allow migration between populations. These are the two largest orangutan populations left in Sumatra, and the combined population represents over 50% of the remaining wild Sumatran orangutan population. A model was developed that assumed migration of 50% of the sub-adult (i.e., age 12-20 years) male orangutans between the two populations to form a metapopulation.

Table 4.21 gives the model results for current conditions as well as the reduction or cessation of logging and habitat restoration for the combined Trumon-Singkil and West Leuser HUs. Continued logging at an annual rate of 10% will result in population extinction in about 50-80 years due to continual population reduction and loss of habitat, and overrides much of the benefit of reconnecting the two populations. Slowing the rate of habitat loss from 10% to 1% allows the population to persist for about 450 years, but with continued logging the probability of eventual extinction is 100% in about 650 years with no restoration of habitat. This is essentially the same fate as that of the two individual populations when considered separately.

Because of the large population inhabiting these combined areas, it would not be necessary to cease logging immediately to ensure long-term viability for a much smaller orangutan population. Even after 20 years of logging, which would reduce habitat and carrying capacity by 88%, a genetically healthy population of about 350 orangutans could persist for 1000 years. The more quickly logging can be stopped, however, the larger and more genetically diverse the resulting population will be. Efforts to reduce and ultimately halt logging quickly are necessary to preserve this large orangutan population.

Table 4.21. ***Vortex*** **model results for the combined Trumon-Singkil and West Leuser population (PE = % probability of extinction; N = mean population size; GD = % of initial gene diversity).**

	50 Years			100 Years			1000 Years			Year at PE 5%
Logging Management	PE	N	GD	PE	N	GD	PE	N	GD	
Current (annual 10%)	**0**	**25**	**98**	**100**	**--**	**--**	**100**	**--**	**--**	**53**
Reduce Logging										
Reduce to annual 5%	0	403	100	0	34	97	**100**	**--**	**--**	124
Reduce to annual 1%	0	2497	100	0	1508	100	**100**	**--**	**--**	518
Stop Logging										
Stop in 20 yrs	0	312	100	0	351	99	0	347	91	>1000
Stop in 15 yrs	0	553	100	0	616	100	0	613	95	>1000
Stop in 10 yrs	0	1000	100	0	1098	100	0	1054	97	>1000
Stop in 5 yrs	0	1898	100	0	1915	100	0	1823	98	>1000
Stop immediately	0	3301	100	0	3257	100	0	3136	99	>1000
Reforestation										
Stop in 10 yrs, reforest (1%)	0	1185	100	0	1329	100	0	1304	98	>1000

Puncak Sidiangkat Habitat Unit

Current Status

Sidiangkat Habitat Unit is a small area of orangutan habitat along the border of Aceh and North Sumatra provinces in northern Sumatra (Block 12) just south of West Leuser HU and the Leuser Ecosystem Conservation Area (see Sumatran Habitat Unit Map). The current orangutan population is estimated at 134 individuals and believed to be at ecological carrying capacity for the area, with no major fragmentation of the population. The estimated level of logging in this area is 5% per year of the available orangutan habitat. Potential conservation strategies to improve population viability include prevention of additional logging, reduction or cessation of logging, and reforestation of logged areas to increase habitat. The removal of orangutans (e.g., hunting) is associated with logging and therefore was not modeled directly but in association with logging effects (see Baseline Model discussion).

The baseline model for the Sidiangkat orangutan population suggests that the population will undergo a steady decline due to habitat and population loss from logging. At an annual loss of 5%, the carrying capacity of the population will decrease by 50% in only 14 years; in 100 years, essentially all of the habitat will be lost. The orangutan population would be expected to disappear in 50-100 years if logging continues at the current rate.

Effects of Conservation Action

Table 4.22 presents the model results for reduction or cessation of logging and habitat restoration. Continued logging will ultimately result in population extinction due to continual population reduction and loss of habitat. Slowing the rate of habitat loss (from the current estimated rate of 5% per year) will delay population extinction and allow the population to persist for 100 years,

Table 4.22. *Vortex* model results for the Sidiangkat orangutan population (PE = % probability of extinction; N = mean population size; GD = % of initial gene diversity).

Logging Management	50 Years			100 Years			1000 Years			Year at PE 5%
	PE	N	GD	PE	N	GD	PE	N	GD	
Current (annual 5%)	**1**	**12**	**94**	**99**	**2**	**75**	**100**	**--**	**--**	**53**
Reduce Logging										
Reduce to annual 2.5%	0	46	98	1	12	90	100	--	--	113
Reduce to annual 1%	0	85	98	0	49	96	100	--	--	206
Stop Logging										
Stop in 20 yrs	0	36	97	1	33	93	100	--	--	159
Stop in 15 yrs	0	48	97	0	46	94	99	12	29	243
Stop in 10 yrs	0	66	98	0	62	96	92	16	50	307
Stop in 5 yrs	0	88	98	0	81	97	64	30	58	448
Stop immediately	0	112	98	0	105	99	29	48	67	624
Reforestation										
Stop in 10 yrs, reforest (1%)	0	77	98	0	76	96	69	26	58	440
Stop in 10 yrs, reforest (2%)	0	86	98	0	90	97	45	37	63	536
Stop in 10 yrs, reforest (3%)	0	97	98	0	107	97	26	56	69	642

but even with an annual logging rate of 1%, the probability of extinction is 100% in about 400 years (Fig. 4.25). Extinction of this population is inevitable in the face of unsustainable logging with no restoration of habitat.

Complete cessation of logging is more effective in promoting population persistence over the next few hundred years (Fig. 4.26). However, even an immediate and complete logging moratorium will be insufficient to ensure the survival of this small population (29% risk of extinction in 1000 years). The current habitat available in Sidiangkat is insufficient to allow this population to grow large enough to ensure long-term viability. Under the suggested reforestation scenario described earlier, logging would continue for another 10 years, resulting in a net loss of habitat despite reforestation efforts. Even a reforestation rate of 3% over years 11-30 would only bring the carrying capacity of this HU to 145 orangutans. The Sidiangkat orangutan population is not likely to be viable long-term without interventive management strategies to counteract demographic instability or genetic deterioration, such as habitat expansion or supplementation. It would be useful to investigate the possibility of connecting this population to the southeast portion of the West Leuser orangutan population, which may also be at risk due to a proposed road (see West Leuser Habitat Unit section). Immediate action to stop logging in this HU will be important in promoting the persistence of orangutans in this area for the next few hundred years.

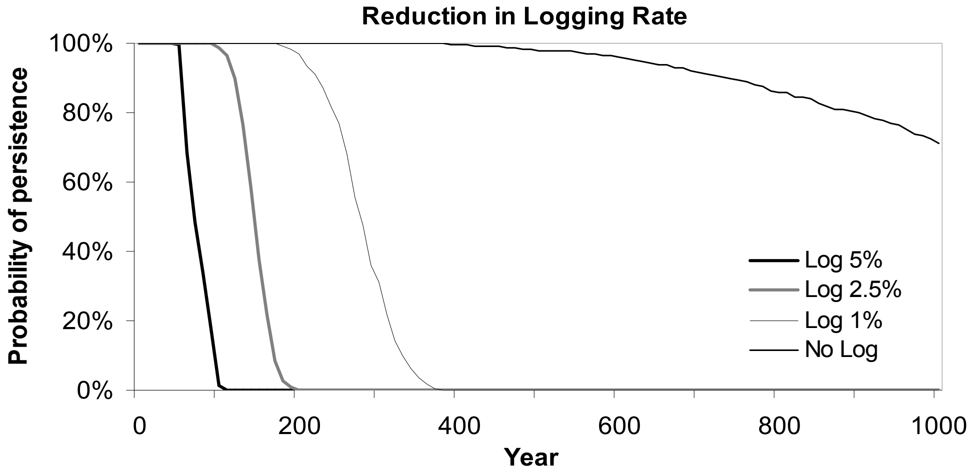


Figure 4.25. Probability of survival for the Sidiangkat orangutan population with annual logging rates of 5%, 2.5%, 1% and 0%.

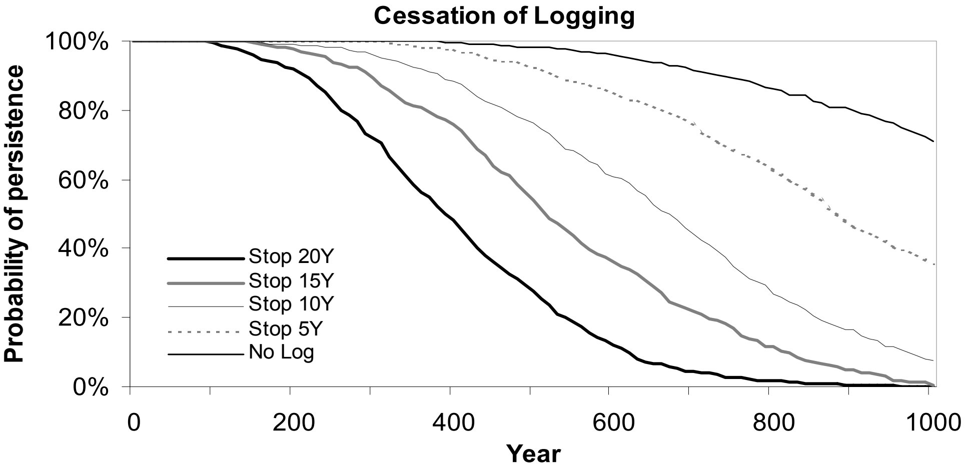


Figure 4.26. Probability of survival for the Sidiangkat orangutan population with cessation of logging at 20, 15, 10 and 5 years and immediately.

East Singkil Swamp Habitat Unit

Current Status

East Singkil Swamp Habitat Unit is a small area of orangutan habitat along the southern coast of Aceh province in northern Sumatra (Block 19) and is separated by a river from Trumon-Singkil Swamp HU (see Sumatran Habitat Unit and Sumatran Orangutan Distribution Maps). A section of the Ladia Galaska roads scheme runs through this area. The current orangutan population is estimated at 160 individuals and believed to be at ecological carrying capacity for the area, with little fragmentation of the population. The estimated level of logging in this area is 20% per year of the available orangutan habitat. Potential conservation strategies to improve population viability include prevention of additional logging, reduction or cessation of logging, and reforestation of logged areas to increase habitat. The removal of orangutans (e.g., hunting) is associated with logging and therefore was not modeled directly but in association with logging effects (see Baseline Model discussion).

The baseline model for the East Singkil orangutan population suggests that the population will undergo very rapid and steady decline due to habitat and population loss from logging. At an annual loss of 20%, the carrying capacity of the population will decrease by about 50% within 3 years and almost all habitat will disappear within about 20 years. Habitat restoration efforts will come too late (only 11% of habitat will remain after 10 years) unless logging can be reduced or stopped.

Effects of Conservation Action

Table 4.23 presents the model results for reduction or cessation of logging and habitat restoration. Continued logging at an annual rate of 20% will quickly result in population extinction in about

Table 4.23. ***Vortex*** **model results for the East Singkil orangutan population (PE = % probability of extinction; N = mean population size; GD = % of initial gene diversity).**

	50 Years			100 Years			1000 Years			Year at PE 5%
Logging Management	PE	N	GD	PE	N	GD	PE	N	GD	
Current (annual 20%)	**100**	**--**	**--**	**100**	**--**	**--**	**100**	**--**	**--**	**19**
Reduce Logging										
Reduce to annual 10%	98	2	73	100	--	--	100	--	--	37
Reduce to annual 5%	0	14	95	94	2	70	100	--	--	55
Reduce to annual 1%	0	101	99	0	59	97	100	--	--	221
Stop Logging										
Stop in 20 yrs	100	2	63	100	--	--	100	--	--	18
Stop in 15 yrs	68	3	74	95	3	65	100	--	--	27
Stop in 10 yrs	6	10	89	31	10	79	100	--	--	50
Stop in 5 yrs	0	34	96	1	36	93	100	--	--	172
Stop immediately	0	134	99	0	126	98	13	67	72	810
Reforestation										
Stop in 10 yrs, reforest (1%)	3	12	90	21	12	81	100	--	--	57

15-25 years due to continual population reduction and loss of habitat. Slowing the rate of habitat loss from 20% to 5% allows the population to persist a little longer, but even with a logging rate of only 1% the probability of eventual extinction is 100% about 400 years with no restoration of habitat (Fig. 4.27).

Complete cessation of logging is more effective in promoting population persistence, but only if it is accomplished quickly (Fig. 4.28). Logging must be stopped within 5 years to ensure that the population will survive for 70 years. An immediate halt to logging will maintain a population of moderate size and genetic diversity with no risk of extinction for about 200 years. However, even an immediate and complete logging moratorium will be insufficient to ensure the survival of this small population (13% risk of extinction in 1000 years). The current habitat available in East Singkil is insufficient to allow this population to grow large enough to ensure long-term viability. Reforestation (in which logging is stopped in 10 years, and habitat is increased at 1% annually during years 11-30) is not effective for securing long-term viability unless logging can be stopped immediately. The East Singkil orangutan population is not likely to be viable long-term without immediate action to control habitat loss along with interventive management strategies to counteract demographic instability or genetic deterioration, such as habitat expansion or supplementation. It would be useful to investigate the possibility of connecting this population to the larger Trumon-Singkil orangutan population, especially if logging could be controlled in both areas.

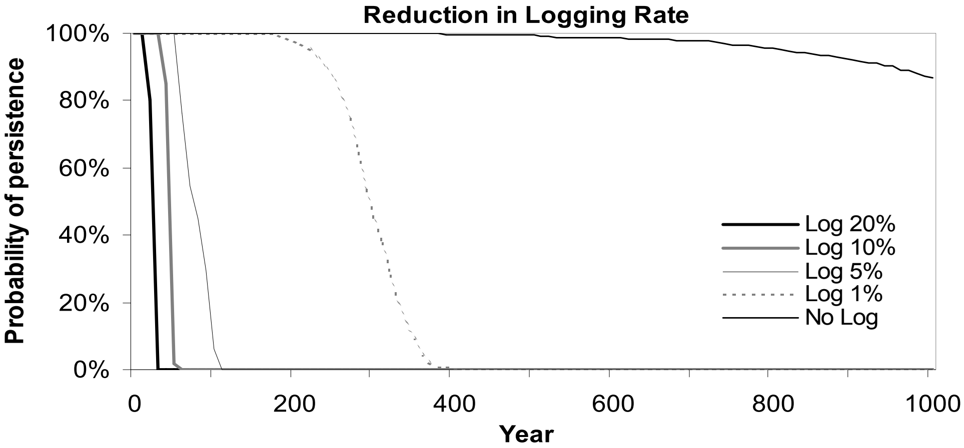


Figure 4.27. Probability of survival for the East Singkil orangutan population with annual logging rates of 20%, 10%, 5%, 1% and 0%.

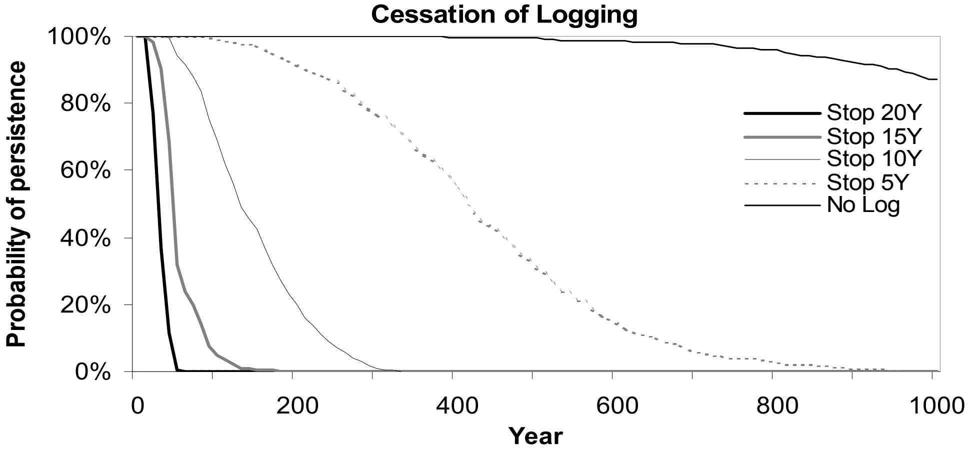


Figure 4.28. Probability of survival for the East Singkil orangutan population with cessation of logging at 20, 15, 10 and 5 years and immediately.

East Sarulla Habitat Unit

East Sarulla Habitat Unit is a small area of orangutan habitat in North Sumatra province south of Lake Toba (Block 21) and is separated from West Batang Toru HU by existing roads (see Sumatran Habitat Unit Map). The current orangutan population is estimated at 150 individuals and believed to be at ecological carrying capacity for the area. A small portion of the orangutan population falls within the Cagar Alam Dolok Sipirok Conservation Area. The estimated level of logging in this area is 20% per year of the available orangutan habitat. This orangutan population is approximately the same size as that in East Singkil HU and is subject to a similar rate of habitat loss, but the population distribution is more fragmented and therefore may be more vulnerable to extinction. Potential conservation strategies to improve population viability include prevention of additional logging, reduction or cessation of logging, and reforestation of logged areas to increase habitat. The removal of orangutans (e.g., hunting) is associated with logging and was not modeled directly but in association with logging effects (see Baseline Model discussion).

The baseline model for the East Sarulla orangutan population suggests that the population will undergo very rapid and steady decline due to habitat and population loss from logging. At an annual loss of 20%, the carrying capacity of the population will decrease by about 50% within 3 years and almost all habitats will disappear within about 20 years. Habitat restoration efforts will come too late (only 11% of habitat will remain after 10 years) unless logging can be reduced or stopped.

Effects of Conservation Action

Table 4.24 presents the model results for reduction or cessation of logging and habitat restoration. Continued logging at an annual rate of 20% will quickly result in population extinction in about

Table 4.24. ***Vortex*** **model results for the East Sarulla orangutan population (PE = % probability of extinction; N = mean population size; GD = % of initial gene diversity).**

	50 Years			100 Years			1000 Years			Year at PE 5%
Logging Management	PE	N	GD	PE	N	GD	PE	N	GD	
Current (annual 20%)	**100**	**--**	**--**	**100**	**--**	**--**	**100**	**--**	**--**	**18**
Reduce Logging										
Reduce to annual 10%	99	2	75	100	--	--	100	--	--	37
Reduce to annual 5%	0	14	95	98	2	69	100	--	--	55
Reduce to annual 1%	0	93	98	0	55	96	100	--	--	227
Stop Logging										
Stop in 20 yrs	100	2	63	100	--	--	100	--	--	18
Stop in 15 yrs	69	3	73	97	4	59	100	--	--	27
Stop in 10 yrs	8	9	88	37	9	77	100	--	--	49
Stop in 5 yrs	0	33	96	0	34	92	100	--	--	173
Stop immediately	0	128	99	0	120	98	22	58	72	706
Reforestation										
Stop in 10 yrs, reforest (1%)	5	11	89	23	11	80	100	--	--	49

15-25 years due to continual population reduction and loss of habitat. Slowing the rate of habitat loss from 20% to 5% allows the population to persist a little longer, but even with a logging rate of only 1% the probability of eventual extinction is 100% about 400 years with no restoration of habitat (Fig. 4.29).

Complete cessation of logging is more effective in promoting population persistence, but only if it is accomplished quickly (Fig. 4.30). Logging must be stopped within 5 years to ensure that the population will survive for 80 years. An immediate halt to logging will maintain a population of moderate size and genetic diversity with no risk of extinction for about 300 years. However, even an immediate and complete logging moratorium will be insufficient to ensure the survival of this small population (22% risk of extinction in 1000 years). Population fragmentation would further hasten extinction. The current habitat available in East Sarulla is insufficient to allow this population to grow large enough to ensure long-term viability. Reforestation (in which logging is stopped in 10 years, and habitat is increased at 1% annually during years 11-30) is not effective for securing long-term viability unless logging can be stopped immediately. The East Sarulla orangutan population is not likely to be viable long-term without immediate action to control habitat loss along with interventive management strategies to counteract demographic instability or genetic deterioration, such as habitat expansion or supplementation.

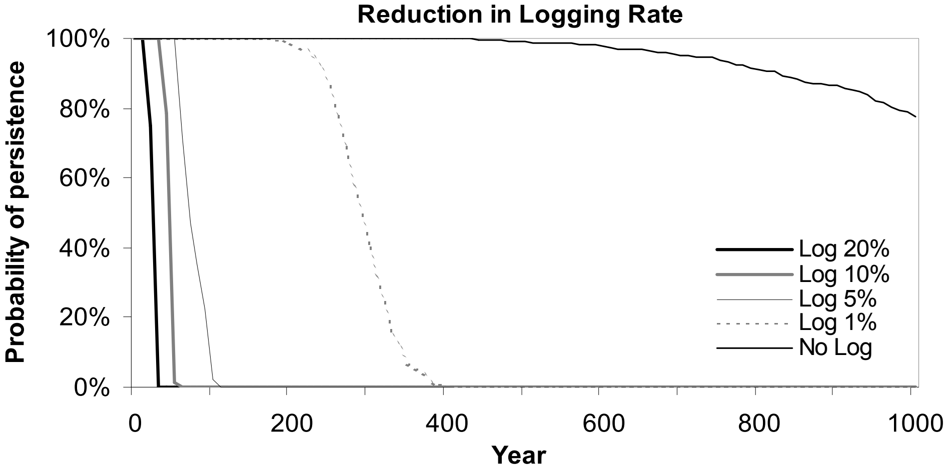


Figure 4.29. Probability of survival for the East Sarulla orangutan population with annual logging rates of 20%, 10%, 5%, 1% and 0%.

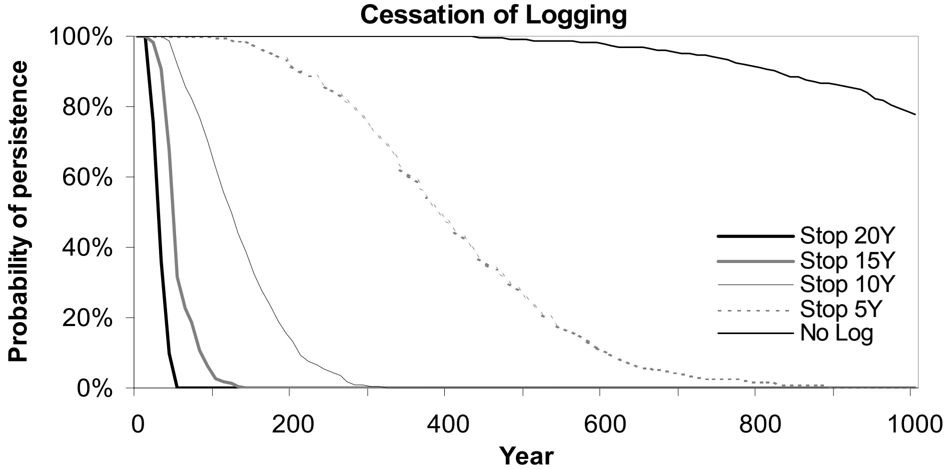


Figure 4.30. Probability of survival for the East Sarulla orangutan population with cessation of logging at 20, 15, 10 and 5 years and immediately.

West Batang Toru Habitat Unit

West Batang Toru Habitat Unit comprises an area of orangutan habitat in North Sumatra province south of Lake Toba (Block 20) and surrounded by existing roads, separating it from the East Sarulla HU (see Sumatran Habitat Unit Map). The current orangutan population is estimated at 400 individuals and believed to be at ecological carrying capacity with little fragmentation. A very small portion of the orangutan population falls within the Cagar Alam Dolok Sibual-buali Conservation Area. The estimated level of logging in this area is relatively low at 2% per year of the available orangutan habitat. Potential conservation strategies to improve population viability include prevention of additional logging, reduction or cessation of logging, and reforestation of logged areas to increase habitat. The removal of orangutans (e.g., hunting) is associated with logging and was not modeled directly but in association with logging effects (see Baseline Model discussion).

The baseline model for the West Batang Toru orangutan population suggests that the population will undergo a steady decline due to habitat and population loss from logging. At an annual loss of 2%, carrying capacity will decrease by about 50% within 35 years, and only 13% of habitat will remain after 100 years. This is a relatively slow rate of habitat loss when compared to most areas of orangutan habitat in Sumatra. The population is projected to persist for at least 159 years (at reduced population size and genetic variation), but faces 100% probability of extinction within 275 years. If the rate of habitat loss is higher than estimated or if habitat loss increases, then extinction will occur much sooner (in 55-125 years if logging is 5% annually).

Effects of Conservation Action

Table 4.25 presents the model results for reduction or cessation of logging and habitat restoration. Continued logging will ultimately result in population extinction due to continual

Table 4.25. *Vortex* model results for the West Batang Toru orangutan population (PE = % probability of extinction; N = mean population size; GD = % of initial gene diversity).

	50 Years			100 Years			1000 Years			Year at PE 5%
Logging Management	PE	N	GD	PE	N	GD	PE	N	GD	
Current (annual 2%)	**0**	**177**	**99**	**0**	**62**	**98**	**100**	**--**	**--**	**188**
Reduce Logging										
Reduce to annual 1%	0	256	99	0	151	99	100	--	--	313
Stop Logging										
Stop in 20 yrs	0	240	99	0	216	99	1	152	86	>1000
Stop in 15 yrs	0	264	99	0	240	99	0	177	87	>1000
Stop in 10 yrs	0	282	99	0	265	99	0	199	89	>1000
Stop in 5 yrs	0	309	99	0	291	99	0	233	90	>1000
Stop immediately	0	331	99	0	320	99	0	267	91	>1000
Reforestation										
Stop in 10yrs, reforest (1%)	0	321	99	0	322	99	0	262	91	>1000

population reduction and loss of habitat. Slowing the rate of habitat loss (from the current estimated rate of 2% per year) will delay population extinction, but even with an annual logging rate of 1%, the probability of extinction is 100% in about 500 years (Fig. 4.31). Extinction of this population is inevitable in the face of unsustainable logging with no restoration of habitat.

Complete cessation of logging is very effective in promoting population persistence. Because the current population is of moderate size and the logging rate is relatively low, an immediate halt to logging is not necessary to prevent population extinction (Fig. 4.32). The sooner habitat loss is controlled, the larger the resulting orangutan population will be and the greater its long-term viability. Based upon data estimates at this workshop, the West Batang Toru population is under less immediate threat than most orangutan populations on Sumatra. It will be important to control habitat loss in this area to promote the viability of this population in the future.

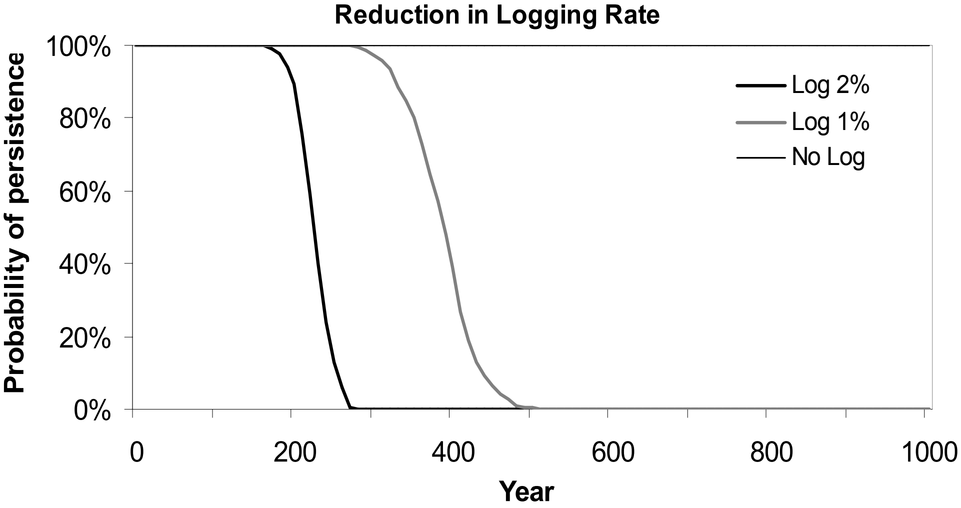


Figure 4.31. Probability of persistence for the West Batang Toru orangutan population with annual logging rates of 2%, 1% and 0%.

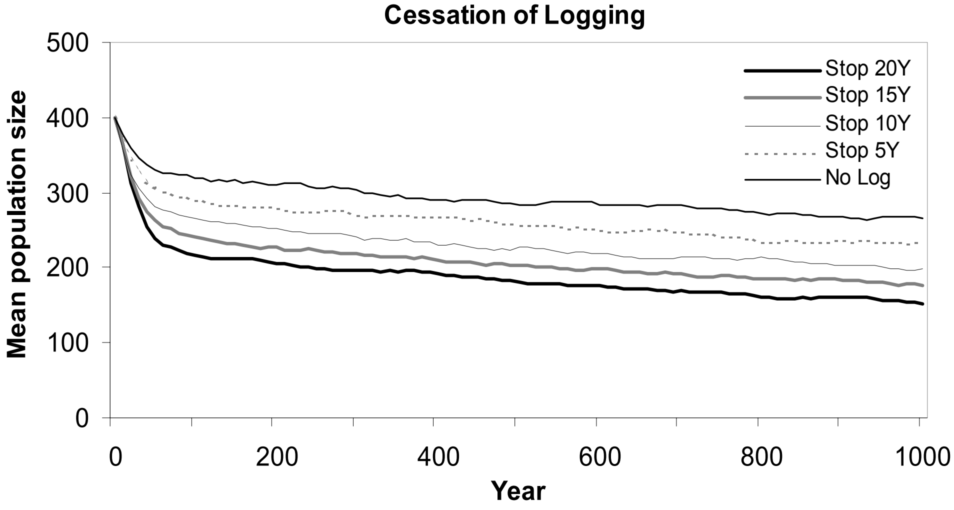


Figure 4.32. Mean population size of surviving West Batang Toru orangutan populations with cessation of logging at 20, 15, 10 and 5 years and immediately.

Summary of Model Projections for Orangutan Populations on Sumatra

Participants at this PHVA workshop used the most current field data and other expertise and resources to develop a baseline population model that appears to be a reasonable model for wild Sumatran orangutans. This model differs only slightly from that developed for Bornean orangutans, primarily in its reduced capacity for population growth (see *Modeling of Populations of Orangutans on Borneo Report*). These *Vortex* models are based upon our best estimates of orangutan biology and threats to orangutan populations and, unless otherwise indicated, assume that these conditions will remain constant over time. Because our understanding of orangutan dynamics may be incomplete, or because conditions are not likely to remain constant, it is difficult to produce accurate population projections over hundreds of years. However, these models can be useful in predicting population trends and evaluating the relative effectiveness of various conservation options. As more accurate information is gathered and management actions implemented, these results can be re-evaluated to promote effective conservation action.

With current estimated rates of logging and the associated removal of orangutans, model results indicate that habitat loss and other factors will cause Sumatran orangutan populations to decline quickly toward extinction. Sensitivity testing of the baseline model suggests that orangutan populations of about 250 have a high probability of survival in the absence of human-related mortality, habitat loss or unforeseen catastrophic events, but will be significantly reduced in size and genetic variation. Populations of 500 or more are more demographically and genetically stable and may contribute to the long-term conservation of this species. Smaller populations that are linked by occasional exchanges of animals could also contribute to the overall stability of a larger meta-population but are not likely to persist long-term in isolation. Logging decreases viability, and high logging rates of 10-20% annually quickly drive even large populations to extinction.

Of the 13 identified orangutan populations on Sumatra, only 7 are estimated to contain 250 or more individuals. Of these 7 populations, 6 are believed to be subject to 10-15% annual habitat loss due to logging and are expected to decline quickly. This includes the largest Sumatran orangutan populations, which are found in West and East Leuser and in Singkil; these populations are projected to decline dramatically within the next few years due to high rates of illegal logging and are at risk of rapid extinction if habitat loss is not checked. Only the West Batang Toru population contains at least 250 orangutans and is experiencing a relatively low rate of habitat loss (2% annually). It is therefore likely that this population may persist longer than other populations if current conditions continue, but it will also eventually go extinct.

Vortex model results suggest that Sumatran orangutans will disappear outside of West Batang Toru sometime between 50 and 100 years from now (Fig. 4.33). The West Batang Toru population is likely to persist for at least 150 years under current conditions, but will disappear within 275 years. Thus, the model results indicate that all wild Sumatran orangutan populations may disappear within 275 years, failing to meet the Sumatran Orangutan Working Group's goal of zero risk of extinction of wild Sumatran orangutans within 1000 years.

Even though orangutans are expected to persist outside of West Batang Toru for at least 50 years under current logging conditions, the number of orangutans on Sumatra is expected to decline

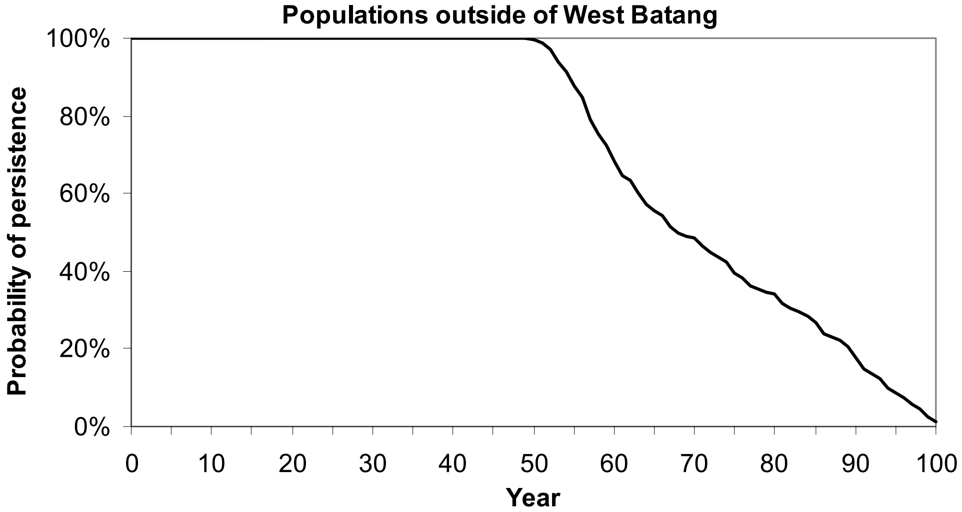


Figure 4.33. Probability of persistence of any Sumatran orangutan populations outside of West Batang Toru under current conditions over the next 100 years.

sharply during that time (Fig. 4.34). By year 50 only 7 of the current 13 orangutan populations are expected to remain; 6 of these will consist of fewer than 20 individuals, while West Batang Toru may retain about 177 orangutans, for a total mean projected population of 234 (a decline of 97% of wild Sumatran orangutan populations). These model results assume no increase in habitat loss. It is possible, however, that the construction of roads such as the proposed Ladis Galaska system may lead to increased logging and habitat erosion, resulting in additional reductions in orangutan populations and habitat carrying capacity. Increased habitat loss and/or removal of orangutans would hasten the decline and extinction of wild orangutan populations. In contrast, if logging and removal of orangutans could be halted today, the number of orangutans expected to remain in 50 years would be about 6570.

It is unlikely that logging could be eliminated immediately in Sumatra. A more realistic timeline might be to prevent logging rates from increasing and to end all logging within 5 years. Projections under this management scenario suggest that about 2758 orangutans would still remain after 1000 years (Fig. 4.35), probably in 5-9 different populations. Although a delay of 5 years in ending logging might not result in species extinction, it could lead to over a 50% reduction in the number of orangutans that can be maintained in Sumatra under the conditions modeled. Therefore, quick action to reduce and stop logging can have long-term implications for orangutan populations.

These projections assume that there is no removal of orangutans (e.g., hunting) in the absence of logging. The slow growth rate of this population under optimal environmental conditions indicates that Sumatran orangutans cannot withstand a rate of removal above 1% annually, even with no loss of habitat. Therefore it is important to control any hunting that occurs, particularly in the absence of logging (also see *Modeling of Populations of Orangutans on Borneo Report*).

Efforts to reduce fragmentation and link orangutan populations to form meta-populations may contribute to the viability of Sumatran orangutans. Ultimately, however, continued habitat loss and removal of individuals associated with logging will drive this species close to extinction within a few decades. To counteract this threat, efforts need to be made to reduce high levels of logging and ultimately to stop further loss of habitat and carrying capacity through cessation of

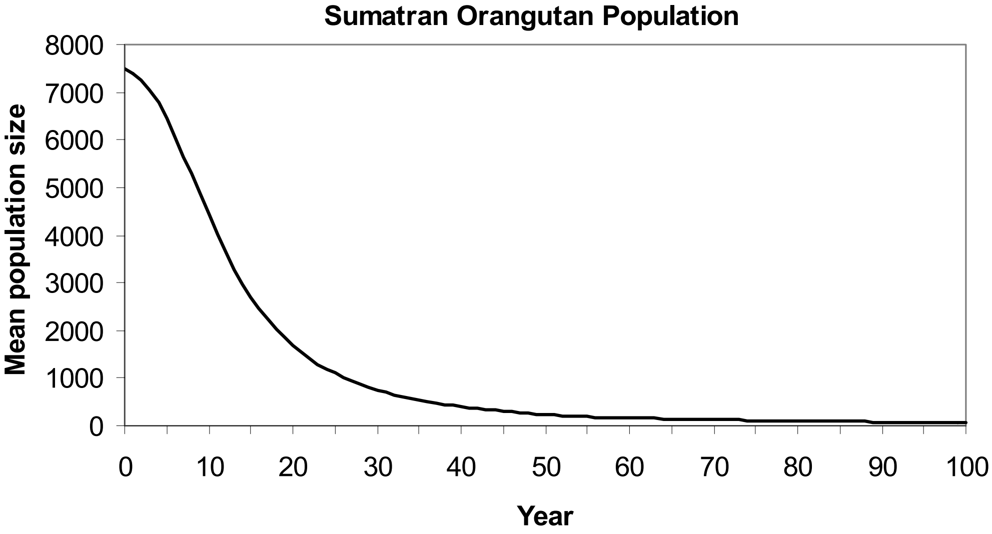


Figure 4.34. Mean population size of all surviving orangutan populations in all 13 habitat units in Sumatra over the next 100 years under current rates of logging.

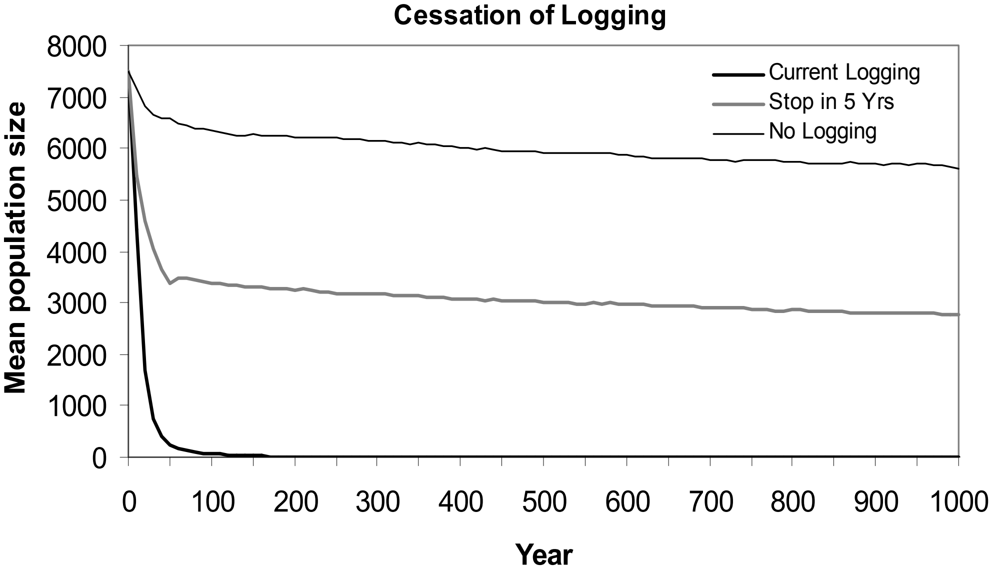


Figure 4.35. Mean population size of all surviving orangutan populations in all 13 habitat units in Sumatra over the next 1000 years under current rates of logging and with logging stopped in 5 years.

logging and/or habitat restoration. The urgency for action varies among the habitat units and is dependent upon the current rate of logging and size of the orangutan population; for some habitat units, the need for action is immediate if orangutans are to persist. Fragmentation due to the presence of roads or other factors exacerbates the urgency for such conservation action.

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Figure 4.36

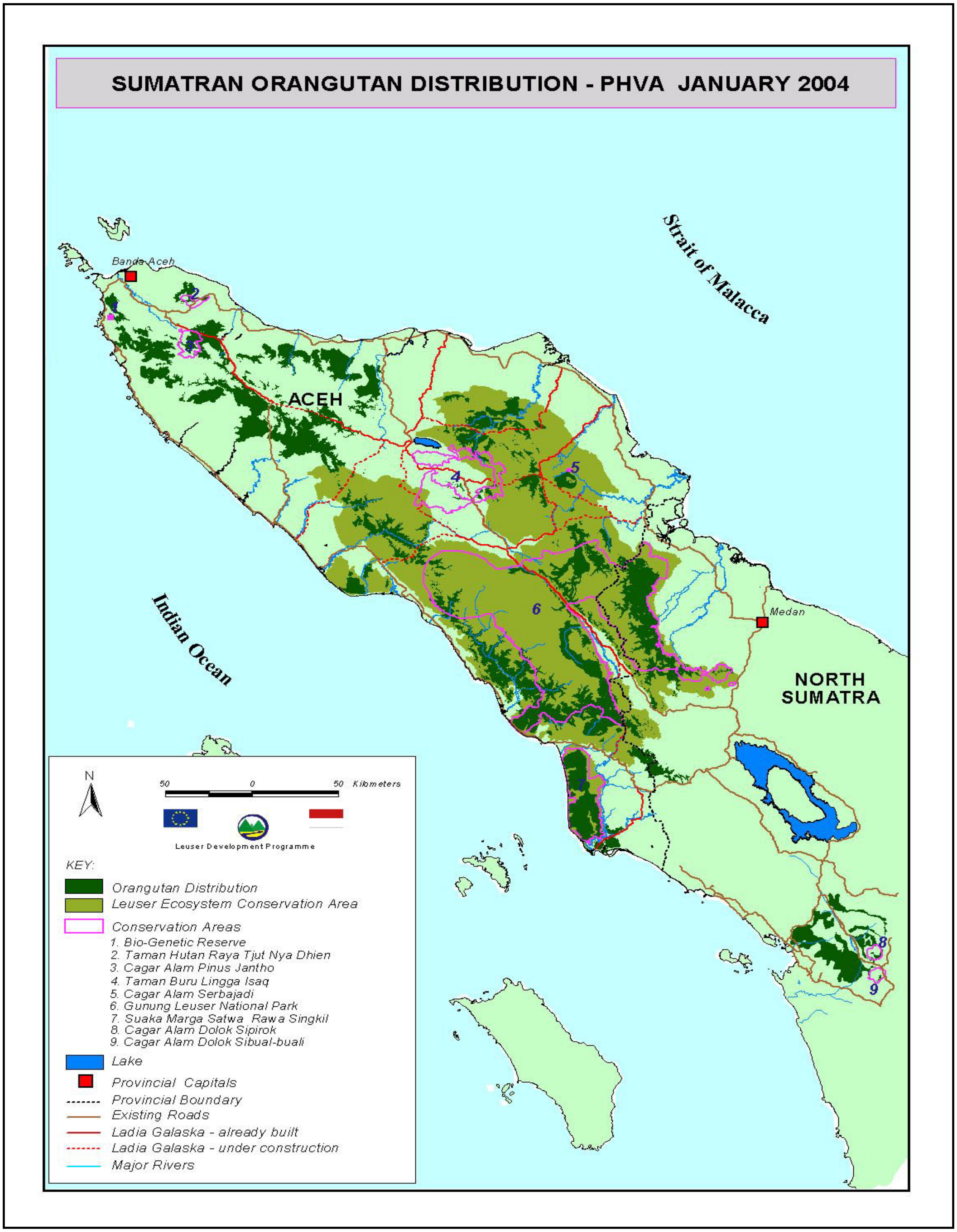
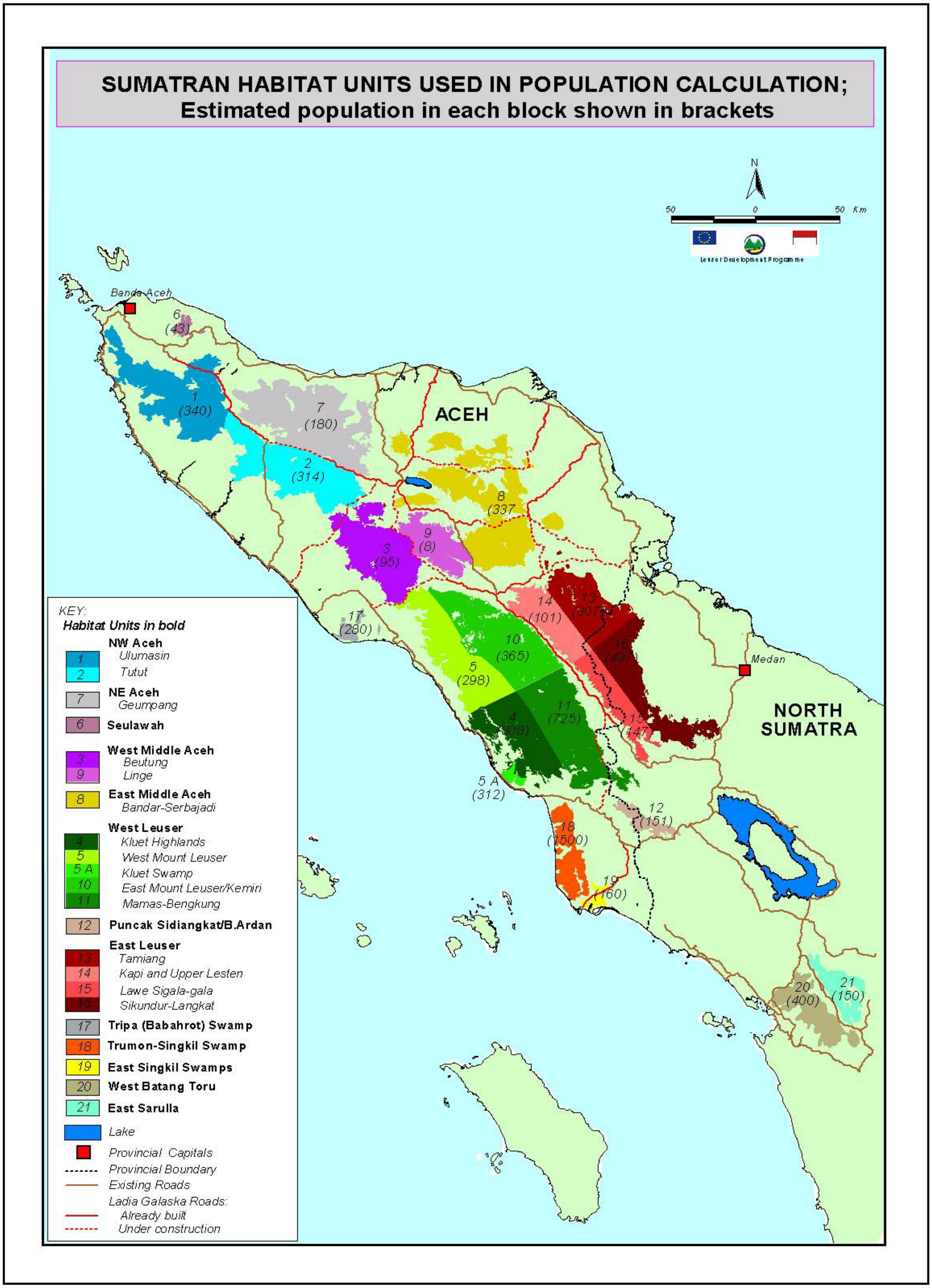
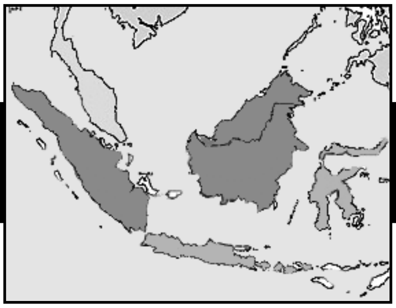

SUMATRAN ORANGUTAN DISTRIBUTION - PHVA JANUARY 2004
Banda Aceh
ACEH
Strait of Malacca
Indian Ocean
Medan
NORTH SUMATRA
1
2
3
4
5
6
7
8
9
N
50
0
50
Kilometers
Leuser Development Programme
KEY:
Orangutan Distribution
Leuser Ecosystem Conservation Area
Conservation Areas
1. Bio-Genetic Reserve
2. Taman Hutan Raya Tjut Nya Dhien
3. Cagar Alam Pinus Jantho
4. Taman Buru Lingga Isaq
5. Cagar Alam Serbajadi
6. Gunung Leuser National Park
7. Suaka Marga Satwa Rawa Singkil
8. Cagar Alam Dolok Sipirok
9. Cagar Alam Dolok Sibual-buali
Lake
Provincial Capitals
Provincial Boundary
Existing Roads
Ladia Galaska - already built
Ladia Galaska - under construction
Major Rivers

Figure 4.37


SUMATRAN HABITAT UNITS USED IN POPULATION CALCULATION;
Estimated population in each block shown in brackets
N
50
0
50 Km
Leuser Development Programme
Banda Aceh
ACEH
Medan
NORTH SUMATRA
1 (340)
2 (314)
3 (95)
4 (808)
5 (298)
5 A (312)
6 (43)
7 (180)
8 (337)
9 (8)
10 (365)
11 (725)
12 (151)
13 (307)
14 (101)
15 (147)
16 (497)
17 (280)
18 (1500)
19 (160)
20 (400)
21 (150)
KEY:
Habitat Units in bold
NW Aceh
1 Ulumasin
2 Tutut
NE Aceh
7 Geumpang
6 Seulawah
West Middle Aceh
3 Beutung
9 Linge
East Middle Aceh
8 Bandar-Serbajadi
West Leuser
4 Kluet Highlands
5 West Mount Leuser
5 A Kluet Swamp
10 East Mount Leuser/Kemiri
11 Mamas-Bengkung
12 Puncak Sidiangkat/B.Ardan
East Leuser
13 Tamiang
14 Kapi and Upper Lesten
15 Lawe Sigala-gala
16 Sikundur-Langkat
17 Tripa (Babahrot) Swamp
18 Trumon-Singkil Swamp
19 East Singkil Swamps
20 West Batang Toru
21 East Sarulla
Lake
Provincial Capitals
Provincial Boundary
Existing Roads
Ladia Galaska Roads:
Already built
Under construction

FINAL REPORT



ORANGUTAN

Population and Habitat Viability Assessment

15-18 January 2004
Jakarta, Indonesia

Section 5

BORNEAN ORANGUTAN WORKING GROUP

Bornean Orangutan (*Pongo pygmaeus*) Working Group Report

REGIONAL/SUBSPECIES WORKING GROUP REPORTS

After the Borneo Working Group decided upon the baseline values of parameters for the models, the working group broke up into 4 regional groups: West Kalimantan and Sarawak (*Pongo pygmaeus pygmaeus* and some populations of *P. pygmaeus wurmbii*), Central Kalimantan (*P. pygmaeus wurmbii*), East Kalimantan (*P. pygmaeus morio*), and Sabah (*P. pygmaeus morio*). Each group created a list of major orangutan habitat units where orangutans are known to still occur in their geographical regions. The overall goals for selecting and ranking orangutan habitat units were chosen and are described below.

1. There must be representatives of each subspecies and representatives from each province in the next 1000 years (i.e. sites within subspecies are prioritized, not between subspecies, acknowledging that each subspecies is of equal priority for conservation).
2. Present populations and distributions must be maintained into the future; that is, sites must be selected and prioritized to:
    - Ensure orangutans are no longer threatened by industrial and regional development activities (i.e. the current status of protected areas must be maintained to avoid development).
    - Secure the orangutan population and maintain the good quality of their habitat in Borneo.
    - Maintain the legal status of conservation areas and protect them from degradation.
    - Establish and/or maintain corridors connecting important orangutan habitat units (e.g., Gunung Gajah & Kutai).
    - It was also suggested that conservation focus be maintained on the broad goals rather than the specific methods for achieving them.

The criteria for ranking Bornean orangutan habitat units are borrowed from the Sumatra Working Group and are as follows:

Criteria for prioritizing sites:

1. Ability to sustain a viable population
    (a.) Orangutan population size
    (b.) Degree of threat
    (c.) Size of habitat unit
    (d.) Legal status of site - protected vs. non-protected
2. Uniqueness (e.g., habitat type, habitat quality, overall biodiversity value, orangutan culture, etc.)
3. Stakeholder diversity

Table 5.1. Orangutan habitat units initially assessed for Borneo.

East Kalimantan
Taman Nasional Kutai
Berau & Sungai Lesan (excluding Gunung Gajah Forestry Concession)
Gunung Gajah Forestry Concession
Kutai Timur N.P.
Sangatta – Bengalon & Muara Wahau
Samarinda, Muara Badak, Marang Kayu
NW Sangkulirang
Meratus (ex-captive population)
Sungai Wain (ex-captive population)
Central Kalimantan
Tanjung Puting
Bukit Raya
Mawas
Sebangau-Katingan swamps
Sebangau-Kahayan swamps
Katingan-Sampit swamps
Rungan-Kahayan swamps
Kahayan-Kapuas swamps
Kahayan-Barito uplands
Samba-Kahayan uplands
Samba-Katingan uplands
Seryuan uplands
Arut- Belantikan
Lamandau Suaka Margasatwa (mixed ex-captive and wild population)
Pararawen Cagar Alam
Cagar Alam B.Spt
Tanjung Keluang
Kemujan
Bukit Sapak Haung
Nyaru Menteng Arboretum
West Kalimantan & Sarawak
Gunung Palung
Betung Kerihun
Gunung Nyiut
Bukit Baka
Kendawangan Cagar Alam
Hutan Lindung Gunung Tarak
Danau Sentarum
Batang Ai NP
Lanjak-Entimau
Bukit Rongga and Perai
Sabah
Tabin
Sabah Foundation forests
Trus Madi forests
Kulamba
Upper (N) Kinabatangan
Lower Kinabatangan
Ulu Tungud F.R.
Kinabalu N.P.
Silabukan P.F.
Lingkabau F.R.

Bonggaya F.R.	
Sepilok P.F. (ex-captive population)	

F.R. = Forest reserve (exploited)
N.P. = National Park
P.F. = Protected Forest

After some discussion, the lists of candidate sites for consideration as major Habitat Units in each sub-region was narrowed down by combining a few areas that were likely contiguous and by eliminating those that were thought to hold relatively fewer orangutans. The data tallied for these reduced lists are provided below.

West Kalimantan & Sarawak Report

Each orangutan habitat unit was described in terms of estimated population size and habitat size. The level of threat, mortality rate, and uniqueness were ranked on a low (3) to high (1) scale. A total score was then calculated. The following table provides a summary of criteria and priorities:

Table 5.2. Orangutan habitat unit descriptions and ranking.

Location	Population size	Habitat size (Ha)	Rank of threats	Mortality	Uniqueness	Total	Uniqueness description
Gunung Palung	2500	90,000	High	Medium	High	1.6	8 types of habitat, high biodiversity
Betung Kerihun	1330-2000	450,000	Medium	Medium	High	1.6	6 types of habitat, Transboundary conservation area with Batang Ai and Lanjak Entimau
Batang Ai	119-580	24,050	Low	Low	High	2.6	4 types of habitat, Transboundary conservation area with Betung Kerihun and Lanjak Entimau
Lanjak Entimau	1024-1181	168,768	Low	Low	High	2.2	6 types of habitats, Transboundary conservation area with Betung Kerihun and Batang Ai, high biodiversity
Danau Sentarum	500-1000	109,000-190,000	High	Medium	Medium	2.2	4 habitat types
Bukit Baka	175	35,000	Low	Low	Low	3	Hill forest
Bukit Rongga & Parai	1000	420,000	High	Medium	Medium	1.6	More information needed; Potentially contiguous with Arut-Belantikan block in Central Kalimantan

The West Kalimantan & Sarawak working group created a work plan for proposed conservation activities.

Table 5.3. Preliminary work plan and budget for proposed activities in West Kalimantan.

No.	Activity	Who	Month												Budget in USD, 12 mo.
			1	2	3	4	5	6	7	8	9	10	11	12	
1	**Fundraising**														
1.1	Extensive fundraising for orangutan conservation	Donor (BOSF, WWF, CI, WCS, FFI, OFI, GrASP, GAWHSP, etc)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	
2	**Law enforcement/Capacity building**														
2.1	Encourage government to support conservation programs	NGOs (WWF, Titian, Riak Bumi, Baramega,GPOCP,etc)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨			5,000
2.2	Training for raising the ability and understanding of law enforcement personnel in conservation (police, forestry police, judges)	NGOs (WWF, FFI TRAFFIC, Titian, Riak Bumi, Baramega,GPOCP,etc); Balai TN; local univ.			▨	▨									15,000
2.3	Training for community to strengthen and manage natural resources				▨	▨									15,000
2.4	Develop community-based patrol units	Forestry police, police, community			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	50,000
3	**Awareness and Campaign**														
3.1	Conduct regular promotions, campaigns, and education of orangutan conservation in West Kalimantan	NGOs (WWF, Titian, Riak Bumi, Baramega,GPOCP,etc); Balai TN			▨	▨	▨	▨	▨	▨	▨	▨			20,000

No.	Activity	Who	Month												Budget in USD, 12 mo.
			1	2	3	4	5	6	7	8	9	10	11	12	
4	**Research**														
4.1	Rapid assessment on status of population and distribution of Orangutan in Betung Kerihun Nat'l Park, Danau Sentarum Nat'l Park	NGOs (WWF, Titian, Riak Bumi, Baramega,etc); Balai TN; Research			▨	▨	▨	▨	▨	▨	▨	▨			20,000
4.2	Assessment of possible new site for Orangutan populations	NGOs (WWF, Titian, Riak Bumi, Baramega,GPOCP,etc); Balai TN; Research			▨										10,000
4.3	Attitude survey for communities				▨	▨									10,000
4.4	Long term study in habitat units that have already been identified	NGOs (WWF, Titian, Riak Bumi, Baramega,GPOCP,etc); Balai TN; Research			▨	▨	▨	▨	▨	▨	▨	▨			20,000
5	**Habitat Management**														
5.1	Assessment of possibility to develop corridor sites	Balai TN, Research, Local people			▨	▨	▨	▨							10,000
5.2	Habitat rehabilitation and enrichment with local orangutan food items	NGOs (WWF, Titian, Riak Bumi, Baramega,GPOCP,etc); Balai TN; Academics; Local people; conservation scientists			▨	▨	▨	▨	▨	▨	▨	▨			30,000

No.	Activity	Who	Month												Budget in USD, 12 mo.
			1	2	3	4	5	6	7	8	9	10	11	12	
5.3	Monitoring of habitat and orangutan populations	Researchers; NGOs (WWF, FFI, Titian, Riak Bumi, Baramega,GPOCP,etc); Balai TN; Local people						▨	▨						10,000
6	**Community development**														
6.1	Assessment of potential commodities for alternative income				▨	▨									
6.2	Alternative income based on non-timber forest products	Training agencies, Balai TN; NGOs (WWF, Titian, Riak Bumi, Baramega, GPOCP, etc.)			▨	▨	▨	▨	▨	▨	▨	▨			10,000
7	**Report**														
7.1	Report Writing												▨	▨	20,000
	Total budget for 1 habitat unit														**240,000**
	If there are 5 habitat units: 5x240.000 = **1.200.000**														

Central Kalimantan Report

The Central Kalimantan group stressed the importance of the province as the region with the largest populations of wild Bornean orangutans in the world. Five areas of equal importance were chosen for priority conservation action in no particular order: Tanjung Puting National Park, Sebangau, Mawas, Arut-Belantikan and Sambah-Kahahyan with the emphasis on the fact that all these areas were of the highest priority and represented both lowland forest and peat swamp habitats on one hand and hilly, mountainous terrain on the other. The most strenuous effort must be made to save all of these Habitat Units. The second group of priority areas include (in no particular order): Katingan-Sampit swamps, Seruyan, Lamandau, Bukit Raya National Park, Sapat Hawang, Rungan-Kahayan swamps.

The Central Kalimantan group identified specific recommendations for the region (Table 5.4).

Table 5.4. General recommended actions for Central Kalimantan habitat units, agencies that currently do or could potentially take action, when the action needs to occur, and the estimated amount of funds necessary to support the action.

Recommendations	**Who**	**When**	**Amount of funds needed**
Influence government to *support* conservation programs	OFI, BOS, WWF	ASAP	$10,000/year/habitat unit
Training to increase willingness of law enforcement agencies to *enforce* conservation-related *laws*	BKSDA, NGO, Institusi pendidikan	ASAP	$10,000/year/habitat unit
Implement laws in the field (including patrols)	Government agencies	routine	$20,000/year/site
Awareness & education	Yayorin, OFI, BOS, FNPF (Friends of National Park Foundation), WWF, OuTrop, CIMTROP	ASAP & routine	
Capacity building	OFI, BOS, FNPF	ASAP	
Long term research at established sites	OFI, BOS, OuTrop, CIMTROP	ASAP	
Search for potential sites that can be established by local students	Yayorin, OFI, BOS	ASAP	
Surveys in new sites	OFI, BOS, OuTrop, Yayorin	ASAP	
Socioeconomic research	OFI, BOS, FNPF, CIMTROP, WWF	ASAP	
Wildlife corridors	OFI, BOS	ASAP	
Zoning (land use plans)	OFI, BOS, WWF	ASAP	
Monitoring	OFI, BOS, FNPF, OuTrop	ASAP	
Rehabilitation of land	OFI, BOS, FNPF, CIMTROP	ASAP	
Damming of canals in peat swamp forest habitat	OuTrop, CIMTROP, BOS, WWF	ASAP	
Elevate status of priority habitat units (Mawas, Sebangau, Arut Belantikan, Samba Kahayan) to protected status	OFI, BOS, Yayorin, OUTrop, WWF	ASAP	
Develop alternative income sources for local communities	OFI, BOS, FNPF, WWF	ASAP	
Capacity building for local community	OFI, BOS, FNPF, Yayorin	ASAP	

ASAP: This is contingent upon when funds are available.

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Table 5.5. Major orangutan habitat units and habitat descriptions, used in the initial prioritization of units.

Site	Orangutan pop. size	Threat	Area (ha)	Protected Status	Uniqueness	Habitat quality	Stakeholder Diversity
Bukit Raya	-500	Low	-	P	Monument forest	High	High (5+)
Nyaru Menteng Arboretum	6	Low	65.2	P	Arboretum	High	5+
Tanjung Keluang	200	Medium	2,000	P	3 Ecosystems	Medium	2+, NGOs, Local government
Kahayan Kapuas	300	High	400,000	NP		Low	
Katingan-Samba	<500	High	100,000	NP	Monument forest	Medium	
Cagar Alam Pararaum	>500	Low	50,000	P	Monument forest	High	2+, NGOs, Local government
Cagar Alam B.Spt	>500	Low	>200,000	P	Monument forest	High	2+, NGOs, Local government
Sebangau Kahayan	700	High	70,000	NP	12 fragments	Low	
Rungan Kahayan	1000	High	200,000	NP	Deep Peat	Medium	Low (-)
Seruyan	1000	High	300,000	NP	Monument forest	Low	
Samba-Kahayan	1000	High	150,000	NP	Monument forest	Medium	
Lamandau	1200	High	76,010	P	6 Ecosystems	High	High (5+)
Katingan-Sampit	3000	High	280,000	NP	Mangrove & Deep Peat	Medium	Low (-)
Mawas	3500	High	501,082	Proposed	Deep Peat	Medium	High (5+)
TNTP	6000	High	415,040	P	6 Ecosystems	High	High (5 +)
Arut Belantikan	6000	High	510,000	NP	Monument forest	Medium	Low (2+, Local community, NGOs)
Sebangau	6900	High	578,000	Proposed	Deep Peat	Medium	High (4+)

Protected status: P = Protected, NP = No protection

Priority habitat unit groups

1. Tanjung Puting National Park, Sebangau, Mawas, Arut Belantikan, Samba Kahayan
2. Katingan-Sampit, Seruyan, Lamandau, Bukit Raya, Sapat Hawung, Rungan- Kahayan

Table 5.6. Values to be used in Vortex modeling and assessments of threats for each of the five highest priority habitat units.

				Catastrophe								Management		
	Current N	Mort.	Trends in K	Fire	Disease		Breakdown of law enforcemt	Landslide	El Nino food short	Land Conv./ Encroach.	Hunting	Drainage Prevention	Law Enforcement	Education
Tanjung Puting Natl. Park	6000	Low	stable	HIGH	Yes		Yes (test with no law enforcement)		Low		low		decrease mortality	reduce hunting
Mawas Blok E2	2000	Low	stable	VERY HIGH	yes				Low		low	Fire catastrophe reduced	decrease mortality	reduce hunting
Mawas Blok E1a	545	Mid	stable	VERY HIGH	Yes				Low		low	Fire catastrophe reduced	decrease mortality	reduce hunting
Mawas Blok E1b	260	Mid	stable	VERY HIGH	Yes				Low		low	Fire catastrophe reduced	decrease mortality	reduce hunting
Mawas Blok E1c	175	Mid	stable	VERY HIGH	Yes				Low		low	Fire catastrophe reduced	decrease mortality	reduce hunting
Mawas Blok AB	400	Mid	slight de-crease	VERY HIGH	Yes - HIGH				Low		low	Fire catastrophe reduced	decrease mortality	reduce hunting
Sebangau	6900	Mid	stable	VERY HIGH	Yes				Low		low	Fire catastrophe reduced	decrease mortality	reduce hunting
Arut Belantikan	6000	Mid	De-crease	no	Yes			yes	Yes	high	medium		decrease mortality	reduce hunting
Samba-Kahayan	1000	High	De-crease	no	yes-HIGH			yes	Yes	high	High		decrease mortality	reduce hunting

Table 5.7 Management recommendations for the 5 main habitat units.

Site	Management Action
Mawas	• Damming • Rehabilitation • Law enforcement • Community awareness and education • Habitat monitoring
Sebangau	• Damming canals (HIGH PRIORITY to save ecosystem) • Creation of alternative income streams • Other activities – law enforcement, community awareness and education, habitat monitoring to follow damming
Arut-Belantikan	• Protect area • Status change • Community awareness and education • Promote sustainable forest practice and management of the area for orangutans
Samba-Kahayan	• Promote sustainable forest practice and management of the area for orangutans
Seruyan	• Promote sustainable forest practice and management of the area for orangutans
Taman Nasional Tanjung Puting	• Continue law enforcement – upgrade to entire park • Community awareness and education • Enlargement of park to the East • Rehabilitation of habitat

East Kalimantan Report

An initial attempt was made to roughly rank the priority of habitat units. However, few group members were present at the time so this ranking may be biased and should be considered preliminary. Due to the small number of sites that have high numbers of orangutans, we chose population size as our main criteria. For smaller populations we chose size and uniqueness (such as corridor capability) as factors.

Table 5.8. Preliminary priority ranking of East Kalimantan habitat units

Rank	**Habitat unit**	**Criteria for Site Choice**						
		Orangutan Pop Size	**Threat level**	**Size of habitat unit (ha)**	**Protected status**	**Uniqueness**	**Stakeholder diversity**	**Notes**
1	Kutai National Park	600	High	198,629	yes	5 vegetation types, high biodiversity even after fire, important case study for fire effects, 350 spp birds burung, (old estimate), 200 spp (new estimate), 5 spp hornbill, small limestone formation, many large ulin trees	Nat. local groups, e.g. Forestry Dep, local gov't, KPC, Gas (LNG)	
3	Berau & Sungai Lesan (excluding Gunung Gajah)	400	High		None in Sungai Lesan	High biodiversity – sun bear, pangolin. Very good forest, uncut. Local use of fruit & honey trees, rattan collection. Traditionally owned forest. *4.6 orangutan/km^2. May be a primate hotspot per Meijaard & Nijman.	Local people, The Nature Conservancy, local gov't, Mulawarman Uni.	Estimates based on TNC surveys conducted during 2004 in eastern portion of site (good condition). Western portion is primarily secondary forest.
2	Gunung Gajah	1500	Med	140,000	No	High biodiversity (sun bear, 10+ spp of primates = hotspot). Large tracts of lowland forest. Minimal hunting impact. Little fire damage.	TNC, HPH, Berau & Kutai Timur government.	Estimates based on seven TNC surveys conducted from December 2001 to 2004.

Rank	Habitat unit	Criteria for Site Choice						
		Orangutan Pop Size	**Threat level**	**Size of habitat unit (ha)**	**Protected vs. non-protected legal status**	**Uniqueness**	**Stakeholder diversity**	**Notes**
3	Kutai Timur	980	High	?	Partly protected (i.e. Gunung Beliung)	Suzuki survey data 1997. Report to gov't in 1998. Limestone forest. Unique fauna and flora.	Japan Orangutan Research Committee. Gunung Beliung.	Gunung Beliung has been proposed as a protected area.

Rank	Habitat unit	Criteria for Site Choice						
		Orangutan Pop Size	Threat level	Size of habitat unit (ha)	Protected vs. non-protected legal status	Uniqueness	Stakeholder diversity	Notes
5	Sangatta – Bengalon & Muara Wahau	175	High		No	Fragmented. Fairly uniform lowland dipterocarp forest. Poor habitat quality. Low biodiversity. Important corridor linking Kutai with Gunung Gajah and Sangkulirang.	Almost all is owned by KPC (coal company). Lots of illegal loggers, transmigrants. Forestry concession.	
6	Samarinda, Muara Badak, Marang Kayu	200	High	300+	No	Mangrove already ruined, poor forests, don't know biodiversity, burned in 1998, 200 spp of birds. Highly fragmented.	300 ha teaching forest, shrimp farming, Muara Badak is a big town (big human pop), lots of Bugis and other people of mixed origins	
4	Sangkulirang	160			No	Corridor between Kutai National Park and Berau. Third largest karst formation in the world. Lots of unique species (yet to be discovered). High invertebrate diversity. High endemism.	Birds nest collectors, HPH, transmigrants, cement companies.	
	Meratus**	300		28,000			Logging concessions, illegal loggers, few small villages, BOS	Active illegal logging inside protected forest boundaries by 03/2004
	Sungai Wain**	20		4000	Yes	Important watershed providing clean water for industry and the city of Balikpapan	BOS, City of Balikpapan, Pertamina	Ecotourism has been started in the forest and already affects reintroduced orangutans

*This estimate should be noted with caution because it is based on surveys that were conducted in only one portion of this area and during a short period of time. This estimate may be a result of temporarily high densities in this one area.

**These are release sites for rehabilitated orangutans.

Table 5.9. Meratus work plan (This, and the following preliminary workplans, describe actions working group members feel are needed at these particular sites. Workplans such as these provide conservation planners with an idea of what type of resources and which stakeholders could be utilized to implement recommendations and improve habitat and species onservation.)

Threats	Recommendation	Who	When	Where	Results desired	Time frame
Illegal logging						
1. Habitat degradation	monitor boundary/access	BOS-W, SarVision	ASAP, monthly	Hutan Lindung Meratus (Meratus Protected Forest, HLM) boundary, roads, rivers	1. Regular report 2. Corrective action 3. Capacity building	6 mo & 1 yr review
	mark boundary	BOS-W/KSDA	ASAP	HLM boundary, access points	1. Clear demarcation 2. Impede logging	3 mo
	close/control roads	BOS-W/ITCI (International Timber Corporation Indonesia, now ITCI Kartika Utama)	ASAP	access, across forest	1. Impede logging 2. Better reporting	6 mo & 1 yr review
	mark/monitor ULIN	BOS-W/KSDA	ASAP mark; monthly monitoring	easy access	1. Impede logging 2. Better proof/report	3 mo; could be done in conjunction with marking boundary and personnel training (GPS, botanical ID)
	educate local communities	BOS-W	ASAP, every 3 mos	Gerongan and nearby	1. Better cooperation 2. Better reporting	6 months, 1 yr
	report illegal loggers to authorities (KSDA, ITCI)	BOS-W	Whenever detected	Threatening HLM	1. Enforcement 2. Cooperation	1 yr
	forest rehabilitation	BOS-W, KSDA	Start ASAP	On-site evaluation damaged areas	1. Identify critical degradation 2. Visible progress 3. Visible conserv. presence	full x 1 yr
	capacity building local communities	BOS-W and local people	ASAP	HLM and village	1. Local people help monitoring 2. Capacity building	3 months, 1 year

Threats	Recommendation	Who	When	Where	Results desired	Time frame
Illegal logging						
2. Dangers to orangutans	patrol logging camps	BOS-W	ASAP, weekly	Current logging camps	1. Knowledge of threat	monthly reports x 1 yr
	orangutan awareness/help	BOS-W		Local logging camp	1. Reduce accidents 2. Faster response	monthly reports x 1 yr
	flying team	BOS-W	ASAP	Meratus Post	1. Better orangutan rescue	monthly & 1 yr review
	medical support at Pos	BOS-W		Meratus Post	1. Better orangutan support	monthly & 1 yr review
	Meratus staff training	BOS-W	ASAP	Meratus Post, Wanariset	1. capacity building 2. Faster, better response	2 weeks (training)
Local use of Meratus protected forest (HLM)	education	BOS-W	ASAP, monthly	Gerongan	1. Mutual learning 2. Limit incursions	1 year
	develop alternatives (work, electricity, animal husbandry, fishing)	BOS-W, NGO, local people	ASAP	Gerongan, Printalik, etc.	1. Minimize clear cut areas 2. Improve local economies 3. Obtain support	long term/strategy
	Teachers	volunteer BOS-W, facilitator BOS-W		Gerongan, Printalik, etc.		long term/strategy
	books	donations BOS-I, BOS-world	Meeting with BOS 2004?	Gerongan, Printalik, etc.	1. Obtain support 2. Improve development alternatives	long term/strategy
Orangutan outside of HLM	negotiate with ITCI & other concession holders, Forestry Dep, KSDA	BOS-W, ITCI etc. Department of Forestry, KSDA	ASAP	HLM, authorities of relevant agencies	1. Protection out of HLM 2. Enlarge HLM 3. Education/ response to orangutans	long term/strategy
Commercial development possibilities	develop network of stakeholders (strategy)					long term

Table 5.10. Proposed conservation actions and work plan in East Kalimantan priority sites: Kutai National Park and Gunung Gajah forestry concession.

Kutai National Park	Who	When	USD funds
Policy			
Regulation for orangutan habitat protection (district level)	TNC, BEBSiC*, Gov, All.	Nov 2004 - Nov 2005	10,000
Management meetings every 3 months	TNC, Balai TNK*		7,500/year
Law Enforcement			
Routine patrol	Balai TNK	June 2004-June 2007	20,000/year
Integrated team	BTNK, District Gov, Police, Military Legal Institution	June 2004-June 2007	15,000/year
Post, personnel and equipment	Balai TNK	June 2004-Oct 2004	25,000/year
Zonation and Boundary demarcation	Forestry Dept	June 2004-Oct 2004	25,000/year
Awareness and education			
Media campaign	BEBSiC*, TNC, JPL*, Balai TNK	June 2004	15,000/year
Village to village (community awareness)	BEBSiC, TNC, JPL, Balai TNK	August 2004	10,000/year
School to school	BEBSiC, TNC, JPL, Balai TNK	August 2004	5,000/year
Conservation camp	BEBSiC, TNC, JPL, Balai TNK	December 2004	7,500/year
Training and Capacity Building			
for NGOs, local people, Gov	BEBSiC, TNC	July 2004	20,000/year
Community Development			
Regular meeting in the village	BEBSiC, BIKAL*, TNC, Balai TNK	June 2004-June 2007	10,000/year
Workshop	BEBSiC, BIKAL, TNC, Balai TNK	June 2004-June 2007	15,000/year
Improving local economies	BEBSiC, Balai TNK, LPMK*	August 2004	30,000/year
Community-based ecotourism	BEBSiC, Balai TNK, BIKAL	Sept 2004	40,000/year
Community-based Rehabilitation	BEBSiC, Balai TNK, BIKAL	Oct 2004	50,000/year
Research			
Other species	BEBSiC, Balai TNK	June 2004	35,000/year
Orangutan survey in new area	BEBSiC, Kyoto Univ	Sept 2004	50,000/year
Long term Research in the area	Kyoto Univ	Oct 2004	100,000/year
Research station	BEBSiC, Kyoto Univ, Balai TNK	Agust 2004	75,000/year
Wildlife trade	BEBSiC	July 2004	12,500/year
GUNUNG GAJAH			
Salaries for guards & police	TNC		32,000/year
Patrol infrastructure and equipment	TNC		55,000 once
Forest rehabilitation	TNC		5,000/year
Conservation easement	TNC		once
Research station	TNC		15,000 once
Research station infrastructure upkeep	TNC		5,000/year

* BEBSiC (Borneo Ecological and Biodiversity Conservation); TNK (Taman Nasional Kutai); JPL (Jaringan Pendidikan Lingkungan); BIKAL (Bina Kelola Lingkungan); LPMK (Lembaga Pemberdayaan Masyarakat Kampung)

Sabah Report

Criteria for prioritizing the orangutan population units in Sabah

We used the general framework for Kalimantan with slight changes:

Number of orangutans
We scored 1 for fewer than 500 individuals.
We scored 2 for populations between 500-1000 individuals.
We scored 3 for populations with more than 1000 individuals.

REASON: Concentrate our efforts on larger populations

Threats
We distinguished two kinds of threats:
-habitat threat: priority is given to population(s) under threat, in cases of equal ranking
-hunting threat

For each kind of threat, we assigned values ranging from 3 (for the most threatened areas) to 1 (for the least threatened areas).

Legal status
We give a higher rank to non-protected areas: 1 for protected areas
2 for non-protected areas

Habitat types
We considered the suitability of the habitat in term of diversity of habitat: ranking from 1 for the least diverse habitat) to 3 (for the most diverse habitat).

Habitat suitability for orangutan
We considered the quality of the habitat from the orangutan perspective: from 1 (lowest quality) to 3 (best quality).

Biodiversity
We wanted to emphasis the diversity of other animal species so this parameter was ranked from: 1 (least diverse) to 3 (richest areas).

Orangutan culture
No data are currently available on orangutan cultures except for the Kinabatangan population; as a result we did not use this parameter for our ranking.

Stakeholders
We decided that this parameter is difficult to estimate with respect to the ranking process because in Sabah almost all forests harboring orangutans offer similar opportunities for involving the different stakeholders.

Recommendations for orangutan populations living in Sabah

We estimated today that 13,000 orangutans are living in Sabah today, making Sabah the main stronghold for the subspecies “morio” in Borneo. However 60% of these populations are found outside of protected areas, in Commercial Forest Reserves exploited for timber.

The Sabah government recognizes that these orangutan populations need to be managed both in protected areas and in production forest reserves. In order to manage these populations, the Sabah government recently recognized a set of recommended actions that were included in the Resolution produced during the International Workshop on Orangutan conservation in Sabah, August 25-27, 2003.

1. Forest Management

Sabah’s forests should be managed for orangutan conservation by reviewing the current and future Forest Management Plans in light of a State Wildlife Strategy formulated by the Sabah Wildlife Department, by enhancing collaboration among relevant management authorities and through the issuing of practical guidelines to foresters, especially in Forest Management Units which harbor over 60% of Sabah’s orangutans.

2. Agricultural practices

Agriculture practices must incorporate the needs of orangutans by sensitive protection measures for small-scale agriculture and the strict control of land development for oil-palm plantations in orangutan habitat regions, including the enforcement of Section 38 of the Wildlife Conservation Enactment.

3. Tourism Industry

Policies should be adopted for the enhancement and development of sustainable and responsible orangutan tourism in Sabah, both to minimize its impact on the environment and to enhance the conservation of orangutan populations themselves.

4. *Ex situ* conservation

Current vital ex-situ conservation activities should continue to be enhanced to complement in-situ conservation.

5. Research

Current vital research on Sabah’s orangutans should continue to be promoted and enhanced, especially through activities in local universities, institutions and departments.

6. Public Awareness

Awareness of orangutan needs and the legal framework for their protection must be heightened, especially among policy makers and both forestry and plantation managers and workers.

Recommendations by site

During the PHVA Workshop, we recognized that several orangutan populations require special attention and designed these as "Orangutan High Priority Areas".

1. Populations in commercial forest reserves:

   Sabah Foundation
   North Kinabatangan
   Trus Madi

   - Keep under natural forest management practices those forests in which the largest orangutan populations occur.
   - Conduct sustainable forestry practices following the model developed and implemented in Deramakot FR (Reduced Impact Logging).
   - Initiate studies on the long-term impacts of forest exploitation in Commercial Forests on orangutan ecology and survival.
   - Monitor orangutan population trends with regular aerial surveys.
   - Develop and implement the Forest Management Plans with all relevant stakeholders. A special consideration must be placed in the needs of protecting orangutan (EIA, Honorary Wildlife Wardens, etc).
   - Enhance awareness about orangutan conservation through education campaigns conducted with the workers, contractors, managers and all relevant stakeholders.

2. Populations in Protected Areas

   Lower Kinabatangan Wildlife Sanctuary
   Tabin Wildlife Reserve
   Kulamba Wildlife Reserve

   - Enhance protection against illegal logging or any other human disturbances threatening the habitat.
   - Reduce conflicts with agriculture in identifying solutions to deal with problem animals.
   - Interconnect currently isolated protected areas by creating forest corridors.
   - Monitor orangutan populations through ground and aerial surveys.
   - Promote research activities in those protected areas.
   - Develop orangutan-based ecotourism that will provide economic opportunities to local communities.

Table 5.11. Parameters for each habitat unit to be used in Vortex. Priority sites bolded.

Fragment #	**Name**	**Area Size**	**Mean estimated N**	**Pop SizeRank**	**Habitat Threats Rank**	**Hunting Threat Rank**	**Legal Status**	**Habitat Type Rank**	**Habitat Suitability for OU**	**Biodiversity**	TOTAL SCORE
15	**Sabah Foundation (East)**	**4461** (4085)	**6318** (3344-11903)	**3**	**3**	**2**	**2**	**2**	**3**	**2**	**17**
12	**Lower Kinabatangan**	**517** (412)	**1125** (695-1883)	**3**	**2**	**2**	**1**	**3**	**2**	**3**	**16**
13	**Tabin**	**1200** (1100)	**1285** (785-1790)	**3**	**2**	**1**	**1**	**2**	**3**	**2**	**14**
14	**North of Kinabatangan**	**2000** (1656)	**2298** (1206-4273)	**3**	**2**	**2**	**2**	**1**	**2**	**2**	**14**
9	**Trus Madi forests**	**1897** (500)	**255** (205-418)	**1**	**3**	**3**	**2**	**2**	**1**	**1**	**13**
11	**Kulamba Wildlife Reserve**	**204** (167)	**730** (392-1360)	**2**	**2**	**2**	**1**	**2**	**2**	**2**	**13**
1	Ulu Tungud Forest reserve	1234 (430)	46 (22-95)	1	3	3	2	1	1	1	12
4	Lingkabau Forest Reserve	713	<100	1	3	3	2	1	1	1	12
5	Bongayya Forest Reserve	680 (400)	103 (51-205)	1	3	3	2	1	1	1	12
6	Sepilok Orangutan Rehabilitation Center	43 (43)	150	1	1	1	1	3	3	2	12
7	Croker Range NP	1400 (980)	180 (110-270)	1	2	2	1	3	1	2	12

Fragment #	**Name**	**Area Size**	**Mean estimated N**	**Pop SizeRank**	**Habitat Threats Rank**	**Hunting Threat Rank**	**Legal Status**	**Habitat Type Rank**	**Habitat Suitability for OU**	**Biodiversity**	TOTAL SCORE
10	Ulu Milian (North)	512 (319)	40 19-82)	1	3	3	2	1	1	1	12
10 bis	Ulu Milian (south) and Sapulut Forests (South)	887 (758)	227 (118-437)	1	3	3	2	1	1	1	12
16	South-West Sabah	>7000 (4500)	<450	1	3	3	2	1	1	1	12
2	Kinabalu NP	750 (<200)	50	1	1	1	1	3	1	3	11
8	Ulu Kalumpang Forest Reserve	511 (436)	183 (93-358)	1	1	1	1	1	2	2	9
3	Silabukan Forest Reserve	106 (93)	75 (39-144)	1	1	1	1	2	1	1	8

Table 5.12. Additional parameters for each habitat unit to be used in Vortex, priority sites only.

Fragment #	Name	Vortex Mortality	Area Size Trend	K max	Catastrophe	Linkages
15	Sabah Foundation (East)	Medium	10% loss	7200	General Model	
12	Lower Kinabatangan	Medium	5% increase	800	2:1 adult males/females, extra male mortality due to crop-raidings	
13	Tabin	Medium	same	2200	General Model	
14	North of Kinabatangan	Medium	20% loss	2600	General Model	*test linking Lower Kinabatangan and North Kinabatangan
9	Trus Madi forests	High	10% loss	900	General Model	
11	Kulamba Wildlife Reserve	Medium	same	320	General Model	*test linking Kulamba and Tabin

BORNEO-WIDE RECOMMENDATIONS

Awareness & Education

The need for education is widely recognized in order to prevent hunting and collection, and to minimize habitat destruction. Educational activities that could provide tangible results include public awareness campaigns and training of local researchers and protected area managers. Yayorin was identified as an NGO that does/could assist in such an education effort. Media campaigns could reach a broader audience, particularly those who are customers in the pet trade. Conservation camps could also increase awareness among school children who would not normally have access to wild areas. Conservation awareness should also include the implementation of programs that stress ecological concepts in village schools and communities.

Economic development

Communities that reside around forests that contain good orangutan habitat may need alternative sources of income in order to relieve the pressure of illegal logging and collection of orangutans for the illegal wildlife trade. Some international NGOs may have the capacity to conduct socioeconomic studies of alternative sources of income. Intensifying agriculture and animal husbandry are two alternatives to increase income. The intensification of agriculture can reduce the total amount of land used for agriculture thereby reducing the clearing of forest for this purpose. The extraction of non-timber forest products is an alternative if means of transport and markets exist for these products.

Fundraising

Fundraising is clearly needed in order to support a broad spectrum of conservation activities. However, this was not discussed in depth. Details are provided in some work plans.

Law enforcement

It is recommended that the conservation community should work to encourage government to increase its support of conservation programs. Further, improved implementation of laws in the field is needed. Training may be needed among law enforcement officials (police, judges, prosecutors, forestry police) to increase the ability and the will of law enforcement agencies to enforce conservation-related laws. Salaries are often low, particularly for field assignments; salaries could be supplemented by local NGOs. In areas that are severely threatened by encroachment, such as those near urban areas, regular patrols may be necessary. Posts may help law enforcement to maintain round-the-clock guard. Communities can play a greater role in monitoring and protecting their local wildlife areas. A local presence can be a significant deterrent to intruders. However, the benefits of doing so must be realized at a local level, such as by receiving educational, economic (tourism, research), or health care benefits.

Habitat management

Protected area development needs to be increased in the form of national parks, community conservation, wildlife sanctuaries and conservation easements.

Rehabilitation is also needed in some degraded areas in the form of reforestation, the damming of peat swamp canals and corridor development. Communities may have a vested interest in partaking in habitat rehabilitation, such as in areas in need of flood control or to maximize revenues from non-timber forest products. The closure of logging roads or the control of river access could help reduce illegal logging and collecting. Protected areas should be marked to inform outsiders of the protected status and limited access. Also, better development zoning needs to take place by creating land use management plans at the local government level. More sustainable forestry practices might become more commonplace by using incentives such as access to new markets for timber. The higher value of 'green' timber may encourage some logging concessions to adopt low-impact logging techniques. Local communities can band together in forums that would allow them to negotiate how logging is conducted by timber concessions.

Research (long-term) and population monitoring

Surveys should be conducted in sites where the presence of orangutans remains unknown. Known populations should be surveyed to assess orangutan numbers. Local students should be supported so that they can use certain sites for research and education. Socioeconomic research may help find alternative sources of income to alleviate hunting, illegal logging and collection for the wildlife trade. The Nature Conservancy and the Japan Orangutan Research Committee were identified as two organizations that can, or already do, contribute to research and population/habitat monitoring. Research stations can provide a presence that would deter outsiders from entering. Research in the wildlife trade could help us better understand how to reduce the supply and demand.

Policy

The conservation awareness of government institutions, particularly at the local level, needs to be increased so that conservation becomes a greater priority in land use planning and local legislation. Areas identified as important habitat for orangutans need to receive some form of legal protection. Regular management meetings at the local government level could take place to ensure that management is effective and ongoing.

Wildlife corridors

Most of Borneo is now highly fragmented. In order to reduce the rate of fragmentation, corridors that can connect existing forest patches need to be included in land use plans. Further, areas that are currently degraded could become potential corridors linking existing sites if that land is protected and reforested.

MODELING OF POPULATIONS OF ORANGUTANS ON BORNEO

Parameter values for a baseline scenario for modeling the dynamics of orangutan populations on Borneo

The Borneo Working Group began their development of a baseline model that could represent a "typical" population of orangutans on Borneo by reviewing the input values proposed by the small group that met in Singapore in August 2003. Each parameter was discussed, to determine if the information available to the Borneo Working Group participants led them to concur with the earlier values, or instead to propose alternate values to better represent our understanding of the biology of the species on Borneo. In addition, after presentation of preliminary modeling results to the plenary discussion of the PHVA workshop, the Borneo Working Group reviewed those input values that had been set differently by the Borneo and Sumatra Working Groups. In each case, a decision was made to stay with the value originally specified by the Borneo Working Group (when it was felt that the value better represented the biology of the species on Borneo), or to change to a value the same as or closer to the value specified by the Sumatra Working Group (when it was felt that the information presented by the Sumatra Working Group provided a better insight into the species biology on Borneo as well). The consensus values used for the baseline model are presented below. The Vortex project files with these input values are available at www.vortex9.org/projects/orangutan.zip.

Initial Vortex model parameters

# of iterations: 500 independent iterations (or runs) of the simulation were conducted for each set of parameters tested, in order to provide relatively precise and stable results. This number of iterations results in a standard error around the estimated probability of extinction of about SE = 1% (for scenarios with probabilities of extinction of about 5%) to about SE = 2% (for scenarios with probabilities of extinction of about 20% or higher). Standard errors of mean population sizes were typically about 1% to 2% of the means.

# of years: 1000. It is very unlikely that any projections we can make now will accurately predict populations or habitats for 1000 or even a few hundred years. However, because orangutans are very long-lived and slow breeding, processes that threaten the persistence of populations may not be apparent until many years later. Population declines probably occur very slowly; so long durations of simulated results may be needed to clearly see the trends. Although all simulations projected population dynamics for 1000 years, graphical displays of results will cover that time span, and tables will show results at years 50 and 100 so that the population status over these shorter time spans can be examined.

Extinction definition: The definition of "only one sex remains" was used.

Inbreeding depression: It will be difficult to estimate the impact on breeding or survival of any inbreeding that occurs when population sizes become small. Based on studies of many other mammal species, inbreeding probably does have major effects (especially at small population sizes), but we do not know much about population substructure, or what % of males do the mating, or how many males contribute genetically to next generation. In spite of our uncertainty about the frequency of inbreeding and the likely impacts, we decided that we must include this process in the models because removing it would provide overly optimistic estimates. The analyses of the maximum population growth (r-max, below) do not incorporate any inbreeding effects, but for modeling long-term trends and extinction times it will be essential. Vortex normally assumes that matings result from random mixing throughout the population of the adults that are capable of breeding each year. This may provide overly optimistic estimates of genetic mixing (and lack of inbreeding), but more refined models would require detailed knowledge of dispersal and breeding systems. To specify the impact of any inbreeding that occurs in the simulated populations, we obtained the estimate of "lethal equivalents" (a measure of the average increase in neonatal mortality for each increment in inbreeding) from the analysis of the studbook data for captive orangutans maintained in zoos. Jonathan Ballou of the US National Zoo provided this estimate of 4.06 lethal equivalents. In simulations of populations with 1000 or fewer animals, 50% of the effect of inbreeding was modeled as being due to recessive lethal alleles (which can be removed by natural selection if inbreeding occurs periodically). In populations with more than 1000 animals, the inbreeding effect was specified to be due entirely to recessive lethal alleles. This optimistic and perhaps unrealistic assumption was made to allow the Vortex simulations to run much more quickly. However, inbreeding is so rare in large populations (in the wild and in the simulation) that the results would not be noticeably affected by the value given for the proportion of inbreeding depression due to lethal alleles.

Concordance between environmental variation in reproduction and survival: We lack the field data to adequately address this, but environmental factors such as food shortage could impact both survival and reproduction (although perhaps with a lag). We chose to specify that the fluctuations caused by environmental variation would be concordant, although we do not think that this model parameter will have a large effect on results.

Mating system: Orangutans have a promiscuous breeding system, with both males and females potentially having multiple mates, although animals may breed with the same mate(s) for several years. We modeled the populations as having a short-term polygamous system, in which animals can select new mates every year.

Age of first reproduction: Based on information about the youngest animals observed breeding at Camp Leakey and Ketambe, we assumed that females typically begin breeding at 15 and males at 18. (We had initially specified that males do not typically breed until 20, and there was uncertainty in this parameter – but male breeding age would also not noticeably impact demographic projections.)

Maximum age at reproduction: There is a female at Ketambe that produced an offspring at about 50 years of age, but it was decided that 45 might be a more typical age for a female to be able to produce the last offspring that can be successfully weaned.

Litter size: 1 (in rare cases twins are born, but at least one always dies).

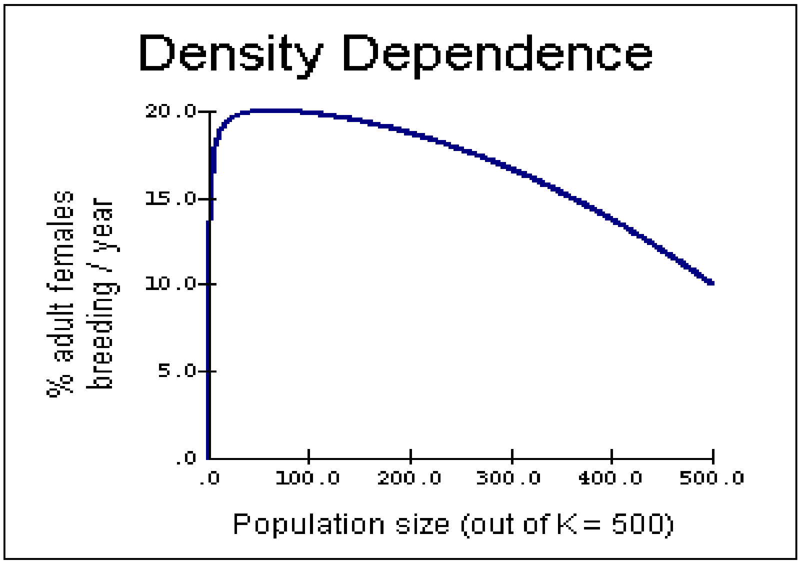
Sex ratio at birth: Based on the data from a number of field sites that suggest a small male bias in births, we specified that 55% of births in the simulation would be male.

Density-dependent reproduction: Within VORTEX, density dependence can be entered by specifying parameters of a particular (but flexible) curve (see Vortex reference for more details), or by entering any other functional shape for the relationship between population density and breeding success. The curve that is often used to represent the functional relationship is: % breeding = $[(P_0 - (P_o - P_k)*(N/K)^B)]*(N/(N+A))$, with the parameters as described below. We used the following parameter values:

$P_0=20.5$	P_0 specifies the % of adult females breeding in an average year when population density is very low (extrapolated to N = 0, when not including an Allee effect). To estimate this parameter, we considered to how short the weaning period could possibly be. We assumed that the inter-birth interval would be as low as about 5 years in high quality habitat with a low density of animals relative to what could be supported by the food supply. Inter-birth intervals as short as 4 years have been observed in food-supplemented populations, but 5 years is probably more realistic of what would occur in a more natural situation. Given the shape of the curve (which includes an Allee effect depressing breeding at very low density), we needed to set P_0= 20.5 to obtain a curve that would have a peak at about 20.
$P_k=10$	P_k is the breeding rate (% females breeding each year) when the population is at its carrying capacity. We assumed that inter-birth intervals would be as long as 10 years in populations that were at peak densities and food limited.
A=1	The Allee parameter, A, specifies the number of females in which breeding has dropped to 0.5 of normal rate because of difficulty in finding mates or lack other social factors. Orangutans are probably able to find mates even when at low densities, so we set A = 1 to minimize the Allee effect in the model.
B=2.0	This parameter defines the steepness with which breeding decreases as the population approaches the carrying capacity of the habitat. To get a relatively steady decline in breeding, we used B=2.

The density dependence curve using the above parameter values is shown below for the case of a population with carrying capacity (K) of 500.

Figure 5.1



Environmental variation in breeding rate: We used SD = 10% for the fluctuation in % of females breeding per year. Across reasonable ranges, this number would probably have little effect on population projections. Orangutans are long-lived, so year-to-year fluctuations in demographic rates tend to average out.

Monopolization of breeding: Although some males are more likely than others to be successful breeders, probably all males over about 18 years attempt to breed (with younger males using a "sneaky" strategy). This parameter would effect only genetics (and that only weakly), not demography, so we were not concerned about estimating it accurately. In the population model, we assumed that all adult males are potential breeders each year.

Mortality: There was considerable discussion about the average natural mortality rates of orangutans. (By "natural", we mean mortality caused by factors other than hunting or direct removal of habitat. However, we recognize that some mortality may be exacerbated by human activities causing, for example, habitat degradation, climate change, or altered rates of disease.) Field researchers in Borneo have observed very few deaths over many years of observing populations. In addition, the notable longevity observed for orangutans suggests that mortality rates can be very low. Finally, natural mortality must typically be low enough to allow persistence of the species in spite of the very slow reproduction. In addition to our uncertainty about mortality rates caused by few data, the group recognized that mortality rates probably vary among populations, based on the quality of the habitats. We therefore decided to test 3 levels ('mortality schedules') in our population modeling, representing plausible mortality rates in undisturbed high–quality habitats, disturbed or medium quality habitats, and very disturbed or low quality habitats. The mortality schedules we assumed for each sex are given below. Although more detailed mortality schedules, with different mortality rates for each juvenile and subadult age class, could and should be derived from field data, at this time we lack sufficient data to make such fine discriminations among age classes. In addition, the demographic projections for a population depend on the total mortality that occurs prior to breeding, not on the specific age at which infant or juvenile mortality occurs.

Female mortality schedules (mean annual mortality) at three levels of habitat quality

	High quality (Best mortality)	Medium	Low quality (Worst mortality)
Age			
0-5	1%	1.5%	2.0%
5+	0.5%	1.0%	1.5%

Male mortality schedules (mean annual mortality) at three levels of habitat quality

	High quality (Best mortality)	Medium	Low quality (Worst mortality)
Age			
0-5	1%	1.5%	2.0%
6-12	0.5%	1.0%	1.5%
12+	1%	1.5%	2.0%

Compared to the mortality estimates used in the preliminary models developed in August 2003, we assumed that infant mortality would be very low, because very few infants observed by Galdikas and by Suzuki died or disappeared. For adults, our best mortality (in high quality habitat) was lower than had been estimated in the preliminary (Singapore) models, the medium values were comparable, and the worst mortality (in low quality habitat) was higher.

Environmental variation in mortality: Environmental variation around male mortality was specified to the same magnitude (as a standard deviation) as the mean mortality rates (e.g., 0.5%, 1%, 1.5%, or 2% -- depending on the age class and mortality schedule). Because annual mortality rates are low, and the species is long-lived, these random fluctuations in mortality across years will have almost no effect on population projections.

Catastrophes: It was recognized that a variety of catastrophes can occur, and that these are often specific to, or more frequent in, or more severe in certain populations. For example, flooding regularly occurs at the head of the Kapuas River; extended droughts can occur, but with greater frequency or impact in East Kalimantan than in some other areas; and droughts can be followed by extensive fires, which can in turn trigger food shortages. Rather than trying to specify each kind of catastrophe, it was recognized that many catastrophes are related to El Niño weather events. We decided to collapse within the model the impacts of a number of kinds of catastrophes into those impacts that occur with typical El Niño events, and those that occur in the more severe El Niño events. Over the past few decades, El Niño has been occurring about every 4 years, with severe El Niño events occurring about every third one of these. Thus, we decided to specify that moderate El Niño related catastrophes occur in 17% of years, and more severe catastrophes in 8% of years.

In discussing the likely severities of catastrophes, it was noted that all orangutans apparently died in some areas that were extensively burned in 1983 (Suzuki), and that 3 orangutans died of disease thought to be related to food stress after a 1972 fire.

An estimated 1,000 out of 40,000 orangutans (2.5%) died from the severe fires in 1997, but that this may well have been an underestimate. For the modeling, we assumed that catastrophes caused by severe El Niño events would kill an average of 3.5% of orangutans, while less severe El Niño catastrophes would kill about 1%.

Carrying capacity (K): We imposed the carrying capacity (the size of population that can be sustained in a habitat without causing long-term degradation of that habitat) by use of the parameter K in the density dependent breeding function (see above). When the simulated population exceeded this K, breeding would drop to a level that would cause the population to decline back toward K. When N < K, the breeding rate was sufficient (in the absence of other factors such as inbreeding depression or catastrophes) to allow the population to grow back toward the carrying capacity. Vortex normally imposes the carrying capacity by truncating the population (killing animals) if the population size exceeds K. To avoid such a mortality-imposed carrying capacity, the level at which this truncation would occur was set arbitrarily high (at 2x the desired K) in the Vortex simulations. For our baseline scenario, we assumed that habitat would not be lost or gained. Later, we examined the impacts of expected rates of habitat loss or gain for some specific populations.

Harvest: We assumed no planned harvests for management purposes. Losses due to poaching were modeled later with scenarios in which we examined impacts of hunting.

Supplementation: We did not model any animals being added to the populations from captive or other sources.

Parameters varied to explore sensitivity of orangutan populations

Initial population size: To explore the stability of various size local populations, we examined scenarios with initial population sizes and carrying capacity set at 50, 100, 250, 500, and 1000.

Mortality schedules: As described above, we tested three levels of mortality to represent three levels of habitat quality. The Medium and Worst mortality rates were 0.5% and 1% higher for each age class than was assumed in the Best mortality schedule.

Inbreeding depression: Because the impact of future inbreeding on survival (and other aspects of fitness) is so uncertain, we examined values for the number of lethal equivalents of 0 (no effect of inbreeding), 2, and 6 – in addition to the 4.06 lethal equivalents that we obtained from the studbook of captive orangutans to use in our baseline model. These values for lethal equivalents cover the range of impacts of inbreeding often measured in mammalian populations, although some species have been observed to be more severely affected (Ralls et al. 1988; Lacy 1997). These varying impacts of inbreeding depression were tested with populations of starting size (and K) of 100.

Hunting rates: To explore the impact that various low levels of hunting would have on orangutan populations with varying levels of natural mortality, we tested scenarios in which 1%, 2%, or 3% of the animals were removed each year. We imposed this hunting in the Vortex model by adding 1%, 2%, or 3% to the mortality of each age class.

RESULTS FOR BASELINE SCENARIOS REPRESENTING "TYPICAL" ORANGUTAN POPULATIONS ON BORNEO

Potential population growth rates (r_{max})
By replacing the function that defines density dependent breeding with the rate (20%) expected at low density (optimal conditions for females), we obtained deterministic projections of annual population growth of 2.5% ($r_{max} = 0.025$), 2.0%, and 1.5% for the cases of best mortality, medium mortality, and worst natural mortality. These are the average rates of population growth that would be expected based on mean birth and death rates, in the absence of any effects of inbreeding, temporary shortage of mates, or other stochastic processes. These rates span what would be plausible rates of population growth for a large, long-lived, slowly breeding ape.

With the breeding rate (10%) expected under crowded conditions (when N = K, with the habitat filled with all the orangutans that can be supported on the resource base), we obtained deterministic projections of annual population growth of 0.1% ($r_{max} = 0.001$), -0.4%, and –0.9% for the cases of best mortality, medium mortality, and worst natural mortality. Thus, the density dependent curve we used for breeding rates would lead to a stable population (or a *very* slowly growing one) in the best quality habitat, while the populations would be projected to decline to a lower equilibrium size in poorer quality habitats. In the simulations of large populations starting at N = 1000 (in which stochastic effects would be minimal), the equilibrium population sizes under the medium and worst mortality schedules were about 900 and 800 (Table 5.14).

Impact of habitat availability and natural mortality rates
One major concern is whether orangutan populations can continue to persist and thrive in forests that are reduced in extent and fragmented. Figures 5.2-5.10 show the projections for 10 simulated populations in habitat sufficient in size to support 1000 (Figs. 5.2, 5.5, and 5.8), 250 (Figs. 5.3, 5.6, and 5.9), or 50 (Figs. 5.4, 5.7, and 5.10) orangutans. The first three figures show the projections when we applied the best mortality rates; Figures 5.5-5.7 show projections with the medium mortality rates, and Figures 5.8-5.9 show projections with the worst mortality rates.

The figures give an indication of the range of uncertainty in population trajectories, caused by the randomness of demographic events, fluctuations in the environments (including sporadic catastrophes), and any inbreeding effects. This uncertainty is greater in the smaller populations. Populations of about 1000 orangutans are fairly stable with all three mortality schedules, although the average population sizes are somewhat lower and the annual fluctuations greater with the worse mortality rates. Populations of 250 also appear to be demographically stable, although they show greater relative fluctuations than do the larger populations. The smallest populations tested, in habitats limited to 50 animals, are not demographically stable even with the best mortality schedule. Such small populations experience large relative fluctuations and sometimes went extinct.

Figures 5.11-5.16 show probabilities of extinction and mean population sizes obtained from 500 simulations for populations of initial size (and K) of 1000, 500, 250, 100, and

50, under assumptions of the best, medium, or worst mortality rates. Table 5.13 provides the numbers from these analyses, and also shows the proportion of gene diversity (or heterozygosity) remaining within the populations at time intervals of 50, 100, and 1000 years. It is not known what impact losses of genetic diversity will have on orangutan populations with respect to survival, disease resistance, reproduction, adaptability, and population persistence (see Lacy 1997 for a discussion of some of the common impacts of losses of genetic diversity). A common conservation goal is to maintain at least 90% of initial levels of gene diversity within managed populations (e.g., Soulé et al., 1986).

As can be seen in the figures and in Table 5.14, with the best mortality rates (those that we expect would be experienced by orangutan populations in the highest quality habitat), populations limited to only 50 animals are at risk of extinction, but only after the populations become highly inbred and therefore suffer greater infant mortality. Populations in high quality forests able to support 100 or more orangutans showed no extinctions in our simulations, but they did lose substantial amounts of gene diversity (dropping to 75% of initial levels, which is the equivalent of all animals being full-siblings). Populations with capacity for 250 or more orangutans were demographically stable and retained at least 90% of their initial gene diversity.

With 0.5% greater mortality across all age classes (the medium mortality scenarios), populations of 50 lost diversity more rapidly, declined in size, and subsequently (usually) went extinct. A few populations of 100 also went extinct, and all lost considerable gene diversity. Populations of 250 were demographically stable, and lost just over 10% of gene diversity. Larger populations were both demographically and genetically stable. The same pattern is seen with the worst mortality rates, although population sizes stabilized at somewhat lower numbers, and losses of gene diversity were greater.

Overall, with the values we estimated as typical for orangutans on Borneo, the results suggest that populations of about 250 would be considered to have long-term potential to contribute to the conservation of the species, and populations of 500 or 1000 would be more robust even if habitat quality is partly degraded. It should be noted, however, that smaller populations that are linked by occasional movements of animals could contribute to the overall stability of a larger meta-population.

Table 5.13. Effects of habitat availability (K) and natural mortality rate.
(PE = % probability of extinction; N = mean population size; GD = % of initial gene diversity)

Input parameters		50 years			100 years			1000 years		
Mortality	K	PE	N	GD	PE	N	GD	PE	N	GD
Best	1000	0	1000	100	0	1006	100	0	974	97
Best	500	0	501	100	0	494	99	0	482	95
Best	250	0	249	99	0	246	99	0	235	89
Best	100	0	98	98	0	96	97	0	81	74
Best	50	0	48	97	0	46	94	27	18	48
Medium	1000	0	924	100	0	916	100	0	896	97
Medium	500	0	460	100	0	452	99	0	433	94
Medium	250	0	229	99	0	226	99	0	209	88
Medium	100	0	91	98	0	87	97	1	60	67
Medium	50	0	44	96	0	41	93	87	2	33
Worst	1000	0	838	100	0	832	100	0	787	96
Worst	500	0	421	100	0	416	99	0	377	93
Worst	250	0	207	99	0	202	98	0	167	85
Worst	100	0	82	98	0	77	96	44	17	56
Worst	50	0	40	96	0	36	92	99	0	25

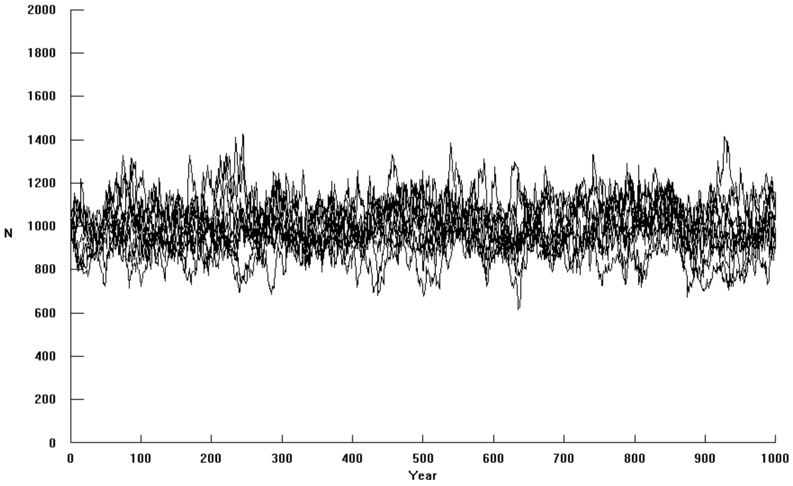


Figure 5.2. Trajectories of 10 simulated populations with initial size of 1000 and the best mortality rates (illustrating the interacting effect of popualtion size and mortality).

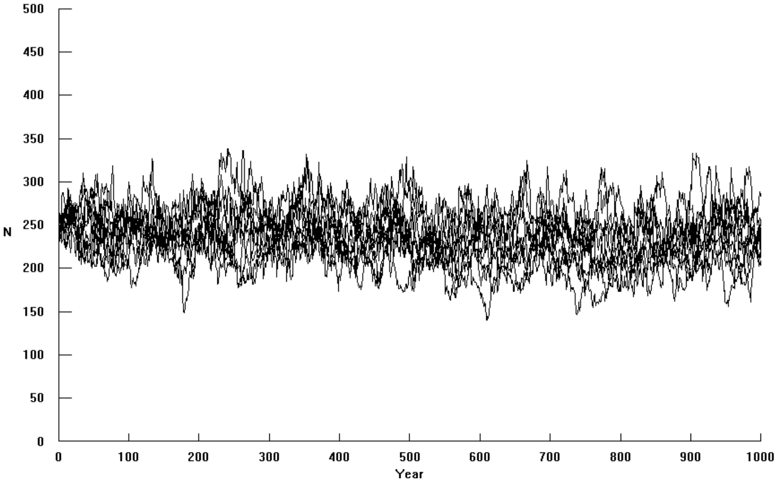


Figure 5.3. Trajectories of 10 simulated populations with initial size of 250 and the best mortality rates

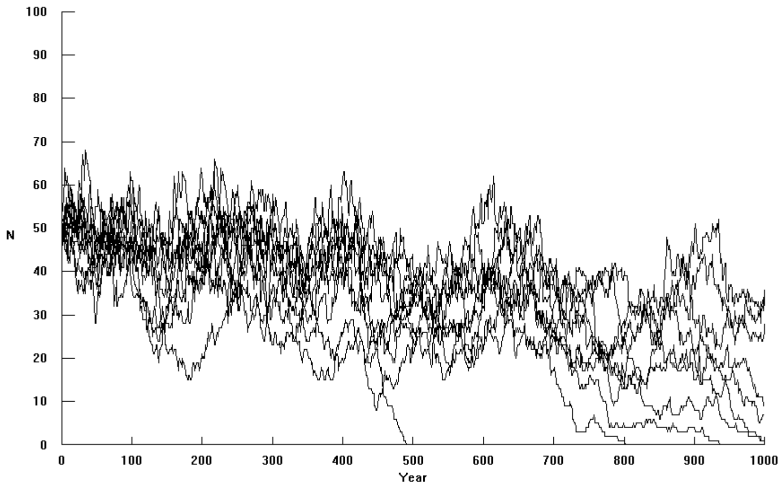


Figure 5.4. Trajectories of 10 simulated populations with initial size of 50 and the best mortality rates

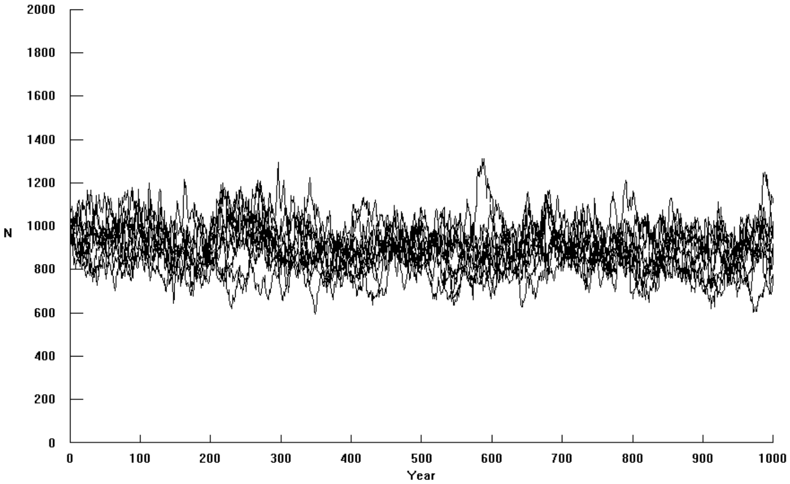


Figure 5.5. Trajectories of 10 simulated populations with initial size of 1000 and medium mortality

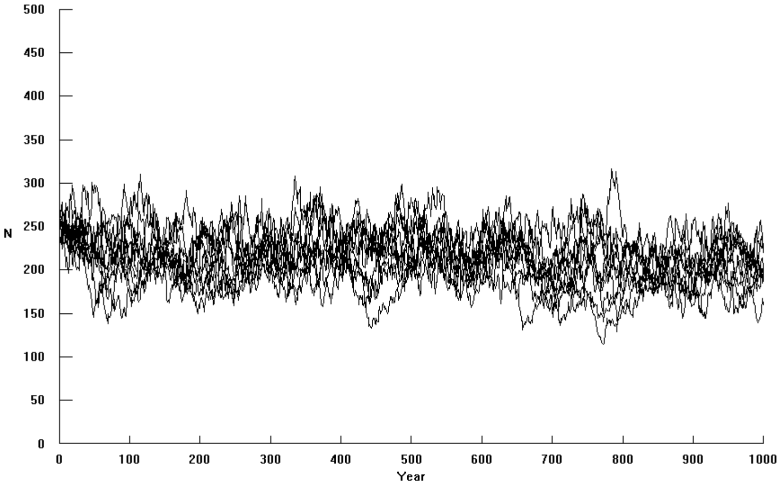


Figure 5.6. Trajectories of 10 simulated populations with initial size of 250 and medium mortality

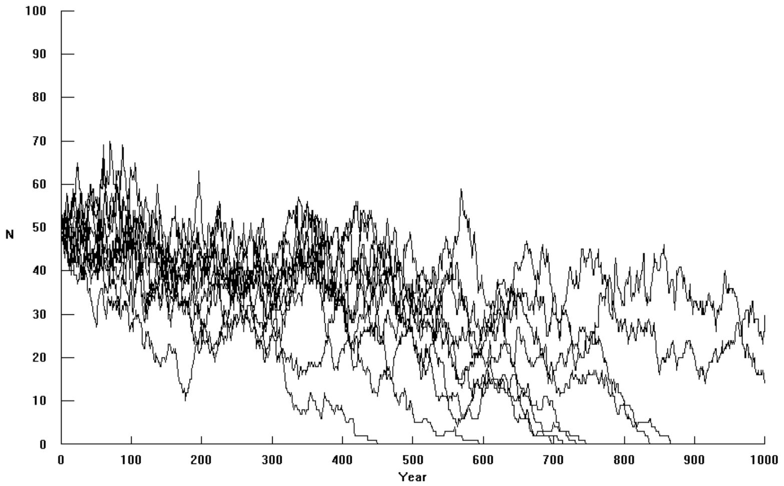


Figure 5.7. Trajectories of 10 simulated populations with initial size of 50 and medium mortality

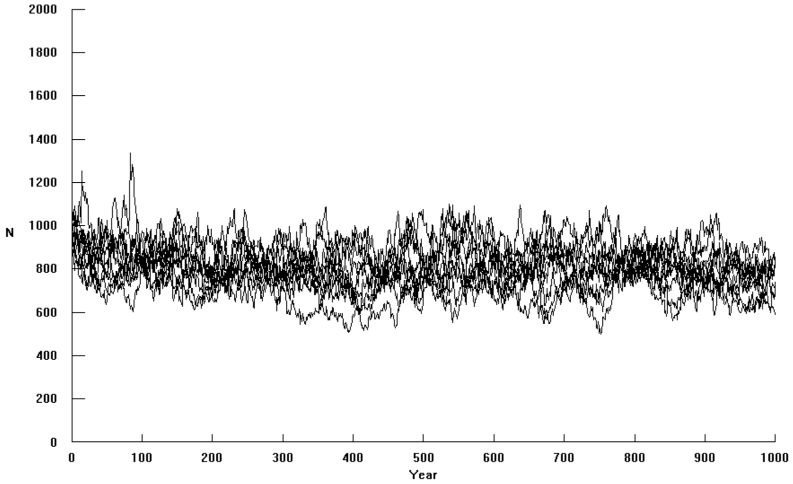


Figure 5.8. Trajectories of 10 simulated populations with initial size of 1000 and the worst mortality rates

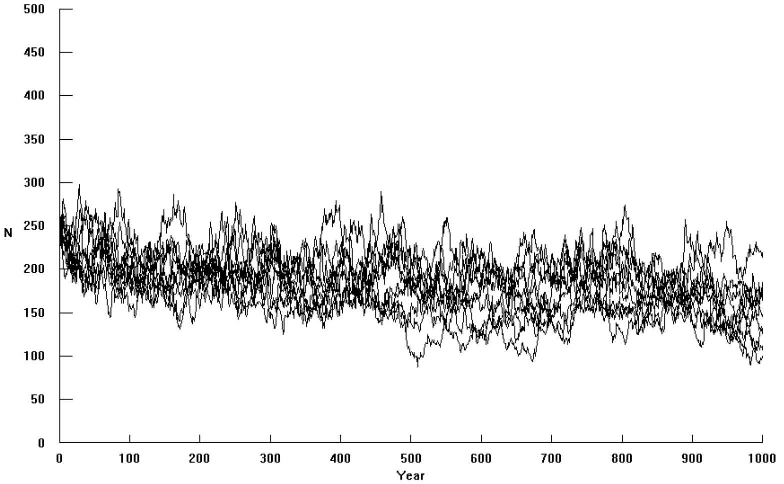


Figure 5.9. Trajectories of 10 simulated populations with initial size of 250 and the worst mortality rates

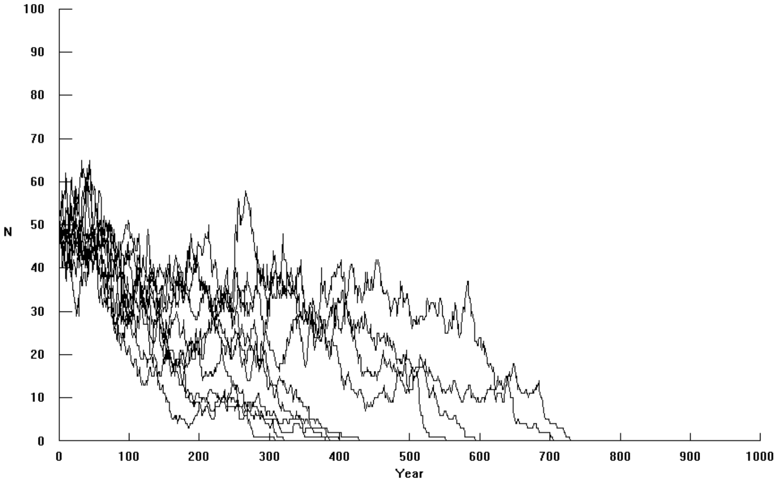


Figure 5.10. Trajectories of 10 simulated populations with initial size of 50 and the worst mortality rates.

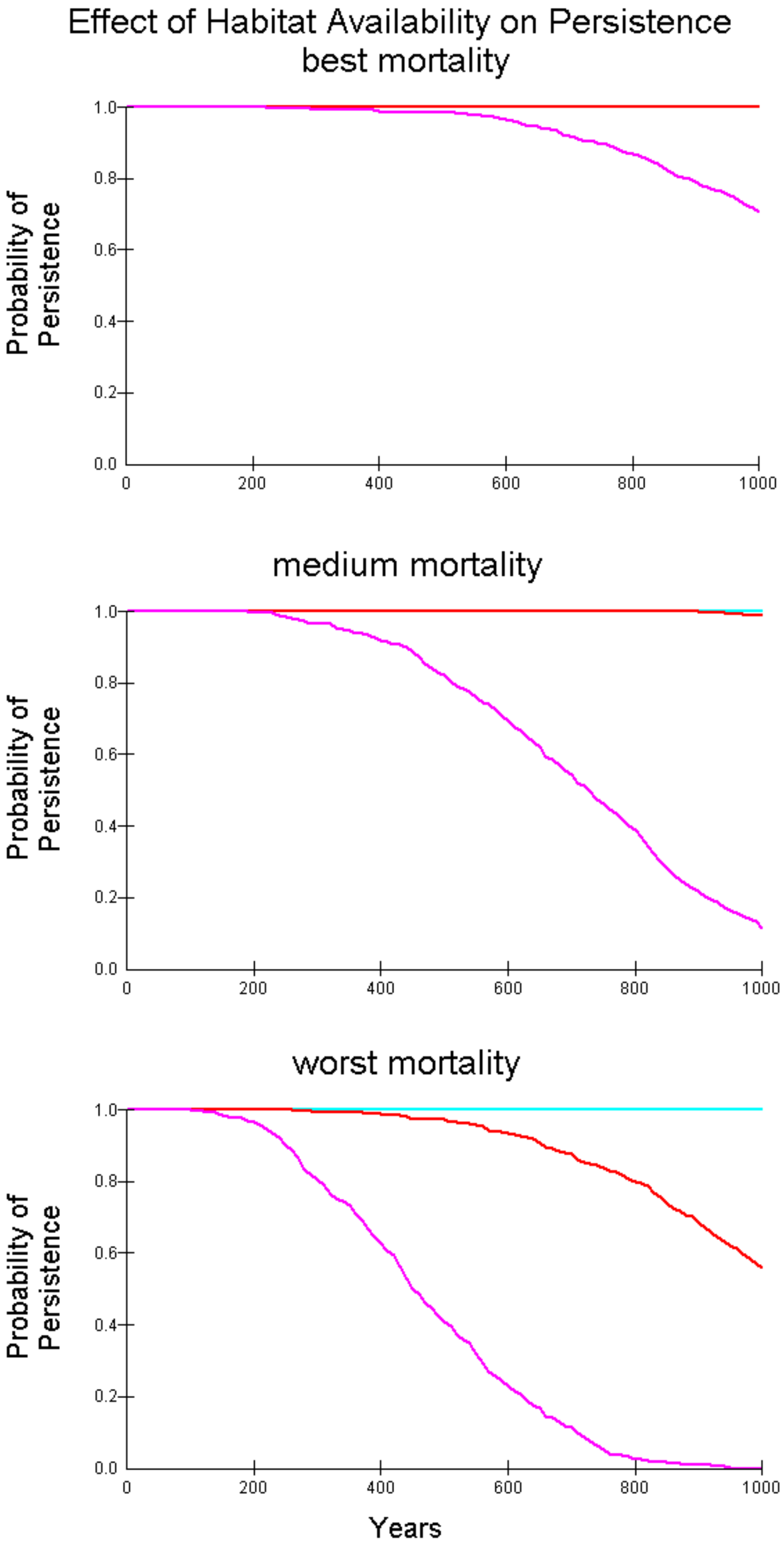


Figure 5.11. Probability of persistence for populations of maximum and initial size of 1000, 500, 250, 100, and 50 (top to bottom, with some top lines superimposed), subjected to three levels of natural mortality

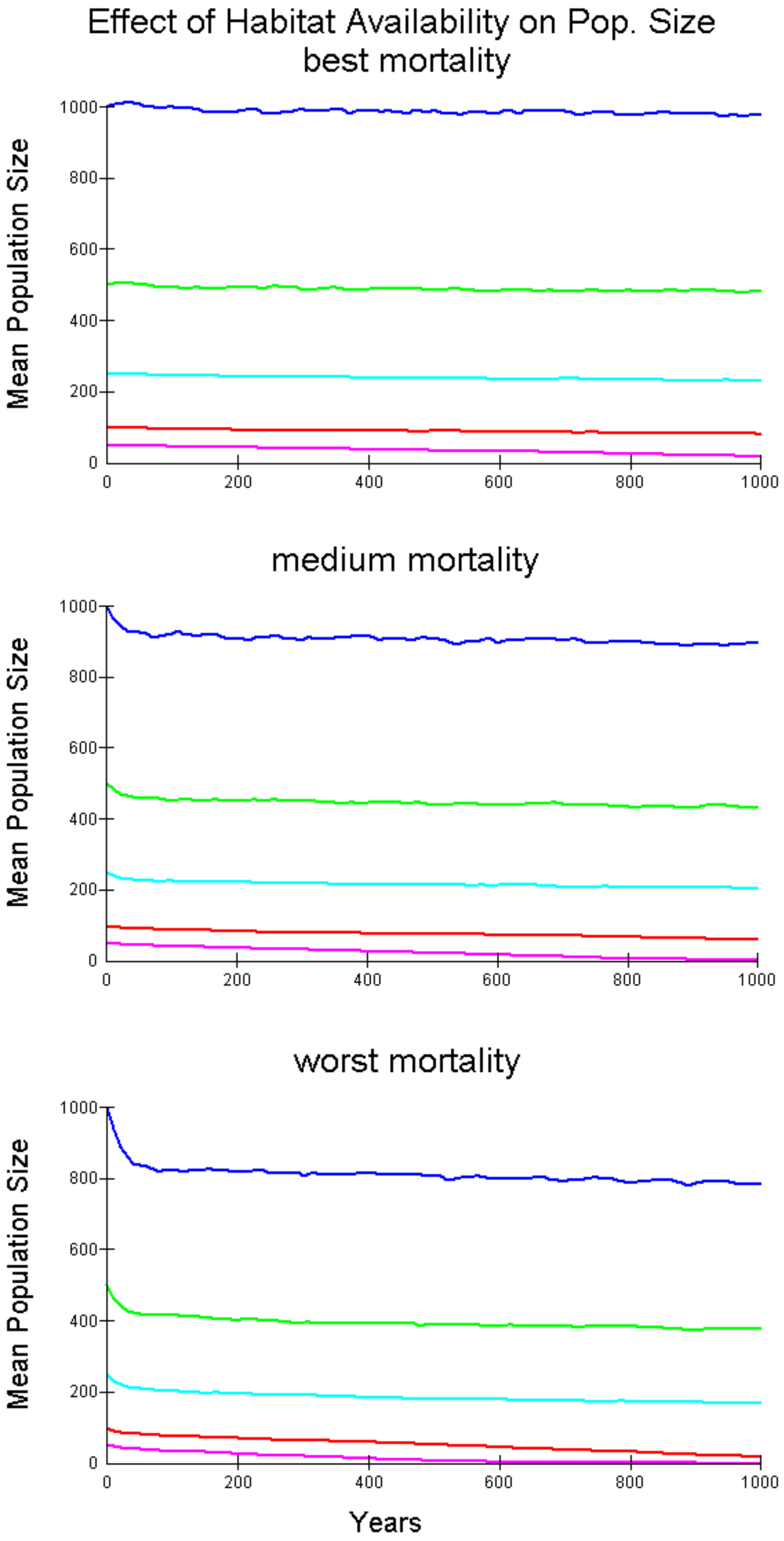


Figure 5.12. Projected sizes of populations with initial sizes of 1000, 500, 250, 100, and 50 (top to bottom), subjected to three levels of natural mortality

Effects of inbreeding depression

Table 5.14 and Figures 5.13 and 5.14 show the impact of inbreeding on population persistence and size under different assumptions about the number of lethal equivalents in populations of small size (initial N = 100). The baseline model used the 4.06 lethal equivalents that has been measured by the effect of inbreeding on infant survival in zoo populations. The impact of inbreeding in wild populations could be higher or lower than this. On each figure are shown comparisons of cases with no effects of inbreeding, 2 lethal equivalents, 4.06 lethal equivalents, and 6 lethal equivalents. Figure 5.13 shows that under the medium or worst mortality rates, inbreeding depression can cause extinctions of small populations if the impact is similar to or greater than the 4.06 lethal equivalents that has been estimated from zoo records. Figure 5.14 shows that in the cases with higher numbers of lethal equivalents, inbreeding depression will cause declines in population sizes. The effect begins to be apparent after about 75 years (several generations), after which time some inbreeding is occurring in the small populations. The impact of inbreeding depression is greatest in those scenarios with worse natural mortality, because the populations are less able to withstand moderate reductions in infant survival.

Table 5.14. Impacts of varying levels of the severity of effects of inbreeding, with 0.0, 2.0, 4.06, or 6.0 lethal equivalents, in populations with initial and maximum size of 100 orangutans and three levels of mortality. All other parameter values as described for the baseline scenario. (PE = % probability of extinction; N = mean population size; GD = % of initial gene diversity)

Input parameters		50 years			100 years			1000 years		
Mortality	Lethal equivalents	PE	N	GD	PE	N	GD	PE	N	GD
Best	0.0	0	99	98	0	98	97	0	97	76
Best	2.0	0	98	98	0	98	97	0	91	76
Best	4.06	0	98	98	0	96	97	0	81	74
Best	6.0	0	97	98	0	95	97	0	66	72
Medium	0.0	0	90	98	0	90	97	0	91	73
Medium	2.0	0	91	98	0	88	97	0	78	71
Medium	4.06	0	91	98	0	87	97	1	60	67
Medium	6.0	0	91	98	0	87	97	25	27	62
Worst	0.0	0	82	98	0	79	96	0	80	68
Worst	2.0	0	83	98	0	78	96	4	57	64
Worst	4.06	0	82	98	0	77	96	44	17	56
Worst	6.0	0	81	98	0	75	96	93	1	55

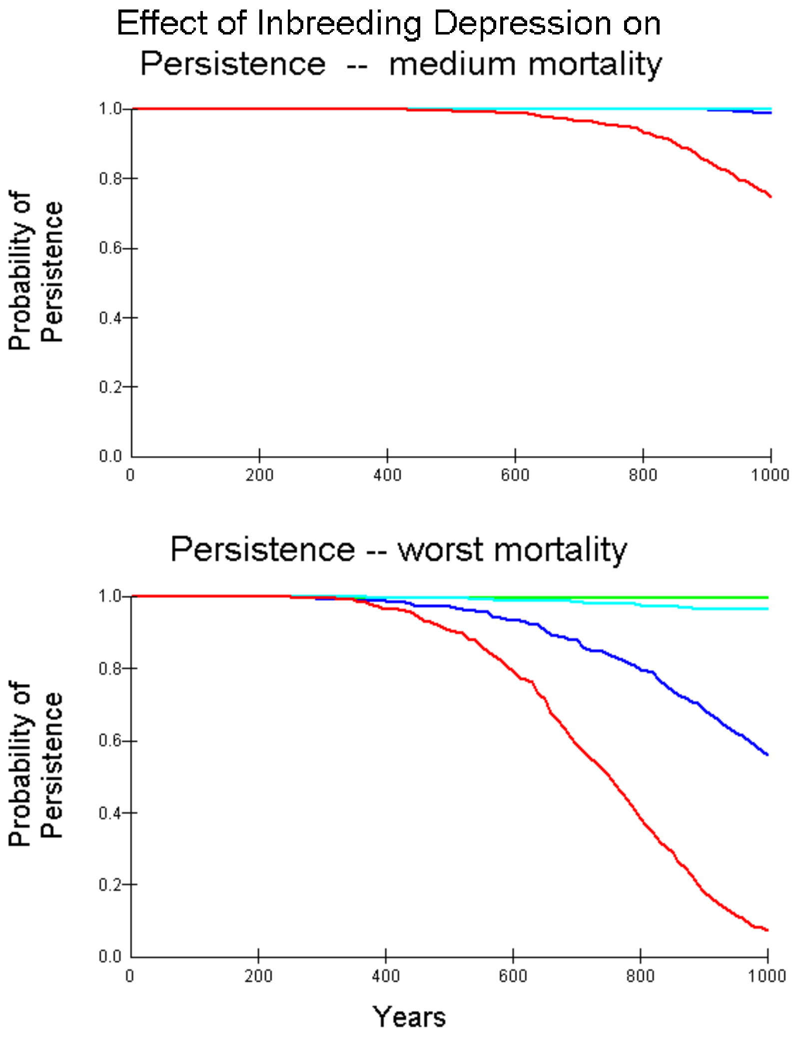


Figure 5.13. Impacts of inbreeding depression due to 0, 2.0, 4.06, and 6.0 lethal equivalents (top to bottom) on the persistence of populations of initial and maximum size 100, subjected to two levels of mortality (with the best mortality, all populations persisted)

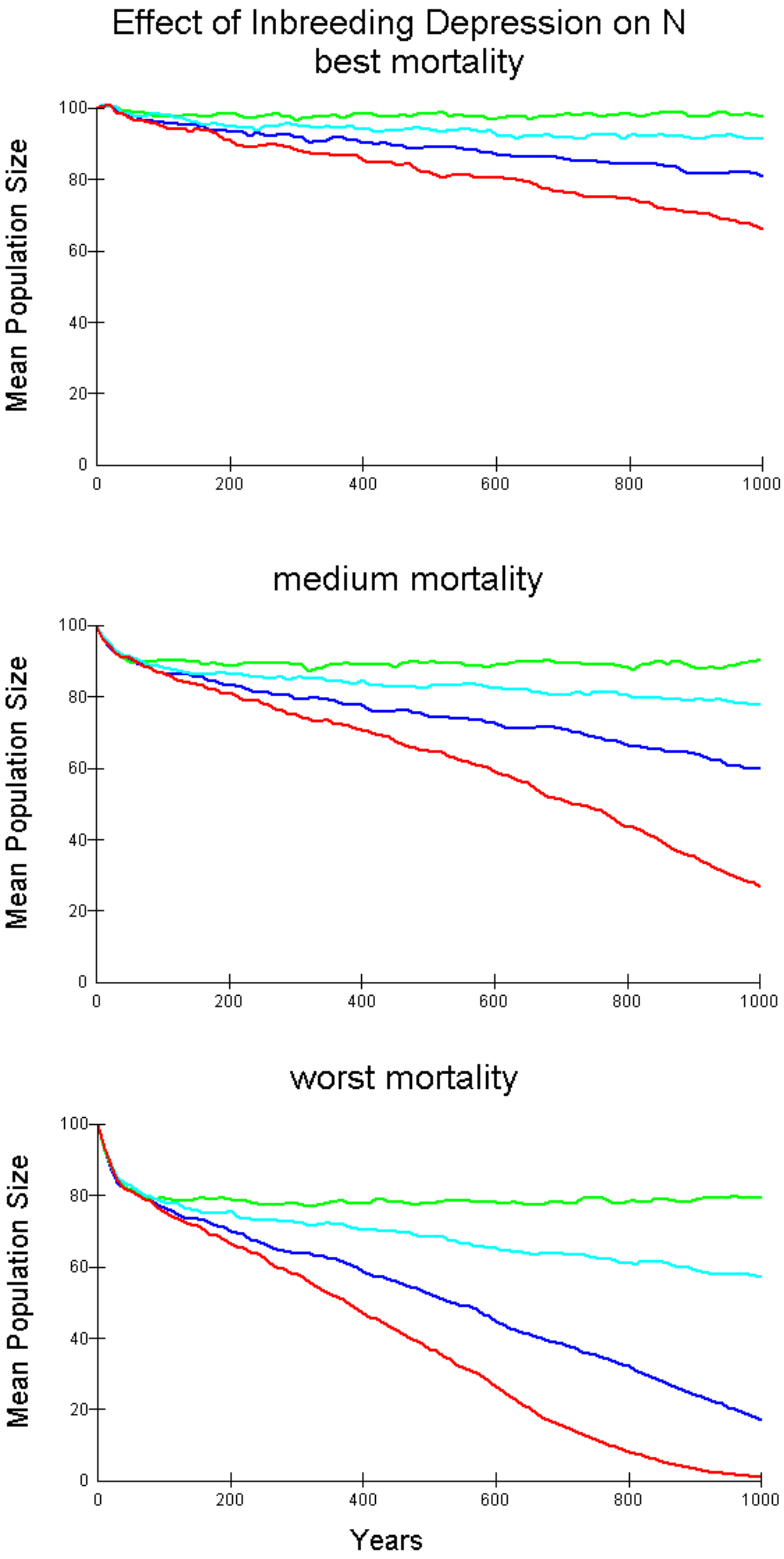


Figure 5.14. Impacts of inbreeding depression due to 0, 2.0, 4.06, and 6.0 lethal equivalents (top to bottom) on the size of populations of initial and maximum size 100, subjected to three levels of natural mortality

Impacts of hunting

Orangutans are a long-lived, slowly reproducing species; so even very low rates of hunting (or other causes of killing) might strongly threaten population growth, stability, and persistence. We examined models with additional annual mortality of all age classes of 1%, 2%, and 3%. Table 5.15 and Figures 5.15 and 5.16 show the impacts of these levels of hunting on populations in habitats capable of supporting, 250 orangutans. With the best natural mortality, a removal due to hunting of 1% of the orangutans per year does not cause population extinction but does lead to depressed population size, while even this low level of hunting can cause declines to extinction if natural mortality is at the levels estimated for less than optimal habitat. Higher rates of hunting are unsustainable even under the best assumption for natural mortality. The current numbers of orangutans estimated to be removed annually by capture for the pet trade or killed to obtain infants as pets is much higher than the rates that would be sustainable. Additional killings of orangutans for food or other purposes would further accelerate decline.

Table 5.15. Impact of hunting at rates of 0%, 1%, 2% and 3% annual removals of animals from populations with initial and maximum size of 250 orangutans and three levels of natural (non-hunting) mortality. All other parameter values as described for the baseline scenario. (PE = % probability of extinction; N = mean population size; GD = % of initial gene diversity)

Input parameters		50 years			100 years			1000 years		
Mortality (natural)	Hunting rate (%)	PE	N	GD	PE	N	GD	PE	N	GD
Best	0	0	249	99	0	246	99	0	235	89
Best	1	0	208	99	0	204	98	0	166	85
Best	2	0	159	99	0	136	98	89	2	59
Best	3	0	112	99	0	72	96	100	0	--
Medium	0	0	229	99	0	226	99	0	209	88
Medium	1	0	184	99	0	170	98	5	82	77
Medium	2	0	136	99	0	101	97	100	0	--
Medium	3	0	94	98	1	48	95	100	0	--
Worst	0	0	207	99	0	202	98	0	167	85
Worst	1	0	161	99	0	137	98	89	3	58
Worst	2	0	114	99	0	74	96	100	0	--
Worst	3	0	76	98	1	30	93	100	0	--

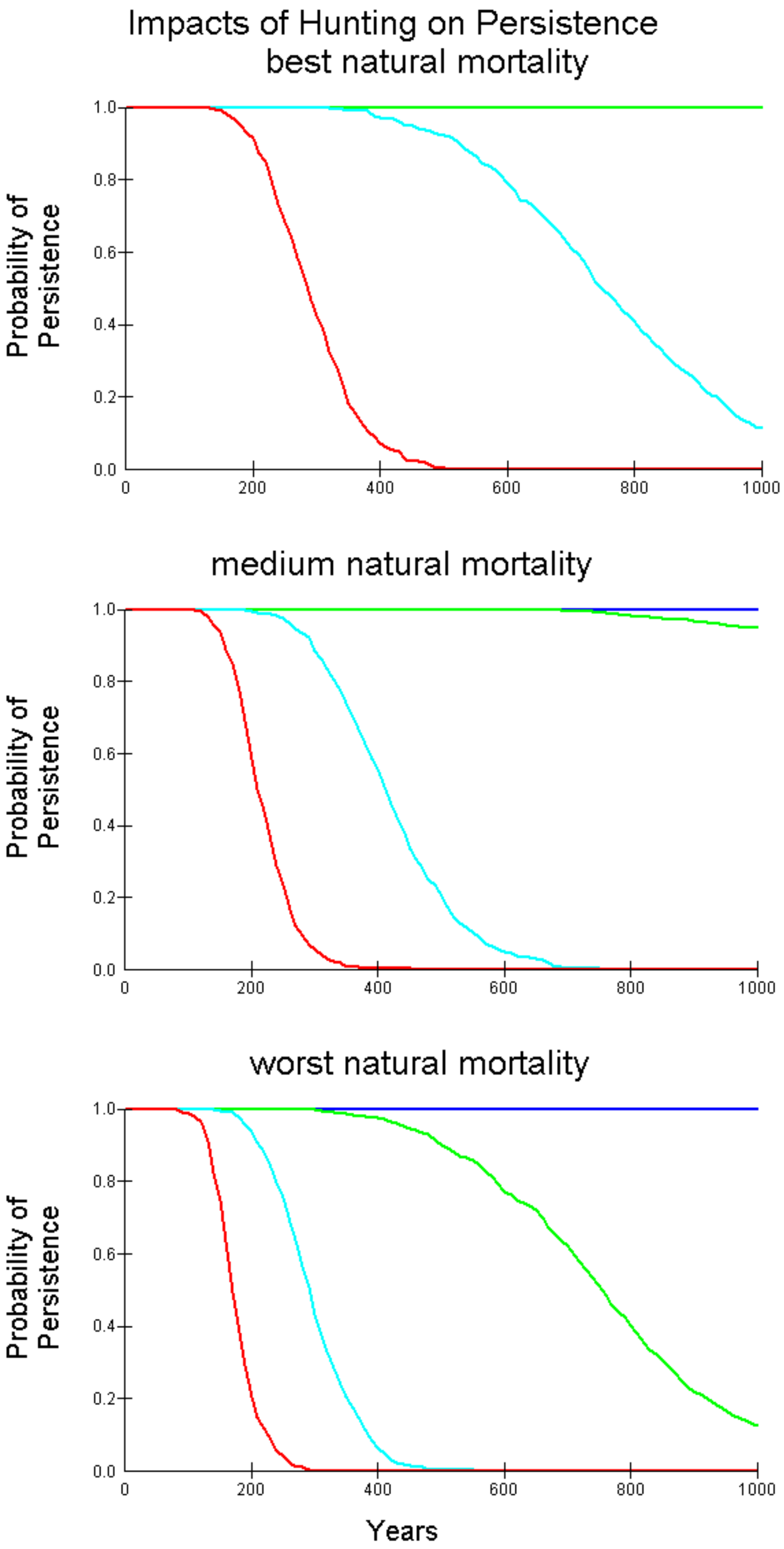
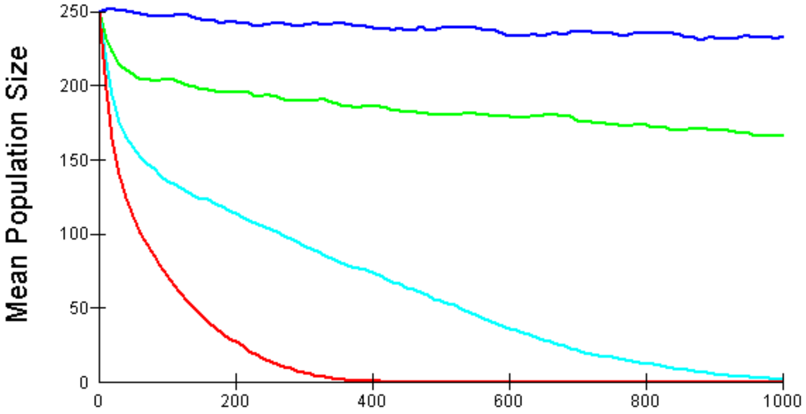
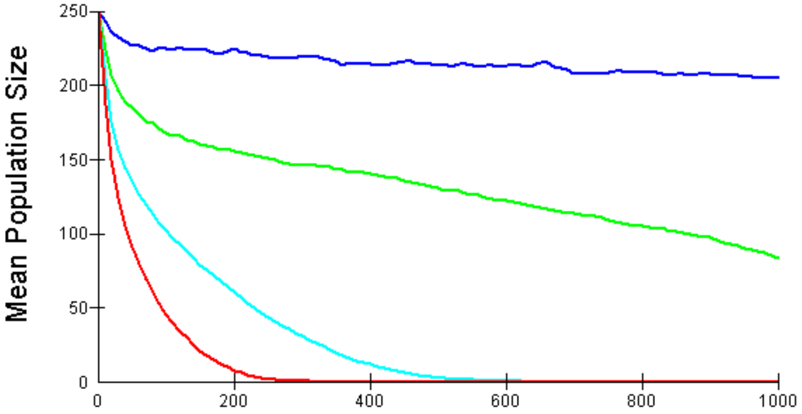


Figure 5.15. Impacts of 0%, 1%, 2%, or 3% hunting (from top to bottom, top two lines superimposed on top graph) on the persistence of populations of initial and maximum size 250, subjected to three levels of mortality

Impacts of Hunting on Population Size
best natural mortality



medium natural mortality



worst natural mortality

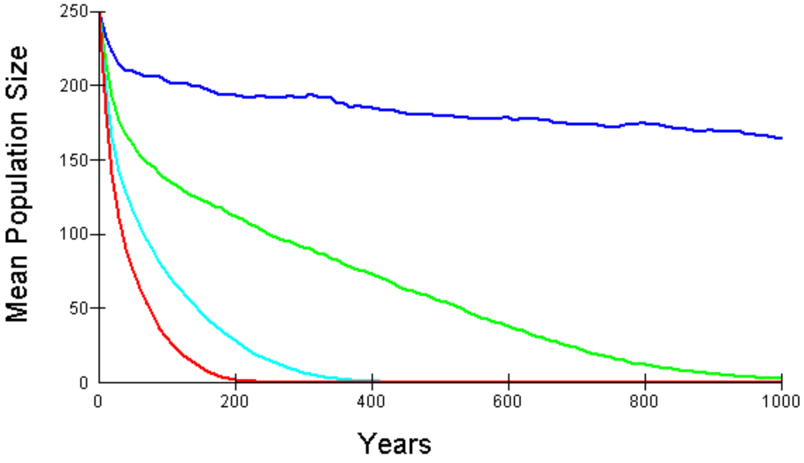


Figure 5.16. Impacts of 0%, 1%, 2%, or 3% hunting (from top to bottom) on the size of populations of initial and maximum size 250, subjected to three levels of mortality

SIMULATIONS OF SPECIFIC POPULATIONS ON BORNEO

After examining the analyses of scenarios that might represent typical populations on Borneo, with varying habitat availability, natural mortality, inbreeding effects, and hunting pressures, the Borneo Working Group split into 4 subgroups. These subgroups listed the larger populations in East Kalimantan, Central Kalimantan, West Kalimantan and Sarawak, and Sabah. For each population, we then specified the estimated current population size, carrying capacity, habitat quality (and therefore the natural mortality schedule expected to be most applicable to the area), ongoing or foreseen trends in habitat availability or quality, and any other model parameters that were assumed to be different from the values used in the baseline scenarios. Work by the subgroups to tabulate populations, identify threats, and rank priority actions are presented elsewhere in this PHVA workshop report report. Tables 5.2, 5.6, 5.8, and 5.11 summarize the information provided by each subgroup for the modeling. Below are presented the results of simulation models for the specific populations that were assessed.

East Kalimantan

Each of the 6 major habitat units that were tallied and analyzed persisted through the 1000 years of the simulation. However, those with habitat carrying capacities (K) of less than 300 lost more than 10% of their gene diversity, and were declining in population size in the latter years of the simulation because of the effects of inbreeding. For two of the habitat units, we examined alternative scenarios (indicated by the asterisks after the names in Table 5.16) that had carrying capacities of K = 300. For the Berau habitat unit, this reduction in K would put the population close to the lower size limit of populations that appear to be demographically and genetically robust. For the Sangkulirang habitat unit, the increase in K to 300 would allow it to grow from a size that was vulnerable to genetic decay to a size that appears more viable over the long-term.

Table 5.16. Results of simulations for major Habitat Units in East Kalimantan.
Berau+ = Berau & Sungai Lesan (not including Gunung Gajah)
Sangatta+ = Sangatta – Bengalon & Muara Wahau
Samarinda+ = Samarinda, Muara Badak, Marang Kayu
Habitat unit names with asterisks are scenarios that were examined to test alternative estimates of habitat carrying capacity. Input parameters: N = estimated current population size; K = estimated carrying capacity of the habitat. Results at 50, 100, and 1000 years: N = mean population size; GD = mean % of original gene diversity. All simulated populations persisted with at least 2 animals remaining through each simulation.

Habitat Unit	Input parameters			50 years		100 years		1000 years	
	N	K	Mortality	N	GD	N	GD	N	GD
TNK	600	600	Worst	503	100	490	99	454	94
Gunung Gajah	1500	1500	Best	1493	100	1504	100	1488	98
Berau+	400	400	Best	394	100	396	99	381	93
Berau*	400	300	Best	290	99	297	99	281	91
KutaiTimur	980	980	Worst	820	100	810	100	773	96
Sangkulirang	160	160	Medium	145	99	143	98	121	81
Sangkulirang*	160	300	Medium	254	99	268	99	252	90
Sangatta+	175	170	Worst	141	99	137	98	97	76
Samarinda+	200	200	Worst	164	99	161	98	123	81

Central Kalimantan

Under the initial assumptions about habitat carrying capacity, the orangutan populations in the major habitat units of central Kalimantan all persisted at sizes near their carrying capacities and retained high levels of genetic diversity. However, those two populations that are expected to decline in habitat (Arut Belantikan, with a projected decline in K of 60%, and Samba-Kahayan, with a projected decline of 20%) showed population declines in parallel with the habitat reductions. Two of the populations (Mawas and Sebangau) are not currently protected, and habitat may be steadily lost until the orangutan populations are extirpated. For Tanjung Puting, an increase in the habitat is possible, and the orangutan populations would be expected to increase in size to exploit any such increase in the quality or extent of available habitat. Overall, the populations in the large Central Kalimantan habitat units are sufficient in size that they would be expected to remain large and genetically healthy if the habitat remains and if hunting or other direct threats are avoided. Losses of habitat from several units, however, might eliminate populations that are currently significant contributors to the overall numbers, distribution, and genetic diversity of the species.

Table 5.17. Results of simulations for major Habitat Units in Central Kalimantan.
TNTP = Taman Nasional Tajung Puting
Habitat unit names with asterisks are scenarios that were examined to test alternative plausible projections of changes in habitat carrying capacity. Input parameters: N = estimated current population size; K = estimated carrying capacity of the habitat, with projected changes. Results at 50, 100, and 1000 years: PE = probability of population extinction by that time; N = mean population size; GD = mean % of original gene diversity.

Habitat Unit	Input parameters			50 years			100 years			1000 years		
	N	K	Mortality	PE	N	GD	PE	N	GD	PE	N	GD
TNTP	6000	6000	Best	0	6000	100	0	6019	100	0	5978	100
TNTP*	6000	6000 + 33% in 50y	Best	0	7505	100	0	8017	100	0	7982	100
Mawas	3500	3500	Best	0	3514	100	0	3502	100	0	3476	99
Mawas*	3500	3500 – 3% / y	Best	0	799	100	1	177	99	100	0	--
Mawas*	3500	3500 – 5% / y	Best	2	141	99	6	29	97	100	0	--
Arut Belantikan	6000	6000 – 60% in 20 y	Medium	0	1763	100	0	2178	100	0	2169	99
Samba Kahayan	1000	1000 – 20% in 20y	Worst	0	680	100	0	660	100	0	636	96
Sebangau	6900	6900	Medium	0	6420	100	0	6342	100	0	6340	100
Sebangau*	6900	6900 – 1% / y	Medium	0	3928	100	0	617	100	100	0	--
Sebangau*	6900	6900 – 2% / y	Medium	1	1229	100	77	9	95	100	0	--

West Kalimantan and Sarawak

Six of the habitat units in West Kalimantan and Sarawak are estimated to be sufficiently large to be capable of continuing to support demographically and genetically healthy populations (Table 5.19). The smaller habitat unit at Bukit Baka also appears able to persist, although with diminished genetic diversity.

Table 5.19. Results of simulations for major Habitat Units in West Kalimantan and Sarawak. Bukit Rongga+ = Bukit Rongga & Bukit Perai
Input parameters: N = estimated current population size; K = estimated carrying capacity of the habitat. Results at 50, 100, and 1000 years: N = mean population size; GD = mean % of original gene diversity. All populations modeled persisted through the simulation.

Habitat Unit	Input parameters			50 years		100 years		1000 years	
	N	K	Mortality	N	GD	N	GD	N	GD
Gunung Palung	2500	2500	Medium	2324	100	2305	100	2286	99
Betung Kerihun	1665	1665	Medium	1404	100	1371	100	1349	98
Batang Ai	350	350	Best	348	100	347	99	333	93
Lanjak Entimau	1100	1100	Best	1097	100	1086	100	1076	98
Danau Sentarum	750	750	Medium	695	100	694	100	662	96
Bukit Baka	175	175	Best	175	99	171	98	158	85
Bukit Rongga+	1000	1000	Medium	930	100	916	100	894	97

Sabah

For the habitat units in Sabah, the survey work of Ancrenaz and colleagues provides evidence that some populations in managed forests (Tabin, Trus Madi, and Sabah Foundation) are likely currently below habitat capacity. In contrast, the population at Kulamba is estimated to be at a size that is more than double the long-term capacity of the habitat. Similarly, the populations in the fragmented forests of Lower Kinabatangan are thought to be above capacity, and to currently have an excess of males, due to the movement of animals into the remaining forests from surrounding areas where habitat has been recently destroyed. In these cases in which the populations were currently over the long-term capacity due to an excess of males, the simulations were started with a number of females that was 50% of K, with the rest of the initial animals being males.

As shown in Table 5.20, the simulations suggest that if the habitats remain with the capacities that are currently estimated, or if the modest projected changes occur, the populations of orangutans are expected to remain viable within these large habitat units of Sabah.

Table 5.20. Results of simulations for major Habitat Units in Sabah.
Input parameters: N = estimated current population size; K = estimated carrying capacity of the habitat, with projected changes. Results at 50, 100, and 1000 years: N = mean population size; GD = mean % of original gene diversity. All populations modeled persisted through the simulation.

Habitat Unit	Input parameters			50 years		100 years		1000 years	
	N	K	Mortality	N	GD	N	GD	N	GD
Sabah Foundation	6318	7200 – 10% in 50y	Medium	6181	100	5932	100	5978	100
Tabin	1285	2200	Medium	1934	100	2042	100	1993	99
Trus Madi	255	900 – 10% in 50y	Worst	454	99	604	99	634	95
Kulamba	730	320	Medium	247	99	289	99	268	91
N Kinabtangan	2298	2600 – 20% in 50y	Medium	2383	100	2411	100	2377	99
L Kinabatangan	1125	800 + 5% in 50y	Medium	695	100	764	100	744	96

Fragmentation of the forests of Lower Kinabatangan

In our initial models, we treated the population within the forests of Lower Kinabatangan as a single large population. However, these forests are highly fragmented, and it is not likely that orangutans can easily move among the forest fragments. We therefore tested also some models in which the Lower Kinabatangan population was fragmented into 9 subpopulations of an overall metapopulation. In the most extreme (and maybe most realistic?) case, we assumed that no orangutans would disperse between any of these fragments. In this case of complete isolation (scenario "Meta-0" in Table 5.21), the combined meta-population always persisted, but the total population size declined after a number of the smaller subpopulations were extirpated due to the effects of inbreeding and the demographic instability of small, isolated populations. Only the largest of the isolated subpopulations (the interconnected set of PSU4-5-7 forest fragments) retained high levels of genetic diversity throughout the simulation.

When we assumed that there would be on average 1% of animals moving from each population to each other population every year (scenario Meta-1A), the subpopulations were much more stable demographically and genetically, as the movement of animals among populations dampened fluctuations in numbers and greatly reduced inbreeding. Only the two smallest subpopulations were extirpated at the end of any of the simulations, although the smallest unit (PSU10) experienced frequent local extinction and then recolonization by immigrants.

Population sizes were lower, losses of genetic diversity greater, and local extinctions more frequent when the dispersal was limited to 1% of animals moving among those forest fragments that are more closely adjacent (scenario Meta-1B). When the overall metapopulation was split into two sets of independent fragments, the system was not as stable and lost much more genetic diversity than was the case if all fragments are connected by dispersing orangutans.

When rates of dispersal or orangutans among fragments of the Lower Kinabatangan forest system was increased to 3% between pairs of fragments (scenarios Meta-3A and Meta-3B), the smallest subunits had somewhat lower rates of local extirpation, but the total population size and the amount of genetic diversity retained was lower than in the comparable cases with 1% dispersal. The higher rates of dispersal probably led to the smallest populations attracting animals away from the larger and more stable subunits, depleting overall numbers in the metapopulation and diminishing the retention of the genetic alleles that were unique to the smaller forest units. Overall, the fragmented forest system of the Lower Kinabatangan appears to require occasional dispersal of animals among subunits to prevent local inbreeding and demographic instability, and the optimal dispersal pattern would be a fully interconnected system with a low rate of movement among forest units.

Table 5.21. Results of simulations for the discontinuous forest fragments in Lower Kinabatangan, Sabah. Input parameters: N = estimated current population size; K(max) = estimated maximum carrying capacity of the habitat. Results at 50, 100, and 1000 years: PE = probability that the population would be extinct; N = mean population size; GD = mean % of original gene diversity.

Input parameters			50 years			100 years			1000 years		
Forest fragment	N	K(max)	PE	N	GD	PE	N	GD	PE	N	GD
Meta-0 scenario: Completely isolated fragments, no dispersal											
PSU1	230	110	0	57	97	0	92	96	0	74	72
PSU2	209	90	0	43	96	0	70	94	5	49	62
PSU3	63	65	0	60	97	0	58	95	37	16	49
PSU4-5-7	377	300	0	267	99	0	287	99	0	262	90
PSU6	55	52	0	47	96	0	46	94	75	4	37
PSU8	22	64	0	45	94	0	51	91	46	14	48
PSU9	49	62	0	56	97	0	54	94	45	13	50
PSU10	23	26	0	23	92	2	20	86	100	0	--
PSU 11	97	85	0	75	98	0	77	96	7	45	63
Combined	1125	854	0	674	100	0	754	100	0	478	95
Meta-1A scenario: 1% annual dispersal between each pair of forest unit fragments											
PSU1	230	110	0	83	98	0	100	98	0	99	93
PSU2	209	90	0	65	98	0	80	97	0	79	92
PSU3	63	65	0	57	97	0	60	97	0	56	92
PSU4-5-7	377	300	0	271	99	0	285	99	0	274	93
PSU6	55	52	0	44	97	0	47	97	1	43	91
PSU8	22	64	0	44	96	0	55	97	0	56	92
PSU9	49	62	0	54	97	0	57	97	0	53	92
PSU10	23	26	0	21	95	3	22	95	60	13	90
PSU 11	97	85	0	74	98	0	79	97	0	75	92
Combined	1125	854	0	712	100	0	786	99	0	749	94
Meta-1B scenario: 1% annual dispersal among 1, 3, 6, & 9; and 2, 4-5-7, 8, 10, &11											
PSU1	230	110	0	74	98	0	97	97	0	91	85
PSU2	209	90	0	59	98	0	78	97	0	79	91
PSU3	63	65	0	58	97	0	59	96	0	51	84
PSU4-5-7	377	300	0	266	99	0	286	99	0	270	92
PSU6	55	52	0	45	97	0	47	95	1	39	84
PSU8	22	64	0	45	96	0	55	96	1	54	90
PSU9	49	62	0	54	97	0	55	96	1	49	84
PSU10	23	26	1	22	95	4	22	95	74	11	89
PSU 11	97	85	0	74	98	0	79	97	0	74	91
Combined	1125	854	0	698	100	0	777	100	0	719	95
Meta-3A scenario: 3% annual dispersal between each pair of forest unit fragments											
PSU1	230	110	0	94	98	0	101	97	0	93	88
PSU2	209	90	0	74	98	0	81	97	0	75	88

Input parameters			50 years			100 years			1000 years		
Forest fragment	N	K(max)	PE	N	GD	PE	N	GD	PE	N	GD
PSU3	63	65	0	56	97	0	58	97	0	53	87
PSU4-5-7	377	300	0	267	99	0	282	98	0	261	89
PSU6	55	52	0	44	97	0	46	96	0	42	87
PSU8	22	64	0	39	96	0	52	96	0	53	87
PSU9	49	62	0	51	97	0	55	97	0	51	87
PSU10	23	26	0	20	95	2	22	94	45	13	85
PSU 11	97	85	0	75	98	0	79	97	0	71	88
Combined	1125	854	0	720	100	0	776	99	0	712	90
Meta-3B scenario: 3% annual dispersal among 1, 3, 6, & 9; and 2, 4-5-7, 8, 10, &11											
PSU1	230	110	0	86	98	0	98	97	0	91	84
PSU2	209	90	0	71	98	0	83	97	0	78	89
PSU3	63	65	0	56	97	0	58	96	1	51	83
PSU4-5-7	377	300	0	268	99	0	288	99	0	264	90
PSU6	55	52	0	45	97	0	46	96	2	40	83
PSU8	22	64	0	44	97	0	54	97	1	54	89
PSU9	49	62	0	53	97	0	56	96	0	49	84
PSU10	23	26	2	21	96	4	22	95	70	13	88
PSU 11	97	85	0	76	98	0	79	98	0	72	89
Combined	1125	854	0	720	100	0	784	99	0	712	94

Effect of Hunting of Orangutans in Habitat Units

To illustrate the effect of various rates of hunting (or killing or removal of any sort) of orangutans in the habitat units, we ran simulations with 1%, 2%, and 3% rates of killing on a small habitat unit with the worst level of natural mortality (Sangatta+, K = 170), a medium size unit with a medium level of natural mortality (Danau Sentarum, K = 750), and a large unit with the best level of natural mortality (Mawas, K = 3500). As shown in Table 5.22 and Figure 5.17, a population in a small habitat unit with degraded quality habitat can be driven extinct with as little as 1% of the orangutans being removed each year; a population in a medium size and quality of habitat can be driven extinct with 2% or more hunting; and a large population in high quality habitat is driven extinct if 3% of the animals are killed each year. Even the rates of hunting low enough to not cause extinctions do in each case cause considerable reductions in population size, after which compensatory breeding stabilizes the population at a lower size (Figure 5.18).

Table 5.22. Effects of hunting on several Habitat Units in Kalimantan.
Results at 50, 100, and 1000 years: PE = probability that the population would be extinct; N = mean population size; GD = mean % of original gene diversity.

Habitat Unit	Input parameters			50 years			100 years			1000 years		
	K	Natural Mortality	Hunting Rate	PE	N	GD	PE	N	GD	PE	N	GD
Mawas	3500	Best	0%	0	3514	100	0	3502	100	0	3476	99
			1%	0	2940	100	0	2879	100	0	2872	99
			2%	0	2278	100	0	2050	100	0	1704	98
			3%	0	1616	100	0	1111	100	95	1	62
Danau Sentarum	750	Medium	0%	0	695	100	0	694	100	0	662	96
			1%	0	556	100	0	526	99	0	453	94

			2%	0	407	100	0	321	99	93	2	67
			3%	1	281	99	1	152	98	100	0	--
Sangatta+	170	Worst	0%	0	141	99	0	137	98	0	97	76
			1%	0	109	98	0	90	97	98	0	47
			2%	0	77	98	0	48	95	100	0	--
			3%	0	52	97	4	20	89	100	0	--

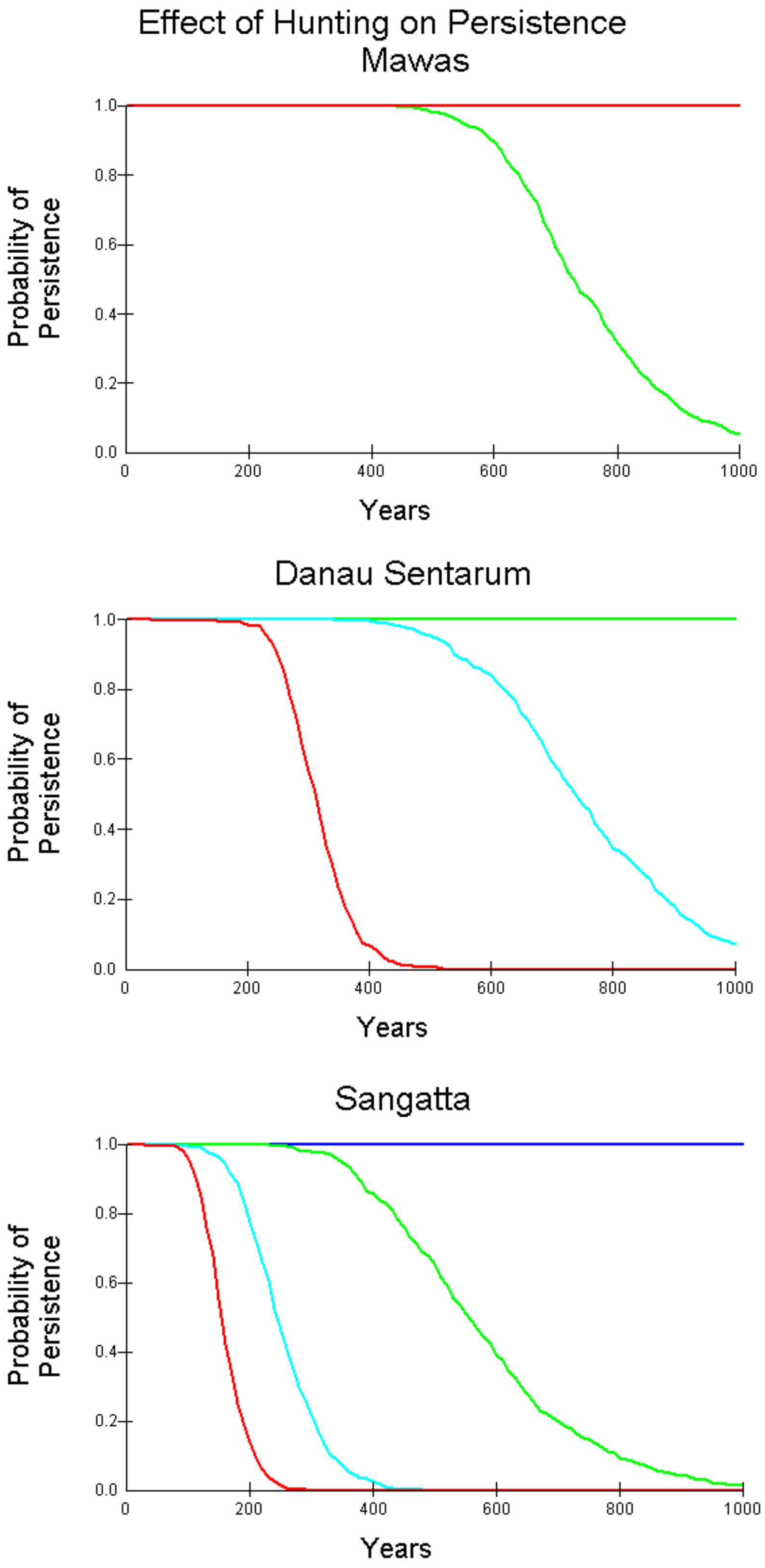
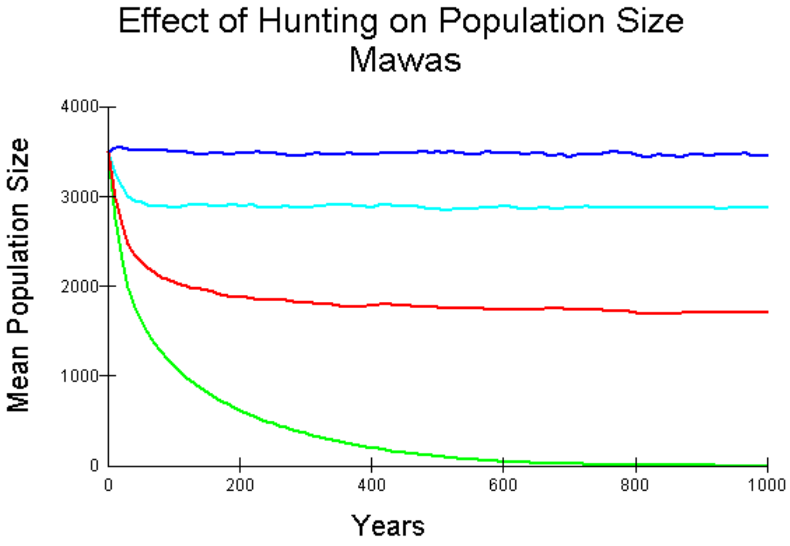
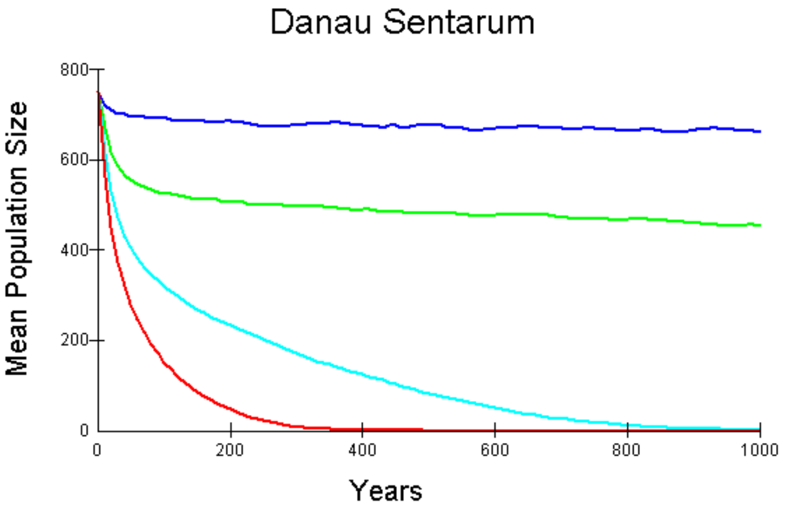


Figure 5.17. Impacts of 0%, 1%, 2%, or 3% hunting (from top to bottom, top few lines superimposed on top two graphs) on the persistence of populations at Mawas, Danau Sentarum, and Sangatta





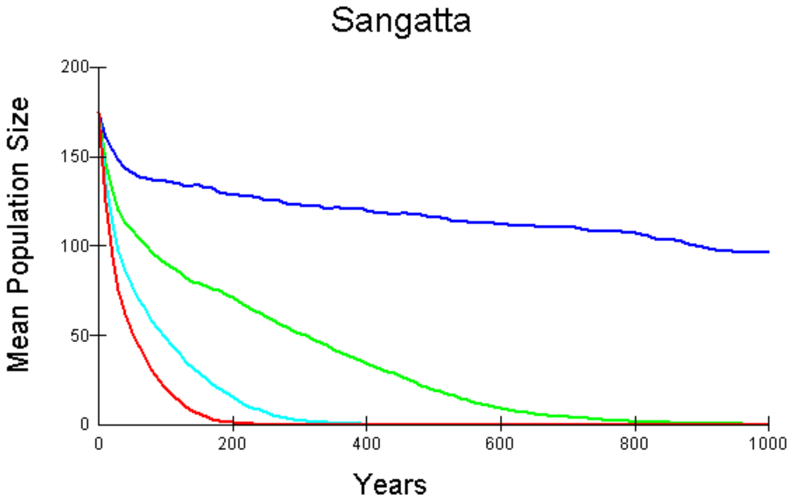


Figure 5.18. Impacts of 0%, 1%, 2%, or 3% hunting (from top to bottom) on the size of populations in Mawas, Danau Sentarum, and Sangatta

SUMMARY OF MODELING BORNEO POPULATIONS OF ORANGUTANS

Based on data available from the 1993 PHVA report, recent field studies, and additional information provided by the working group participants, we developed a baseline model that we believe provides a reasonable representation of the dynamics of typical orangutan populations in relatively undisturbed habitat on Borneo. The baseline model imposes a habitat carrying capacity through density dependent reproduction, with inter-birth intervals rising from 5 years (in low density populations) to 10 years (in crowded populations). At low population densities, when any small population effects such as inbreeding and Allee effects are excluded, the model results in an average of 2.5%, 2.0%, or 1.5% population growth (r_{max}), depending on whether the mortality schedule was as estimated for high quality habitat, medium quality habitat, or lower quality habitat. At high densities (at the estimated "carrying capacity"), the model projects population growth of 0.1%, -0.4%, or -0.9% depending on the mortality schedule. It should be noted that the density dependent relationship we used for breeding rates would lead (for populations large enough to avoid inbreeding problems) to a stable population at the nominal carrying capacity, K, for the high quality habitats (best mortality), populations about 10% lower than this in medium quality habitats, and populations about 20% lower in the worst quality habitats.

The differences between some of the input values used in the Borneo Working Group models and the Sumatra Working Group models reflect partly perceived differences between the population demography in the species on the two islands, with orangutans on Borneo possibly having lower mortality, faster breeding, and consequently capacity for more rapid population growth. Some of the differences in values used by the two working groups reflect different estimates derived from sparse field data from either island. In general, these differences were small enough to not cause large differences in the population projections of the models. It is clearly the case, however, that more demographic data from long-term field studies are needed from both islands, to provide more accurate estimates of population rates and to better document the existence and extent of differences between the two islands (and possibly between different regions within each island).

Our initial exploration of some scenarios representing typical populations on Borneo suggests that orangutan populations restricted to habitats capable of supporting only about 50 animals can persist for a considerable number of years, but are unstable and vulnerable to extirpation. Habitats capable of supporting more than 250 orangutans appeared necessary to ensure good demographic and genetic stability.

At the smaller population sizes, some of the threat to population stability and persistence was due to the effects of inbreeding depression in the models (i.e., the populations were stable if we optimistically assume that inbreeding would have no impact on orangutans), but the effects of inbreeding did not become apparent until after about 100 years in the models. If inbreeding effects are greater than the 4.06 lethal equivalents applied in our baseline models, then the small populations are even less stable, especially if in worse quality habitat.

Low rates of hunting (more than 1% per year) could destabilize and threaten the persistence of even initially large populations in extensive areas of habitat. The impacts are most severe when hunting occurs in lower quality habitat, where the potential population growth rate is low at best, but even in the best habitats, the slow breeding rates of orangutans cannot compensate for hunting at rates of 2% and higher.

Models of populations within specific habitat blocks further reinforced the finding that the smaller populations, if isolated from other populations, would be less stable and eventually decline as they became inbred and lost their genetic diversity. It should be noted that there are many small patches of forest on Borneo that contain very small populations of orangutans. These populations, smaller than any we modeled, would be very vulnerable to extirpation. In addition, some of the forest areas that were considered in our assessments to be single "habitat units" – such as some of the areas in central and west Kalimantan – are partly to severely fragmented. It is not known if orangutans can move among these forest blocks, and the effects of this fragmentation may therefore be to cause the populations in these forest "units" to be much less stable and less secure than appears in our models.

For the highly fragmented forest of the Lower Kinabatangan in Sabah, we examined the impact of complete isolation of fragments, or partial isolation with some movement of orangutans among fragments. If the orangutan populations in the forest fragments are completely isolated, then the smallest fragments do not contribute to the long-term populations in the region. Low rates of dispersal among fragments (as low as 1% to 3%, i.e., about 7 to 21 animals successfully moving among fragments each year) do provide considerable stability to the overall system. However, for such dispersal to occur, and for dispersing animals to not be lost from the population, orangutans will have to be able to move safely among the forest fragments. If there is high mortality during dispersal, then the effect of 1% to 3% attempted dispersal events could be the same as 1% to 3% hunting – steady decline of the currently large population to extinction.

It is also important to recognize that our basic models assume that the habitat units will remain largely unchanged and will not be subjected to stresses larger than (or even, in some cases, as large as) those that they are currently experiencing. ***Yet many of these forests will be cleared or badly degraded unless urgent and forceful action is taken soon. Our models should be seen not as a prediction of what will happen, but rather as projections of the expected stability of the existing large populations of orangutans if the habitat units are preserved and other threats such as hunting do not harm the orangutans within the forests.*** We ran several simulations to project the declines that will occur if habitat is destroyed (for example, in Mawas and Sebangau). Not surprisingly, the models show that even populations that are currently very large could be driven extinct within the next 50 years – a shorter time frame than the known potential longevity of single orangutans in the forest. We also tested the effect of hunting in three sample habitat units – and demonstrated again that even low rates of hunting can depress populations in the best habitat and completely eliminate populations in worse habitat. Higher rates of hunting (e.g., 3% per year) are unsustainable anywhere.

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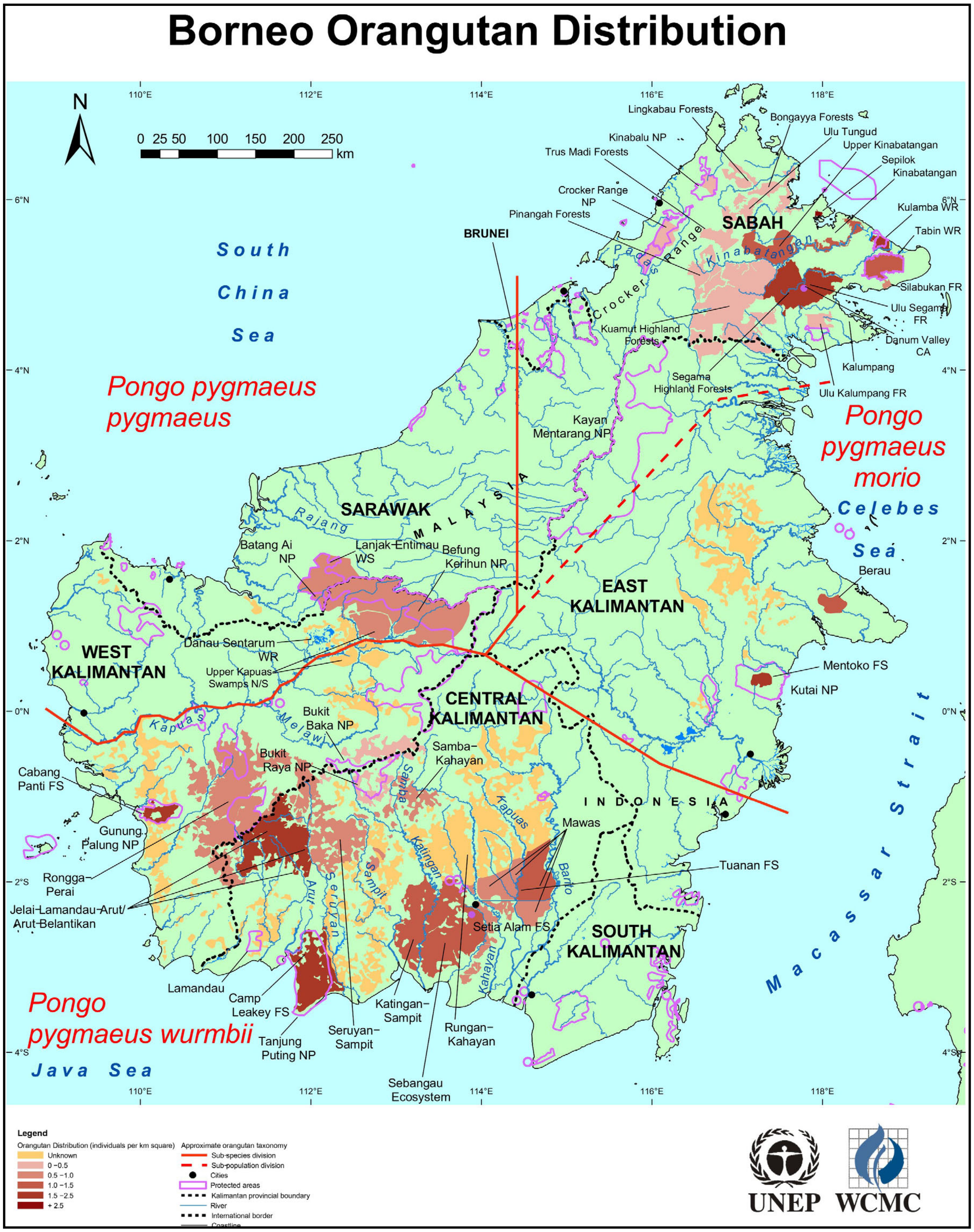
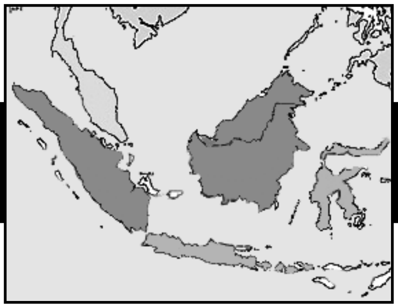
Figure 5.19



Borneo Orangutan Distribution
N
0 25 50 100 150 200 250 km
110°E
112°E
114°E
116°E
118°E
6°N
4°N
2°N
0°N
2°S
4°S
South China Sea
Celebes Sea
Java Sea
Macassar Strait
Pongo pygmaeus pygmaeus
Pongo pygmaeus morio
Pongo pygmaeus wurmbii
BRUNEI
SABAH
SARAWAK
MALAYSIA
INDONESIA
WEST KALIMANTAN
CENTRAL KALIMANTAN
EAST KALIMANTAN
SOUTH KALIMANTAN
Lingkabau Forests
Bongayya Forests
Kinabalu NP
Ulu Tungud
Trus Madi Forests
Upper Kinabatangan
Sepilok
Kinabatangan
Crocker Range NP
Pinangah Forests
Kulamba WR
Tabin WR
Silabukan FR
Ulu Segama FR
Danum Valley CA
Kalumpang
Ulu Kalumpang FR
Kuamut Highland Forests
Segama Highland Forests
Crocker Range
Padas
Kinabatangan
Kayan Mentarang NP
Rajang
Batang Ai NP
Lanjak-Entimau WS
Befung Kerihun NP
Berau
Danau Sentarum WR
Upper Kapuas Swamps N/S
Mentoko FS
Kutai NP
Bukit Baka NP
Melawi
Kapuas
Bukit Raya NP
Samba-Kahayan
Cabang Panti FS
Gunung Palung NP
Rongga-Perai
Jelai-Lamandau-Arut/Arut-Belantikan
Mawas
Tuanan FS
Setia Alam FS
Samba
Katingan
Sampit
Seruyan
Arut
Kahayan
Barito
Lamandau
Camp Leakey FS
Tanjung Puting NP
Seruyan-Sampit
Katingan-Sampit
Rungan-Kahayan
Sebangau Ecosystem
Legend
Orangutan Distribution (individuals per km square)
Unknown
0 –0.5
0.5 –1.0
1.0 –1.5
1.5 –2.5
+ 2.5
Approximate orangutan taxonomy
Sub-species division
Sub-population division
Cities
Protected areas
Kalimantan provincial boundary
River
International border
Coastline
UNEP
WCMC

FINAL REPORT



ORANGUTAN

Population and Habitat Viability Assessment

15-18 January 2004
Jakarta, Indonesia

Section 6

POST WORKSHOP COMMENTARY

Post-workshop Commentary

Ian Singleton, Simon Husson, Serge Wich, Jito Sugardjito, Jatna Supriatna

Please note: *After the Orangutan PHVA workshop, the draft report was circulated to volunteer reviewers who provided editorial comments. As a result of that review, the following concluding sections were prepared to synthesize the workshop discussions and recommendations. These sections were not part of the draft report and have not had as broad a distribution and review as the rest of the document. Therefore, it is possible that the views reflected here may not be shared by all workshop participants.*

CONSERVATION STATUS OF THE SUMATRAN ORANGUTAN, *PONGO ABELII*.

The Current Situation

The modeling work carried out during this workshop suggests that orangutan populations of 500 or more are demographically and genetically stable in the absence of human-related mortality, habitat loss or unforeseen catastrophic events, and may contribute to the long-term conservation of this species. Populations of 250 have a very high probability of survival under the same conditions, but will be markedly reduced in size and lose substantial genetic diversity. Smaller populations that are linked by occasional exchanges of animals could also contribute to the overall stability of a larger meta-population if managed effectively and depending on the levels of threat and the time scale involved in reducing that threat.

Of the 13 identified orangutan populations on Sumatra, only 7 are estimated at 250 or more individuals and only 4 at over 500 individuals. It should also be noted that the NW Aceh population is almost certainly already fragmented into two populations (Ulumasin with ca 340 orangutans and Tutut with ca 314), and that estimates for these two areas were based on old 1998 satellite images. Given this, there is every likelihood that today only 3 populations on the island number above 500 individuals and, of the 7 over 250, 6 are believed to be subject to high levels of habitat loss (annual losses to logging of 10-15%; Table 6.1).

Due to the above, the fundamental finding of this workshop is that under current conditions, ALL Sumatran orangutan populations are predicted to go extinct long before 1000 years, which was the conservation goal set for the Sumatran orangutan, and all but 3 have a 100% probability of extinction in less than 100 years (see also Figure 4.34, page 90). Two of these 3 will likely consist of only a few related individuals that will persist only for a short time. Only the West Batang Toru population appears to have a realistic chance of surviving beyond 100 years under current threat levels, assuming that current threats really are as low as we perceive them to be (i.e., habitat loss is only 2% annually) and do not increase in the future. Note also that orangutans are still being eaten in the Batang Toru and east Sipirok areas. To add to the concern, only 2 of the populations currently over 500 individuals can be confidently expected to exist in 50 years time.

Even though some orangutans are expected to survive for at least another 50 years under current logging conditions, the number of orangutans on Sumatra is predicted to decline sharply during this time (Fig. 4.34). Fifty years from now only 7 of the current 13 orangutan populations are expected to remain. Of these, 6 will consist of fewer than 20 individuals, while West Batang Toru could potentially retain around 177 orangutans. This would mean a projected total world population of wild Sumatran orangutans in the year 2054 of just 234 individuals; if we then add losses due to other factors (e.g. hunting, persecution, disease, illegal trade) we would more than likely not even have these. This represents an estimated decline of 97% of the entire wild Sumatran orangutan population in the next 50 years.

In contrast, if logging and removal of orangutans could be halted today, the number of orangutans expected to remain in 50 years would be approximately 6570. If all logging was halted within 5 years, projections suggest that about 2758 or more orangutans would still remain after 1000 years (Fig. 4.35), probably in 5-9 different populations. Clearly, therefore, a rapid cessation of logging in the region has immense implications for the prospects of Sumatran orangutan survival.

Even if logging could be stopped, the above predictions all assume that there is no additional removal of orangutans (e.g., hunting) over and above the numbers of animals that will be lost directly as a result of habitat loss. It should be noted, however, that orangutans cannot withstand a rate of removal above 1% annually, even with no loss of habitat, and that as habitat recedes and numbers decline, it is highly likely that losses due to hunting and persecution will begin to account for orangutans that would not have otherwise been lost due to forest conversion. Then killing of individuals would almost certainly drive remaining small populations to extinction.

It has also been noted that efforts to reduce fragmentation and link orangutan populations to form meta-populations may contribute to the viability of Sumatran orangutans. However, under current levels of threat an examination of the benefits of corridors connecting East Leuser to West Leuser and Trumon-Singkil to West Leuser did not yield any notable changes in the prognosis for survival (Table 6.1). If habitat loss can be controlled, however, then actions to reduce fragmentation become more relevant and valuable. For example, in Table 4.16 (page 72), we can see clearly that if logging is stopped in 10 years, the prospects for conserving the orangutans of East Leuser in the long term are very much improved if they interact as one contiguous population (PE at 1000 years = 2% with 82% gene diversity) as opposed to existing as two separate populations due to the presence of roads (PE at 100 years = 40% with 67% gene diversity). Ultimately though, continued habitat loss and removal of individuals associated with logging will drive this species close to extinction within a few decades. The urgency for action varies among the habitat units, but for all the need to stop logging is immediate if orangutans are to persist.

Given the above, what are the prospects that the major threat to the Sumatran orangutan, logging, will be reduced or even stopped in the very near future? We have no reason for optimism. Currently habitat conversion is continuing at an alarming rate. The Ministry of Forestry itself acknowledges that the current rate of loss nationwide is ca 3.8 million ha/year and in Aceh alone around 270,000 ha/year. Within the Leuser Ecosystem, analysis of satellite imagery shows that between 1985 and 2001, ca 560,893 ha of primary forest was lost (37,400 ha/year). Looking in detail at the swamp habitats, which are known to support the highest densities of orangutans in Sumatra, van Schaik *et al*. (2001) found that between 1990 and 2000, some 20,000 ha of prime orangutan habitat in the Tripa swamp was lost and converted to Palm Oil, with 10,000 ha being lost in only 2 years. They also deduced that between early 1993 and 1998, 62.2% of forest in the Tripa swamps was lost, along with 45.4% in the Kluet swamps and 47.1% in the Trumon-Singkil swamps. Furthermore, it was only in 1997 after the fall of then President Suharto that illegal logging really went out of control. It is therefore distinctly possible that deforestation rates have increased since 1998 and that the numbers provided here (and earlier in this report) are even conservative. In all orangutan areas, irrespective of protection status, illegal logging is continuing and showing no signs of being reduced. In some areas, like the Leuser Ecosystem, illegal logging is even bound to increase due to road development.

Table 6.1: Summary of model predictions for each habitat unit under current rates of habitat loss (those in italics represent proposed corridors, though it should be noted that work is already underway connecting Trumon to West Leuser).

Habitat unit	**Current Pop**	**Habitat loss/Yr**	**50 Years**			**100 Years**			**1000 Years**			**Year at PE 5%**
			PE	**N**	**GD**	**PE**	**N**	**GD**	**PE**	**N**	**GD**	
Seulawah	43	3%	0	13	93	**68**	3	70	**100**	-	-	61
NW Aceh	**654**	10%	28	5	86	**100**	--	--	**100**	--	--	47
NE Aceh	180	10%	**96**	2	73	**100**	--	--	**100**	--	--	39
East Middle Aceh	337	15%	**100**	--	--	**100**	--	--	**100**	--	--	28
West Middle Aceh	103	10%	**100**	--	--	**100**	--	--	**100**	--	--	32
Tripa swamps	280	15%	**100**	--	--	**100**	--	--	**100**	--	--	28
East Leuser	**1,052**	15%	**100**	--	--	**100**	--	--	**100**	--	--	35
West Leuser	**2,508**	10%	0	17	96	**100**	--	--	**100**	--	--	52
E and W Leuser connected	*3,560*	*10%*	*0*	*24*	*97*	***100***	--	--	***100***	--	--	*52*
Trumon-Singkil swamps	**1,500**	10%	5	8	92	**100**	--	--	**100**	--	--	50
Trumon and W Leuser connected	*4,008*	*10%*	*0*	*25*	*98*	***100***			***100***			*53*
Puncak Sidiangkat	134	5%	1	12	94	**99**	2	75	**100**	--	--	53
East Singkil swamps	160	20%	**100**	--	--	**100**	--	--	**100**	--	--	19
East Sarulla	150	20%	**100**	--	--	**100**	--	--	**100**	--	--	18
Batang Toru	400	2%	0	177	99	0	62	98	**100**	--	--	188

Ladia Galaska

To add to the already existing problems of overlogging (both legal and illegal), the provincial and local governments in Aceh have started to construct a 450-km road system known locally as *Ladia Galaska*. The Ladia Galaska road network, together with related road projects, cuts through the Leuser Ecosystem in at least nine places and through additional orangutan habitat units further north (e.g. North West Aceh and North East Aceh; see maps pages 91 and 93). They cut across the steep slopes of the Bukit Barisan mountain range and through forests specially designated to safeguard water-catchment areas and other protected areas. Proper Environmental Impact Assessments (EIAs [known in Indonesia as AMDALs]) have not been conducted, and the sections at least through protected areas are therefore illegal.

Despite very strong domestic and international concerns, the Government issued contracts in mid-2003 and construction started immediately on three sections of the main Ladia Galaska road network. The roads under construction as part of the first phase are now more than 30-40% completed; this is just an estimate, as monitoring construction in areas controlled by the army (i.e., the war torn province of Aceh) is difficult and there is no transparency of public access to current information on developments.

Alternative solutions have been proposed by the Leuser Management Unit, with the full support of the Minister of the Environment, but none have yet been seriously discussed by the Ministry of Settlement and Regional Infrastructure or the regional Aceh (NAD) government. The alternative routes would achieve the stated aim of Ladia Galaska (i.e., to link the west and east coasts), but would not cut through any protection forests or the Leuser Ecosystem. An offer by the World Bank in 2002 to fund a full study of the transport needs of Aceh was also rejected by the provincial government of Aceh. A team of specialists was, however, established by the central Indonesian Government to investigate the existing proposals and developments. They concluded that at least three key sections of the roads were currently located in areas that are highly susceptible to erosion and earthquakes and were therefore unsuitable for major road schemes.

Many stretches of the proposed roads cover extremely unstable and dangerous terrain. A 4-km section from Meulaboh to Beutung Ateuh in Nagan Raya that cuts through the Leuser Ecosystem has already been affected by landslides, in November 2003. This section of the road cuts through a land system called Bukit Pandan (BPD), which denotes steep mountain slopes (averaging greater than 60%) and thin, erosion-prone soils. Several other long stretches of the Ladia Galaska scheme also cover BPD. As an example of the risks, in November 2003 a 7,000-ha forested area of this land system in the Bohorok water-catchment area of the Gunung Leuser National Park (and Leuser Ecosystem) was struck by a major series of natural landslides that killed more than 230 people. Subsequent field surveys and photographic evidence clearly show that the disaster had no connection with illegal logging. It was simply a result of the terrain, and similar large-scale floods have occurred previously in the same area over many decades. The mechanisms causing flash floods in Leuser have been well documented (Robertson and Soetrisno, 1982; UML, 2003; BAKORNAS, 2003) and the terrain over which the Ladia Galaska roads will be built is precarious to say the least.

Where they cross forested areas the roads will also lead to a massive wave of illegal logging, encroachment and settlements within some of the largest expanses of Sumatran orangutan habitat. The effect of Ladia Galaska can be predicted exactly because of precedents in Leuser. In 1982, a road upgrading project was undertaken that split the Gunung Leuser National Park in two. Aerial photographs taken before and after clearly show that the improved access facilitated uncontrolled illegal settlements along the road inside the National Park around Gumpang and Marpunga (districts of Gayo Lues and Southeast Aceh). These local indigenous settlers were responsible for large-scale illegal encroachment, illegal logging, and poaching of endangered species. The first waves of local people will move in along the main roads, which will quickly lead to the cutting of dozens of additional roads, branching off each main road. This will in turn lead to the destruction of many areas of extremely high biodiversity in the lowland and hill forests, causing the local extinction of all endangered large mammals, followed eventually by thousands of other species. Using long established species-area methods (Krebs 1985; Wilson 1992) it has already been 'conservatively' predicted that the roads themselves will lead to between 13% and 37% loss of species in each of the remaining forest fragments that they create (using $z = 0.3$; see Wilson 1992, p264), without even accounting for the inevitable forest loss that will occur along their length. These additional impacts on habitat loss due to the construction of roads were not included in the models for Sumatran orangutans and would suggest an even faster rate of population decline and probability of extinction.

Significantly, there has never been an economic feasibility study undertaken of the Ladia Galaska road scheme. However, an economic evaluation of the Leuser Ecosystem by a team of international economists (van Beukering *et. al.*, 2001) showed that over a 30-year period, the total economic value of the Leuser Ecosystem was far greater under a policy of conservation (US $22.3 billion), compared to the alternative of conversion and exploitation of the forests (US $16.87 billion). The forest conversion policy only enriches a few elite logging groups in the short-term, whereas the local communities benefit greatest (60%) under the conservation policy in both the short-term and long-term. Thus, conservation of the Leuser Ecosystem creates the conditions for the long-term sustainable development of the surrounding region of Aceh.

The Importance of the Leuser Ecosystem

The Leuser Ecosystem covers some 26,000 sq. km, (2.6 million ha), of tropical rain-forest and harbors over 25,000 of the known species on Earth in a biodiversity hotspot in northern Sumatra. It contains 4.2% of all known bird species and 3.2% of all known species of mammals on the planet. This includes the three largest populations of the Sumatran orangutan (*Pongo abelii*), as well as the largest population of one of the most critically endangered large mammals on earth, the Sumatran rhino (*Dicerorhinus sumatrensis*). It also includes the only scientifically documented viable populations of the Sumatran tiger (*Panthera tigris sumatrae*; Carbone 1998) and probably the Sumatran elephant (*Elephas maximus sumatranus*; Brett 1990). The Leuser Ecosystem is globally important for bird conservation, containing more than 80% of Sumatra's resident breeding species and all of the IUCN "Red Data Book" bird species listed for Sumatra. It is the most complete and representative conservation area in the West Indo-Malayan Realm (Malesia).

Furthermore, Leuser's forests act as a vital resource to local communities and safeguard surrounding areas from erosion, flooding and other natural disasters. There are many examples in North Sumatra, Aceh and elsewhere in Indonesia of significant damage to property and infrastructure, and people being killed, as a result of floods and erosion caused by destructive logging practices. The most recent major event in Aceh occurred in western Aceh in November 2002. This caused several tens of thousands of people from four regencies in western Aceh to evacuate their homes due to devastating flood damage. Roads and main-highway bridges downstream were destroyed, cutting the area off from the rest of Aceh. The damage was estimated at US $11.74 million (Jakarta Post, 28.11.2002). These floods in West Aceh, Nagan Raya, West Aceh Daya, and South Aceh, were all the result of destruction of the adjacent forests in the Leuser Ecosystem, the scale of which had been exacerbated by road networks that had opened up the area for logging operations on mountain slopes. Leuser's forests currently limit the extent of such destruction, but we shall almost certainly see a significant increase in these kinds of disasters in Aceh and North Sumatra (and the vast expense they incur for regional and national government) if it is not protected

World Heritage Site proposal

It would seem that the current Government of Indonesia's proposal to UNESCO for a World Heritage Site including Gunung Leuser National Park is far from optimal with regards to orangutan habitat conservation. A subsequent analysis, after the PHVA workshop but using exactly the same data and methods used in the PHVA (i.e. density estimates at 100m altitude intervals), concluded that the Leuser Ecosystem contains ca 5,598 orangutans whilst in the National Park itself there are only ca 2,025, in many small fragments. Thus there are more orangutans (3,573) within the Ecosystem's borders but outside of the National Park, than there are within the Park. The National Park also does not include the Trumon-Singkil swamps, where ca 1500 orangutans are considered to still survive, nor does it contain the Tripa swamps. The only area of swamp forest within the National Park is the Kluet swamp, an area considered to harbor around 312 orangutans at the present time. The incredible value of the swamps should not be ignored. Trumon-Singkil represents one of only 3 habitat units that still contain over 500 orangutans (if we assume NW Aceh is probably already two non-contiguous populations - see earlier). The swamp forests are also well known for their high orangutan densities and the unique cultural behavior that the orangutans within them exhibit (including tool use).

There may well be legal obstacles to proposing the much larger Leuser Ecosystem as a World Heritage Site. It may also be the case that designation as World Heritage Status might not necessarily afford significant, tangible benefits to orangutan conservation (i.e., would it really help stop illegal logging?). Nevertheless, the concern must be that any designation that focuses solely on the primary forests within the Gunung Leuser National Park is likely to distract attention and conservation action away from the remaining lowland forests which support much greater biodiversity.

A better alternative or addition may be a species-specific designation to declare the orangutan as a World Heritage Species, a new concept that is presently being discussed by relevant bodies. If this becomes possible it might offer better opportunities for protecting far more orangutans than those that would be afforded protection within the National Park alone by increasing the potential for protection of much larger areas.

Summary
The outlook for the Sumatran orangutan is extremely bleak, despite the fact that this PHVA workshop does show that all hope is not yet completely lost. If habitat loss could somehow be miraculously halted within the next 5 years, about 2700 orangutans might still remain after 1000 years. If this does not happen we will almost certainly see the extinction of the Sumatran orangutan within decades.

An unprecedented commitment to stopping habitat loss and considerable diligence in protecting the remaining forests would be a prerequisite for saving the species. If we are to be realistic, however, we have little reason to expect current rates of habitat conversion to stop, or even to slow down in northern Sumatra. In fact, there is every indication that it is on the verge of a dramatic increase, largely as a result of the proposed Ladia Galaska road scheme and an eventual end to the present moratorium on legal logging in Aceh!

If we are to have any hope of protecting the Sumatran orangutan's habitat we must therefore pin these hopes on much improved protection of so-called protected areas, but again, we do not see this happening anytime soon. Several parts of the Ladia Galaska road scheme cut directly through the Leuser Ecosystem, an unparalleled biodiversity region within Indonesia, afforded official protection by Presidential Decree. The importance of the Leuser Ecosystem cannot be understated with respect to Sumatran orangutans, as it contains the 3 largest populations of the species and the only populations considered to still harbor over 500 individuals. Furthermore, the conservation of Leuser's orangutans may be compromised under a proposal to establish the much smaller Gunung Leuser National Park as part of a Cluster World Heritage Site, despite the fact that the majority of orangutans exist outside of the park but within the Ecosystem's boundaries. Efforts are needed to both expand the forested area under official protected status and radically improve the degree of protection that such areas are afforded, not simply for the benefit of a few orangutans but for the preservation of one of the world's most important biodiversity hotspots and for the human population that relies on these resources for its very survival.

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Conservation status of the Bornean orangutan, *Pongo pygmaeus*.

The results of the PHVA survey and modelling exercise offers, on the surface, hope for the conservation of this species. Total estimated numbers, following 10 years of intense surveys across the island, are much higher than the previous, widely quoted estimates of Rijksen and Meijaard (1999). The VORTEX modelling, meanwhile, suggested that populations as small as 500 individuals are both sustainable and genetically stable in the long run. But this rosy picture overlays a much grimmer prognosis. Nine key threats to the Bornean orangutan are highlighted in the main body of this report – illegal logging, forest conversions, hunting, fire, fragmentation, encroachment, peatland drainage, mining and poor forestry management by logging concessions – and numerous underlying causes of these are described. The purpose of this section of the report is to stress the existing and potential future threats to those priority populations decided upon during the PHVA workshop and to suggest possible solutions to these problems.

Recent trends and conservation failures

Densities and population sizes are in decline across the species range, and forest continues to be lost at a rapid rate. For instance, a ten-year ongoing census of orangutans in the Sebangau Ecosystem has recorded a 50% decline in numbers, from 12,000 individuals in 1995 to 6000 today (Husson *et al.*, in prep.). An overall loss of 15.5 million hectares of forest (24% of the total forest area) was recorded between 1985 and 1997 in Sumatra and Kalimantan. In the lowlands – prime orangutan habitat – this figure is 60% (Holmes, 2000). Ten priority populations on Borneo were decided upon during the course of the PHVA, with the recommendation that conservation efforts become focused on these populations. The prioritisation process chose mainly those sites with the largest population sizes, or those that make a unique contribution to orangutan survival, and is an important step for orangutan conservation. Past orangutan conservation failures demonstrate that no existing population, however large or seemingly well protected, should be considered safe and without need of strong protection efforts. For instance, the fate of Kutai National Park is the clearest example of the failure of the protected area system in Indonesia and provides the potential worst-case scenario for the remaining national parks. Since the late 1960s, Kutai has been logged repeatedly and invaded by logging concessions, industrial complexes, open-pit coalmines and settlements. Forty percent of the park burnt during massive forest fires in 1983 and 1998, the intensity of which has been directly related to the level of forest degradation. Perhaps only 10% of this once great park is still forested, and its orangutan population was reduced from an estimated 4000 in 1970 to 500 today (Rijksen and Meijaard, 1999; this report).

In another example, the disastrous Mega-Rice Project, perhaps the largest and most destructive agricultural conversion project in the world in recent times, demonstrated how rapidly areas of orangutan habitat can be destroyed. In a bid to boost the country's rice production, one million hectares of peat-swamp forest was partly cleared and drained during 1995-97 in preparation for conversion to rice fields. Most of this land is covered in highly acidic, deep peat and is useless for agriculture. The construction of a network of massive canals completely drained the peatland during the dry season, and even when it became apparent that rice wouldn't grow and the project was abandoned, the drainage of the proposed rice field areas also drained vast tracts of the surrounding forests. Dead wood and dry peat became a tinderbox, flaring into uncontrollable fires that raged for six months during 1997–98. Over 400,000 hectares of forest burnt (Page *et al*, 2002) and virtually no forest remained for orangutans to seek refuge in. In any case, the canals, rivers and farmland largely prevented orangutans from moving into the remnant forests. If we estimate an approximate orangutan density for the area of 2 individuals per square kilometre, that equates to 8,000 individuals that perished in the fires. A wasteland is left where before there was diverse rainforest.

Illegal logging epidemic in National Parks

The designation of protected area status on some of the most important forest areas for orangutans provides a theoretical basis for conservation in those areas. But, whilst the threat of conversion is perhaps less imminent in such areas, illegal activities are damaging the integrity of all protected areas in Borneo.

Illegal logging in the Indonesian National Parks is rampant and has caused a huge drop in orangutan numbers. Failure to stop illegal logging in any of these areas will inevitably lead to a further dramatic reduction in forest cover and orangutan population size. The *P.p. pygmaeus* sub-species is the most endangered of the three Bornean sub-species, and its core populations are found in four protected areas in western Borneo. Lanjak Entimau and Batang Ai in Sarawak are understaffed and suffer from illegal logging and hunting, as well as probable cross-border logging from Kalimantan. Meanwhile Danau Sentarum and Betung Kerihun in West Kalimantan are being destroyed by illegal logging with little concerted effort made to prevent this. Both of these parks are understaffed and underfunded and the management units simply do not have the capacity to protect these important areas. Urgent NGO and donor activities are required to focus attention and enforcement efforts on these areas. We fear that both these Indonesian National Parks will be lost before the mechanisms to control this illegal logging are put in place.

Illegal logging activities have been controlled to some extent in Tanjung Puting and Gunung Palung National Parks, i.e. those areas with the most active NGO's and government agencies, through the efforts of direct action *Wana laga* teams comprising members of the military and Special Forces. Commendable as these efforts are, they are merely serving to slow the removal of logs from the forest and the protection of some core areas of the parks, without tackling the root of the problems. They may also offer only a temporary reduction in logging, unless they are regularly carried out and the loggers never know when they're coming. If a more secure future for these parks is to be achieved, major changes in the law enforcement process, government policy and legal system are needed, as discussed in the reports of the Balikpapan and Palangkaraya Orangutan Protection Workshops (Rosen, Russon and Byers, 2001; Rosen and Byers, 2002). Even if all logging activities are stopped, further declines in orangutan numbers are to be expected as a result of compression effects. This mechanism of decline was demonstrated in the Sebangau Ecosystem where intense logging activities caused distribution shifts and consequent overcrowding in unlogged areas. Although most orangutan individuals apparently survived for three to four years after illegal logging activities and overcrowding started, years of malnutrition or a single bad fruit year resulted in a sudden, dramatic die-off of 30% of the population (Husson *et al.*, in prep.). Even without compression, orangutans may be expected to survive for several years on low-quality food but will eventually succumb until the population matches the lower carrying capacity of the logged forest. Such arguments may be academic though, as, importantly, logging still continues.

The boundaries of these parks are often not clearly delineated, making them difficult to police, and as a result, shifting cultivators, oil palm companies and logging concessions have encroached into all the parks. Aside from direct forest-loss, encroachment brings with it other problems, principally the spread of fire, hunting and human-animal conflict. These are the major problems affecting protected areas in Sabah, where illegal logging is being fought far more effectively than in Indonesia. Fire damaged parts of the Kulamba Wildlife Reserve in 1987, and areas surrounded by oil palm estates, e.g. Tabin Wildlife Reserve, suffer from ‘pest control’, i.e. the illegal shooting of orangutans that enter the estate.

Deep-peat swamp forests, drainage and fire

Concession logging and illegal logging have removed much of the commercially valuable timber from the vast peat swamp forests of Central Kalimantan, and this has inevitably caused many animals to starve and die. However, orangutans appear to be surviving in the logged habitat, albeit at lower densities, and some of the populations in this habitat-type so far remain substantial. Concession logging in peat swamp forest has to date been limited by the relative difficulty of extracting timber compared to dry-land areas, and a lower incentive to log when compared to the dryland forests due to lower densities of the major timber species. Nevertheless waves of illegal loggers continue to enter areas such as Sebangau, Katingan and Mawas and are removing trees of ever-smaller diameter and of species not previously removed by logging concessions. This will eventually threaten the viability of the orangutan populations. Furthermore, it is not just the loss of logged trees themselves (and their neighbours) that threatens these habitats. There are two associated and equally serious immediate threats to orangutan survival in these habitats – peat drainage and consequent degradation leading to forest collapse (as tree roots are exposed and no longer provide sufficient support) and/or fire (dry peat burns ferociously), and conversion to oil palm or other kinds of agriculture.

Peat is formed by the incomplete breakdown of organic matter under waterlogged conditions, and rapidly dries out and degrades if drained. If one section of a peat-dome is drained, knock-on hydrological changes eventually affect the entire dome, as has been witnessed with temperate peat bogs. Central Kalimantan’s swamps are being drained by two mechanisms (i) inadvertently along long, narrow channels dug for the purposes of extracting illegally logged timber and (ii) deliberately by a network of large, deep canals built under the auspices of the ‘Mega-Rice Project’ (MRP). The Sebangau and Katingan forests are riddled with canals of the first type, whilst the proposed Mawas reserve has several large canals of the second type traversing it. Peat-surface degradation undermines tree roots and, if left unchecked results in massive tree-falls – forest collapse in effect. Remote-sensing techniques detected the collapse of 15,000 hectares of peat swamp forest between the Kahayan and Kapuas rivers that was drained by a 45km long MRP canal that passed directly through the centre of the peat dome (Smits, pers. comm.). Drained peat is also highly flammable; fire spreads quickly and large fires are near impossible to extinguish once established as they can burn persistently underground, reappearing large distances from their source. The 1997-98 fires burnt 51.3% of the MRP area compared to 19.3% of surrounding, un-drained peat swamp forest (including the Sebangau Ecosystem, logging extraction canals had not been built then) (Page *et al*, 2002).

Despite the trend to convert large tracts of peat forest to oil palm plantations, it is well known that oil palm grows very badly on peatland >1m thick. Nevertheless, proposals by several companies to convert areas of deep peatland, e.g. the southern Mawas area and northern Katingan area, are still being made. Whether these are genuinely misguided attempts at plantation, or simply bogus excuses to harvest profitable timber, is unknown, but these schemes threaten to clear further large areas of forest. Certainly, the failure of the Mega-Rice Project and the resulting habitat destruction and socio-economic impacts must be considered as a forewarning of what may happen.

Fires occur frequently in Borneo but reach devastating levels whenever there are El Niño climatic events. Another strong El Niño, like the one that occurred during 1997-98, will inevitably result in further destruction by fire, and if the drainage remains unchecked these peat swamp forests will certainly be lost. Damming these canals, and thus restoring normal hydrological regimes in the peatlands, is required immediately if the orangutan populations found here are to be saved. This is clearly the top-priority essential management activity that must be made in Central Kalimantan's deep-peat swamp forests.

Managing production forests for orangutan conservation

One of the most exciting findings to come out of the extensive surveys carried out before the PHVA was the high numbers of orangutans remaining in low-hill forest throughout the island, e.g. in the foothills of the central-Bornean Schwaner range, especially in the headwaters of the Kotawaringan river and its major Arut, Belantikan and Lamandau tributaries in Central Kalimantan; in the Segama highland forests surrounding Danum Valley and in the upper reaches of the Kinabatangan river, both in Sabah; and in the hill forests of Gunung Gajah in Berau District, East Kalimantan. Nearly all of these forests are unprotected, however, and under logging concession management. It is vital for orangutan conservation that (i) all these areas remain under natural-forest management and (ii) they are managed in such a way that any timber exploitation is compatible with orangutan conservation.

We are witnessing a rapid expansion of palm oil estates in Borneo in response to international demand, and all unprotected dry lowland forests in Borneo are potential sites for such conversion. The area of oil palm plantations in Indonesia has increased from 106,000 ha in 1967 to approximately 4.1 million ha in 2002 and Indonesia is committed to expanding this industry still further (Casson, 2003). Already much of the forest in the southern part of the Arut-Belantikan forest block is planned for conversion. Large sections of the plains between the Sampit and Seruyan rivers in Central Kalimantan have been cleared recently and horrifying reports have emerged of hundreds of orangutans being shot in the process (Droscher-Nielsen, pers. comm.). Oil palm in Sabah remains a major industry, with demands for more land.

Conversion of land to oil palm carries other problems. The massive forest fires of 1997-98 which affected many areas of orangutan habitat, especially in East and Central Kalimantan, were partly blamed on plantation owners that illegally started fires to burn land (EIA, 1998), and orangutans that enter oil palm plantations are routinely shot.

Well-managed concessions are unfortunately, however, few and far between. Illegal logging in concessions is a major problem – in Kalimantan it is having such an impact on legal concessions' finances that several companies have resorted to consorting with the illegal logging teams in order to extract timber more cheaply. It would be far better if the timber companies worked together as an industry to approach the government to solve this problem. An inevitable consequence of over-logging these managed forests is a shortage of timber in the future, thus making conversion to oil palm and other kinds of plantation/agriculture a more attractive and profitable option for exhausted concessions, further increasing pressure for timber on protected areas.

In Sabah there is a major recommendation to base sustainable logging practices on those adopted in the Deramakot Forest Reserve. This is part of the Upper Kinabatangan forests, in which a rotation system of reduced impact logging has been adopted and has resulted in a mosaic of lowland habitats at different stages of exploitation and regeneration. Deramakot supports one of the highest orangutan densities in Sabah with a population of over 1000 individuals, and is considered to be a good model for combining logging practices with orangutan conservation. We also recommend that major research is carried out in this area to determine how exactly the forest management practices benefit the orangutan and to ensure the population isn't compressed and/or declining over time. The production forests of Sabah are the major stronghold of the *P.p.morio* sub-species, and it is essential these areas stay under natural-forest management

Fragmentation by logging roads opens the forest up to fire, hunting and encroachment, as well as harmfully impacting upon orangutan genetic diversity. Some roads are developed into major transport routes; others are abandoned but their highly compacted soil prevents immediate recolonisation by a large proportion of forest species. Often the forest near to logging routes is cleared and converted to plantation and farmland under the HTI (*Hutan Tanaman Industri*) system, permanently isolating forest blocks. A major recommendation for management of these areas should be the closing and rehabilitation of disused logging routes, ensuring connectivity between sub-populations and preventing human access.

Hunting of orangutan is the likely cause of the very low estimated densities of orangutans in several other areas of low-hill forest in Kalimantan, particularly in the upper reaches of the Katingan and Barito rivers in Central Kalimantan and Pawan river in West Kalimantan. (Simorangkir *et al*, in prep.). As the modelling showed, hunting pressures of higher than 1% per year causes a steep decline in numbers even in good quality habitat. Hunting intensity appears to vary from region-to-region and is probably a result of cultural and religious differences – hunting by certain Dayak tribes is believed to have caused local extinctions of orangutans in many parts of Sarawak. The actual intensity of hunting depends on the level of forest fragmentation, isolation, human activity, access routes, law enforcement and education activities associated with each particular logging concession.

A well-managed logging concession does have potential to support populations of orangutans over the long-term. It is therefore a major recommendation of this workshop for conservation organisations to work together with timber companies to help protect major populations that still occur within concessions (e.g., those mentioned above). Such cooperation is urgent, as under the current situation we are losing these populations.

All orangutan populations in Borneo are under threat and their future persistence should not be taken for granted. Indeed, it will only happen with committed management and law enforcement efforts. The lessons of Kutai National Park, of the Mega-Rice Project and of over-hunting in hill forests must not be ignored or all current orangutan populations will continue to decline dramatically and disappear. Strong law enforcement efforts against illegal logging; continued natural forest management in production forests and active management to reverse drainage regimes in peat swamp forest are essential activities to prevent the extinction of the orangutan in Borneo.

At the moment our efforts to save the orangutan may be viewed as simply slowing the decline until the last tree of any value is removed, at which point we are faced with trying to conserve what's left – which may not be any population of viable size. If the conversion of forests to oil palm and illegal logging – through all of its problems: destroying habitat, deliberate starting of fires and building extraction canals that drain peatlands – are left unchecked, they will undoubtedly cause the extinction of the orangutan in Borneo. We need immediate action to stop illegal logging. If we achieve that we can work on creating lasting solutions to conserve and manage areas for perpetuity, among them environmental education, development of alternative incomes, rescue and rehabilitation of pet orangutans, capacity building, forest rehabilitation projects and timber certification schemes. However, if we fail to solve the big problems of logging, conversion and peat drainage with haste, these secondary efforts will prove worthless.

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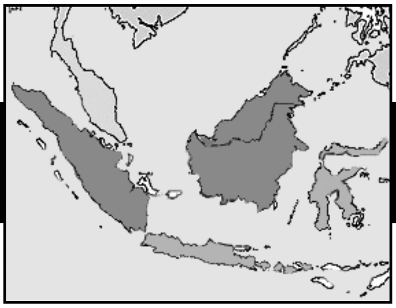
FINAL REPORT



ORANGUTAN

Population and Habitat Viability Assessment

15-18 January 2004
Jakarta, Indonesia

Section 7
PRE-PHVA
DATA COLLECTION REPORT:
The Status of the Orangutan in Indonesia, 2003

The Status of the Orangutan in Indonesia, 2003

Report to the Orangutan Foundation, UK (Ashley Leiman)
January, 2004

Contributors:
Simon Husson
Erik Meijaard
Ian Singleton
Carel van Schaik *(final editor)*
Serge Wich

Additional information from:
Andi Erman
Fazrin Rahmadani
Stephen Brend

Abstract

The objective of this report is to provide an overview of the status of wild orangutans in Indonesia, and to develop recommendations for conservation action by listing the conservation units of top priority.

We first considered changes in the known orangutan distribution since the situation in the early 1990s. For Sumatra, many areas south of Lake Toba that were thought to contain unknown numbers of orangutans at that time are now known not to contain any at all. The main northern population has not seen major reductions in its distribution area, except through extensive forest loss at their edges and severe fragmentation due to the loss of key lowland corridors. This process has resulted in 11 conservation units where orangutans occur, of which only one probably has a population of larger than 2000 individuals, which is approximately an effective population of 500 individuals. For Kalimantan, 4 of the original 44 blocks are gone and 7 are no longer considered to be containing orangutans (older information is now considered to be too generous). Another 10 blocks have lost more than half of their forest or have been badly fragmented.

Analysis of deforestation indicates that Kalimantan has lost at least 39% of its orangutan habitat within the orangutan's range over the last decade (1992-2002). Similar studies are not available for Sumatra, but the available information suggests very similar trends.

Detailed knowledge of distribution and densities in Sumatra allowed us to make an estimate of the total number as of 2002. We estimate that Sumatra still contains about 7,300 orangutans, distributed over 21 forest blocks. Only three of these contain over 1,000 orangutans, all part of the Leuser Ecosystem, and the four habitat units that currently make up the Leuser Ecosystem were all connected until a decade ago or less. Reconnecting the four separate habitat units in the Leuser Ecosystem would produce a large and viable population. For Kalimantan, the

information is presented separately for the three subspecies. Of them, *P. p. wurmbii* is the best represented, with at least 5 remaining areas with 2,500 individuals or more. For P. *p. pygmaeus*, no strong population probably remains in Indonesia, whereas for *P. p. morio* in Indonesia, the Gunung Gajah/ Berau/ Kutai population may offer the last hope.

Introduction

Serious downward trends in the integrity of Indonesia's forest estate occurred throughout the 1990s due to widespread logging and conversion for plantation agriculture, although protected areas were, in retrospect, left relatively unscathed. Since the change in government in 1998, however, conservation in Indonesia has seen a virtual collapse and deforestation has been enormous regardless of the legal status of the land (Holmes 2000; Jepson et al. 2001; Robertson and van Schaik 2001). As a result, wild orangutans are in steady decline due to logging, habitat conversion, fires and poaching. Based on case studies of single populations, predictions have been made that the ecological extinction of the orangutan is only decades away (Rijksen & Meijaard 1999; van Schaik et al. 2001; Wich et al. 2003; Galdikas pers. comm.).

A new PHVA of the orangutan was therefore held to develop a strategic recovery plan for this threatened species and its habitat. At the PHVA they were integrated with estimates of human-based threats, such as current and projected land-use patterns. Computer models were used to evaluate current and future risk of population decline or extinction under alternative management scenarios. This report compiles all the known data on population demography, genetics and ecology in preparation of the workshop.

To properly prepare for the workshop, we decided to assemble information on orangutan distribution and densities in several less known areas in both Sumatra and Borneo. In this task, we received help from numerous fieldworkers. We were also able to commission special surveys overseen by Simon Husson, Erik Meijaard and Ian Singleton (see appendix). Funding for these surveys was kindly provided by the Orangutan Foundation, UK and the Golden Arc Foundation, The Netherlands. Note that the results reported here only cover the territory of Indonesia.

The goals of this report are:

1. synthesize all the information on current distribution and numbers in conservation units,
2. document trends in forest cover and quality as well as numbers where available, and
3. identify the major conservation units and develop an estimate of the number of orangutans therein, including new areas that have not received adequate protection yet, in order to make possible that protection priorities for the last remaining viable orangutan populations be developed at the PHVA.

The analysis is based on *habitat units*. A habitat unit contains one or more forest blocks, as used by Rijksen & Meijaard (1999). It refers to distinct areas of orangutan habitat separated by normally impassable barriers such as major rivers or wide swaths of cultivation. A habitat unit therefore corresponds to a separate population, one not easily colonized by individuals from other populations. Where there was doubt about how separate the habitat units are, conservative decisions were made so that habitat units could be fused when future work confirms the presence of corridors or corridors can be reconstituted. Note that a single protected area can contain multiple habitat units. For instance, the new Mawas reserve in Central Kalimantan contains three separate blocks: one west and two east of the Kapuas Murung, with the latter two separated by large canals. Numbers for protected areas may therefore be split to reflect orangutan habitat units.

For the purpose of this report, we consider four separate taxonomic units. Nomenclature follows Groves (2001), which corresponds to the divisions in Kalimantan made by Warren et al. (2001), and is consistent with the impressions of fieldworkers and rehabilitation experts:

1. the Sumatran species (*Pongo abelii*; there is now sufficient genetic evidence to regard Bornean and Sumatran orangutans as distinct species [Zhang et al. 2001], and ecological and life-history differences also seem significant [e.g. Delgado & van Schaik 2000]);
2. the northwestern Bornean subspecies, north of the Kapuas and into Sarawak (*Pongo pygmaeus pygmaeus*);
3. the central Bornean subspecies, south of the Kapuas and west of the Barito (*Pongo pygmaeus wurmbii*); and
4. the northeastern Bornean subspecies, in Sabah and East Kalimantan (*Pongo pygmaeus morio*).

1. Distribution

In this section, we provide information on current distribution. Figures 4.36 and 5.19 provide the best estimate of the current distribution for Sumatra and Kalimantan, respectively. This distribution map differs from the previous distribution map (Rijksen & Meijaard 1999) due to three kinds of changes: (i) changes that reflect corrections on earlier information now considered to be false, (ii) changes that reflect loss of populations due to loss of habitat or loss of animals, and (iii) changes that reflect the discovery of hitherto unknown populations. The changes relative to their map, which reflected the state of knowledge and forest around 1992, over the past decade are provided in Fig. 7.1 for Kalimantan and 7.3 for Sumatra.

Sumatra

It has been known since the earliest work in the 1930s that the Sumatran orangutan distribution is concentrated in Aceh, but there has been much speculation as to the distribution farther south. Recent survey work on Sumatra (Wich et al. 2003, Singleton unpubl. data, Wich unpubl. data) has indicated that several of the areas that previously were considered to contain orangutans (Rijksen & Meijaard 1999) do not contain these anymore (Wich et al. 2003, Table 7.1). The occurrence of orangutans in several of these areas was based on old and possibly inaccurate reports, and it is unlikely that some of these areas actually contained orangutans in the recent past (Table 7.1). Rijksen & Meijaard (1999) and Rijksen (pers. com.) mention a further 14 areas that they expected to possibly contain orangutans, although they did not provide numerical estimates for the populations in them (see Table 7.1 in Wich et al. 2003). We could not confirm the presence of orangutans in any of these blocks, and they should therefore henceforth be considered as outside the current distribution area. For at least one of these areas, however (Rimbo Panti), where the presence of orangutans was still ascertained only some 7 years ago, recent habitat loss, degradation and hunting are the most likely causes for their disappearance (Table 7.1).

Recent surveys nonetheless identified three key areas near Lake Toba that contain orangutans: Puncak Sidiangkat, West Batang Toru and East Sarulla (Table 7.1). Among these three areas, West Batang Toru, the forest block between the towns of Tarutung, Sibolga, and Padangsidempuan, is the largest and therefore the most interesting from a conservation perspective (see below).

Table 7.1. Habitat units lost in Sumatra since Rijksen & Meijaard's (1999) overview, and the remaining habitat units south of Toba.

Area	Orangutan presence 1994-7*	Update orangutan presence 2002**	Reason for absence
Rimbo Panti/G. Talamau	Yes	No	habitat loss/hunting
Pasaman Barat	Yes	No	old info
Baruman	Yes	No	old info
Habinsaran	Yes	No	old info
Ankola-Siondop	Yes	No	old info
Kalang-Anggolia	Yes	No	old info
Tapanuli Tengah	Yes	No	old info
Dolok Sembelin	Yes	No	forest gone
West Batang Toru	Yes	Yes	(south of Toba)
East Sarulla/ Sipirok	Yes	Yes	(south of Toba)

* based on Rijksen and Meijaard 1999

** based on Wich et al. 2003, Singleton unpubl. data, van Schaik unpubl. data, Wich unpubl. data

North of Lake Toba, no habitat units have disappeared. However, the main changes there are a sharp decline in habitat size and loss of connectivity between major habitat units. This has resulted in the loss of the corridors between the West and East Leuser conservation units.

In conclusion, although the actual distribution of Sumatran orangutans has not changed much in the past 10 years, we now know that most of the areas south of Lake Toba, previously thought to contain orangutans, are now confirmed as having no orangutans.

Kalimantan

Since the last survey (Rijksen & Meijaard 1999), many changes have taken place in the forests of Kalimantan. Here, we present a qualitative comparison, recording whether the forest blocks recognized by them are still present, whether they have become badly fragmented, or have lost much of their area. Table 7.2 compiles these blocks (the numbers follow the codes used in Rijksen & Meijaard 1999). The assessment of the recent situation is based on the TREES (Tropical Ecosystem Environment Observations by Satellites) map produced by the European Union and the analysis of recent MODIS images (provided by Dr. D. Fuller, U Michigan) by Erik Meijaard (see below), both with a resolution of about 0.25 km^2.

Table 7.2. Habitat units for Kalimantan that existed in the orangutan range in Kalimantan in 1994-1997, as recognized by Rijksen & Meijaard (1999), which had disappeared, been fragmented or seriously reduced by 2002.

No.	Subspecies	Orangutan Presence ca 1992	Orangutan Presence 2002	Nature of major change
A.	**WEST KALIMANTAN**			
1	Sambas	Yes	Yes	Badly fragmented
2	Mempawah	Yes	No	Nearly gone
3	Gunung Niut	Yes	Yes	Badly fragmented
10	Kapuas swamps	Yes	Yes	Badly fragmented
11	Sukadana-Kendawangan	Yes	Yes	Badly fragmented
B.	**CENTRAL KALIMANTAN**			
12	Jelai-Lamandau-Arut	Yes	Yes	Badly fragmented
14	East Pembuang-Seruyan	Yes	Yes	Southern half nearly gone
15	W.Sampit floodplains	Yes	Yes	Nearly gone
16	Katingan floodplains	Yes	Yes	Northern half nearly gone
20	Sebangau-Kahayan	Yes	Yes	Some 30% remains, fragmented
22	Kapuas Murung-Barito plains	Yes	Yes	Northern and southern ends converted
28	Bandang East	Yes	No	Probably ecologically extinct due to hunting
29	Upper Dusun	Yes	No	Probably ecologically extinct due to hunting
30	Busang Hulu	Yes	No	Probably ecologically extinct due to hunting
C.	**EAST KALIMANTAN**			
31	Liangpran	Yes	No	Probably ecologically extinct due to hunting
32	Boh catchment	Yes	No	Probably ecologically extinct due to hunting
33	Pari-Sentekan	Yes	No	Probably ecologically extinct due to hunting
34	Belayan-Kedangkepala	Yes	No	Probably ecologically extinct due to hunting
35	West Muara Kaman	Yes	Yes	Nearly gone, mainly burned
36	Coastal Kutai	Yes	Yes	Nearly gone, mainly burned
38	Tinda-Hantung Hills	Yes	Yes	Southern half nearly gone

The results indicate that of the 44 forest blocks recognized by Rijksen & Meijaard, 4 are now nearly gone, with tiny parts of the original forest remaining, making it unlikely that any viable orangutan populations still exist in these areas. This set includes Coastal Kutai (#36) where virtually no forest remains in what was once a national park. We also note that 5 blocks have become badly fragmented as shown on both the TREES and MODIS maps. Another 5 have lost half or more of their forest. Finally, 7 blocks, mainly near the uplands in the central Bornean mountain range are now considered to contain no more than transient orangutan populations (sightings of males only), and are therefore better no longer regarded as orangutan habitat.

In conclusion, over the past 10 years, the distribution area of the Kalimantan orangutans has shrunk considerably due to habitat loss and fragmentation, and due to the recognition that foothill and hill areas in the center of the island do not currently contain viable populations.

2. Trends in Forest within the Orangutan Distribution Area

Over the past few years, much attention has been focused on the state of Indonesia's forests. Tropical deforestation rates in Indonesia are among the highest in the world. Estimates based on satellite-image interpretation, show that between 1985 and 1997, the average annual loss was about 10,000 km^2, (Holmes 2000; FWI/GFW 2002). By the mid 1990s, the deforestation rate for Kalimantan had increased to about 12,640 km^2 / year (Holmes 2000), or 14,000 km^2 / year (FWI/GFW, 2002). Considering this high deforestation rate and the likelihood that the figure is even higher in 2002 due to recent (1997–1998 and 2002) forest fires and rampant illegal logging, there is an urgent need to reassess the species' distribution and status.

The analysis undertaken by Erik Meijaard and Rona Dennis for this project (Fig. 7.2) showed that in 2002, the total area of breeding habitat for Kalimantan orangutans amounted to 85,835 ± 4,500 km^2, divided over some 300 spatially distinct areas. This is down from some 141,500 km^2 in the early 1990s as indicated by the habitat classification in Rijksen and Meijaard (1999), or a decline of 39% in about a decade (Fig. 7.1). This number actually paints a rosy picture of the situation because the remaining areas are increasingly fragmented. For instance, 148 of the currently recognized 306 habitat units are less than 100 km^2, and together cover 4,716 km^2 (or 5.5% of the total area).

In addition, we also assessed the quality of the remaining forests, based on the MoF classification (see methods). We found that most of the remaining forest is now classified as degraded, especially in East and Central Kalimantan, where only 22 % and 11 %, respectively, of the remaining habitat consists of primary forest (Table 7.3), the rest being affected by logging.

Table 7.3. Subdivision of remaining Orangutan habitat in Indonesian Borneo by forest quality

Forest class (MoF, 2002)	West Kalimantan (total Orangutan habitat = 15,670 km^2)	Central Kalimantan (total Orangutan habitat = 33,517 km^2)	East Kalimantan (total Orangutan habitat = 8,319 km^2)
Primary dry land	42 %	5 %	20 %
Primary swamp	1 %	6 %	2 %
Disturbed dry land	31 %	38 %	78 %
Disturbed swamp	26 %	50 %	0 %

The low resolution of the imagery and the necessarily arbitrary decisions made in assigning each pixel to forest or non-forest may lead to some ambiguities in this map. For instance, almost none of the remaining patches in the former Kutai national park are recognized due to their very small size. This weakness is shared by other similar large-scale approaches; thus the TREES map produced by the European Union does not recognize them either. Nonetheless, these results strongly agree with the overall trend noted in various case studies that focus on smaller regions relevant to orangutan conservation, for Gunung Palung; Danau Sentarum (R. Dennis, pers. com.), Muara Wahau (R. Dennis, pers. com.), Sebangau (S. Husson, pers. com.), and Mahakam Lakes.

We do not have an equally quantified overview of changes in the Sumatran forests beyond Fig. 7.3. One detailed study is available for West Batang Toru, which is being converted into agricultural land and degraded by illegal logging at most of its edges. This has resulted in a reduction of forest cover or degradation of around 12% between 1990 and 2001 (Wich pers.

comm.). The map of changes in forest inside the orangutan range shows a spectacular decline (Fig. 7.4). As discussed above, most of the changes south of Toba result from new information that show that areas previously thought to hold orangutans no longer do so. However, the northern part of the range also shows rapid loss of habitat at the edges of the habitat units.

3. Population Status in Conservation Units

In this section, we develop the best possible estimates of orangutan numbers in each of a series of conservation units or habitat units. The analysis for Borneo closely corresponds to the forest blocks and codes used in Rijksen & Meijaard (1999), whereas the study for Sumatra uses an independent classification of habitat units.

3.1 Sumatra

The process of determining an estimate for the total number of orangutans on Sumatra consisted of two steps. In the first step, GIS was used to determine the extent of primary forest at different altitudes and the second was to use the surfaces to generate population estimates.

Using LANDSAT images (kindly made available by Unit Management Leuser) of North Sumatra and Aceh, a comprehensive and detailed coverage of vegetation was digitized by Nick Jewel. This map was then overlain on a coverage of altitude. In this way it was possible to summarize each vegetation class by altitude to give the total area of each class within each 100 m interval up to 1600 m asl. We then identified key forest blocks within Sumatra according to inferred geographical boundaries or according to known variations in density between areas at similar altitudes. Thus we identified 16 areas of primary forest, and three swamp forests from the area north and west of Lake Toba. An additional two populations are known to the South of Lake Toba and these were examined separately using up to date information from the field. This work allowed us to use altitude specific density estimates within each forest block ranging all the way from Toba in the South to Seulawah in the extreme north.

Densities were derived based on extensive line transect work conducted by a range of workers (especially R. Buij, I. Singleton, S. Wich, and C. van Schaik) in this region. Because Sumatran orangutans are known to respond negatively to selective logging and because individual knowledge of areas digitized as degraded suggested that these areas were very heavily damaged we decided to ignore the area of degraded forests (this procedure was not adopted for Bornean forests because of the different biology of the Bornean orangutans; see below). Furthermore, field knowledge also suggests that less heavily degraded areas were often included as primary forest during the digitizing process (which inevitably has led to overestimates of populations in most areas). Thus, we assumed that the small errors produced by ignoring disturbed forests and by including some disturbed forests into the primary forest class would tend to cancel each other. Nonetheless, we acknowledge the uncertainty in the estimates derived here.

The LANDSAT images used in these analyses were from 2002, except for the ones in Aceh north of the Leuser Ecosystem (Conservation unit 1, the North West Aceh Block and Seulawah), which were from 1998. Given an estimated loss of orangutans in the Leuser Ecosystem of 45% over a 6.5-year period (van Schaik et al. 2001), we therefore felt it necessary to reduce the estimates for North West Aceh according to estimated forest loss there. Assuming that the rate of loss is similar in areas farther south, we could then argue that estimates for the North West Aceh block should be reduced by 35% over the 5-year period (1998 – 2002). However, there is considerable uncertainty concerning the extent to which concessionaires and illegal loggers have continued operations in these war torn areas since hostilities intensified in 1997/98. To allow for this we conservatively reduced population estimates for North West Aceh by only 20%. In contrast, the small forest area at Seulawah is considered unlikely to have been reduced considerably during the period because it is a well-known local protected area. Some illegal logging will undoubtedly have occurred but probably has had relatively little impact on the orangutan population there to date.

Table 7.4. Estimated numbers of *Pongo abelii* in the confirmed Sumatran habitat units, approximately representing the situation in 2001/2. (OU = orangutan)

Area	Habitat unit	Primary Forest (km^2)	Estd. OU number	**OU Number per habitat unit**
1- Ulumasin (Aceh Besar)	1	*2066*	*340*	
2- Tutut (Woyla; N.W. Aceh)	1	*1918*	*314*	
7-Geumpang	1	*2116*	*180*	***667* (N W Aceh)***
6- Seulawah	2	*103*	*43*	***43***
3- Beutung (W. Aceh)	3	*1297*	*95*	
8- Bandar-Serbajadi (E.Aceh+)	3	*2117*	*337*	
9- Linge	3	*352*	*8*	***440 (Middle Aceh)***
4- Kluet Highlands (S.W. Aceh)	4	*1209*	*808*	
5-West Mt. Leuser	4	*1261*	*298*	
5-A—Kluet swamp	4	*125*	*312*	
10- East Mt. Leuser/Kemiri	4	*358*	*365*	
11- Mamas-Bengkung	4	*1727*	*725*	***2508 (West Leuser)***
12- Puncak Sidiangkat/B. Ardan	5	*303*	*151*	***134***
13- Tamiang	6	*1056*	*307*	
14- Kapi + Upper Lesten	6	*592*	*101*	
15- Lawe Sigalagala (S.E. Aceh)	6	*680*	*147*	
16- Sikundur-Langkat	6	*1352*	*497*	***1052 (East Leuser)***
17- Tripa (Babahrot) swamps	7	*140*	*280*	***280***
18- Trumon-Singkil swamps	8	*725*	*1500*	***1500***
19- East Singkil swamps	9	80	*160*	***160***
20- West Batang Toru Block	10	*600*	*400*	***400***
21- East Sarulla Block (Sipirok)	11	375	*150*	**150**
TOTALS		**20177**		**7334**

*Total before removing 20% (see text) = 834.

Conclusion for Sumatra

The analysis of the remaining forests on Sumatra indicates that we can recognize 11 distinct habitat units, some of which are composed of several adjacent smaller forest blocks. The results show that three habitat units contain more than a 1000 orangutans. Of these the West Leuser block contains the largest number of orangutans, followed by the Trumon-Singkil swamps and the East Leuser area. Of the habitat units that contain less than a 1000 orangutans the North West Aceh area contains most orangutans, followed by Middle Aceh and the West Batang Toru area.

Outside of these six areas there are five smaller habitat units, of which the Tripa swamp is the largest with around 280 orangutans.

The major finding is that of habitat shrinkage and fragmentation. The Leuser Ecosystem is still the most important stronghold of the Sumatran orangutan, but is now fragmented into 4 major areas: West Leuser, Trumon-Singkil, East Leuser and Tripa. A decade ago, only the West-East Leuser connection was more or less severed. Conservation action aimed at restoring the connections between these habitat units is therefore a top priority. Inside the two major Leuser blocks, logging and conversion has encroached in such a way that most land below 1,000 m is now cleared, creating jagged edges and numerous habitat islands. Forests in the more densely populated lowland patches are still connected, but any dispersing animals between them are now forced to move deep into the mountains. This may lead to de facto isolation of these patches.

Outside of the Leuser Ecosystem, the North West Aceh and the West Batang Toru habitat units are the most important conservation areas for orangutans. Hence conservation efforts should focus on these areas.

The total number of orangutans presented here is higher than that by Wich et al. (2003). This difference is mainly due to the fact that the Wich et al. (2003) estimate was based on orangutan numbers estimated by Rijksen and Meijaard (1999). These authors based their estimates on less detailed information than is available now and were therefore conservative. The number is also somewhat higher than the one presented for the Leuser Ecosystem presented by van Schaik et al. (2001). This discrepancy is probably due to the fact that this classification necessarily recognizes more primary forest than is truly present (a trend that we tried to counteract by not including the badly damaged forest at all). We cannot decide which of these different sets of numbers are closer to the truth. Nonetheless, the differences in numbers should not detract from the very real trends in habitat loss noted above. It is clear that this trend is steeply negative and that as a result of this orangutan numbers are declining rapidly.

3.2 Kalimantan

As shown by Meijaard and Dennis (appendix 1), the number of distinct forest blocks in Kalimantan has grown dramatically over the past decade. It is therefore impossible to attempt a detailed description and discussion of all these areas. Instead, we will present descriptions and reviews of (i) the areas with major orangutan concentrations, (ii) the areas that were surveyed especially for this report, and (iii) the major protected areas that contain orangutan populations. The aim is to arrive at a list of priority areas that are either high-quality habitat units or protected areas (which may contain multiple habitat units) rather than an exhaustive estimate of all remaining numbers. All habitat units in Kalimantan follow the number codes given by Rijksen & Meijaard (1999).

3.2.1 West Kalimantan: *Pongo pygmaeus pygmaeus*

3.2.1.1 Danau Sentarum (area code 5)

Two national parks, Betung Kerihun and Danau Sentarum in the upper Kapuas area in West Kalimantan contain significant areas of orangutan habitat, although in the former area the habitat appears to be concentrated in the swamps that lie south of the park's border, whereas the forest in the latter area is now cut off from the Betung Kerihun forest by road construction and logging.

Russon et al. (2001) estimated the population in the Danau Sentarum (D.S.) National Park at 1,024, with an additional 1,717 orangutans occurring outside the national park. Given new knowledge of nesting parameters in Kalimantan, these estimates were probably too high by about one quarter to one third, producing a total population for D.S. in 1996 of approximately 750 individuals, and a total estimate for the greater D.S. area of ca 2,050 (as defined in their paper). Intensive illegal logging is likely to have reduced these numbers since then. We know that some of the areas surveyed by Russon have been converted, whereas others have been subject to intensive logging. In 2003 A. Erman (see appendix 2) surveyed the eastern part of this area. He found relatively low densities in the swamp areas (<1 orangutan/km^2), while towards the north in drier forest nest densities declined to zero. In the latter areas orangutans were allegedly hunted for food, while illegal logging and forest clearance for agriculture provides another likely explanation for the absence of orangutans. In conclusion, the D.S. and greater D.S. areas will currently have far fewer orangutans than estimated in 1996. Our most optimistic guesses are ca 500 and ca 1,400 for the current numbers.

3.2.1.2 Betung Kerihun (area code 5)

Little is known about the orangutan population in the large Betung Kerihun national park. Takahashi et al. (2003) estimated an orangutan density of 0.38 orangutans/km^2 on the southern edge along the upper Embaloh River, based on 12 km of line transects and using the parameters of Russon et al. (2001). The best density estimate may therefore be even slightly lower. It is not known to what extent this number can be extrapolated to the rest of the park, although most of the park is at higher altitude on dry land. Illegal logging was rampant throughout the upper Embaloh region. However, it may be premature to write off the park because it is still connected to Batang Ai and Lanjak Entimau in Malaysia and therefore may represent an important re-colonization sink in the future.

3.2.1.3 Upper Kapuas swamps (North) (adjacent to area code 5)

North of the Upper Kapuas River lies a region with much swampy forest and gradually grading into the foothills of the Betung Kerihun forests. While recognized by Rijksen & Meijaard (1999), this area was not discussed in their text. It was therefore surveyed by Andi Erman in 2003. His results indicate that hunting is common in this area, but that there are pockets with reasonable density (>1 orangutan/km^2), e.g. the aptly named Mayas River. Given these findings, it is worth considering the recommendation that the area north of the Putussibau-Lanjak road be added to the Betung Kerihun national park because of the low densities in most of the uplands in this park.

3.2.2 West Kalimantan: *Pongo pygmaeus wurmbii*

3.2.2.1 Upper Kapuas swamps (South) (adjacent to area code 7)

The lower parts of the Melawi River valley and its tributaries were not recognized by Rijksen & Meijaard as orangutan habitat. However, the area north of the Sintang- Putussibau road, still contains a large area of somewhat fragmented swamp forests. Andi Erman's surveys (appendix 2) indicate the presence of orangutans throughout this area. However, reports do indicate hunting at places and the survey suggests moderate to low densities (probably largely <1 orangutan/km^2). Thus, although the area contains orangutans, it is not of the highest conservation priority.

3.2.2.2 Bukit Baka (area codes 8)

Previous reports had indicated a modest presence of orangutans in the Bukit Baka part of the Bukit Baka/Bukit Raya National Park (and virtually none in the Bukit Raya portion in Central Kalimantan). Husson's survey team went into the northwestern part of Bukit Baka, and found an area of primary hill dipterocarp forest that contained orangutans at low density (ca 0.5 individuals/km^2). It is suspected that because this site represents a small lowland pocket in the park, the distribution of orangutans in the extensive high-altitude forests of Bukit Baka is likely to be patchy at best. The area below 500 m is about 350 km^2; and could therefore contain ca 175 orangutans. The national park is still largely intact and protection of this modest orangutan population is therefore feasible.

3.2.2.3 Rongga Perai (area code 9)

This is a large area of remote, hilly foothill forests in the upper reaches of the Sungai Pawan, near the peaks of Bukit Rongga and Bukit Perai. Orangutans had been reportedly common within logging concessions in the region. However, nearly all of the lowland floodplain forest in the area has been badly damaged by logging or cleared. It seems likely that any remaining orangutan populations here are limited to small pockets in the hills. Local informants claim that the western part of this complex, known as Bukit Lawang near the township of Senduruhan, has a large population of orangutans. In reality, few nests were found in all but one site, probably as a result of heavy hunting in the recent past. Illegal logging is rampant throughout the area. Apart from a single pocket of reasonable density (ca 1.6), densities were low at all sites. Thus, because most of the area is highland and hunting and illegal logging are known to be intense in parts, it is unlikely that the Rongga Perai complex (ca 4,200 km^2) contains more than some 1000 orangutans. This area is apparently contiguous with the Arut-Belantikan habitat unit in Central Kalimantan, however, raising its importance.

3.2.3.4 Lower Kapuas Swamps (area code 10)

The Lower Kapuas swamps have become badly fragmented since the early 1990s. An over-flight in early 2003 indicated logging activity and slash-and-burn activity in several parts. The orangutan status in this region remains unknown.

3.2.2.5 Gunung Palung and surroundings (area code 11)

The eastern and southern edges of block 11 have disappeared. This block includes Gunung Palung National Park and surroundings. By June 2001, 58% of this park had been affected by illegal logging and only 9% of the total forest area was still in very good condition (Dermawan 2003). Johnson et al. (in press) estimated that the park currently has a population of 2,500 individuals. If surrounding contiguous areas are included, higher numbers are still possible, but no published figures exist. It should be noted that the impact of selective logging are less than has been found in Sumatra; Felton et al. (2003) found a 21% decline in nest densities due to logging in peat swamp, whereas Johnson et al. (in press) found 22% in peat swamp, and a mere 7% in lowland forest on dry land.

This block also includes the Kendawangan nature reserve. Imagery indicates, however, that this has largely disappeared, and the reserve is no longer indicated as such on maps of PHKA (the Indonesian conservation authority).

3.2.3 Central Kalimantan: *Pongo pygmaeus wurmbii*

3.2.3.1 Tanjung Puting National Park (area code 13)

This national park contains a mosaic of habitat types, including dry land and swamp forests and areas recovering from shifting agriculture. Despite its high national and international profile, since 1998, Tanjung Putting has suffered from widespread illegal logging and gold mining. Also, large tracts of the park, particularly in the south, were damaged by forest fires in 1997/98. Government action in early 2003 has reduced the pressure from illegal logging, but mining and other illegal activities continue to threaten the integrity of the park.

Results of surveys carried out across the park indicate high nest densities in all areas, ranging from >2 individuals/km^2 in minimally disturbed dry land forest and peat swamp forest, down to 1.6 in heavily disturbed dry land forest. The survey concludes that of the park's 4016 km^2, 3132 km^2 (78%) remains inhabited by orangutans, with a mean density of 1.9 individuals/km^2. Thus, a population of 6,000 orangutans is estimated (Galdikas et al., MS).

3.2.3.2 Katingan-Sampit catchment (area code 16)

The Katingan floodplain is a large expanse of peat swamp forest and mangrove (in the south). The entire area has been logged by the logging concession system (HPH). Illegal logging is now widespread but still recent. Hunting occurs but is believed to be light, as the local Dayaks tend to be Muslims and are restricted from eating certain wildlife. Four separate tributaries were surveyed, three on the eastern (i.e. Katingan) side and one on the western (i.e. Sampit) side. Orangutans occur throughout the area. Densities varied from 1 to 3 orangutans/km^2, with a mean of 1.9. If the interior parts away from the rivers are conservatively considered to have a density of 0.8 animals/km^2 (equivalent to low pole density in the Sebangau) we obtain a preliminary minimum estimate for the whole area of (1,000*1.9 + 1,800*0.8 = 3340). Thus, this is a hitherto unrecognized major orangutan population that needs to be examined in greater detail and, if these numbers are confirmed, deserves a high conservation priority.

3.2.3.3 Sebangau (area code 17)

The Sebangau catchment is a large area of peat swamp forest habitat, of which 5,782 km^2 is currently still under forest. The entire area has been logged under the concession system in the past. This regime finished by 1997. Since then, illegal logging has become ubiquitous, and a dense network of small canals (tatah's) has been established. These tatah's are draining the swamp in the dry season, leading to degradation of peat and high tree mortality and increasing the risk of forest fires. Orangutans are distributed continuously throughout the catchment, with the probable exception of the extremely wet low interior forest. The highest-density areas are found in the tall interior forest on the top of the peat domes, a habitat type unique to Sebangau.

The majority of the orangutan population is found in the mixed swamp forest, which occurs on the outskirts of the peat domes and near the rivers. The best estimate for the 1996 situation was 13,000 orangutans in 6,573 km^2. Since 1996, 1000 km^2 has been lost (=15% in 7 years), and logging has continued in the remaining forests. For 2002, Husson et al. (MS) estimate a total population of 6,900, corresponding to a 49% decline in numbers since 1996. A compression effect is strongly implicated in this decline with a third of the total population perishing during the one year period following the heaviest logging (Husson et al., MS). Illegal logging is slowing as the forest has been largely logged out. The number one priority for conservation is damming the illegal logging canals and reversing the damaging effects of drainage.

3.2.3.4 Rungan- Kahayan catchment (area code 19)

No detailed information is known for this area, the lower half of which is likely to contain significant peat swamp forests, and thus potentially harbours a significant orangutan population. Applying a conservative density estimate of 0.5 individuals per square kilometre to the ca. 2,000 km^2 of forest remaining in the block gives a minimum estimate of 1000 individuals in the region. The long narrow shape of the block is vulnerable to encroachment and hunting pressure. Surveys remain necessary.

3.2.3.5 Sebangau- Kahayan catchment (area code 20)

This area has been badly damaged by drainage and massive forest fires. It is estimated to have contained some 2,700 orangutans before the fires in 1996 (Husson et al, MS, based on Morrogh-Bernard et al. 2003). At present, some fragments remain, the largest of which is just southeast of Palangkaraya (near Kalampangan), and covers only 130 km^2. In total 12 major fragments occur containing ca. 700 orangutans. This general area is heavily drained, the forest fringes burn every year, and there is little hope for the future. Numerous orangutans must have perished in this region. There is little hope that these unconnected fragments can be adequately protected in the future.

3.2.3.6 Mawas Reserve (area codes 21 and 22)

With a total area of ca 510,000 ha, the Mawas Reserve is a substantial part of the ex-PLG area. Most of the forest has been subject to logging at various intensities, first by logging concessions and then by informal loggers. The southern part contains two main peat domes, now dissected by large drainage canals; the western part contains a degrading peat dome. Peat depth declines toward the north and toward the major rivers (Kapuas Murung and Barito). During 2002 and 2003, detailed aerial and ground surveys in its eastern unit (Blok E, ca 2730 km^2, and Blok AB, ca 400 km^2) have been done by Odom, A. Russon, C. van Schaik, and S. Wich, whereas most work in the western unit has been from the air (aerial estimates have been ground-truthed and found to provide a reliable density index). The minimum estimate based on detailed work for the eastern part is 2,500 animals (2070 in Blok E; 430 in Blok AB); the minimum estimate for the western part is 850 animals in three fragments separated by rivers (using a conservative 0.5 ind/km^2, lower than indicated by limited surveying along the Mangkutup and Morrogh-Bernard et al.'s surveys near Palangkaraya). The minimum estimate for the total Mawas Reserve is therefore 3,350 orangutans.

3.2.3.7 Seruyan – Sampit – Katingan uplands (area code 14)

This is a large, fairly unknown area of dipterocarp forest swathing the hills and plains surrounding the headwaters of the Seruyan and Sampit Rivers and extending up into the main body of the Schwaner range. The entire area is likely to be subject to varying levels of logging, hunting, fragmentation and conversion threats. Most of the area is designated HPH with the northern part, bordering the provincial boundary, classed as *hutan lindung*. Surveys carried out by Husson's team in the area nearest to the Seruyan River recorded a density of 1.5 individuals per square kilometre. This is likely to vary considerably across the area, in probable correlation with hunting pressure. Nevertheless the population is likely to number at least 1,000 individuals in an unknown number of fragments, which are mainly divided by logging roads. If habitat quality and the absence of hunting are as in the Upper Arut, this may also be an important orangutan population.

3.2.3.8 Uplands enclosed by Katingan and Samba rivers and Bukit Raya National Park (area codes 26/27)

The habitat here is similar to the Samba-Rungan-Kahayan uplands. Hunting seems to have removed most of the orangutans from this area. Very few are reported from Bukit Raya National Park and only a small number of nests (0-2 per km of transect) were encountered in extensive dipterocarp plains west of the Samba River. The total population of this area may number less than 500 individuals in an unknown number of habitat blocks.

3.2.3.9 Upland between Samba, Rungan and Kahayan Rivers (area codes 26/27)

The upper reaches of these three rivers enclose an area with steep topography covered in dipterocarp forests at altitudes below 400 m. Husson's team estimated a mean density of 0.7 orangutans/km^2, reaching 1.25 in the easternmost parts. There is potentially 1,500 km^2 of contiguous low hill forest, which implies a population of ca 1,050 orangutans in this area. Hunting and past logging damage appears to be lower here than west of the Samba river, perhaps owing to the steep topography.

3.2.3.10 Arut-Belantikan region (area code 12)

This is an area of dipterocarp forest clothing the foothills of the Schwaner mountains and surrounding the upper reaches of the Arut and Belantikan rivers at altitudes of roughly 140 to 300 m asl. It is defined by the Lamandau River to the west, Seruyan River to the east and the provincial border to the north. Part of the area (5%?) surveyed by Togu Simorangkir (OF-UK) and Husson's team (OuTrop) is former dry rice fields, and thus covered in secondary forest. The rest of the area has been lightly logged by concessions, and nearly all is planned to be logged under the HPH system over the next 30 years. However, orangutans are common here, and extensive surveys in three separate areas have estimated densities of between 2.2 and 2.6 orangutans/km^2. Local people do not hunt orangutans here. With a total area of ca 5,800 km^2 this area may support a very large orangutan population of at least 6,500 orangutans. It is apparently contiguous with a further 4,200 km^2 of forest in the Rongga-Perai complex, further raising its importance. This area is the most promising upland area for orangutans on dry-land forest in Kalimantan and of high conservation priority.

3.2.4 East Kalimantan: *Pongo pygmaeus morio*

3.2.4.1 Coastal Kutai district (area code 36)

This region has been subject to devastating fires during the 1997/98 droughts. Recent satellite imagery indicates that the only remaining forest in this district is in the Kutai National Park, where some primary and secondary dipterocarp forest appears to remain, especially among rivers. Nonetheless, orangutans have survived, and nest counts by Borneo Ecology & Biodiversity Conservation (BEBSiC, 2003) suggest remarkably high densities (minimally 2 - 4 orangutans/km^2, well above the earlier estimates of long-term researchers in the intact forest (2 individuals/km^2). This undoubtedly reflects concentration of the orangutans into the remaining intact forest patches. It is difficult to extrapolate the estimates in the three patches sampled to the entire area lacking knowledge of the relative surface area of the intact patches. However, A. Suzuki (unpubl.) recently estimated the orangutan population of the Kutai national park at ca 600 individuals in almost 2,000 km^2. Time will tell whether these animals can survive in the long run in the degraded habitat.

3.2.4.2 Gunung Beliung (East Kutai)

Partly protected limestone forest. 1997 survey data (Suzuki, unpubl. report) suggested a population of 1,000 animals at that time. This is likely to have reduced since then given the high degree of threats.

3.2.4.3 Gunung Gajah (area code 38 [and not 40!])

The hill dipterocarp forest of Gunung Gajah area (mean altitude ca 350 m) in the Berau district has recently been surveyed. In the 1,400-km2 area, seven nest surveys conducted by The Nature Conservancy (December 2001 to present) indicate a mean density of 2.0 orangutans/km^2. If the area is homogeneous, this would produce a total estimate of about 2,800 animals, which would make this population the most important one of the eastern subspecies in Indonesia. If it is not, as suggested by other reports, 1,450 is the most reasonable estimate. The lower estimate has been adopted. Meijaard/Suzuki previously surveyed this area in 1997 and much lower density estimates were obtained. A tentative hypothesis is that orangutans made homeless by the 1997-98 fires moved to this area, however an alternative hypothesis is that historical hunting pressures have been low.

3.2.4.4 Sungai Lesan.

This is an excellent quality forest, with high biodiversity recorded. Estimated orangutan densities of 4.6 individuals per km^2 are among some of the highest recorded in Borneo, although there is uncertainty about whether compression may play a role in this high density. The Nature Conservancy conducted surveys in 2004, but only in the eastern portion of this site. The western portion is logged primary forest (20+ years) so it may contain lower densities. Some 400 individuals are estimated to occur across this site.

3.2.4.5 Balikpapan and Samarinda

The orangutans here are all reintroduced. The Wanariset-Samboja project reintroduced ca 70 individuals into Sungai Wain protectin forest, as well as over 300 individuals into the Meratus area. In both cases, an unknown percentage survives. Near Samarinda, a few small pockets with a few orangutans still occur.

3.2.5 Kalimantan Overview

The estimated numbers for the areas discussed above have been compiled in Table 7.5. This compilation contains estimates for the major areas, assuming there is information, and leaves out various small pockets with unknown but small numbers of animals. The sum totals therefore do not refer to the total known number of animals remaining in the wild, but rather to estimates of the larger or better-known populations.

Table 7.5. Estimated numbers of orangutans in the Kalimantan habitat blocks discussed in this report (numbers refer to codes used in Rijksen & Meijaard 1999).

No.	Name of area	Area in 2002 (km^2)	Current orangutan population estimate
A.	**P. p. pygmaeus**		
5	Danau Sentarum	1090-1500	ca 500 (ca 1,500 for greater DS)
5	Betung Kerihun	4500	1330-2000 (**prelim**. **est**.)
5	Upper Kapuas swamps (north)	?	Unknown
B.	**P. p. wurmbii**		
7	Upper Kapuas swamps (south)	?	Unknown
8	Bukit Baka lowlands	350	ca 175
9	Rongga Perai	4,200	max 1000
10	Lower Kapuas swamps		unknown
11	Gunung Palung	900	2,500
13	Tanjung Puting	4,000 (3132 forested)	6,000
16	Katingan-Sampit catchment	2,800	Min 2,800
17	Sebangau	5,584 (forested)	6,900
19	Rungan-Kahayan	2000	ca 1000
20	Sebangau-Kahayan	720	ca 700 in 12 pockets
21 + 22	Mawas Reserve	5,100	Min 3350 (east: 2500; west: 850)
26/27	Upland between Samba, Rungan and Kahayan	1,350	Ca. 950
25/26	Upland between Katingan, Samba and Bukit Raya	ca. 2000	<500
14	Seruyan	4000	Min 1000
12	Arut-Belantikan	5800	Min 6000
C.	**P. p. morio**		
36	Coastal Kutai district	2,000 (% habitat unknown)	< 700
39	Gunung Gajah	1,450 (proposed reserve)	Min 1,550
	Sungai Lesan	?	400
	Gunung Beliung	?	980 (1997 estimate)
41-44	Sebuku/Sembakung area	?	Unknown but few

Discussion

Methodological issues

Differential bias?

Different teams have produced divergent numbers over the years, due to variation in methods and degrees of conservatism in arriving at the extrapolated total numbers (the last few years have seen a trend away from using highly conservative estimates toward using far more liberal ones). Most of the teams have now settled on using line transect estimates of nests. Most recent studies have made an effort to estimate production rates and disappearance times of nests that were more appropriate for the areas they were applied to. Hence, density estimates based on nest counts, while biased, can now be compared across areas.

Recent experience suggests that most estimates derived in this way are too low. Several comparisons (Johnson et al., in press; van Schaik et al., MS; Husson et al. MS) now suggest that, compared to a single-pass line transect estimate, (i) a double pass of the same line produces an increase in the estimated density of 12-30% (n=3 tests), (ii) multiple repeat passes produce an increase of 37% (n=1), whereas (iii) plot counts increase the estimated density by almost 50% (n=2). Since we may safely assume that plot counts in fact provide the least biased estimates (all estimates were based on the same parameter values), then it follows that many of the estimates published the past few years, including the ones used in this study, may yield density estimates that are too low by as much as 33% of the actual values. However, many of the estimates used in this report are based on repeat surveys, leading to much smaller underestimates.

This bias serves to build in a downward correction for the errors associated with extrapolation. Direct extrapolation inevitably involves upward bias (because estimates are never taken in habitat that is so disturbed that no animals occur and because it is never certain that a larger area actually contains orangutans everywhere). Earlier estimates (e.g. used in the 1993 PHVA; Rijksen & Meijaard 1999) used a correction factor to correct for this, but because most recent ones do not, the errors are in opposite directions and may in fact tend to cancel.

Thus, while there is still variation across studies in bias, variation in methods is not a major factor in variation in the estimated densities and population numbers used in this report.[2]

Over the past few years, we have also come to appreciate the important biological differences among the various orangutans. The more frugivorous Sumatran orangutans tend to live at higher densities, but are quite sensitive to logging. Among the Bornean orangutans, *Pongo pygmaeus wurmbii* and *P.p. pygmaeus* seem to be somewhat sensitive to logging, losing some 20% or less of their densities in logged areas, whereas the eastern *P.p. morio* displays a remarkable tenacity to coping with damage by logging and even fire. These figures obviously refer to the direct

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[2] Another issue, not relevant to this report, is whether aerial surveys produce comparable results to those of ground surveys. Experience in Mawas (van Schaik, Wich, Russon, unpubl.) and in Sabah (Ancrenaz et al., MS) suggests that estimated nest densities produced by aerial and ground surveys show very good correlations across sites.

ecological impact of logging. In many areas, this impact cannot be measured because logging is accompanied by an increase in hunting pressure, compounding any possible impact of logging. We should stress that these assessments are still preliminary in that the species and subspecies may differ more in the speed with which they respond to habitat damage rather than in the extent of this response. It is not inconceivable that the improved ability of the Bornean orangutans to deal with low-quality fibrous foods allows them to survive for longer after logging has reduced the abundance of fruits, but that eventually serious population losses will still be incurred when animals finally succumb after several years of starvation diets.

It is also becoming apparent that *Pongo abelii* has the slowest life history, whereas *P.p. morio* may have the fastest among orangutans. Because of these differences, it is important to separate these four taxonomic units for conservation and management purposes, and to ensure that any confiscated animals will be reintroduced only into the range of their original species or subspecies.

The important conservation message that emanates from this recent work is that forest damaged by logging can still represent important orangutan habitat, especially in Kalimantan, and perhaps even more so in the eastern subspecies (*P.p. morio*). While this is not to be construed as an endorsement of selective logging (many other organisms remain highly sensitive and may disappear after logging), it does suggest that populations in logged areas can form the nucleus of viable populations in future.

Another important conclusion is that we should consider these four taxa as separate conservation units as much as possible.

Trends in distribution, habitat quality and numbers

The data compiled in Tables 7.1 and 7.2 and Figures 7.1-7.4 leave little room for complacency: Indonesia's orangutans are declining as rapidly as ever. These trends mirror the now widely known general trends in deforestation.

Nonetheless, the improved coverage by distribution surveys and especially the presence of improved or less conservative estimates of numbers in limited areas have led to larger numbers of orangutans known in the wild than were reported in the past few years. It should be pointed out immediately, however, that the total number of orangutans on a given island is a meaningless number for conservation purposes. The only meaningful numbers are the numbers per habitat unit or protected area, for each separate species or subspecies.

The total known from Sumatra (*P. abelii*) now stands at somewhat over 7,000. However, the Sumatran orangutans are distributed over at least 11 distinct and separate habitat units, the largest of which contains some 2,500 orangutans. If the four Leuser blocks can be reconnected, we would have a single population of about 5,400 (this number may be slightly inflated by 10 or 20%, but indicates the ballpark).

For Kalimantan, we consider the three subspecies separately.

P. p. pygmaeus is in poor shape in Indonesia, with its stronghold Danau Sentarum being badly affected by logging and hunting, with a mere 1,500 or so remaining. Many nearby swamp areas are small and fragmented and subject to hunting. The main hope is that adjacent Betung Kerihun can be expanded with some lowland habitat to the south, and be connected effectively to its transnational counterparts in Sarawak. There is an urgent need to get good information on Kerung Betihun, or at least that available information be properly analyzed and published.

P. p. wurmbii has the largest population by far, especially in the large swamp areas of Central Kalimantan, with a current estimate of at least 35,000, with major strongholds in Tanjung Puting, Sebangau and Arut-Belantikan, a very respectable population in Mawas, and an interesting far-west population in Gunung Palung. Various other once sizeable populations are disappearing fast.

P. p. morio has its main stronghold in the Berau/Gunung Gajah population, although the remnants in what was once Kutai national park may be worthy of protection. There is a need to explore the establishment of corridors between these areas. It is becoming clear that *P.p. morio* has a strong presence in Sabah.

We leave it up to the PHVA workshop to integrate this information with the data from Sarawak and Sabah and use the total update to develop recommendations for conservation policy. Although two of the Bornean subspecies have populations in both Malaysia and Borneo, we should not forget that conservation of species in multiple political units is best served when each country takes its measures as if it is the only one in the species' range.

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APPENDIX 1: METHODS USED BY MEIJAARD AND DENNIS (2003)

We used the absence/presence data from Rijksen and Meijaard's (1999) surveys, and combined these with a 2002 forest/non-forest classification kindly provided by Doug Fuller of George Washington University (in association with The Nature Conservancy). This classification was based on imagery from the Moderate Resolution Imaging Spectrometer (MODIS) on board the NASA Terra satellite imaging almost the entire surface of the Earth every day[3]. The nominal spatial (or ground) resolution of MODIS imagery used for this classification is 500m x 500m; for comparison the spatial resolution of Landsat TM is 30m x 30m. The classification provided by Fuller was based on imagery selected and processed for the period from 10 February - 22 April 2002[4] to create composite reflectance images largely free of cloud and other atmospheric perturbations. He then classified these images using standard image-processing algorithms to derive a forest/non-forest map of Borneo.

We visually compared the 2002 forest/non-forest cover product with the Orangutan distribution map (Rijksen and Meijaard, 1999), and used this and recent information from the field to digitally update boundaries for the remaining Orangutan habitat using ESRI ArcView 3.2a software.

The accuracy of the classification was checked against a number of sources, including recent Landsat ETM imagery, the forest-/non-forest classification provided by the Indonesian Ministry of Forestry (MoF)[5], the TREES map produced by the European Union in 2003 (based on 1999 satellite images), and several detailed vegetation studies by Dennis et al, (2000; 2000; 2002), Suyanto et al. (2000), and Colfer et al (2000). We used the Landsat ETM images and detailed vegetation studies by Dennis et al. to adjust our 2002 habitat classification, whenever we found areas that had been classified on the MODIS imagery as non-forest, but which clearly appeared as forest on the Landsat ETM images. We then compared our classification with the MoF land cover classification, which is based on 1999–2000 satellite data, to assess the differences between these two classifications. Because, the MoF classification only covers Indonesian Borneo, we could not assess the accuracy of our classification for the Malaysian states of Sabah and Sarawak. The accuracy checking was done by converting both classifications to a raster format (using the ArcView Spatial Analyst extension), and counting the grid cells that both classifications had in common, or where one classification excluded the other. Also, because the MoF classification classified the following forest types: Primary dry, primary swamp, secondary dry, secondary swamp, we were able to assess what percentage of the remaining habitat consisted of these forest quality types.

In comparison with the MoF classification, our classification overestimated orangutan habitat in ca. 5% of the grid cells (i.e. we classified such grid cells as orangutan habitat, whereas the MoF

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[3] Perhaps the greatest benefit of MODIS for land cover monitoring is the daily imaging capability for almost any point on the earth. Other satellites such as Landsat have a higher spatial resolution but provide imagery of the same point on the earth only 1-2 times per month which means that the likelihood of receiving a cloudless image is severely reduce, especially in the humid tropics.

[4] Prior to the 2002 fires.

[5] Land cover classification produced by Badan Planologi of the Ministry of Forestry, Indonesia. The classification is based on a mosaic of Landsat satellite imagery dated between 1999 and 2000.

classification classified them as non-forest); we underestimated orangutan habitat by about 27% in comparison with the MoF classification. Taking into consideration that the MoF classification is based on 1999–2000 data and that the Kalimantan forest area declines by about 10,000 km^2/year (FWI/GFW 2002), justifies a lower margin or error of our classification of 5%. We thus decided to use a confidence interval of -5% and +5% for all estimates, unless we had detailed Landsat ETM imagery to check our initial MODIS classification results.

APPENDIX 2: SUMMARY OF ORANGUTAN SURVEY IN THE UPPER KAPUAS AREA, WEST KALIMANTAN, INDONESIA; JUNE-AUGUST 2003.

Written by Andi Erman and Erik Meijaard

The following 15 sites were visited for the survey (numbers refer to Fig. 7.1). Sites 1 through 6 are part of the extended Madi plateau and Melawi catchment recognized by Rijksen and Meijaard (1999) as area 7, but in the more downstream and swampy parts. Sites 7 through 13 are foothills and swamps to the south of Betung Kerihun and Kapuas Hulu mountain blocks (area codes 5 and 6), whereas 14 & 15 are adjacent to the Danau Sentarum area.

Nr	**Locality**	**Description**	**Transect coordinates**	**Transect length**	**Total number of nests**	**Remarks**
1	Silat River; Desa Nanga Lungu (1)	Hilly area with *ladang* and some logging; logging concessions have expired	N 0 12’ 00” E 112 11’ 19”	2,300 m	10	1 orangutan killed and eaten in 2001
2	Silat River; Desa Nanga Lungu (2)	Good forest with tall trees (40-50 m). Hutan adapt.	N 0 11’ 39” E 112 12’ 13”	2,250 m	3	Will be logged soon
3	Danau Tang area	Previously logged peat swamp forest	N 0 37’ 46” E 112 26’ 10”	2,250 m	12	
4	Danau Selogan area	Previously logged peat swamp forest	N 0 38’ 12” E 112 25’ 59”	2,350 m	15	
5	S. Bunut	Previously logged peat swamp forest	N 0 33’ 09” E 112 33’ 54”	2,100 m	10	Orangutan often seen in the transition zone between peat and hills
6	Dusun Jongkong Mandai	Parts good forest, parts secondary.	N 0 42’ 40” E 112 48’ 41”	2,000 m	25	Orangutan often hunted in the *Kecamatan* Nanga Bidak
7	Nanga Erak	Hill and peat swamp forest	N 0 46’ 41” E 113 11’ 12”	1,700 m	12	
8	Sibau Hilir/Sibau Hulu	Peat swamp with ongoing selective logging	N 0 57’ 53” E 112 57’ 53”	2,050 m	3	
9	S. Mayas/S. Potan/S. Pekaran/S. Mungin/S. Long Gurung	Hill forest (probably surrounded by swamps)	N 1 03’ 21” E 112 58’ 34”	2,000 m	44	Orangutan skulls found in a local village suggest that hunting occurs
10	Tanjung Kerja	Old *ladang* and hill and peat swamp forest	N 1 01’ 55” E 112 46’ 31”	?	26	Orangutan often seen in fruit season and hunted for meat

11	Ulok Palin (Dayak Embaloh)	Old rubber plantations, *ladang*, and peat swamp forest; expired logging concession, but timber extraction still common	N 1 03’ 17” E 112 48’ 49”	?	7	Orangutan often hunted
12	Apan (Dayak Iban)	Forest very much affected by logging and few forested patches were left	N 1 07’ 27” E 112 30’ 09”	?	0	Taboo against eating orangutan, but also orangutan had been eaten as recently as 1999
13	Ulak Pauk	Logged riparian and peat swamp forest with mostly small trees	N 1 04’ 06” E 112 30’ 17”	?	0	Orangutan are eaten and have apparently never been seen on the west side of the Embaloh River, but many on the east side
14	Ulak Pauk (Dayak Embaloh); Danau Tunggal	Peat swamp forest with *rengas* and *gerunggan*	N 1 02’ 07” E 112 33’ 27”	?	17	Orangutan often seen
15	Klawik (Dayak Kantuk)	*Ladang*, logged forest and degraded forest patches	N 0 54’ 46” E 112 32’ 38”	?	30	Orangutan often encountered in this area; sometimes killed and eaten

APPENDIX 3: SUMMARY OF ORANG-UTAN SURVEYS 2003 IN SCHWANER FOOTHILLS

Compiled by Simon Husson

(NB: density estimates produced using DISTANCE. p = 0.9, r = 1.1, t = 300)

Nr	Location	Team	Description	Start coordinates	Total transect length (m)	Total nests	Nests /km	Nest density (/km2)	Orang-utan density (/km2)	Remarks
A	**North and East of Sendurahan, in SW Schwaner range, edge of so-called Rongga-Perai complex**	OuTrop (Hearn, Ross, Ella)	Hill dipterocarp forest, some primary, some logged, some heavily logged		14950	85	5.7	137	0.46	Information from Ketapang and Sandai suggested a sizeable population North and East of Sendurahan (particularly the Sungai Bahana area). In Sendurhan, however, we were told the area north of Senduruhan was extremely logged and devoid of orangutans, but the NE was still good, more specifically the Bukit Lawang area. In reality we found few nests in all but one area. The effects of past hunting in most of this area is believed to explain low densities from within otherwise very good forest - many people said they used to hunt in this area up to about 5 years ago. Other forest speces abundant. Despite repeated attempts, it proved impossible to travel further upriver, or past Batulapis, as planned because of low water levels.
A1	Sungai Bahana - 14km NE of Senduruhan	OuTrop	Primary dipterocarp forest. Transects started 100m in from logging road	00.951° S, 110.873° E	2450	11	4.5	not approp.	not approp.	Steep, hilly topography. Two logging companies, Korunia Hutan Lestari and Alas Kusumer, operate in this area. Logging of the Sungai Bahana area occurred during 2001 but was limited to 25 m from the river. No evidence of further logging was found within The area surveyed, although chainsaws were

A2	Sungai Bahana - 14km NE of Senduruhan	OuTrop	Primary dipterocarp forest. Transects started 100m in from logging road	00.950° S, 110.854° E	2500	5	2.0	not approp.	not approp.	The area surveyed, although chainsaws were heard daily. Illegal logging is also present in this region. In Sandai we spoke with the head of an illegal logging team, which operates between Senduruhan and Nanga Sokan. There is a long history of forest use by the local people, which continues to this day; human pathways, both old and new, were abundant. Anecdotal evidence suggests that hunting by local villagers is abundant, although orangutan hunting is now largely opportunistic due to the low population, which has apparently decreased significantly over the past 6-7 years. To the south of the survey area lies Bukit Lawang which has been afforded some legal protection and is apparently unlogged. Villagers in Senduruhan suggest that orangutan are abundant in this area, and that few people go there due to its' poor accessibility.
A3	East of Sungai Kerabai - 45km NE of Sandai	OuTrop	Logged dipterocarp forest	01.100° S, 110.856° E	2500	50	20.0	[487]	[1.64]	Steep, hilly topography. In this area signs of illegal logging were abundant; logging pondoks were visible along all of the parts of the S. Kerabai that we travelled along. As we travelled from Randujungkal we saw many open areas of forest adjacent to the river, which reduced in abundance and size with increased distance from the last village. Illegal logging activity within the area of both midlines was in progress at the time of survey.
A4	East of Sungai Kerabai - 45km NE of Sandai	OuTrop	Logged dipterocarp forest	01.100° S, 110.856° E	2500	8	3.2	not approp.	not approp.	
A5	West of Sungai Kerabai - 45km NE of Sandai	OuTrop	Logged dipterocarp forest	01.098° S, 110.845° E	2500	8	3.2	not approp.	not approp.	Steep, hilly topography. Illegal logging activity was ongoing at the time of study within the area of midline 5, but had recently ceased within the area of midline 6. Disturbance as a result of logging was intense (greater than midlines 3 and 4), with large areas of open

A6	West of Lower Sungai Kerabai	OuTrop	Logged dipterocarp forest	01.111° S, 110.832° E	2500	3	1.2	not approp.	not approp.	forest and many gaps in the canopy.
B	**Bukit Baka**	OuTrop (Hearn, Ross, Sampang)	Hill Dipterocarp forest, mainly primary on podzolic soils. Altitude varied between 150-350 m a.s.l.		7500	44	5.9	128	0.43	North-western corner of the Bukit Baka-Bukit Raya National Park (181.090 ha), on the KalBar side. The timber company Pt. Sari Bumi Kusumah owns a large concession neighbouring the park boundary, and appears to be practising clear felling. There appears to be some contention over the exact location of the northeastern boundary of the national park. The area between the S. Ella Hulu and the logging road (mapped as national park land) has been subject to logging by local people, however, there was no evidence of illegal logging in the areas surveyed within the park to the east of the S. Ella Hulu. Effectively, therefore, the Sungai Ella Hulu is now considered the northeastern boundary of the park.
B1	NW corner T.N. Bukit Baka/Bukit Raya	OuTrop	Primary dipterocarp forest	00.604º S, 112.240º E	2500	6	2.4	not approp.	not approp.	Steep, hilly topography. Access to the forest was via a patrol pathway (well-walked, ~ 1-2m wide) which ran north east from the logging road (km 37). The start of midline B1 was situated 2.5 km along this pathway.
B2	NW corner T.N. Bukit Baka/Bukit Raya	OuTrop	Primary dipterocarp forest	00.627° S, 112.255° E	2500	20	8.0	[169]	[0.57]	Steep, hilly topography. Access to midlines B2 and B3 was approximately 2.7 km further south east along the logging road. They followed a bearing of 120º and began 2 km and 3 km in from the road, respectively.
B3	NW corner T.N. Bukit Baka/Bukit Raya	OuTrop	Primary dipterocarp forest	00.627° S, 112.255° E	2500	18	7.2			

C	**Sungai Arut**	Togu (OFI)	Generally logged/lighty logged or secondary dipterocarp habitat with some swamp		15000	346	23.1	not analysed	not analysed (~1.7-2.2)	Survey carried out around Riam, Penahan and Penyombaan villages in North Arut District. Discussions in all these villages suggest orang-utans are not hunted, even though they are considered a pest as they eat durian fruit from plantations. Numbers are reported to have decreased with loging however. The major industry is farming (esp. rice), and many HTI's have been set up in the area, although the local people are resisting selling their land to the concessions because of low price. Pests from nearby HTI / kelapa sawit plantations are attacking rice-crops. Around Penyombaan mining is a major activity.
C1	Kampung Gambir (2km from Riam)	Togu	Secondary (~30-40yrs)	01°55.1' S 111°52.8' E	2500	64	25.6			This area used to be rice field approximately 30-40 years ago. The general forest condition is good; bamboo is dominant vegetation in this area. Some places have swamp forest. We heard the sound of chainsaws from nearby HTI.
C2	Selombang (6km from Riam)	Togu	Foothill	01°54.1' S 111°51.6' E	2500	16	6.4			Selombang, a foothill of Bukit Balang. This place used to be a PT. Korindo concession. Now, HTI (forest of industry planting) running by PT. Aspek (Korindo group) has begun. The general forest condition is heavily logged and disturbed by company roads.
C3	Tahap (5km from Penahan)	Togu	Foothill	01°52.3' S 111°56.5' E	2500	79	31.6			Tahap is a hill in Penahan village administration. . One concession, PT. Alaska works in this area but the general forest condition, although lightly logged, is still good.
C4	Tongkip (6km from Penahan)	Togu	Hill	01°52.4' S 111°57.0' E	2500	67	26.8			PT. Alaska has concession in this area but the general forest condition is still good. On the top of the hill there is a concession road.

C5	Nyampa (2 km from Penahan)	Togu	Secondary (~10-20 yrs)	01°51.9' S 111°53.0' E	2500	23	9.2			Survey area use to be rice field approximately 10-20 years ago. Just 150 metres from the river we saw rice fields to be planted in September 2003.
C6	Batu Tutup (5km from Penyombaan)	Togu	Hill	02°01.1' S 111°54.0' E	2500	97	38.8			PT. Daya Bambu used to work here but they left the area about 6-8 months ago. General forest condition is lightly logged.
D	**Sungai Samba (Upper Katingan)**	**OuTrop (Husson, D'Arcy, Ciscoes, Topan)**	**Hill dipterocarp forest, some primary, some logged (5-15 yrs ago)**		**12300**	**65**	**5.3**	**not approp.**	**not approp.**	**NB: transects here only surveyed once. All surveys carried out within PT. Dwima Jaya Utama logging concession. Forest within this area generally good condition. However, neighbouring concessions through which we passed had large cleared areas, areas of ladang agriculture and HTI development. Illegal logging appeared widespread near rivers, virtually absent in steeper, hillier areas. Hunting seems to have been widespread 10 years ago and before, judging from discussions with village elders, and still occurs (3 infants recently confiscated from Tumbang Manggu logging base).**
D1	Camp Kecubung area, E of Sg.Samba	OuTrop	Dipterocarp, mostly primary, some lightly logged 1986 (and poss 1997 also)	UTM 49 0742700 E 9882900 N	4900	51	10.4	214	0.72	Steep, hilly topography. Very good forest, nests highly spatially clumped, particularly around ridges and the steepest hllsides. Areas of past-logging almost deviod of nests. Locals say that orang-utans are common from the area we surveyed into the forest extending north and east, probably to the upper Kahayan river.
D2	Camp Kucu area, E of Sg. Samba	OuTrop	Dipterocarp, lightly logged 1989, also some illegal	UTM 49 0736500 E 9883500 N	2800	4	1.4	not approp.	not approp.	Steep, hilly topography. More badly logged than Kecubung area, but loggers say that they never saw orangutans here even when they first started working in the area. As this area is only 8km from Kecubung (despite a couple of small roads between) this difference is strange. Fruiting ficus, lianas and durian were seen

D3	W of Sg. Samba	OuTrop	Dipterocarp, illegally logged 15-20 yrs ago, also last 3 years	UTM 49 0718600E 9881600 N	4600	10	2.2	not approp.	not approp.	Fairly, flat topography, not concession logged but illegally, possibly by neighbouring concession 20 yrs ag and also by illegal loggers within the last 3 years. Some quite high damage associated with the latter. Generally nice forest bu very few nests. Contiguous with area in the north-west of the concession (~700000 E, 989000N) where loggers reported many orang-utans 10-12 years ago when this area was logged.
E1	**Katingan swamps (between Katingan and Sampit rivers)**	OuTrop	Peat swamp forest. Southern part mangrove (unsurveyed)		18300	355	19.4	576	1.94	Entire area has been concession logged at some time, illegal logging now widespread but still recent. Hunting probably occurs but believed to be at low levels, Dayak community surrounding this area is generally muslim. Orangutans appear distributed throughout.
E1	Sungai Tarantang (8km SE of Kotabesi)	OuTrop (Hearn, Ross, Sampang	Peat swamp forest. Highly illegally logged (ongoing)	02.453° S 110.143° E	4000	63	15.8	502	1.69	Two areas 3km apart were surveyed. Illegal logging began 1997, stopped in first area 2000, the other still ongoing. All reports confirm orang-utans have always been abundant here.
E2	Sungai Kalaruan (15km SW of Asem Kumbang)	OuTrop (McLardy, Agus, Amat)	Peat swamp forest (shallow). Highy illegally logged, ongoing	UTM 49 0755700 E 9755100 N	4300	44	10.2	279	0.94	East of Sg. Kalaruan very damaged. West side pretty good. Peat very shallow. Plenty of illegal logging, based out of Telaga village.
E3	Sungai Kajang Pamali (5km W of Galinggang)	OuTrop (D'Arcy, Sampang Arie)	Peat swamp forest, some illegal logging	UTM 49 0754000 E 9714100 S	5000	104	20.8	579	1.95	Some good forest, some cleared. Many canals and skids. Illegal loggers present (average age 16!!), been logging here since 2002. About 1/2 of the area has yet to be logged, but it is due. Logging teams coordinated - not opportunistic.

E4	Sungai Perigi (~5km W of Perigi)	OuTrop (Ella, Arie)	Peat swamp forest, some illegal logging	02.520° S 113.142° E	5000	144	28.8	873	2.94	Illegal logging about to start, survey team camped at pondok (hut) village of ~20 people.

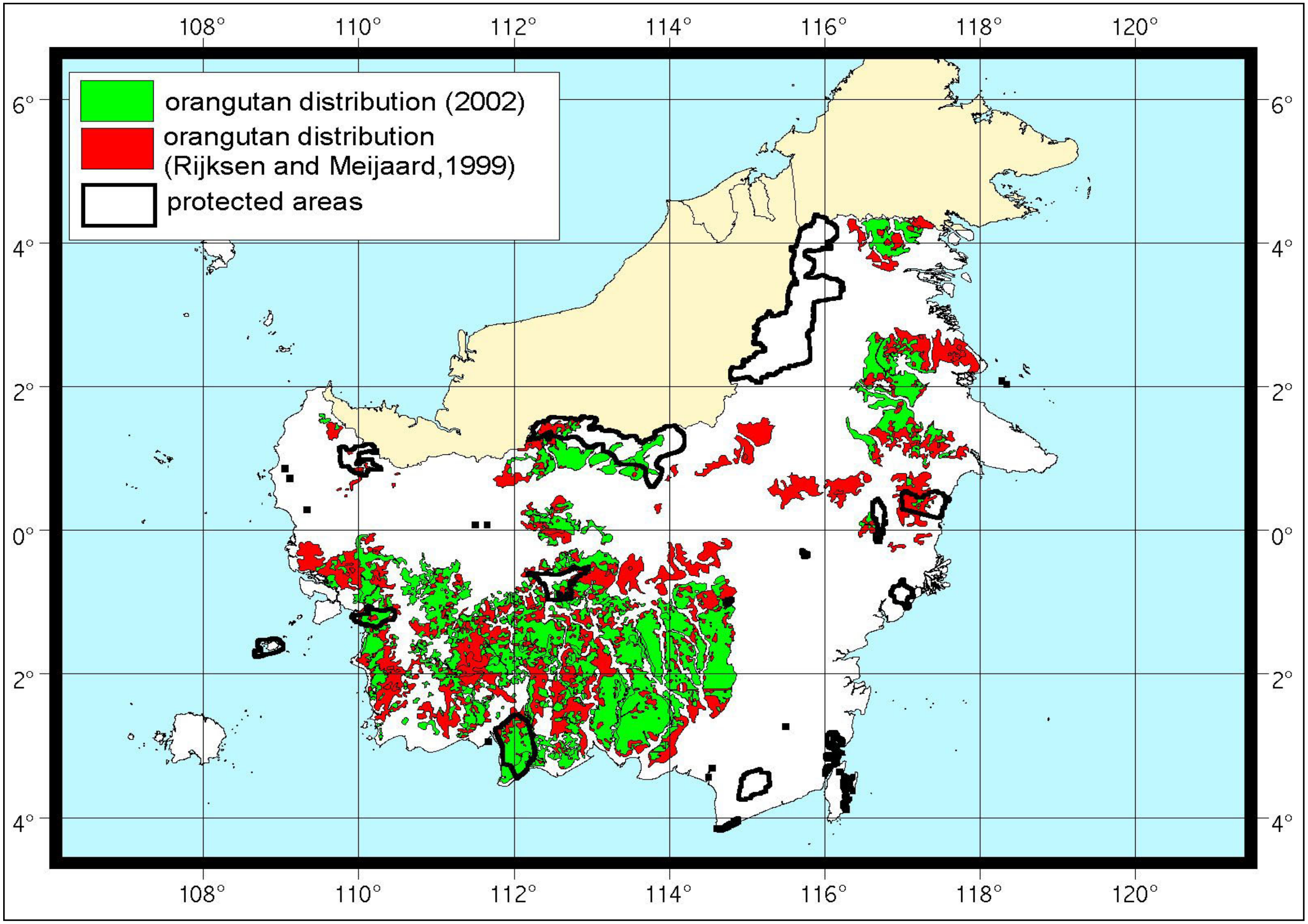

Figure 7.1 Comparison of the distribution of Kalimantan populations 1992-2002.

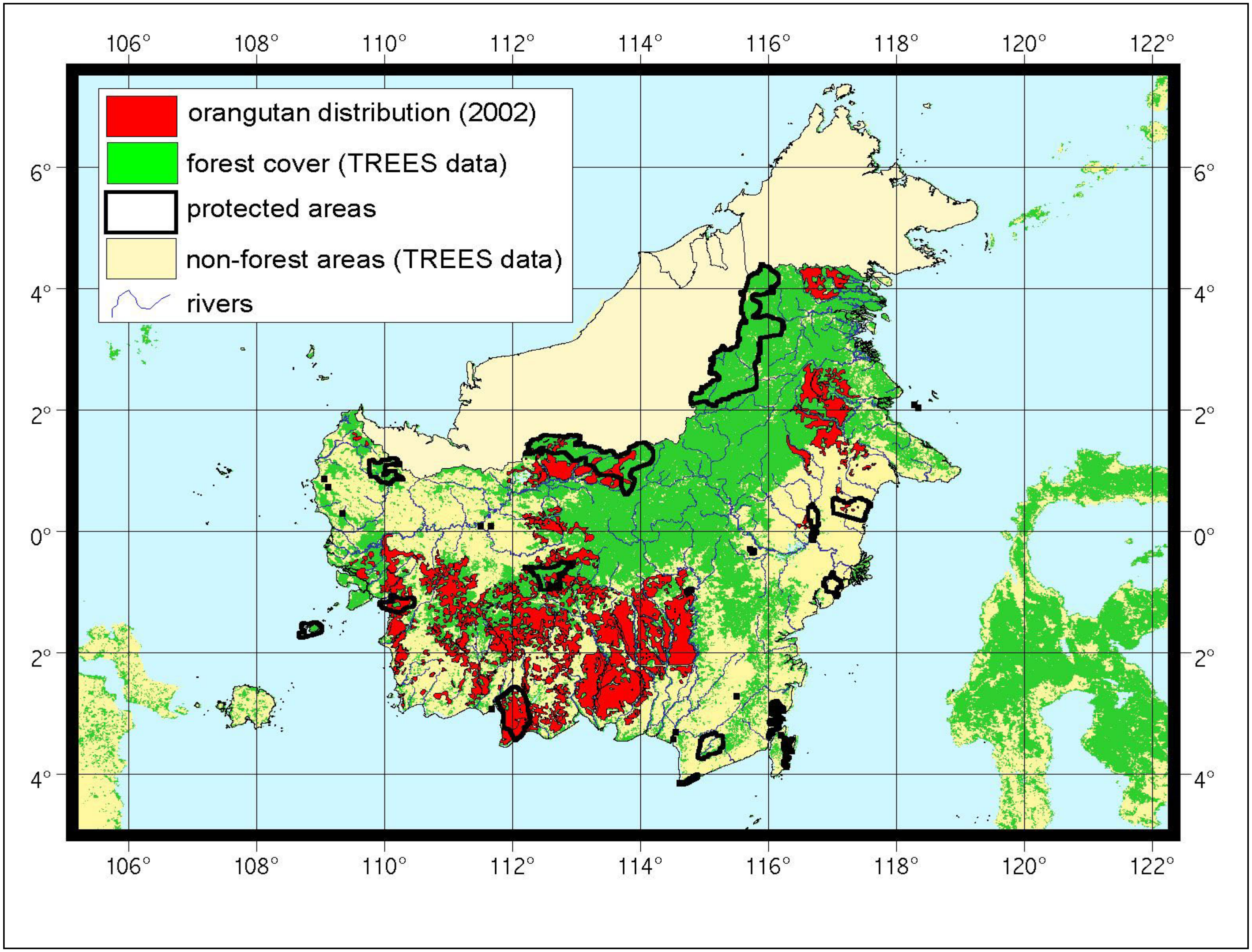

Figure 7.2. Distribution of breeding populations of Kalimantan orangutans, based on 2002 forest classification data.

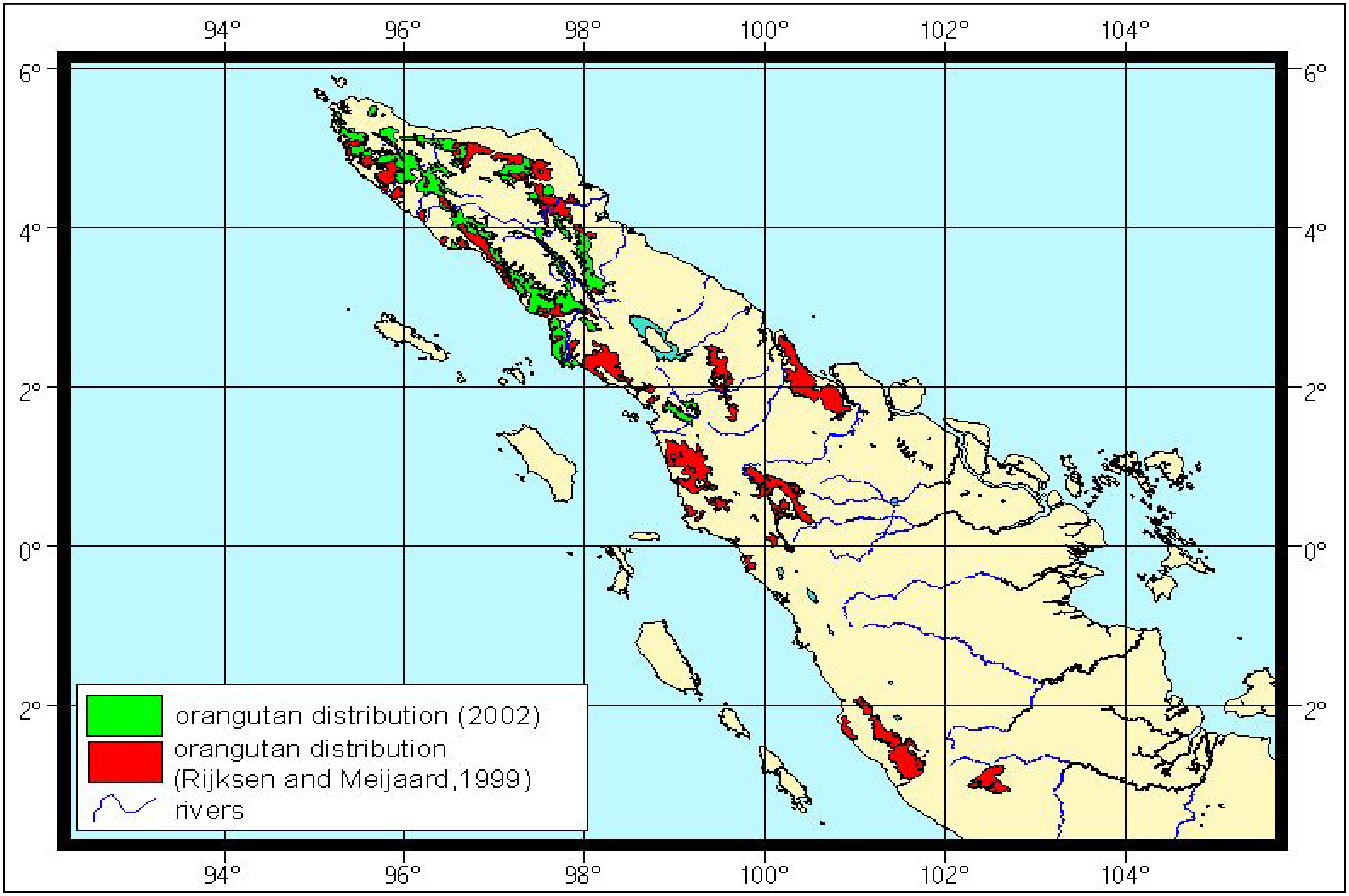

Figure 7.3. Comparison of the distribution of Sumatran populations 1992-2002.

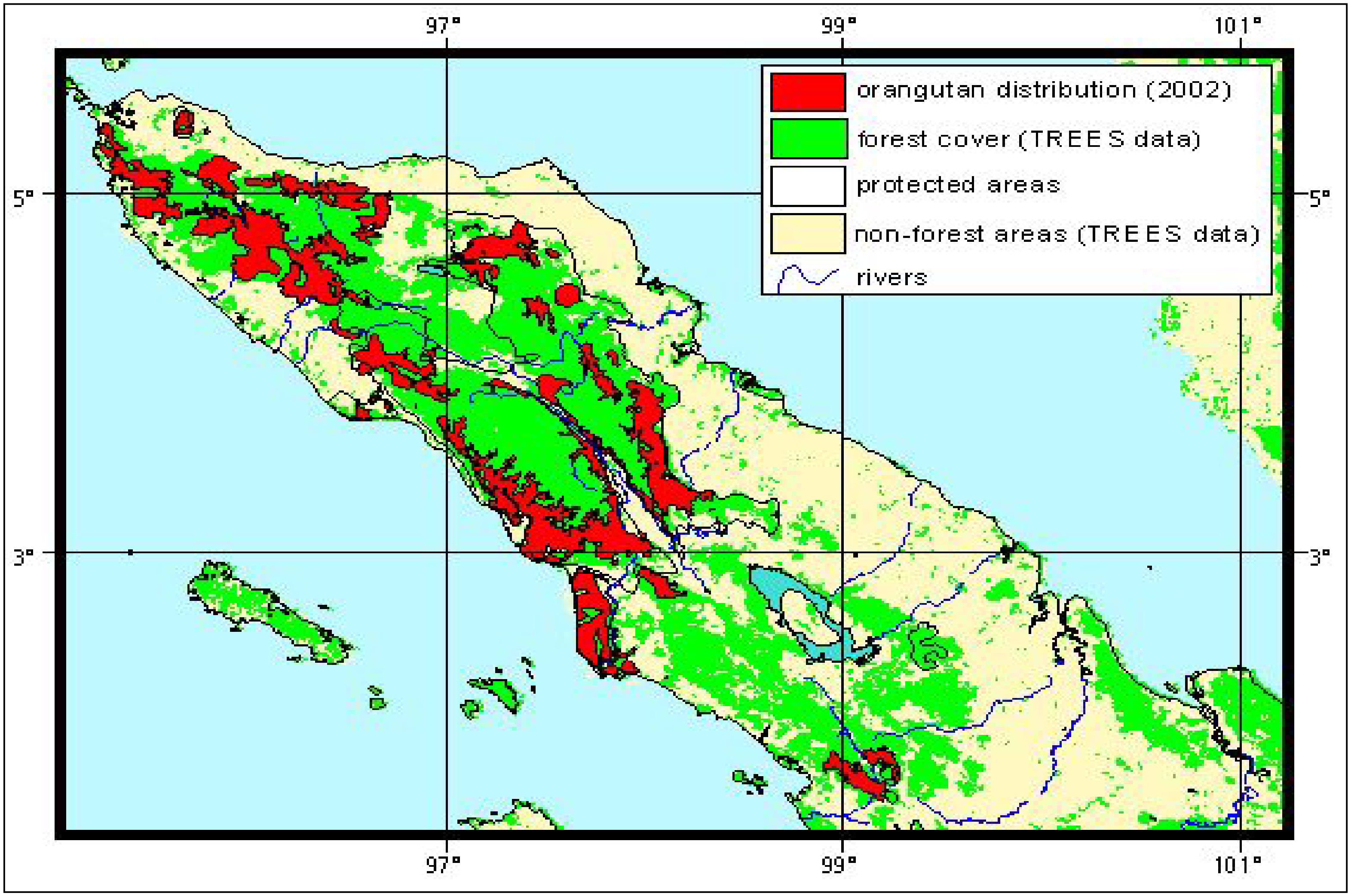

Figure 7.4. Distribution of breeding populations of Sumatran orangutans, based on 2002 forest classification data.

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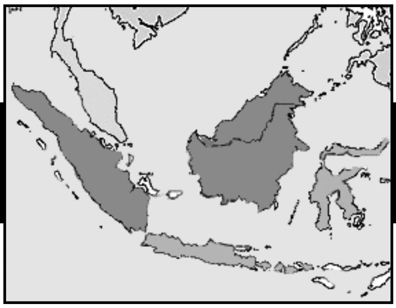

ORANGUTAN

Population and Habitat Viability Assessment

15-18 January 2004
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Section 8

PARTICIPANT LIST

Participant List

Marc Ancrenaz
Kinabatangan OU Conservation Project
Po.Box. 3109
90734 Sandakan, Sabah, Malaysia
hutan1@tm.net.my
Ph.: 088-250540

Noviar Andayani
WCS-IP
Jl. Pangrango no: 8, Bogor
Jawa Barat, Indonesia
noviar@wcsip.org
Ph.: +62-21-7863431

Andy Antilla
BOS-USA / Woodland Park Zoo
119 19th Ave. E. #312 Seatlle WA 98112
USA
pongop@aol.com
Ph.: +1-206-7065469

Riswan Bangun
Taman Nasional Gn. Leuser
(Bukit Lawang-Bohorok)
Jl. Sisingamangaraja km 5,5 no: 14,
Medan
Sumatera Utara, Indonesia
riswanbangun@yahoo.com
Ph.: +62-61-4142574

Aschta Nita Boestani
Geography Dept. Edinburgh University
Drummond street, Edinburgh EH8 9XP,
UK
Aschta.boestani@ed.ac.uk

Stephen Brend
Orangutan Foundation
7 Kent Terrace, London NW1 4RP, UK
clovenhoof@easynet.co.uk
Ph.: 081349743712

Onnie Byers
CBSG
12101 Johnny Cake Ridge Road
Apple Valley, MN 55124, USA
onnie@cbsg.org
Ph.: +1-952-997-9800

Leif Cocks
Australian OU Project
10 Dunford st., Wikagee, NA 6156,
Australia
leif@orangutan.org.au
Ph.: +61-409-100426

Ketut Djati
USAID Jakarta
Wisma Metropolitan II
Ph.: +62-21-3806694

Renie Djojoasmoro
ORCP-OFI
Jl. Kumpai Batu Bawah, Pasir Panjang,
Pangkalan Bun
Kalimantan Tengah, Indonesia
rdjojoasmoro@yahoo.com
Ph.: 08128432474

Djuwantoko
APAPI / Fak. Kehutanan Universitas
Gajah Mada
Jl. Papandayan no: 2, Perum. Banteng III
Yogyakarta, Indoensia
juwantoko@yahoo.com

Matt Doughty
UNEP-WCMC
219 Huntingdon Road
Cambridge, CB3 0DL, UK
matt.doughty@unep-wcmc.org
Ph.: (01223)277314

Susie Ellis
CI – International
1919 M Street, 5th Floor
Washington, D. C. 20036
USA
s.ellis@conservation.org

Ermayanti
CI – Indonesia Programme
Jl. Pejaten Barat no: 16 A, Kemang
Jakarta 12550, Indonesia
erma@conservation.or.id
Ph.: +62-21-7883 8624

Ivona Foitova
UMI-Saving of Pongidae Foundation
Samalova 90, 615 00 Brno,
Czech Republic
Ivona_foi@hotmail.com
Ph.: +420545575297

Birute Galdikas
ORCP-OFI
Jl. Kumpai Batu Bawah , Pasir Panjang,
Pangkalan Bun
Kalimantan Tengah, Indonesia
siswoyo@aol.com

Andrea Gibson
Andrea_gibson1@yahoo.co.uk

Kunkun Jaka Gurmaya
Biology FMIPA Universitas Pajajaran
Jl. Raya Jatinangor, Sumedang
Jawa Barat, Indonesia
kunjakagurmaya@bdg.centrin.net.id
Ph.: +61-22-7796412/7564094

John Harting
GPOP
Texas Tech University
jrharting@yahoo.com

Junann Holmes
OFI
1101 New Hampshire Ave, NW,
Apt.906
Washington DC 20037, USA
Ph.: +1-202-223-3725

Kathy Holzer
CBSG
12101 Johnny Cake Ridge Rd.
Apple Valley, MN, USA
Kathy@cbsg.org
Ph.: +1-952-997 9800

Simon Husson
OUTROP
C/o. CIMTROP, Kampus UNPAR
Jl. Tanjung Nyaho, Palangka Raya,
Kalimantan Tengah 73112, Indonesia
Simon_husson@yahoo.com
Ph.: +62-536-36880

M. Ali Imron
Fakultas Kehutanan, Universitas Gajah Mada
Kampus Bulaksumur, Yogyakarta,
Indonesia
imron@hotmail.com
Ph.: +62-274-388 132

Entang Iskandar
Pusat Studi Satwa Primata IPB
Jl. Lodaya II no: 5, Bogor 16151
Jawa Barat, Indonesia
eiskandar@bogor.net
Ph.: +62-251-313637

Agustinus Krisdiantoro
Taman Nasional Kutai
Jl. Awang Long Box. 1, Bontang 75311
Kalimantan Timur, Indonesia
Ph.: +62-548-27218

Bob Lacy
CBSG
12101 Johnny Cake Ridge Road
Apple Valley, MN 55124 USA
rlacy@ix.netcom.com
Ph.: +1-952-997-9800

Mark Leighton
Harvard University
Peabody Museum
50 D, 11 Divinity Ave.
Cambridge, MA 02138, USA
Leighton@fas.harvard.edu
Ph.: +1-617-493 2288

Ashley Leiman
OFI
7 Kent Terrace, London NW1 4RP, UK
Ashley@orangutan.org.uk
Ph.: +44-207-724 2912

Darmawan Liswanto
Yayasan Titian
Jl. Parit H.Husein II,
Komp. Telkom no: F1
Pontianak 78124, Kalimantan Barat,
Indonesia
darmawanliswanto@telkom.net
Ph.: +62-561-713039

Abu Hanifah Lubis
CI- Indonesia Programme
Jl. Rajawali 38, Sei Sikambing, Medan
Sumatera Utara, Indonesia
Ah_lubis@conservation.or.od
Ph.: +62-61-8454534
Fax.: +62-61-844 3836

Jansen Manansang
CBSG Indonesia
Taman Safari Indonesia
Cisarua, Bogor, Indonesia

Barita O Manullang
CI- Indonesia Programme
Jl. Pejaten Barat no: 16 A, Kemang
Jakarta 12550, Indonesia
bmanullang@conservation.or.id
Ph.: +62-21-7883 8624
Fax.: +62-21-780 6723

Gatot Margianto
ORCP-OFI
Jl. Kumpai Batu Bawah, Pasir Panjang,
Pangkalan Bun
Kalimantan Tengah, Indonesia
gatotmyoi@yahoo.co.uk
Ph.: 08125154187

Andrew Jon Marshall
Harvard University
Peabody Museum
50D, 11 Divinity Ave.
Cambridge, MA 02138, USA
amarshall@fas.harvard.edu
Ph.: +1-617-495 5243

James McCaul
Gn. Palung OU Conservation Project
Jl. Sutan Sjahrir 39, Ketapang
Kalimantan Barat, Indonesia
jamesmccaul@yahoo.com
Ph.: 08125743567

Erik Meijaard
Australia University
1/14 Portas Place
Canberra, Australia
erik.meijaard@anu.edu.au

Helen Morrogh Bernard
OUTROP
Jl. Vergo Ameko, Palangka Raya
Kalimantan Tengah, Indonesia
hmorroghbernard@yahoo.com
Ph.: +62-536-22039

Abdul Muin
BKSDA Kalimantan Tengah
Jl. Yos Sudarso no: 3, Palangka Raya
Kalimantan Tengah, Indonesia
Abd_moein@yahoo.com
Ph.: +62-536-21268 / Fax.: 37034

Citrakasih Nente
Proyek Reintroduksi Wanariset (BOS-F)
PoBox. 500, Balikpapan 76103
Kalimantan Timur, Indonesia
citrakasih@indo.net.id

Julia Ng-Su-Chen
TRAFFIC SouthEast Asia
9-3A, Jl. SS23/11, Tmn. Sea, 47400 P.J.
Kuala Lumpur, Malaysia
Julia_ng@myjaring.net

Lone D.Nielsen
Proyek Rientroduksi Nyaru Menteng
(BOS-F)
Po.Box. 70, Palangka Raya 73000
Kalimantan Tengah, Indonesia
lone@savetheorangutan.info
Ph.: +62-536-39912 / 0868-12106232

Ivan Yusfi Noor
BKSDA Kalimantan Timur
Jl. MT Haryono, Samarinda 1001
Fax.: +62-541-743 556

Kisar Odom
Mawas Programme (BOS-F)
Jl. Yos Sudarso no: 1A, Palangka Raya
Kalimantan Tengah, Indonesia
mawaskahiyu@yahoo.com
Ph.: +62-536-20998

Lusman Pasaribu
Taman Nasional Tanjung Puting
Jl. H.M. Rafii Km 1,5, Pangkalan Bun
Kalimantan Tengah
Ph.: +62-532-23832

Peter-Hinrich Pratje
SOCP/ FZS
Jl. Bangka 43, Kebun Handil
Jambi, Indonesia
phpratje@gmx.net
Ph.: +62-741-43080

Dolly Priatna
Unit Managemen Leuser
Jl. Dr. Mansyur 68, Medan, Indnesia
dollyp@indosat.net.id
Ph.: +62-61-821 6800 / Fax.: +62-61-821 6808

Fazrin Rahmadani
BEBSic
Jl. P.Anatasari 2, Perum GPH, AA-6
Samarinda, Kalimantan Timur,
Indonesia
Fazrin_r@telkom.net.id
Ph.: +62-541-744520

M. Rajuli
Proyek Reintroduksi Wanariset (BOS-F)
PO Box 500, Balikpapan 76103
Kalimantan Timur, Indonesia

Ian Redmond
The Great Ape Survival Programme
GrASP
ele@globalnet.co.uk

Norman Rosen
CBSG
27 16 th St.
Hermosa Beach, CA 90254
normrosen@aol.com
Ph.: +1-310-318 3778

Anne Russon
York University
Glendon College, 2275 Bay View Ave,
Toronto, Canada
arusson@gl.yorku.ca
Ph.: +1-416-462 1039

Hartati Saat
ORCP-OFI
Jl. Kumpai Batu Bawah,
Pasir Panjang, Pangkalan Bun
Kalimantan Tengah, Indonesia

Samedi
Kep. Sub.Dir. Konvensi Departemen Kehutanan
Gd. Manggala Wanabhakti Blok 7 Lt. 7
Jl. Gatot Subroto, Jakarta Pusat,
Indonesia

Koes Saparjadi
Direktur Jenderal PHKA –
Departemen Kehutanan
Gd. Manggala Wanabhakti Blok I, Lt.8
Jl. Gatot Subroto, Jakarta Pusat,
Indonesia

Azri Sawang
KOCP
PO Box 3109, 90374 Sabah, Malaysia
Ph.: +60-89-230220

Rob Shumaker
IPLS
1533 Linden St., Suite 200, Des Mones,
Iowa, USA
rshumake@gmu.edu
Ph.: +1-515-243 3580

Tatang Mitra Setia
Fakultas Biologi Universitas Nasional
Jl. Sawo Manila, Pejaten, Jakarta 12520,
Indonesia
tatangtiara@yahoo.com
Ph.: +1-62-21-788 333 84

Drh. Eddy Setiarto
Director of Taman Margasatwa Ragunan
Jl. Harsono RM no: 1, Ragunan
Jakarta 12550, Indonesia

Christian Nahot Simanjuntak
ORCP – OFI
Jl. Kumpai Batu Bawah
Pasir Panjang, Pangkalan Bun
Kalimantan Tengah, Indonesia

Togu Simorangkir
YAYORIN (ORCP-OFI)
yayorin@indo.net.id
Ph.: +62-21-747 06214

Ian Singleton
SOCP
Taman Setia Budi Indah N27, Medan
Sumatera Utara, Indonesia
mokko@indo.net.id
Ph.: +62-61-8200737

Dhany Sitaparasti
Proyek Reintroduksi Wanariset (BOS-F)
PoBox. 500, Balikpapan 76103
Kalimantan Timur, Indonesia
sitaparasti@yahoo.com
Ph.: +62-542-410 365

Willie Smits
Borneo Orangutan Survival Foundation
Jl. Pepaya Raya no: 40, Jagakarsa
Jakarta 12620, Indonesia
gibbonf@cbn.net.id
Ph.: +62-21-727 0468

Suzette Stephens *(pre-29 June 2004)*
The Nature Conservancy
Jl. Pemuda no: 92, Tanjung Redeb
Kalimantan Timur, Indonesia
(as of 29 June 2004)
c/o Lisa Stephens
1620 Camino Olmo, #C
Thousand Oaks, CA 91320
LeoASalas@netscape.net

Jito Sugardjito
FFI
Jl. Bangbarang raya no: 74, Bogor,
Indonesia
ffi@indo.net.id
Ph.: +62-251-326408 / Fax: 372101

I Made Sugiarta
FNPF
Jl. Harimau 74, Pangkalan Bun
Kalimantan Tengah, Indonesia
fnpf@dps.centrin.id
Ph.: +62-532- 21611

Tri Dibyo Sumbogo
BKSDA Kalimantan Barat
Jl. A Yani no: 121, Pontianak
Kalimantan Barat, Indonesia
Tri_ds@yahoo.com
Ph.: +62-561-747 004

Sunarto
CI- Indonesia Programme
Jl. Pejaten Barat 16 A, Kemang
Jakarta 12550, Indonesia
sunarto@conservation.org
Ph.: +62-21-7883 8624

Jatna Suprijatna
CI – Indonesia Programme
Jl. Pejaten Barat no: 16 A, Kemang
Jakarta 12550, Indonesia
jatna@cbn.net.id
Ph.: +62-21-7883 8624

Retno Susanti
PHKA/ Dit. KK Departemen Kehutanan
Gd. Manggala Wanabhakti Blok 7 Lt.7
Jl. Gatot Subroto, Jakarta, Indonesia
retno@centrin.net.id

Drs. Ing. Djoko Herry Susilo
Dir.Executive BOS Foundation
Jl. Pepaya Raya no: 40, Jagakarsa
Jakarta, Indonesia
Herrysusilo@Yahoo.com

Bambang Suyikno
BKSDA SumUt II – Sibolga
Jl. Kemenyan III no: 6, Medan 20141
Sumatera Utara, Indonesia
bambangkin@hotmail.com
Ph.: 08126578965

Akira Suzuki
Orangutan conservation and Research
5-11-8, Ikuta, Tama, Kawasaki,
Kanagawa, Japan
orangutan@livedoor.com
Ph.: +81-44-955 7406

Boris Thiemig
BOS-Germany
Spremberger str. 9, 12047 Berlin,
Germany
b.thiemig@web.de
Ph.: +49-30-616 25333

Albertus Tjiu
WWF Project Betung Kerihun N.P.
Jl. Kom Yos Sudarso No. 97
Putussibau - Kalimantan Barat
Indonesia
albertustjiu@hotmail.com
wwf@pontianak.wasantara.net.id
Ph.: +62-5667-22258

WWF Indonesia Programme
Kantor Taman A9, Unit A1
Jl. Mega Kuningan Lot 8.9/A9, Kawasan
Mega Kuningan
Jakarta 12950, Indonesia

Augustine Tuuga
Wildlife Departmen Sabah
5th floor, Block B, Wisma Muis, Kota
Kinibalu 88100
Sabah, Malaysia
Augustine.tuuga@sabah.gov.my
Ph.: 088-215 330

Sri Suci Utami Atmoko
Fakultas Biologi Universitas Nasional
BOS Foundation
Jl. Pepaya Raya no: 40, Jagakarsa
Jakarta 12620, Indonesia
Suci-azwar@cbn.net.id
Ph.: +62-21-8725 701

Carel P. van Schaik
Dept. Biology and Anthropology
Duke University
05 A Bio Science Bldg, Box. 90383
Durham, NC 27708-0383, USA
vschaik@acpub.duke.edu

Serge A. Wich
Utrecht University
PoBox. 80086, 3508 TB Utrecht
The Netherlands
s.a.wich@bio.uu.nl
Ph.: +31-30-2535401

Wira
CI – Indonesia Programme
Jl. Pejaten Barat no: 16 A, Kemang
Jakarta 12550, Indonesia
wirahan@indo.net.id
Ph.: +62-21-7883 8624

Lucy Wisdom
SOS
PoBox. 92, Ubud 80571, Bali, Indonesia
lucywisdom@freeuk.com
Ph.: 08159097757

Franky Zamzani
Taman Nasional Gn. Palung
Jl. KH Wahid Hasyim 41A, Ketapang
Kalimantan Barat, Indonesia
btngp@yahoo.com
Ph.: +62-534-33539

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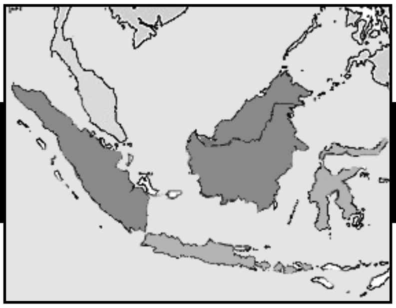

ORANGUTAN

Population and Habitat Viability Assessment

15-18 January 2004
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Section 9

INVITATION LIST

Invitation List

	Name	Occupation/Institution	*E-mail*
1.	**Doughty, Matt**	Wolrd Atlas of Great Apes	Matt.Doughty@unep-wcmc.org
2.	**Gibson, Andrea**		
3.	**Gurmaya, Kun Kun Jaka**	Former chairman-research	kunjakagurmaya@bdg.centrin.net.id
4.	**Redmond, Ian**	GrASP	ele@globalnet.co.uk
5.	**Ancrenaz, Marc**	Kinabatangan Orang Utan Conservation Project	hutan1@tm.net.my
6.	**Ambu, Laurentius**	Deputy Director, Sabah Wildlife Department	
7.	**Brend, Stephen**		clovenhoof@easynet.co.uk
8.	**Byers, Onnie**		onnie@cbsg.org
9.	**Cocks, Leif**	Curator Australian Orangutan Project	leif.cocks@perthzoo.wa.gov.au
10.	**Djojoasmoro, Renie**		rdjojoasmoro@yahoo.com
11.	**Drasospolino (Ino)**	WWF	Drasospolino@wwf.or.id; sospolino@yahoo.com
12.	**Ellis, Susie**	CI	s.ellis@conservation.org
13.	**Eudey, Ardith**	South east Asian primate SSC SG	eudey@aol.com
14.	**Foitova, Ivona**		ivona_foi@hotmail.com
15.	**Galdikas, Birute**	President of OFI	ofi@orangutan.org
16.	**Harting, John**	Works with Cheryl Knott	
17.	**Holzer, Kathy**	CBSG	kathy@cbsg.org
18.	**Husson, Simon**	Orangutan Tropical Peatland Research Project	simon_husson@yahoo.com
19.	**Lacy, Bob**	CBSG	rlacy@ix.netcom.com
20.	**Leighton, Mark**	Director of Tropical Ecology, Dept. of Anthropology, Harvard Univ.	leighton@fas.harvard.edu
21.	**Leiman, Ashley**	Director of Orangutan Found. UK	Ashley@orangutan.org.uk
22.	**Lubis, Abu**	CI	abulubis@hotmail.com, ah_lubis@conservation.or.id.
23.	**Marshall, Andrew John**	Anthropology Ph.D Candidate Harvard University/ Gunung Palung Project	amarshal@fas.harvard.edu andrew_marshall@usa.net (summer 2002)
24.	**McCaul, James**	Field Director of Gunung Palung Orangutan Conservation Prog.	jamesmccaul@yahoo.com
25.	**Meijaard, Erik**		erik.meijaard@anu.edu.au
26.	**Morrogh Bernard, Helen**		simon_husson@yahoo.com
27.	**Julia Ng Su -Chen**	Programme Officer TRAFFIC Southeast Asia	julia_ng@myjaring.net
28.	**Jumrafiah, Abd. Shukor**		Augustine.Tuuga@sabah.gov.my
29.	**Manullang, Barita**	Conservation International Indonesia	bmanullang@conservation.or.id barita@manullang.org
30.	**Nielsen,Lone D.**	Project Manager of Nyaru Menteng	Project.o-u@lycos.com
31.	**Noviar, Andayani**		noviar@wcsip.org
32.	**Pratje, Peter-Hinrich**		ppratje@eudoramail.com
33.	**Priatna, Dolly**		dpriatna@indosat.net.id
34.	**Rahmadani, Fazrin**	BEBSiC, Institute for Natural Resources and Community Development	fazrin_r@telkom.net, bebsic@telkom.net
35.	**Rosen, Norman**	Great Ape Coord. /CBSG	Normrosen@AoL.com
36.	**Russon, Anne**	York University	arusson@gl.yorku.ca

		BOSF, BOS USA, WORP	
37.	**Sawang, Azri**	(with Marc A)	
38.	**Schumaker, Rob**		rshumake@gmu.edu
39.	**Singleton, Ian**	Sumatran Orangutan Conservation Programme	mokko@indo.net.id
40.	**Siregar, Rondang S.E.**	Biologist WORP	rses2@hermes.cam.ac.uk rsiregar@indo.net.id
41.	**Smits, Willie**		gibbonf@cbn.net.id
42.	**Suzette Stephens**	Conservation Scientist, TNC	sstephens@samarinda.org
43.	**Sugardjito, Jito**		jitoffi@bogor.wasantara.net.id, ffi@indo.net.id
44.	**Pak Sunarto**	CI	sunarto@conservation.or.id
45.	**Supriatna, Jatna**	CI	jatna@conservation.or.id
46.	**Suzuki, Akira**		orangutan@livedoor.com
47.	**Tjiu, Albertus**	WWF	albertustjiu@hotmail.com
48.	**Simorangkir, Togu**	Yayasan Orangutan Indonesia	togu_redape@yahoo.com
49.	**Tuuga, Augustine**		Augustine.Tuuga@sabah.gov.my
50.	**Utami, Suci**		azwarbgr@yahoo.co.uk, tiua@cbn.net.id
51.	**van Schaik, Carel**	Duke University, Dept. Biological Anthropology &Anatomy	vschaik@acpub.duke.edu
52.	**Wich, Serge**		sawich@hetnet.nl
53.	**Wisdom, Lucy**	Founding Director of Sumatran Orangutan Society	lucywisdom@freeuk.com
54.	**Ramono, Widodo**	PHKA	wsramono@eudoramail.com, dirkw.pka@dephut.cbn.net.id
55.	**Bruford, Mike**		
56.	**Commitante, Raffaella**	Research Student Ph.D, Cambridge University	rc292@cam.ac.uk
57.	**Davison, Geoffrey**	Borneo Programme Director WWF Malaysia	gdavison@tm.net.my
58.	**Geurts,Tine**		tinegeurts@yahoo.com
59.	**Groves, Colin**	Australian National University	colin.groves@anu.edu.au
60.	**Hearn, Andrew**	Works with Simon H.	Ajhearn_@hotmail.com
61.	**Knott, Cheryl**	Harvard University	knott@fas.harvard.edu
62.	**Kormos, Rebecca**	SSC primate SG	r.kormos@conservation.org
63.	**Lee, Rob**	Director of WCS-primatologist by training	rlee@wcs.org
64.	**Rijksen, Herman**		RijksenCC@hetnet.nl
65.	**Ross, Jo**	Works with Simon H.	Jross_@hotmail.com
66.	**Swan, Ralph A.**	Professor Clinical Studies Murdoch Univ.	r.swan@murdoch.edu.au
67.	**Warren, Kristin**	Murdoch University	k.warren@murdoch.edu.au
68.	**Pak Adi**		dirkkh@dephut.cbn.net.id
69.	**Agus**		dirkw.pka@dephut.cbn.net.id
70.	**Ancrenaz, Isabelle**		hutan1@tm.net.my
71.	**Andau, Patrick**	Director, Sabah Wildlife Department	
72.	**Butcher, Fleur**		fleur@froggy.com.au
73.	**Chai, Paul P.K.**	ITTO Sarawak Office, Kuching, Sarawak Malaysia	itto@po.jaring.my
74.	**Chivers, David**		djc7@cam.ac.uk
75.	**Witjaksono Hadi, Djati**		dirkkh@dephut.cbn.net.id
76.	**Djuwantoko**	Chairman of Indonesia Primatologist Association	iwild@indo.net.id
77.	**Fitri, Arni Diana**	DVM Proyek Nyaru Menteng	hananadiana@yahoo.com
78.	**Fox, Beth**		eafox@mindspring.com

79.	**Frey, Regina**		rfrey@paneco.ch
80.	**Gaman, Ella**		
81.	**Goossens, Benoit**	Per Marc A. (Mike Bruford's postdoc, Cardiff University)	
82.	**Gumal, Melvin**		melter@pc.jaring.my
83.	**Jensen, Soren**	DANSET - Danish AID	
84.	**Jumrafiah, Puan**	District Officer, Sabah Wildlife Department, Tawau	
85.	**Kurnia, Rauf**		dirkkh@dephut.cbn.net.id
86.	**Manansang, Jansen**	CBSG Indonesia	safari@indo.net.id
87.	**Malim, Peter**	District Officer, Sabah Wildlife Department, Kota Kinabatangan	
88.	**Nente, Citrakasih**	Veterinarian of WORP	citrakasih@yahoo.com
89.	**Okayama, Toshinao**	Expert Ph.D LIPI	lox@indo.net.id
90.	**Patterson, Anne**	USAID	a.patterson@usaid.gov
91.	**Payne, Junaidi (John)**	WWF Malaysia	gdavison@tm.net.my
92.	**Perkins, Laurie**	AZA	
93.	**Robertson, Yarrow**		yarrow@attglobal.net
94.	**Rubis, June**		tajai76@yahoo.com
95.	**Rustam, Effendy**		rustam_ffi@yahoo.com
96.	**Saleh, Chairul**	WWF species manager	csaleh@wwf.org.id
97.	**Pak Sarmaedi**		dirkkh@dephut.cbn.net.id
98.	**Tatang Mitra Setia**		mitrasetia@hotmail.com mitrasetia@softhome.net
99.	**Sundai Silang, Sunsai**	ITTO Sarawak Office, Kuching, Sarawak Malaysia	sundais@sarawaknet.gov.my
100	**Pak Sudarno**		dirkkh@dephut.cbn.net.id
101	**Scott Stanley**	TNC Borneo	sstanley@tnc.org
102	**Susilo, Heri Joko**		dirkw.pka@dephut.cbn.net.id
103	**Witjaksono Hadi, Djati**		dirkkh@dephut.cbn.net.id
104	**Yeager, Carey**	American Embassy USAID	cyeager@usaid.gov careyyeager@yahoo.com

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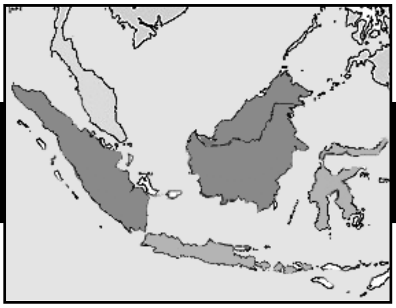

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Section 10

VORTEX REFERENCE

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VORTEX: A Computer Simulation Model for Population Viability Analysis

Robert C. Lacy

Department of Conservation Biology, Chicago Zoological Society,
Brookfield, Illinois 60513, U.S.A.

Abstract

Population Viability Analysis (PVA) is the estimation of extinction probabilities by analyses that incorporate identifiable threats to population survival into models of the extinction process. Extrinsic forces, such as habitat loss, over-harvesting, and competition or predation by introduced species, often lead to population decline. Although the traditional methods of wildlife ecology can reveal such deterministic trends, random fluctuations that increase as populations become smaller can lead to extinction even of populations that have, on average, positive population growth when below carrying capacity. Computer simulation modelling provides a tool for exploring the viability of populations subjected to many complex, interacting deterministic and random processes. One such simulation model, VORTEX, has been used extensively by the Captive Breeding Specialist Group (Species Survival Commission, IUCN), by wildlife agencies, and by university classes. The algorithms, structure, assumptions and applications of VORTEX are described in this paper.

VORTEX models population processes as discrete, sequential events, with probabilistic outcomes. VORTEX simulates birth and death processes and the transmission of genes through the generations by generating random numbers to determine whether each animal lives or dies, to determine the number of progeny produced by each female each year, and to determine which of the two alleles at a genetic locus are transmitted from each parent to each offspring. Fecundity is assumed to be independent of age after an animal reaches reproductive age. Mortality rates are specified for each pre-reproductive age–sex class and for reproductive-age animals. Inbreeding depression is modelled as a decrease in viability in inbred animals.

The user has the option of modelling density dependence in reproductive rates. As a simple model of density dependence in survival, a carrying capacity is imposed by a probabilistic truncation of each age class if the population size exceeds the specified carrying capacity. VORTEX can model linear trends in the carrying capacity. VORTEX models environmental variation by sampling birth rates, death rates, and the carrying capacity from binomial or normal distributions. Catastrophes are modelled as sporadic random events that reduce survival and reproduction for one year. VORTEX also allows the user to supplement or harvest the population, and multiple subpopulations can be tracked, with user-specified migration among the units.

VORTEX outputs summary statistics on population growth rates, the probability of population extinction, the time to extinction, and the mean size and genetic variation in extant populations.

VORTEX necessarily makes many assumptions. The model it incorporates is most applicable to species with low fecundity and long lifespans, such as mammals, birds and reptiles. It integrates the interacting effects of many of the deterministic and stochastic processes that have an impact on the viability of small populations, providing opportunity for more complete analysis than is possible by other techniques. PVA by simulation modelling is an important tool for identifying populations at risk of extinction, determining the urgency of action, and evaluating options for management.

Introduction

Many wildlife populations that were once widespread, numerous, and occupying contiguous habitat, have been reduced to one or more small, isolated populations. The causes of the original decline are often obvious, deterministic forces, such as over-harvesting,

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habitat destruction, and competition or predation from invasive introduced species. Even if the original causes of decline are removed, a small isolated population is vulnerable to additional forces, intrinsic to the dynamics of small populations, which may drive the population to extinction (Shaffer 1981; Soulé 1987; Clark and Seebeck 1990). Of particular impact on small populations are stochastic processes. With the exception of aging, virtually all events in the life of an organism are stochastic. Mating, reproduction, gene transmission between generations, migration, disease and predation can be described by probability distributions, with individual occurrences being sampled from these distributions. Small samples display high variance around the mean, so the fates of small wildlife populations are often determined more by random chance than by the mean birth and death rates that reflect adaptations to their environment.

Although many processes affecting small populations are intrinsically indeterminate, the average long-term fate of a population and the variance around the expectation can be studied with computer simulation models. The use of simulation modelling, often in conjunction with other techniques, to explore the dynamics of small populations has been termed Population Viability Analysis (PVA). PVA has been increasingly used to help guide management of threatened species. The Resource Assessment Commission of Australia (1991) recently recommended that 'estimates of the size of viable populations and the risks of extinction under multiple-use forestry practices be an essential part of conservation planning'. Lindenmayer *et al.* (1993) describe the use of computer modelling for PVA, and discuss the strengths and weaknesses of the approach as a tool for wildlife management.

In this paper, I present the PVA program VORTEX and describe its structure, assumptions and capabilities. VORTEX is perhaps the most widely used PVA simulation program, and there are numerous examples of its application in Australia, the United States of America and elsewhere.

The Dynamics of Small Populations

The stochastic processes that have an impact on populations have been usefully categorised into demographic stochasticity, environmental variation, catastrophic events and genetic drift (Shaffer 1981). Demographic stochasticity is the random fluctuation in the observed birth rate, death rate and sex ratio of a population even if the probabilities of birth and death remain constant. On the assumption that births and deaths and sex determination are stochastic sampling processes, the annual variations in numbers that are born, die, and are of each sex can be specified from statistical theory and would follow binomial distributions. Such demographic stochasticity will be important to population viability only in populations that are smaller than a few tens of animals (Goodman 1987), in which cases the annual frequencies of birth and death events and the sex ratios can deviate far from the means. The distribution of annual adult survival rates observed in the remnant population of whooping cranes (*Grus americana*) (Mirande *et al.* 1993) is shown in Fig. 1. The innermost curve approximates the binomial distribution that describes the demographic stochasticity expected when the probability of survival is 92·7% (mean of 45 non-outlier years).

Environmental variation is the fluctuation in the probabilities of birth and death that results from fluctuations in the environment. Weather, the prevalence of enzootic disease, the abundances of prey and predators, and the availability of nest sites or other required microhabitats can all vary, randomly or cyclically, over time. The second narrowest curve on Fig. 1 shows a normal distribution that statistically fits the observed frequency histogram of crane survival in non-outlier years. The difference between this curve and the narrower distribution describing demographic variation must be accounted for by environmental variation in the probability of adult survival.

Catastrophic variation is the extreme of environmental variation, but for both methodological and conceptual reasons rare catastrophic events are analysed separately from the more typical annual or seasonal fluctuations. Catastrophes such as epidemic disease,

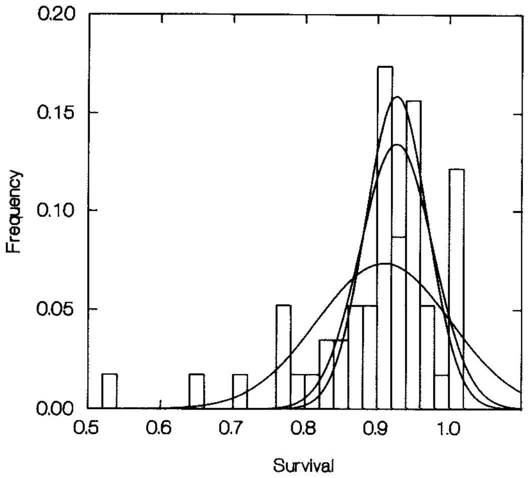

Fig. 1. Frequency histogram of the proportion of whooping cranes surviving each year, 1938–90. The broadest curve is the normal distribution that most closely fits the overall histogram. Statistically, this curve fits the data poorly. The second highest and second broadest curve is the normal distribution that most closely fits the histogram, excluding the five leftmost bars (7 outlier 'catastrophe' years). The narrowest and tallest curve is the normal approximation to the binomial distribution expected from demographic stochasticity. The difference between the tallest and second tallest curves is the variation in annual survival due to environmental variation.

hurricanes, large-scale fires, and floods are outliers in the distribution of environmental variation (e.g. five leftmost bars on Fig. 1). As a result, they have quantitatively and sometimes qualitatively different impacts on wildlife populations. (A forest fire is not just a very hot day.) Such events often precipitate the final decline to extinction (Simberloff 1986, 1988). For example, one of two populations of whooping crane was decimated by a hurricane in 1940 and soon after went extinct (Doughty 1989). The only remaining population of the black-footed ferret (*Mustela nigripes*) was being eliminated by an outbreak of distemper when the last 18 ferrets were captured (Clark 1989).

Genetic drift is the cumulative and non-adaptive fluctuation in allele frequencies resulting from the random sampling of genes in each generation. This can impede the recovery or accelerate the decline of wildlife populations for several reasons (Lacy 1993). Inbreeding, not strictly a component of genetic drift but correlated with it in small populations, has been documented to cause loss of fitness in a wide variety of species, including virtually all sexually reproducing animals in which the effects of inbreeding have been carefully studied (Wright 1977; Falconer 1981; O'Brien and Evermann 1988; Ralls *et al.* 1988; Lacy *et al.* 1993). Even if the immediate loss of fitness of inbred individuals is not large, the loss of genetic variation that results from genetic drift may reduce the ability of a population to adapt to future changes in the environment (Fisher 1958; Robertson 1960; Selander 1983).

Thus, the effects of genetic drift and consequent loss of genetic variation in individuals and populations have a negative impact on demographic rates and increase susceptibility to environmental perturbations and catastrophes. Reduced population growth and greater fluctuations in numbers in turn accelerate genetic drift (Crow and Kimura 1970). These synergistic destabilising effects of stochastic process on small populations of wildlife have been described as an 'extinction vortex' (Gilpin and Soulé 1986). The size below which a population is likely to be drawn into an extinction vortex can be considered a 'minimum viable population' (MVP) (Seal and Lacy 1989), although Shaffer (1981) first defined a MVP more stringently as a population that has a 99% probability of persistence for 1000 years. The estimation of MVPs or, more generally, the investigation of the probability of extinction constitutes PVA (Gilpin and Soulé 1986; Gilpin 1989; Shaffer 1990).

Methods for Analysing Population Viability

An understanding of the multiple, interacting forces that contribute to extinction vortices is a prerequisite for the study of extinction–recolonisation dynamics in natural populations inhabiting patchy environments (Gilpin 1987), the management of small populations (Clark and Seebeck 1990), and the conservation of threatened wildlife (Shaffer 1981, 1990; Soulé 1987; Mace and Lande 1991). Because demographic and genetic processes in small populations are inherently unpredictable, the expected fates of wildlife populations can be described in terms of probability distributions of population size, time to extinction, and genetic variation. These distributions can be obtained in any of three ways: from analytical models, from empirical observation of the fates of populations of varying size, or from simulation models.

As the processes determining the dynamics of populations are multiple and complex, there are few analytical formulae for describing the probability distributions (e.g. Goodman 1987; Lande 1988; Burgmann and Gerard 1990). These models have incorporated only few of the threatening processes. No analytical model exists, for example, to describe the combined effect of demographic stochasticity and loss of genetic variation on the probability of population persistence.

A few studies of wildlife populations have provided empirical data on the relationship between population size and probability of extinction (e.g. Belovsky 1987; Berger 1990; Thomas 1990), but presently only order-of-magnitude estimates can be provided for MVPs of vertebrates (Shaffer 1987). Threatened species are, by their rarity, unavailable and inappropriate for the experimental manipulation of population sizes and long-term monitoring of undisturbed fates that would be necessary for precise empirical measurement of MVPs. Retrospective analyses will be possible in some cases, but the function relating extinction probability to population size will differ among species, localities and times (Lindenmayer *et al.* 1993).

Modelling the Dynamics of Small Populations

Because of the lack of adequate empirical data or theoretical and analytical models to allow prediction of the dynamics of populations of threatened species, various biologists have turned to Monte Carlo computer simulation techniques for PVA. By randomly sampling from defined probability distributions, computer programs can simulate the multiple, interacting events that occur during the lives of organisms and that cumulatively determine the fates of populations. The focus is on detailed and explicit modelling of the forces impinging on a given population, place, and time of interest, rather than on delineation of rules (which may not exist) that apply generally to most wildlife populations. Computer programs available to PVA include SPGPC (Grier 1980*a*, 1980*b*), GAPPS (Harris *et al.* 1986), RAMAS (Ferson and Akçakaya 1989; Akçakaya and Ferson 1990; Ferson 1990), FORPOP (Possingham *et al.* 1991), ALEX (Possingham *et al.* 1992), and SIMPOP (Lacy *et al.* 1989; Lacy and Clark 1990) and its descendant VORTEX.

SIMPOP was developed in 1989 by converting the algorithms of the program SPGPC (written by James W. Grier of North Dakota State University) from BASIC to the C programming language. SIMPOP was used first in a PVA workshop organised by the Species Survival Commission's Captive Breeding Specialist Group (IUCN), the United States Fish and Wildlife Service, and the Puerto Rico Department of Natural Resources to assist in planning and assessing recovery efforts for the Puerto Rican crested toad (*Peltophryne lemur*). SIMPOP was subsequently used in PVA modelling of other species threatened with extinction, undergoing modification with each application to allow incorporation of additional threatening processes. The simulation program was renamed VORTEX (in reference to the extinction vortex) when the capability of modelling genetic processes was implemented in 1989. In 1990, a version allowing modelling of multiple populations was briefly named VORTICES. The only version still supported, with all capabilities of each previous version, is VORTEX Version 5.1.

VORTEX has been used in PVA to help guide conservation and management of many species, including the Puerto Rican parrot (*Amazona vittata*) (Lacy *et al.* 1989), the Javan rhinoceros (*Rhinoceros sondaicus*) (Seal and Foose 1989), the Florida panther (*Felis concolor coryi*) (Seal and Lacy 1989), the eastern barred bandicoot (*Perameles gunnii*) (Lacy and Clark 1990; Maguire *et al.* 1990), the lion tamarins (*Leontopithecus rosalia* ssp.) (Seal *et al.* 1990), the brush-tailed rock-wallaby (*Petrogale penicillata penicillata*) (Hill 1991), the mountain pygmy-possum (*Burramys parvus*), Leadbeater's possum (*Gymnobelideus leadbeateri*), the long-footed potoroo (*Potorous longipes*), the orange-bellied parrot (*Neophema chrysogaster*) and the helmeted honeyeater (*Lichenostomus melanops cassidix*) (Clark *et al.* 1991), the whooping crane (*Grus americana*) (Mirande *et al.* 1993), the Tana River crested mangabey (*Cercocebus galeritus galeritus*) and the Tana River red colobus (*Colobus badius rufomitratus*) (Seal *et al.* 1991), and the black rhinoceros (*Diceros bicornis*) (Foose *et al.* 1992). In some of these PVAs, modelling with VORTEX has made clear the insufficiency of past management plans to secure the future of the species, and alternative strategies were proposed, assessed and implemented. For example, the multiple threats to the Florida panther in its existing habitat were recognised as probably insurmountable, and a captive breeding effort has been initiated for the purpose of securing the gene pool and providing animals for release in areas of former habitat. PVA modelling with VORTEX has often identified a single threat to which a species is particularly vulnerable. The small but growing population of Puerto Rican parrots was assessed to be secure, except for the risk of population decimation by hurricane. Recommendations were made to make available secure shelter for captive parrots and to move some of the birds to a site distant from the wild flock, in order to minimise the damage that could occur in a catastrophic storm. These recommended actions were only partly implemented when, in late 1989, a hurricane killed many of the wild parrots. The remaining population of about 350 Tana River red colobus were determined by PVA to be so fragmented that demographic and genetic processes within the 10 subpopulations destabilised population dynamics. Creation of habitat corridors may be necessary to prevent extinction of the taxon. In some cases, PVA modelling has been reassuring to managers: analysis of black rhinos in Kenya indicated that many of the populations within sanctuaries were recovering steadily. Some could soon be used to provide animals for re-establishment or supplementation of populations previously eliminated by poaching. For some species, available data were insufficient to allow definitive PVA with VORTEX. In such cases, the attempt at PVA modelling has made apparent the need for more data on population trends and processes, thereby helping to justify and guide research efforts.

Description of VORTEX

Overview

The VORTEX computer simulation model is a Monte Carlo simulation of the effects of deterministic forces, as well as demographic, environmental and genetic stochastic events, on wildlife populations. VORTEX models population dynamics as discrete, sequential events that occur according to probabilities that are random variables, following user-specified distributions. The input parameters used by VORTEX are summarised in the first part of the sample output given in the Appendix.

VORTEX simulates a population by stepping through a series of events that describe an annual cycle of a typical sexually reproducing, diploid organism: mate selection, reproduction, mortality, increment of age by one year, migration among populations, removals, supplementation, and then truncation (if necessary) to the carrying capacity. The program was designed to model long-lived species with low fecundity, such as mammals, birds and reptiles. Although it could and has been used in modelling highly fecund vertebrates and invertebrates, it is awkward to use in such cases as it requires complete specification of the percentage of females producing each possible clutch size. Moreover, computer memory limitations often hamper such analyses. Although VORTEX iterates life events on an annual cycle, a user could model 'years' that are other than 12 months' duration. The simulation of the population is itself iterated to reveal the distribution of fates that the population might experience.

Demographic Stochasticity

VORTEX models demographic stochasticity by determining the occurrence of probabilistic events such as reproduction, litter size, sex determination and death with a pseudo-random number generator. The probabilities of mortality and reproduction are sex-specific and pre-determined for each age class up to the age of breeding. It is assumed that reproduction and survival probabilities remain constant from the age of first breeding until a specified upper limit to age is reached. Sex ratio at birth is modelled with a user-specified constant probability of an offspring being male. For each life event, if the random value sampled from the uniform 0–1 distribution falls below the probability for that year, the event is deemed to have occurred, thereby simulating a binomial process.

The source code used to generate random numbers uniformly distributed between 0 and 1 was obtained from Maier (1991), according to the algorithm of Kirkpatrick and Stoll (1981). Random deviates from binomial distributions, with mean p and standard deviation s, are obtained by first determining the integral number of binomial trials, N, that would produce the value of s closest to the specified value, according to

$$N = p(1-p)/s^2 .$$

N binomial trials are then simulated by sampling from the uniform 0–1 distribution to obtain the desired result, the frequency or proportion of successes. If the value of N determined for a desired binomial distribution is larger than 25, a normal approximation is used in place of the binomial distribution. This normal approximation must be truncated at 0 and at 1 to allow use in defining probabilities, although, with such large values of N, s is small relative to p and the truncation would be invoked only rarely. To avoid introducing bias with this truncation, the normal approximation to the binomial (when used) is truncated symmetrically around the mean. The algorithm for generating random numbers from a unit normal distribution follows Latour (1986).

VORTEX can model monogamous or polygamous mating systems. In a monogamous system, a relative scarcity of breeding males may limit reproduction by females. In polygamous or monogamous models, the user can specify the proportion of the adult males in the breeding pool. Males are randomly reassigned to the breeding pool each year of the simulation, and all males in the breeding pool have an equal chance of siring offspring.

The 'carrying capacity', or the upper limit for population size within a habitat, must be specified by the user. VORTEX imposes the carrying capacity via a probabilistic truncation whenever the population exceeds the carrying capacity. Each animal in the population has an equal probability of being removed by this truncation.

Environmental Variation

VORTEX can model annual fluctuations in birth and death rates and in carrying capacity as might result from environmental variation. To model environmental variation, each demographic parameter is assigned a distribution with a mean and standard deviation that is specified by the user. Annual fluctuations in probabilities of reproduction and mortality are modelled as binomial distributions. Environmental variation in carrying capacity is modelled as a normal distribution. The variance across years in the frequencies of births and deaths resulting from the simulation model (and in real populations) will have two components: the demographic variation resulting from a binomial sampling around the mean for each year, and additional fluctuations due to environmental variation and catastrophes (see Fig. 1 and section on The Dynamics of Small Populations, above).

Data on annual variations in birth and death rates are important in determining the probability of extinction, as they influence population stability (Goodman 1987). Unfortunately, such field information is rarely available (but see Fig. 1). Sensitivity testing, the examination of a range of values when the precise value of a parameter is unknown, can help to identify whether the unknown parameter is important in the dynamics of a population.

Catastrophes

Catastrophes are modelled in VORTEX as random events that occur with specified probabilities. Any number of types of catastrophes can be modelled. A catastrophe will occur if a randomly generated number between zero and one is less than the probability of occurrence. Following a catastrophic event, the chances of survival and successful breeding for that simulated year are multiplied by severity factors. For example, forest fires might occur once in 50 years, on average, killing 25% of animals, and reducing breeding by survivors by 50% for the year. Such a catastrophe would be modelled as a random event with 0·02 probability of occurrence each year, and severity factors of 0·75 for survival and 0·50 for reproduction.

Genetic Processes

Genetic drift is modelled in VORTEX by simulation of the transmission of alleles at a hypothetical locus. At the beginning of the simulation, each animal is assigned two unique alleles. Each offspring is randomly assigned one of the alleles from each parent. Inbreeding depression is modelled as a loss of viability during the first year of inbred animals. The impacts of inbreeding are determined by using one of two models available within VORTEX: a Recessive Lethals model or a Heterosis model.

In the Recessive Lethals model, each founder starts with one unique recessive lethal allele and a unique, dominant non-lethal allele. This model approximates the effect of inbreeding if each individual in the starting population had one recessive lethal allele in its genome. The fact that the simulation program assumes that all the lethal alleles are at the same locus has a very minor impact on the probability that an individual will die because of homozygosity for one of the lethal alleles. In the model, homozygosity for different lethal alleles are mutually exclusive events, whereas in a multilocus model an individual could be homozygous for several lethal alleles simultaneously. By virtue of the death of individuals that are homozygous for lethal alleles, such alleles would be removed slowly by natural selection during the generations of a simulation. This reduces the genetic variation present in the population relative to the case with no inbreeding depression, but also diminishes the subsequent probability that inbred individuals will be homozygous for a lethal allele. This model gives an optimistic reflection of the impacts of inbreeding on many species, as the median number of lethal equivalents per diploid genome observed for mammalian populations is about three (Ralls *et al.* 1988).

The expression of fully recessive deleterious alleles in inbred organisms is not the only genetic mechanism that has been proposed as a cause of inbreeding depression. Some or most of the effects of inbreeding may be a consequence of superior fitness of heterozygotes (heterozygote advantage or 'heterosis'). In the Heterosis model, all homozygotes have reduced fitness compared with heterozygotes. Juvenile survival is modelled according to the logarithmic model developed by Morton *et al.* (1956):

$$\ln S = A - BF$$

in which S is survival, F is the inbreeding coefficient, A is the logarithm of survival in the absence of inbreeding, and B is a measure of the rate at which survival decreases with inbreeding. B is termed the number of 'lethal equivalents' per haploid genome. The number of lethal equivalents per diploid genome, $2B$, estimates the number of lethal alleles per individual in the population if all deleterious effects of inbreeding were due to recessive lethal alleles. A population in which inbreeding depression is one lethal equivalent per diploid genome may have one recessive lethal allele per individual (as in the Recessive Lethals model, above), it may have two recessive alleles per individual, each of which confer a 50% decrease in survival, or it may have some other combination of recessive deleterious alleles that equate in effect with one lethal allele per individual. Unlike the situation with fully recessive deleterious alleles, natural selection does not remove deleterious alleles at heterotic loci because all alleles are deleterious when homozygous and beneficial when present in heterozygous combination with other alleles. Thus, under the Heterosis model, the impact of inbreeding on survival does not diminish during repeated generations of inbreeding.

Unfortunately, for relatively few species are data available to allow estimation of the effects of inbreeding, and the magnitude of these effects varies considerably among species (Falconer 1981; Ralls *et al.* 1988; Lacy *et al.* 1993). Moreover, whether a Recessive Lethals model or a Heterosis model better describes the underlying mechanism of inbreeding depression and therefore the response to repeated generations of inbreeding is not well-known (Brewer *et al.* 1990), and could be determined empirically only from breeding studies that span many generations. Even without detailed pedigree data from which to estimate the number of lethal equivalents in a population and the underlying nature of the genetic load (recessive alleles or heterosis), applications of PVA must make assumptions about the effects of inbreeding on the population being studied. In some cases, it might be considered appropriate to assume that an inadequately studied species would respond to inbreeding in accord with the median (3·14 lethal equivalents per diploid) reported in the survey by Ralls *et al.* (1988). In other cases, there might be reason to make more optimistic assumptions (perhaps the lower quartile, 0·90 lethal equivalents), or more pessimistic assumptions (perhaps the upper quartile, 5·62 lethal equivalents).

Deterministic Processes

VORTEX can incorporate several deterministic processes. Reproduction can be specified to be density-dependent. The function relating the proportion of adult females breeding each year to the total population size is modelled as a fourth-order polynomial, which can provide a close fit to most plausible density-dependence curves. Thus, either positive population responses to low-density or negative responses (e.g. Allee effects), or more complex relationships, can be modelled.

Populations can be supplemented or harvested for any number of years in each simulation. Harvest may be culling or removal of animals for translocation to another (unmodelled) population. The numbers of additions and removals are specified according to the age and sex of animals. Trends in the carrying capacity can also be modelled in VORTEX, specified as an annual percentage change. These changes are modelled as linear, rather than geometric, increases or decreases.

Migration among Populations

VORTEX can model up to 20 populations, with possibly distinct population parameters. Each pairwise migration rate is specified as the probability of an individual moving from one population to another. This probability is independent of the age and sex. Because of between-population migration and managed supplementation, populations can be recolonised. VORTEX tracks the dynamics of local extinctions and recolonisations through the simulation.

Output

VORTEX outputs (1) probability of extinction at specified intervals (e.g., every 10 years during a 100-year simulation), (2) median time to extinction if the population went extinct in at least 50% of the simulations, (3) mean time to extinction of those simulated populations that became extinct, and (4) mean size of, and genetic variation within, extant populations (see Appendix and Lindenmayer *et al.* 1993).

Standard deviations across simulations and standard errors of the mean are reported for population size and the measures of genetic variation. Under the assumption that extinction of independently replicated populations is a binomial process, the standard error of the probability of extinction (*SE*) is reported by VORTEX as

$$SE(p)=\surd[p\times(1-p)/n]\,,$$

in which the frequency of extinction was p over n simulated populations. Demographic and genetic statistics are calculated and reported for each subpopulation and for the metapopulation.

Availability of the VORTEX Simulation Program

VORTEX Version 5.1 is written in the C programming language and compiled with the Lattice 80286C Development System (Lattice Inc.) for use on microcomputers using the MS-DOS (Microsoft Corp.) operating system. Copies of the compiled program and a manual for its use are available for nominal distribution costs from the Captive Breeding Specialist Group (Species Survival Commission, IUCN), 12101 Johnny Cake Ridge Road, Apple Valley, Minnesota 55124, U.S.A. The program has been tested by many workers, but cannot be guaranteed to be error-free. Each user retains responsibility for ensuring that the program does what is intended for each analysis.

Sequence of Program Flow

(1) The seed for the random number generator is initialised with the number of seconds elapsed since the beginning of the 20th century.

(2) The user is prompted for input and output devices, population parameters, duration of simulation, and number of interations.

(3) The maximum allowable population size (necessary for preventing memory overflow) is calculated as

$$N_{max}=(K+3s)\times(1+L)$$

in which K is the maximum carrying capacity (carrying capacity can be specified to change linearly for a number of years in a simulation, so the maximum carrying capacity can be greater than the initial carrying capacity), s is the annual environmental variation in the carrying capacity expressed as a standard deviation, and L is the specified maximum litter size. It is theoretically possible, but very unlikely, that a simulated population will exceed the calculated N_{max}. If this occurs then the program will give an error message and abort.

(4) Memory is allocated for data arrays. If insufficient memory is available for data arrays then N_{max} is adjusted downward to the size that can be accommodated within the available memory and a warning message is given. In this case it is possible that the analysis may have to be terminated because the simulated population exceeds N_{max}. Because N_{max} is often several-fold greater than the likely maximum population size in a simulation, a warning it has been adjusted downward because of limiting memory often will not hamper the analyses. Except for limitations imposed by the size of the computer memory (VORTEX can use extended memory, if available), the only limit to the size of the analysis is that no more than 20 populations exchanging migrants can be simulated.

(5) The expected mean growth rate of the population is calculated from mean birth and death rates that have been entered. Algorithms follow cohort life-table analyses (Ricklefs 1979). Generation time and the expected stable age distribution are also estimated. Life-table estimations assume no limitation by carrying capacity, no limitation of mates, and no loss of fitness due to inbreeding depression, and the estimated intrinsic growth rate assumes that the population is at the stable age distribution. The effects of catastrophes are incorporated into the life-table analysis by using birth and death rates that are weighted averages of the values in years with and without catastrophes, weighted by the probability of a catastrophe occurring or not occurring.

(6) Iterative simulation of the population proceeds via steps 7–26 below. For exploratory modelling, 100 iterations are usually sufficient to reveal gross trends among sets of simulations with different input parameters. For more precise examination of population behaviour under various scenarios, 1000 or more simulations should be used to minimise standard errors around mean results.

(7) The starting population is assigned an age and sex structure. The user can specify the exact age–sex structure of the starting population, or can specify an initial population size and request that the population be distributed according to the stable age distribution calculated from the life table. Individuals in the starting population are assumed to be unrelated. Thus, inbreeding can occur only in second and later generations.

(8) Two unique alleles at a hypothetical genetic locus are assigned to each individual in the starting population and to each individual supplemented to the population during the simulation. VORTEX therefore uses an infinite alleles model of genetic variation. The subsequent fate of genetic variation is tracked by reporting the number of extant alleles each year, the expected heterozygosity or gene diversity, and the observed heterozygosity. The expected heterozygosity, derived from the Hardy–Weinberg equilibrium, is given by

$$H_e = 1 - \Sigma(p_i^2),$$

in which p_i is the frequency of allele i in the population. The observed heterozygosity is simply the proportion of the individuals in the simulated population that are heterozygous. Because of the starting assumption of two unique alleles per founder, the initial population has an observed heterozygosity of 1·0 at the hypothetical locus and only inbred animals can become homozygous. Proportional loss of heterozygosity by means of random genetic drift is independent of the initial heterozygosity and allele frequencies of a population (assuming that the initial value was not zero) (Crow and Kimura 1970), so the expected heterozygosity remaining in a simulated population is a useful metric of genetic decay for comparison across scenarios and populations. The mean observed heterozygosity reported by VORTEX is the mean inbreeding coefficient of the population.

(9) The user specifies one of three options for modelling the effect of inbreeding: (a) no effect of inbreeding on fitness, that is, all alleles are selectively neutral, (b) each founder individual has one unique lethal and one unique non-lethal allele (Recessive Lethals option), or (c) first-year survival of each individual is exponentially related to its inbreeding coefficient (Heterosis option). The first case is clearly an optimistic one, as almost all diploid

populations studied intensively have shown deleterious effects of inbreeding on a variety of fitness components (Wright 1977; Falconer 1981). Each of the two models of inbreeding depression may also be optimistic, in that inbreeding is assumed to have an impact only on first-year survival. The Heterosis option allows, however, for the user to specify the severity of inbreeding depression on juvenile survival.

(10) Years are iterated via steps 11–25 below.

(11) The probabilities of females producing each possible litter size are adjusted to account for density dependence of reproduction (if any).

(12) Birth rate, survival rates and carrying capacity for the year are adjusted to model environmental variation. Environmental variation is assumed to follow binomial distributions for birth and death rates and a normal distribution for carrying capacity, with mean rates and standard deviations specified by the user. At the outset of each year a random number is drawn from the specified binomial distribution to determine the percentage of females producing litters. The distribution of litter sizes among those females that do breed is maintained constant. Another random number is drawn from a specified binomial distribution to model the environmental variation in mortality rates. If environmental variations in reproduction and mortality are chosen to be correlated, the random number used to specify mortality rates for the year is chosen to be the same percentile of its binomial distribution as was the number used to specify reproductive rate. Otherwise, a new random number is drawn to specify the deviation of age- and sex-specific mortality rates for their means. Environmental variation across years in mortality rates is always forced to be correlated among age and sex classes.

The carrying capacity (*K*) of the year is determined by first increasing or decreasing the carrying capacity at year 1 by an amount specified by the user to account for linear changes over time. Environmental variation in *K* is then imposed by drawing a random number from a normal distribution with the specified values for mean and standard deviation.

(13) Birth rates and survival rates for the year are adjusted to model any catastrophes determined to have occurred in that year.

(14) Breeding males are selected for the year. A male of breeding age is placed into the pool of potential breeders for that year if a random number drawn for that male is less than the proportion of breeding-age males specified to be breeding.

(15) For each female of breeding age, a mate is drawn at random from the pool of breeding males for that year. The size of the litter produced by that pair is determined by comparing the probabilities of each potential litter size (including litter size of 0, no breeding) to a randomly drawn number. The offspring are produced and assigned a sex by comparison of a random number to the specified sex ratio at birth. Offspring are assigned, at random, one allele at the hypothetical genetic locus from each parent.

(16) If the Heterosis option is chosen for modelling inbreeding depression, the genetic kinship of each new offspring to each other living animal in the population is determined. The kinship between a new animal, *A*, and another existing animal, *B* is

$$f_{AB}=0\cdot 5\times(f_{MB}+f_{PB})$$

in which f_{ij} is the kinship between animals *i* and *j*, *M* is the mother of *A*, and *P* is the father of *A*. The inbreeding coefficient of each animal is equal to the kinship between its parents, $F=f_{MP}$, and the kinship of an animal to itself is $f_{AA}=0\cdot 5\times(1+F)$. [See Ballou (1983) for a detailed description of this method for calculating inbreeding coefficients.]

(17) The survival of each animal is determined by comparing a random number to the survival probability for that animal. In the absence of inbreeding depression, the survival probability is given by the age and sex-specific survival rate for that year. If the Heterosis model of inbreeding depression is used and an individual is inbred, the survival probability is multiplied by e^{-bF} in which *b* is the number of lethal equivalents per haploid genome.

If the Recessive Lethals model is used, all offspring that are homozygous for a lethal allele are killed.

(18) The age of each animal is incremented by 1, and any animal exceeding the maximum age is killed.

(19) If more than one population is being modelled, migration among populations occurs stochastically with specified probabilities.

(20) If population harvest is to occur that year, the number of harvested individuals of each age and sex class are chosen at random from those available and removed. If the number to be removed do not exist for an age–sex class, VORTEX continues but reports that harvest was incomplete.

(21) Dead animals are removed from the computer memory to make space for future generations.

(22) If population supplementation is to occur in a particular year, new individuals of the specified age class are created. Each immigrant is assigned two unique alleles, one of which will be a recessive lethal in the Recessive Lethals model of inbreeding depression. Each immigrant is assumed to be genetically unrelated to all other individuals in the population.

(23) The population growth rate is calculated as the ratio of the population size in the current year to the previous year.

(24) If the population size (N) exceeds the carrying capacity (K) for that year, additional mortality is imposed across all age and sex classes. The probability of each animal dying during this carrying capacity truncation is set to $(N-K)/N$, so that the expected population size after the additional mortality is K.

(25) Summary statistics on population size and genetic variation are tallied and reported. A simulated population is determined to be extinct if one of the sexes has no representatives.

(26) Final population size and genetic variation are determined for the simulation.

(27) Summary statistics on population size, genetic variation, probability of extinction, and mean population growth rate, are calculated across iterations and printed out.

Assumptions Underpinning VORTEX

It is impossible to simulate the complete range of complex processes that can have an impact on wild populations. As a result there are necessarily a range of mathematical and biological assumptions that underpin any PVA program. Some of the more important assumptions in VORTEX include the following.

(1) Survival probabilities are density independent when population size is less than carrying capacity. Additional mortality imposed when the population exceeds K affects all age and sex classes equally.

(2) The relationship between changes in population size and genetic variability are examined for only one locus. Thus, potentially complex interactions between genes located on the same chromosome (linkage disequilibrium) are ignored. Such interactions are typically associated with genetic drift in very small populations, but it is unknown if, or how, they would affect population viability.

(3) All animals of reproductive age have an equal probability of breeding. This ignores the likelihood that some animals within a population may have a greater probability of breeding successfully, and breeding more often, than other individuals. If breeding is not at random among those in the breeding pool, then decay of genetic variation and inbreeding will occur more rapidly than in the model.

(4) The life-history attributes of a population (birth, death, migration, harvesting, supplementation) are modelled as a sequence of discrete and therefore seasonal events. However, such events are often continuous through time and the model ignores the possibility that they may be aseasonal or only partly seasonal.

(5) The genetic effects of inbreeding on a population are determined in VORTEX by using one of two possible models: the Recessive Lethals model and the Heterosis model. Both models have attributes likely to be typical of some populations, but these may vary within and between species (Brewer *et al.* 1990). Given this, it is probable that the impacts of inbreeding will fall between the effects of these two models. Inbreeding is assumed to depress only one component of fitness: first-year survival. Effects on reproduction could be incorporated into this component, but longer-term impacts such as increased disease susceptibility or decreased ability to adapt to environmental change are not modelled.

(6) The probabilities of reproduction and mortality are constant from the age of first breeding until an animal reaches the maximum longevity. This assumes that animals continue to breed until they die.

(7) A simulated catastrophe will have an effect on a population only in the year that the event occurs.

(8) Migration rates among populations are independent of age and sex.

(9) Complex, interspecies interactions are not modelled, except in that such community dynamics might contribute to random environmental variation in demographic parameters. For example, cyclical fluctuations caused by predator–prey interactions cannot be modelled by VORTEX.

Discussion

Uses and Abuses of Simulation Modelling for PVA

Computer simulation modelling is a tool that can allow crude estimation of the probability of population extinction, and the mean population size and amount of genetic diversity, from data on diverse interacting processes. These processes are too complex to be integrated intuitively and no analytic solutions presently, or are likely to soon, exist. PVA modelling focuses on the specifics of a population, considering the particular habitat, threats, trends, and time frame of interest, and can only be as good as the data and the assumptions input to the model (Lindenmayer *et al.* 1993). Some aspects of population dynamics are not modelled by VORTEX nor by any other program now available. In particular, models of single-species dynamics, such as VORTEX, are inappropriate for use on species whose fates are strongly determined by interactions with other species that are in turn undergoing complex (and perhaps synergistic) population dynamics. Moreover, VORTEX does not model many conceivable and perhaps important interactions among variables. For example, loss of habitat might cause secondary changes in reproduction, mortality, and migration rates, but ongoing trends in these parameters cannot be simulated with VORTEX. It is important to stress that PVA does not predict in general what will happen to a population; PVA forecasts the likely effects only of those factors incorporated into the model.

Yet, the use of even simplified computer models for PVA can provide more accurate predictions about population dynamics than the even more crude techniques available previously, such as calculation of expected population growth rates from life tables. For the purpose of estimating extinction probabilities, methods that assess only deterministic factors are almost certain to be inappropriate, because populations near extinction will commonly be so small that random processes dominate deterministic ones. The suggestion by Mace and Lande (1991) that population viability be assessed by the application of simple rules (e.g., a taxon be considered Endangered if the total effective population size is below 50 or the total census size below 250) should be followed only if knowledge is insufficient to allow more accurate quantitative analysis. Moreover, such preliminary judgments, while often important in stimulating appropriate corrective measures, should signal, not obviate, the need for more extensive investigation and analysis of population processes, trends and threats.

Several good population simulation models are available for PVA. They differ in capabilities, assumptions and ease of application. The ease of application is related to the number of simplifying assumptions and inversely related to the flexibility and power of the model. It is unlikely that a single or even a few simulation models will be appropriate for all PVAs. The VORTEX program has some capabilities not found in many other population simulation programs, but is not as flexible as are some others (e.g., GAPPS; Harris *et al.* 1986). VORTEX is user-friendly and can be used by those with relatively little understanding of population biology and extinction processes, which is both an advantage and a disadvantage.

Testing Simulation Models

Because many population processes are stochastic, a PVA can never specify what will happen to a population. Rather, PVA can provide estimates of probability distributions describing possible fates of a population. The fate of a given population may happen to fall at the extreme tail of such a distribution even if the processes and probabilities are assessed precisely. Therefore, it will often be impossible to test empirically the accuracy of PVA results by monitoring of one or a few threatened populations of interest. Presumably, if a population followed a course that was well outside of the range of possibilities predicted by a model, that model could be rejected as inadequate. Often, however, the range of plausible fates generated by PVA is quite broad.

Simulation programs can be checked for internal consistency. For example, in the absence of inbreeding depression and other confounding effects, does the simulation model predict an average long-term growth rate similar to that determined from a life-table calculation? Beyond this, some confidence in the accuracy of a simulation model can be obtained by comparing observed fluctuations in population numbers to those generated by the model, thereby comparing a data set consisting of tens to hundreds of data points to the results of the model. For example, from 1938 to 1991, the wild population of whooping cranes had grown at a mean exponential rate, r, of 0·040, with annual fluctuations in the growth rate, SD (r), of 0·141 (Mirande *et al.* 1993). Life-table analysis predicted an r of 0·052. Simulations using VORTEX predicted an r of 0·046 into the future, with a SD (r) of 0·081. The lower growth rate projected by the stochastic model reflects the effects of inbreeding and perhaps imbalanced sex ratios among breeders in the simulation, factors that are not considered in deterministic life-table calculations. Moreover, life-table analyses use mean birth and death rates to calculate a single estimate of the population growth rate. When birth and death rates are fluctuating, it is more appropriate to average the population growth rates calculated separately from birth and death rates for each year. This mean growth rate would be lower than the growth rate estimated from mean life-table values.

When the simulation model was started with the 18 cranes present in 1938, it projected a population size in 1991 ($N \pm \mathrm{SD} = 151 \pm 123$) almost exactly the same as that observed ($N = 146$). The large variation in population size across simulations, however, indicates that very different fates (including extinction) were almost equally likely. The model slightly underestimated the annual fluctuations in population growth [model SD (r) = 0·112 *v.* actual SD (r) = 0·141]. This may reflect a lack of full incorporation of all aspects of stochasticity into the model, or it may simply reflect the sampling error inherent in stochastic phenomena. Because the data input to the model necessarily derive from analysis of past trends, such retrospective analysis should be viewed as a check of consistency, not as proof that the model correctly describes current population dynamics. Providing another confirmation of consistency, both deterministic calculations and the simulation model project an over-wintering population of whooping cranes consisting of 12% juveniles (less than 1 year of age), while the observed frequency of juveniles at the wintering grounds in Texas has averaged 13%.

Convincing evidence of the accuracy, precision and usefulness of PVA simulation models would require comparison of model predictions to the distribution of fates of many replicate populations. Such a test probably cannot be conducted on any endangered species, but could and should be examined in experimental non-endangered populations. Once simulation models are determined to be sufficiently descriptive of population processes, they can guide management of threatened and endangered species (see above and Lindenmayer *et al.* 1993). The use of PVA modelling as a tool in an adaptive management framework (Clark *et al.* 1990) can lead to increasingly effective species recovery efforts as better data and better models allow more thorough analyses.

Directions for Future Development of PVA Models

The PVA simulation programs presently available model life histories as a series of discrete (seasonal) events, yet many species breed and die throughout much of the year. Continuous-time models would be more realistic and could be developed by simulating the time between life-history events as a random variable. Whether continuous-time models would significantly improve the precision of population viability estimates is unknown. Even more realistic models might treat some life-history events (e.g., gestation, lactation) as stages of specified duration, rather than as instantaneous events.

Most PVA simulation programs were designed to model long-lived, low fecundity (K-selected) species such as mammals, birds and reptiles. Relatively little work has been devoted to developing models for short-lived, high-fecundity (r-selected) species such as many amphibians and insects. Yet, the viability of populations of r-selected species may be highly affected by stochastic phenomena, and r-selected species may have much greater minimum viable populations than do most K-selected species. Assuring viability of K-selected species in a community may also afford adequate protection for r-selected species, however, because of the often greater habitat-area requirements of large vertebrates. Populations of r-selected species are probably less affected by intrinsic demographic stochasticity because large numbers of progeny will minimise random fluctuations, but they are more affected by environmental variations across space and time. PVA models designed for r-selected species would probably model fecundity as a continuous distribution, rather than as a completely specified discrete distribution of litter or clutch sizes; they might be based on life-history stages rather than time-increment ages; and they would require more detailed and accurate description of environmental fluctuations than might be required for modelling K-selected species.

The range of PVA computer simulation models becoming available is important because the different assumptions of the models provide capabilities for modelling diverse life histories. Because PVA models always simplify the life history of a species, and because the assumptions of no model are likely to match exactly our best understanding of the dynamics of a population of interest, it will often be valuable to conduct PVA modelling with several simulation programs and to compare the results. Moreover, no computer program can be guaranteed to be free of errors. There is a need for researchers to compare results from different PVA models when applied to the same analysis, to determine how the different assumptions affect conclusions and to cross-validate algorithms and computer code.

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Appendix. Sample Output from VORTEX

Explanatory comments are added in italics

```
VORTEX—simulation of genetic and demographic stochasticity
TEST
```

Simulation label and output file name

```
Fri Dec 20 09:21:18 1991
  2 population(s) simulated for 100 years, 100 runs
```

VORTEX first lists the input parameters used in the simulation:

```
  HETEROSIS model of inbreeding depression
    with 3·14 lethal equivalents per diploid genome

  Migration matrix:
       1       2
  1  0·9900  0·0100
  2  0·0100  0·9900
```

i.e. 1% probability of migration from Population 1 to 2, and from Population 2 to 1

```
  First age of reproduction for females: 2   for males: 2
  Age of senescence (death): 10
  Sex ratio at birth (proportion males): 0·5000

Population 1:

  Polygynous mating; 50·00 per cent of adult males in the breeding pool.
  Reproduction is assumed to be density independent.
    50·00 (EV=12·50 SD) per cent of adult females produce litters of size 0
    25·00 per cent of adult females produce litters of size 1
    25·00 per cent of adult females produce litters of size 2
```

EV is environmental variation

```
    50·00 (EV=20·41 SD) per cent mortality of females between ages 0 and 1
    10·00 (EV=3·00 SD) per cent mortality of females between ages 1 and 2
    10·00 (EV=3·00 SD) per cent annual mortality of adult females (2<=age<=10)
    50·00 (EV=20·41 SD) per cent mortality of males between ages 0 and 1
    10·00 (EV=3·00 SD) per cent mortality of males between ages 1 and 2
    10·00 (EV=3·00 SD) per cent annual mortality of adult males (2<=age<=10)
```

```
EVs have been adjusted to closest values possible for binomial distribution.
   EV in reproduction and mortality will be correlated.
   Frequency of type 1 catastrophes: 1·000 per cent
     with 0·500 multiplicative effect on reproduction
      and 0·750 multiplicative effect on survival
   Frequency of type 2 catastrophes: 1·000 per cent
     with 0·500 multiplicative effect on reproduction
      and 0·750 multiplicative effect on survival

   Initial size of Population 1: (set to reflect stable age distribution)
 Age  1   2   3   4   5   6   7   8   9   10    Total
      1   0   1   1   0   1   0   0   1   0      5  Males
      1   0   1   1   0   1   0   0   1   0      5  Females
    Carrying capacity = 50 (EV = 0·00 SD)
     with a 10·000 per cent decrease for 5 years.

   Animals harvested from population 1, year 1 to year 10 at 2 year intervals:
     1 females 1 years old
     1 female adults (2<=age<=10)
     1 males 1 years old
     1 male adults (2<=age<=10)
   Animals added to population 1, year 10 through year 50 at 4 year intervals:
     1 females 1 years old
     1 females 2 years old
     1 males 1 years old
     1 males 2 years old
```

Input values are summarised above, results follow.

VORTEX now reports life-table calculations of expected population growth rate.

```
Deterministic population growth rate (based on females, with assumptions of no limitation of mates
  and no inbreeding depression):
     r = −0·001     lambda = 0·999     RO = 0·997
   Generation time for:  females = 5·28   males = 5·28
```

Note that the deterministic life-table calculations project approximately zero population growth for this population.

```
Stable age distribution:   Age class    females    males
                               0         0·119     0·119
                               1         0·059     0·059
                               2         0·053     0·053
                               3         0·048     0·048
                               4         0·043     0·043
                               5         0·038     0·038
                               6         0·034     0·034
                               7         0·031     0·031
                               8         0·028     0·028
                               9         0·025     0·025
                              10         0·022     0·022
Ratio of adult (>=2) males to adult (>=2) females: 1·000

Population 2:
```

Input parameters for Population 2 were identical to those for Population 1.
Output would repeat this information from above.

Simulation results follow.

```
Population1
```

```
Year 10
    N[Extinct] =        0, P[E] = 0·000
    N[Surviving] =  100, P[S] = 1·000
    Population size =            4·36  (0·10 SE,   1·01 SD)
    Expected heterozygosity =  0·880 (0·001 SE, 0·012 SD)
    Observed heterozygosity =  1·000 (0·000 SE, 0·000 SD)
    Number of extant alleles = 8·57  (0·15 SE,   1·50 SD)
```

Population summaries given, as requested by user, at 10-year intervals.

```
Year 100
    N[Extinct] =      86, P[E] = 0·860
    N[Surviving] =  14, P[S] = 0·140
    Population size =            8·14  (1·27 SE,   4·74 SD)
    Expected heterozygosity =  0·577 (0·035 SE, 0·130 SD)
    Observed heterozygosity =  0·753 (0·071 SE, 0·266 SD)
    Number of extant alleles = 3·14  (0·35 SE,   1·29 SD)

In 100 simulations of 100 years of Population1:
  86 went extinct and 14 survived.
This gives a probability of extinction of 0·8600 (0·0347 SE),
  or a probability of success of          0·1400 (0·0347 SE).
99 simulations went extinct at least once.
Median time to first extinction was 5 years.
Of those going extinct,
  mean time to first extinction was 7·84 years (1·36 SE, 13·52 SD).
123 recolonisations occurred.
Mean time to recolonisation was 4·22 years (0·23 SE, 2·55 SD).
110 re-extinctions occurred.
Mean time to re-extinction was 54·05 years (2·81 SE, 29·52 SD).

Mean final population for successful cases was 8·14 (1·27 SE, 4·74 SD)
  Age 1    Adults    Total
  0·14      3·86      4·00   Males
  0·36      3·79      4·14   Females

During years of harvest and/or supplementation
  mean growth rate (r) was 0·0889 (0·0121 SE, 0·4352 SD)
Without harvest/supplementation, prior to carrying capacity truncation,
  mean growth rate (r) was −0·0267 (0·0026 SE, 0·2130 SD)
```

Population growth in the simulation (r = −0·0267) was depressed relative to the projected growth rate calculated from the life table (r = −0·001) because of inbreeding depression and occasional lack of available mates.

```
Note:   497 of 1000 harvests of males and 530 of 1000 harvests of females could not be completed
        because of insufficient animals.

Final expected heterozygosity was    0·5768 (0·0349 SE, 0·1305 SD)
Final observed heterozygosity was    0·7529 (0·0712 SE, 0·2664 SD)
Final number of alleles was          3·14   (0·35 SE,    1·29 SD)

Population2
```

Similar results for Population 2, omitted from this Appendix, would follow.

```
  ********  Metapopulation Summary  ********
Year 10
    N[Extinct] =        0, P[E] = 0·000
    N[Surviving] =  100, P[S] = 1·000
    Population size =            8·65  (0·16 SE,   1·59 SD)
    Expected heterozygosity =  0·939 (0·000 SE, 0·004 SD)
    Observed heterozygosity =  1·000 (0·000 SE, 0·000 SD)
    Number of extant alleles = 16·92 (0·20 SE,   1·96 SD)
```

Metapopulation summaries are given at 10-year intervals.

```
Year 100
    N[Extinct] =     79, P[E] = 0·790
    N[Surviving] =  21, P[S] = 0·210
    Population size =              10·38  (1·37 SE,  6·28 SD)
    Expected heterozygosity =   0·600 (0·025 SE, 0·115 SD)
    Observed heterozygosity =   0·701 (0·050 SE, 0·229 SD)
    Number of extant alleles =  3·57   (0·30 SE,   1·36 SD)

In 100 simulations of 100 years of Metapopulation:
  79 went extinct and 21 survived.
This gives a probability of extinction of   0·7900 (0·0407 SE),
  or a probability of success of             0·2100 (0·0407 SE).
97 simulations went extinct at least once.
Median time to first extinction was 7 years.
Of those going extinct,
  mean time to first extinction was 11·40 years (2·05 SE, 20·23 SD).
91 recolonisations occurred.
Mean time to recolonisation was 3·75 years (0·15 SE, 1·45 SD).
73 re-extinctions occurred.
Mean time to re-extinction was 76·15 years (1·06 SE, 9·05 SD).

Mean final population for successful cases was 10·38 (1·37 SE, 6·28 SD)
  Age 1     Adults     Total
  0·48        4·71        5·19   Males
  0·48        4·71        5·19   Females

During years of harvest and/or supplementation
  mean growth rate (r) was 0·0545 (0·0128 SE, 0·4711 SD)
Without harvest/supplementation, prior to carrying capacity truncation,
  mean growth rate (r) was  −0·0314 (0·0021 SE, 0·1743 SD)

Final expected heterozygosity was   0·5997 (0·0251 SE, 0·1151 SD)
Final observed heterozygosity was   0·7009 (0·0499 SE, 0·2288 SD)
Final number of alleles was            3·57    (0·30 SE,    1·36 SD)
```

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