SUMATRAN RHINO

POPULATION AND HABITAT

VIABILITY ANALYSIS WORKSHOP

BRIEFING BOOK

BANDAR LAMPUNG, SOUTH SUMATRA, INDONESIA
11-13 NOVEMBER 1993

PREPARED BY RONALD L. TILSON AND KATHY TRAYLOR-HOLZER
MINNESOTA ZOO

SUPPORTING ORGANIZATIONS:

INDONESIAN FOREST PROTECTION AND NATURE CONSERVATION (PHPA); IUCN/SSC CAPTIVE BREEDING SPECIALIST GROUP; INTERNATIONAL RHINO FOUNDATION (IRF); MINNESOTA ZOO; NYZS/INTERNATIONAL WILDLIFE CONSERVATION PARK; CINCINNATI ZOO AND BOTANICAL GARDEN; THE HOWLETTS AND PORT LYMPNE FOUNDATION

A Joint Endeavor of the
Indonesian Forest Protection and Nature Conservation (PHPA)
&
IUCN/SSC Captive Breeding Specialist Group

The work of the Captive Breeding Specialist Group is made possible by generous contributions from the following members of the CBSG Institutional Conservation Council:

Conservators ($10,000 and above)
Australian Species Management Program
Chicago Zoological Society
Colombus Zoological Gardens
Denver Zoological Foundation
Fossil Rim Wildlife Center
Friends of Zoo Atlanta
Greater Los Angeles Zoo Association
International Union of Directors of Zoological Gardens
Jacksonville Zoological Park
Lubee Foundation
Metropolitan Toronto Zoo
Minnesota Zoological Garden
New York Zoological Society
Omaha's Henry Doorly Zoo
Saint Louis Zoo
White Oak Plantation
Zoological Parks Board of New South Wales
Zoological Society of Cincinnati
Zoological Society of San Diego
TheWILDS

Guardians ($5,000 - $9,999)
Cleveland Zoo
Detroit Zoological Park (5 year commitment)
King's Island Wild Animal Habitat
Loro Parque
North Carolina Zoological Park
John G. Shedd Aquarium
Toledo Zoological Society

Protectors ($1,000 - $4,999)
Audubon Institute
Caldwell Zoo
Calgary Zoo
Cologne Zoo
El Paso Zoo
Federation of Zoological Gardens of Great Britain and Ireland
Fort Wayne Zoological Society
Gladys Porter Zoo
Japanese Association of Zoological Parks and Aquariums
Jersey Wildlife Preservation Trust
Kansas City Zoo
The Living Desert
Marwell Zoological Park
Milwaukee County Zoo
NOAHS Center
North of Chester Zoological Society
Oklahoma City Zoo
Phoenix Zoo
Paignton Zoological and Botanical Gardens
Penscynor Wildlife Park
Philadelphia Zoological Garden
Pittsburgh Zoo
Riverbanks Zoological Park
Royal Zoological Society of Antwerp
Royal Zoological Society of Scotland
San Francisco Zoo
Schoenbrunn Zoo
Sunset Zoo (10 year commitment)
The ZOO
Urban Council of Hong Kong
Washington Park Zoo
Wilhelma Zoological Garden
Woodland Park Zoo
Zoological Society of London
Zoological Society of Wales
Zurich Zoological Garden

Stewards ($500 - $999)
Aalborg Zoo
Arizona-Sonora Desert Museum

Stewards ($500 - $999) *continued)*
Banham Zoo
Copenhagen Zoo
Dutch Federation of Zoological Gardens
Erie Zoological Park
Fota Wildlife Park
Givskud Zoo
Granby Zoological Society
Howletts & Port Lympne Foundation
Knoxville Zoo
National Geographic Magazine
National Zoological Parks Board of South Africa
Odense Zoo
Orana Park Wildlife Trust
Paradise Park
Porter Charitable Trust
Rostock Zoo
Royal Zoological Society of Southen Australia
Rotterdam Zoo
Species Survival Committee of Japan
Tierpark Rheine
Twycross Zoo
Union of German Zoo Directors
Wellington Zoo
World Parrot Trust
Yong-In Farmland
Zoo de la Casa de Campo - Madrid
Zoological Society of Wales

Curators ($250 - $499)
Cotswold Wildlife Park
Emporia Zoo
Roger Williams Zoo
Thrigby Hall Wildlife Gardens
Topeka Zoological Park
Tropical Bird Gardens

Sponsors ($50 - $249)
African Safari
Apenheul Zoo
Belize Zoo
Claws 'n Paws
Darmstadt Zoo
Dreher Park Zoo
Fota Wildlife Park
Hancock House Publishers
Kew Royal Botanic Gardens
Nagoya Aquarium
National Audubon Society - Research Ranch Sanctuary
Parco Faunistico "La Torbiera"
Potter Park Zoo
Touro Parc -France
Wassenaar Wildlife Breeding Center

Supporters ($25 - $49)
Alameda Park Zoo
Buttonwood Park Zoo
Chahinkapa Zoo
DGHT Arbeitsgruppe Anuren
International Crane Foundation
Jardin aux Oiseaux
King Khalid Wildlife Research Center
Maui Zoo
Natal Parks Board
Oglebay's Good Children's Zoo
Safari Park
Speedwell Bird Sanctuary
Sylvan Heights Waterfowl
Ueno Zoological Gardens
Wildwood
Zoological Animal Exchange
Zoo Conservation Outreach Group

SUMATRAN RHINO POPULATION AND HABITAT VIABILITY ANALYSIS WORKSHOP

TABLE OF CONTENTS

SUMATRAN RHINO

POPULATION AND HABITAT

VIABILITY ANALYSIS WORKSHOP

BRIEFING BOOK

SECTION 1: WORKSHOP OVERVIEW

SUMATRAN RHINO PHVA WORKSHOP

Problem Statement

President Soeharto of the Republic of Indonesia, in his letter of 25 January 1990 to the Duke of Edinburgh, President of the **World Wildlife Fund for Nature**, stated:

> *"...I fully support the `Pointsof Agreement' with its recommendations to save the Java and Sumatra Rhinos.*
>
> *I have requested the Minister of Forestry to take the necessary steps and the Minister of State for Population and Environment to coordinate our efforts in saving and enhancing our Rhino population..."*

Previously, the IUCN/SSC CBSG, in conjunction with Department of Forest Protection and Nature Conservation of Indonesia (PHPA), coordinated a Javan Rhino Population Viability Analysis Workshop held in Bogor in June 1989 in which these Points of Agreement were developed. As a follow-up, an International Rhino Conference was held in San Diego in May 1991, and an Indonesian Rhino Conservation Workshop was conducted in Bogor in October 1991. Extreme polarization between the *ex situ* and *in situ* conservation agendas precluded the initiation of any implementation of these Points of Agreement.

Out of this controversy, the *Indonesian Rhino Conservation Strategy*, and its companion document, the *Indonesian Rhinoceros Conservation Action Plan Priorities*, was produced in June 1993. These documents give precise direction for the implementation of conservation strategies that will fulfill the statements of President Soeharto of Indonesia. This Sumatran Rhino PHVA Workshop is designed to determine specific management strategies for the free-ranging populations of Sumatran rhinos and how *in situ* programs in Sumatra might contribute to this process.

The Sumatran rhinoceros *(Dicerorhinus sumatrensis)* was once found from the foothills of the Himalayas in Bhutan and eastern India, through Myanmar, Thailand, and the Malay peninsula, and on the islands of Sumatra and Borneo. There have also been unconfirmed reports of the species in Cambodia, Laos and Vietnam. In general this species has survived much better in its native habitats than the Javan rhino. This may be partly because it mainly inhabits the mountains and forests of higher elevations which were not so subject to development and logging.

The largest number of the species *D. sumatrensis* now survives on the island of Sumatra and it is possible that several hundred animals still exist. However, the island is now in a phase of intense development resulting from Indonesia's transmigration program and the habitat available to the species is being rapidly reduced. In addition the sheer size of the island, compared to the available PHPA staff for protecting the species, makes adequate protection almost impossible. Even in areas where there is a strong presence of PHPA staff, poaching is active.

An estimated 420-785 Sumatran rhinos are living in seven or more mostly disjunct protected areas: 250-500 living in Kerinci-Seblat National Park (14,846 km^2), 130-200 in Gunung Leuser National Park (8,025 km^2), 25-60 Barisan Selatan National Park (3,568 km^2), perhaps in Berbak National Park (1,900 km^2); one was reputed to have been sighted in Way Kambas National Park (1,300 km^2), and a few may still remain in forests near Torgamba, Gunung Patah, Gunung Abong-abong and Lesten-Lukup. These numbers, from the *IUCN/ SSC Asian Rhino Action Plan* from 1989, are estimates only, are not based on quantitative methods, and are thus not considered reliable. There is little or no gene flow among these highly fragmented populations, poaching from hunters with firearms and trappers with wire snares is ongoing but undetermined in scope, and human encroachment continues to erode the edges of the protected areas. Clearly, this species is critically endangered.

The *International Studbook for Sumatran Rhinos* as of 20 August 1993 lists 10 males and 14 females living in captivity, of which two males and three females are at Taman Safari Indonesia, Ragunan Zoo and the Surabaya Zoo. No offspring have yet been produced. The Sumatran Rhino Trust, which was actively capturing isolated rhinos on the western edge of Kerinci Seblat National Park, has terminated its Memorandum of Understanding with PHPA. Thus, there is no *in situ* program underway in Indonesia other than the small collection of Sumatran rhinos being held at three zoos. Clearly there is a need to reevaluate the role of how *in situ* programs can contribute to a holistic conservation program for the species in Indonesia.

To provide direction to these issues, the goals of this workshop are designed to: 1) conduct a metapopulation and habitat viability assessment by utilizing a Geographic Information System (GIS) for all wild populations of Sumatran rhinos; 2) formulate management strategies for each population with risk assessments to prevent extinction and achieve the objective of maintaining viable, self-sustaining populations within the historic range of this subspecies; and 3) prepare a report of the analyses and results of the meeting with recommendations to the Indonesian Directorate General for PHPA and the IUCN/SSC Asian Rhino Specialist Group.

Workshop Objectives

1) Estimate probable populations of rhinos in protected areas of Sumatra using GIS-based habitat assessment techniques, the degree of fragmentation of these populations, and their probabilities for long-term survival with no intervention;
2) Determine numbers of rhinos and subpopulations required for various probabilities of survival and preservation of genetic diversity for specified periods of time (i.e. 50, 100, 200 years) given known sizes of protected areas;
3) Project the potential expansion or decline of rhino population numbers due to poaching, habitat alteration and differing management plans;
4) Evaluate possible role of *in situ* captive propagation as a component of the above management options;
5) Evaluate current management, conservation and education efforts in place in other countries which could serve as models for Sumatran rhinos;
6) Recommend additional scenarios for action and future needs for research.

The combination of the above objectives form the basis for supporting and refining the *Indonesian Rhino Conservation Strategy* already in place. The document will be prepared in draft form during the workshop, and will be reviewed and revised by all participants during the workshop to achieve consensus on its content before departure. It will include specific recommendations and priorities for conservation management of both *ex situ* and *in situ* programs. Once consensus is reached the document will be translated into Bahasa Indonesian for distribution and implementation throughout Indonesia. The results of this workshop will be refined and used as a model for developing PHVAs for remaining extant populations elsewhere in Asia.

Submitted by: Ronald L. Tilson, Ph.D.
CBSG Sumatran Rhino PHVA Workshop Coordinator

AGENDA
SUMATRAN RHINO POPULATION AND HABITAT VIABILITY ANALYSIS (PHVA) WORKSHOP
MARCO POLO HOTEL, BANDAR LAMPUNG, SOUTH SUMATRA
11-13 NOVEMBER 1993

Sunday, 7 November

	Workshop participants and attendees arrive in Bandar Lampung.
	Late afternoon registration.
18:00-19:00	Workshop Coordinators meeting (after dinner)

Monday-Wednesday, 8-10 November

Asian Elephant and White-Winged Wood Duck PHVA Workshops

Thursday, 11 November

09:00-12:00	**Sumatran Rhino PHVA Workshop convenes.**
	Opening comments (Sutisna, Komar, Bandar Lampung officials, Seal)
	Overview of rhino distribution and threats (Widodo, Santiapillai, Griffiths, van Strien)
	Survey of Sumatran rhinos in Kerinci Seblat NP (Wells, Franklin, Mega, Sukianto)
12:00-13:00	Lunch
13:30-14:30	Presentation of map-linked database and land use patterns (Tilson, Sukianto)
	PHVA overview/initial modelling of rhino populations and GIS (Seal, Widodo, Santiapillai)
14:30-17:30	Working groups:
	Protected areas, vortex models, *in situ* programs (Komar, PHPA, YMR & IRF)
	Discussion and data verification of working groups
18:00	Dinner
20:00	Continue working groups
	Rhino videos

Friday, 12 November

08:30-12:00	Status reports of working groups (Komar, PHPA Chiefs, YMR & IRF)
	Overview of wild Sumatran rhino management strategies (Komar, Seal, Santiapillai)
12:00-13:00	Lunch
13:30-16:30	Working groups: Evaluation of management strategies (PHPA staff, YMR & IRF)
18:00	Dinner
19:30	Continue working groups

Saturday, 13 November

08:30-12:00	Working group reports (PHPA staff, YMR & IRF)
	Genetic management of metapopulations
	Integration of management strategies (Seal, Tilson)
12:00-13:00	Lunch
13:30	Workshop draft recommendations: overall and site-specific (Workshop Coordinators)
	Workshop wrap-up

Workshop Participants

Sutisna Wartaputra, Director General of PHPA
Komar Soemarna, Director of Nature Conservation, PHPA
Widodo Ramono, Chief Sub-Directorate Species Conservation, PHPA
Local government (8 provinces)
Kanwil (8 participants)
Balai/Sub-Balai (8 participants)
PHPA (3 additional participants)
Friends of the Indonesian Rhino Foundation (2 participants)
Nico van Strien, National Parks Investment, Indonesia
Philip Wells, Sumatran Rhino Survey Project
Neil Franklin, Sumatran Rhino Survey Project
Mike Griffiths, Gunung Leuser National Park
Sukianto Lusli, WWF-Kerinci Seblat National Park
Ulysses Seal, IUCN/SSC CBSG Chair
R. Sukumar, IUCN/SSC Asian Elephant SG Chair
Charles Santiapillai, IUCN/SSC Asian Elephant SG Executive Secretary
Jim Jackson, Fossil Rim Wildlife Center, Glenrose, TX, USA
Thomas Foose, International Rhino Foundation
James Doherty, AAZPA Sumatran Rhino SSP Co-Coordinator
Edward Maruska, Cincinnati Zoological and Botanical Gardens
Richard Jakob-hoff, Auckland Zoo, Auckland, New Zealand
Peter Stroud, Werribee Zoological Park, Werribee, Australia
F.M. Lockyer or C. Furley, Howletts/Port Lympne Zoo Parks
Pisit na Patalung, Wildlife Fund Thailand
Ronald Tilson, Minnesota Zoo and IUCN/SSC CBSG
Kathy Traylor-Holzer, Minnesota Zoo

Invited participants:

Mohammed Khan, IUCN/SSC Asian Rhino SG Chair
Simon Stuart, IUCN/SSC Executive Office
William Conway, NYZS/The Wildlife Conservation Center
Paul Garland, ASMP Artiodactyl Taxon Advisory Group Chair
Graeme Phipps, Taronga Zoo, Sydney, Australia
Darryl Miller, Perth Zoo, Perth, Australia
Michael Broklehurst, Melbourne Zoo, Melbourne, Australia
David Langdon, Monarto Zoo, Monarto, Australia
Kuno Bleijenberg, EEP Asian Elephant Coordinator
Reinhart Frese, EEP Rhino Taxon Advisory Group Chair
Jeremy Mallinson, Jersey Wildlife Preservation Trust
Robert Reece, AAZPA Rhino Taxon Advisory Group Chair
James Dolan, AAZPA Sumatran Rhino SSP Co-Coordinator
Dale Tuttle, AAZPA Asian Elephant SSP Coordinator
John Lukas, White Oak Plantation
Nick Lindsay, JMSC Rhino Taxon Advisory Group Chair
John Stronge, JMSC Asian Elephant Coordinator
Yukio Kawaguchi, SSCJ Asian Elephant Coordinator
Patrick Andan Mahedi, AESG and ARSG, Malaysia
Khyne U Mar, Yezin, Pyinmana, Myanmar
Anan Nalampoon, AESG, Thailand
Bouaphanh Phantharong, AESG, Lao PDR
Michael Hutchins, AAZPA Executive Office
Doug Myers, San Diego Zoo
Mark Goldstein, Los Angeles Zoo
Ted Beatty, Fort Worth Zoo
Terry Maple, Zoo Atlanta
Jo Gipps, London Zoo

SUMATRAN RHINO

POPULATION AND HABITAT

VIABILITY ANALYSIS WORKSHOP

BRIEFING BOOK

SECTION 2: LETTER FROM THE PRESIDENT OF INDONESIA

PRESIDEN
REPUBLIK INDONESIA

Jakarta, 25 Januari 1990

Sri Paduka;

Surat Sri Paduka tanggal 24 Oktober 1989 sungguh menggembirakan hati saya; karena telah dapat memperbaharui pengenalan dan pertukaran pikiran dengan Sri Paduka.

Saya sepenuhnya menyokong pokok-pokok persetujuan beserta rekomendasinya tentang penyelamatan Badak Jawa dan Sumatera.

Saya juga telah meminta kepada Menteri Kehutanan untuk mengambil langkah-langkah yang diperlukan dan kepada Menteri Negara Kependudukan dan Lingkungan Hidup untuk mengkoordinasikan usaha-usaha kami dalam menyelamatkan dan meningkatkan populasi badak.

Dengan bantuan Sri Paduka, saya berharap usaha kami tidak hanya terbatas pada upaya penyelamatan badak dari kepunahan, tetapi juga dapat menunjukkan kepada dunia suatu contoh kerjasama internasional di bidang lingkungan hidup.

Akhirnya, perkenankan saya untuk menyampaikan ucapan Selamat Tahun Baru.

PRESIDEN REPUBLIK INDONESIA

SOEHARTO

Sri Paduka
PANGERAN EDINBURGH
Presiden "The World Wildlife Fund For Natures"
CH-1196 Gland

UNOFFICIAL TRANSLATION

26 FEV. 1990

PRESIDEN
REPUBLIK INDONESIA

Jakarta, January 25, 1990

Your Royal Highness;

In acknowledging your letter of October 24th, 1989, it gives me great pleasure to renew our acquaintance and to exchange ideas with you.

I fully support the "Points of Agreement" with its recommendations to save the Java and Sumatra Rhinos.

I have requested the Minister of Forestry to take the necessary steps and the Minister of State for Population and Environment to coordinate our efforts in saving and enhancing our Rhino population.

With your cooperation, I hope that our endeavor will not only serve to save the Rhinos from extinction, but also provide the world with an example of international cooperation in the field of the environment.

Allow me to convey to you a Happy New Year.

PRESIDENT OF THE REPUBLIC OF INDONESIA

Sgd.

SOEHARTO

REC: 23 FEV. 1990

	ACT	
DG O		
OD		MWH
PPD		SNS
FIN		
CMC		
C[illegible]		

His Royal Highness
THE DUKE OF EDINBURGH
President of the World Wildlife Fund for Natures
CH-1196 Gland
SWITZERLAND

SUMATRAN RHINO

POPULATION AND HABITAT

VIABILITY ANALYSIS WORKSHOP

BRIEFING BOOK

SECTION 3: INDONESIAN RHINO CONSERVATION STRATEGY

SUMATRAN RHINO

POPULATION AND HABITAT

VIABILITY ANALYSIS WORKSHOP

BRIEFING BOOK

SECTION 4: INDONESIAN RHINOCEROS CONSERVATION ACTION PLAN PRIORITIES (1993)

SUMATRAN RHINO

POPULATION AND HABITAT

VIABILITY ANALYSIS WORKSHOP

BRIEFING BOOK

SECTION 5: IUCN/SSC ASIAN RHINO SPECIALIST GROUP

Asian Rhinos

An Action Plan for their Conservation

Compiled by

Mohd. Khan bin Momin Khan

Chairman

IUCN/SSC Asian Rhino Specialist Group

Contents

1. Introduction

The foundation for this action plan was laid by Professor Ruedi Schenkel, and his wife Lotte, at the Bangkok meeting of the IUCN/SSC Asian Rhino Specialist Group (ARSG) in 1979. As the first ARSG Chairman, he was was instrumental in creating the interest for the intensive surveys, studies, and conservation activities that have since been carried out.

Today all three species of Asian rhinoceros are among the rarest species of animal in the world. And yet, during the last century the greater one-horned rhinoceros was killed for sport. The Maharajah of Cooch Bihar alone killed 207 rhinos between 1871 and 1907. This gives an idea of the former abundance of the species. Perhaps more significantly than over-hunting, agricultural development to meet the needs of the rapidly expanding human population resulted in extensive losses of rhino habitat. These two pressures on the species brought it to the brink of extinction. By 1908 there were only a handful of animals remaining, mainly in Kaziranga in Assam, India, and Chitawan in Nepal. In order to save the species, Kaziranga was made a forest reserve in 1908 and a wildlife sanctuary eight years later, and was essentially closed to the public until 1938.

As a result of these and other conservation activities, the great one-horned rhinoceros is now considered to be the least threatened of the Asian rhinos. Numbers have increased and the species has been translocated successfully to establish new populations within its former range (though additional translocations would be most desirable). The total population is estimated to be more than 1,700 animals, and the Indian and Nepalese authorities deserve much credit for bringing the situation under control, though continuing strict conservation measures will be needed for some time.

The Javan rhinoceros formerly occurred through most of south-east Asia, but has disappeared from almost all of its former range in Assam, Burma, Thailand, Malaysia and Sumatra, and is currently restricted to Java, with scattered populations still surviving in Cambodia, Laos and Vietnam. The cause of decline is mainly attributable to the excessive demand for rhino horn and other products for Chinese and allied medicine systems.

The animals on Java are restricted to the Ujung Kulon National Park, where, as a result of strict protection, the population increased from about 25 animals in 1967 to 50-54 animals in 1984. However, more recent information is lacking, and the status of the species in the Indochinese countries is not yet adequately known.

The Sumatran rhinoceros occurs more widely than the other two species in highly scattered and fragmented populations. Little is known about the current status of the population restricted to northern Burma. Most animals probably occur in Peninsular Malaysia and Sumatra. On Sumatra there are perhaps 420-785 animals, with viable populations possibly surviving in Gunung Leuser, Kerinci Seblat, North Aceh (Gunung Abongabong and Lesten-Lukup) and Barisan Selatan. Sizeable populations also occur on Peninsular Malaysia in Taman Negara National Park and Endau Rompin. Small, but important populations also survive in Sabah, Sarawak and possibly Kalimantan.

The ARSG held a meeting in Frazer's Hills, Malaysia, in 1982, where, for the first time, a critical analysis of Asian rhino distribution, numbers and conservation requirements was carried out. This led to the October 1984 meeting in Singapore, at which a strategy for the captive breeding of the Sumatran rhinoceros in Malaysia, Indonesia, and European and North American zoos was endorsed. Strong protests from the public in Malaysia in fact prevented any animals from being sent overseas from that country. This highlighted the need to develop a comprehensive conservation action plan for all three species of Asian rhino, in which captive breeding could be set within the the overall conservation objectives for each species.

The ARSG therefore met again in Jakarta in 1986 and Kuala Lumpur in 1987, and this action plan is the result. In addition to the decisions taken at these meetings, the plan has also benefitted from much useful advice received from ARSG members and others. There is now much to be done in the implementation of the various recommendations. This action plan should be studied carefully, and should be revised and improved as necessary in the years to come.

2. The Asian Rhinos: Three Species on the Brink of Extinction

This action plan is intended to recommend both general strategies and specific measures to protect and preserve the three species of Asian rhino: the great one-horned or Indian rhino, *Rhinoceros unicornis*; the lesser one-horned or Javan rhino, *Rhinoceros sondaicus*; and the Asian two-horned or Sumatran rhino, *Dicerorhinus sumatrensis*.

The three species of rhino in Asia are among the most remarkable animals on earth, and are of great cultural importance in Asia. Tragically, all three species are now in a very precarious situation. They once ranged widely across southern and south-eastern Asia, but all are now reduced to small pockets. Although this decline is in part related to habitat shrinkage and fragmentation, it seems likely that all these species have been declining for many centuries, principally due to the excessive demand for rhino horn for use in oriental medicine. This represents one of the least sustainable uses of a natural resource ever, and poaching of all three species continues today. This action plan should therefore be seen in the context of continuing attempts to close down the trade in rhino products.

Two of the species, the great one-horned and the Javan, are quite closely related to each other. However, the Sumatran rhinoceros (sometime called the hairy rhino) is particularly distinct. The great one-horned is a species of the open and marshy habitats of the Terai and the Brahmaputra Basins. The other two species are denizens of the rainforest, and consequently, accurate information on their status is difficult to obtain.

Protection of both animals and their habitat is necessary for conservation programmes for Asian rhino. However, such protection is unlikely to be sufficient. The combined pressures of habitat destruction and poacher activity are both reducing and fragmenting rhino populations in the wild. When populations become small and fragmented, they become vulnerable to extinction for genetic and demographic reasons, in addition to the direct threats of habitat disturbance and poaching. Moreover, the smaller the population, the greater these genetic and demographic threats become. As a consequence, it becomes essential to maintain some Minimum Viable Population (MVP) size or sizes to preserve the species against the genetic and demographic problems. MVPs also imply minimum areas necessary to accommodate populations of the specified sizes. Determination of what MVP and area are required is a central problem for the emerging science of conservation biology. This action plan for Asian rhino has been formulated with reference to the principles of conservation biology (see Appendix 1). Thus, many of the goals, objectives and recommendations are oriented to the maintenance or attainment of genetically and demographically viable populations of rhino.

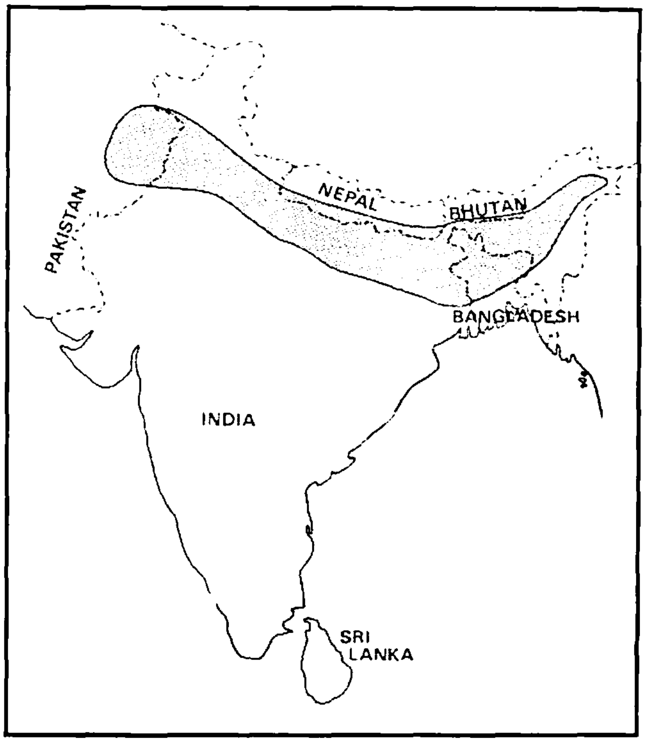


Figure 1a Approximate former distribution of the great one-horned rhinoceros (shaded area).

2.1 The Great One-horned Rhinoceros

The great one-horned rhinoceros once existed across the entire northern part of the Indian subcontinent from Pakistan to the Indian - Burmese border, and including parts of Nepal and Bhutan. It may have also existed in Burma, southern China and Indochina. The species now exists in a few small population units generally situated on the northern border of eastern India and in Nepal. The past and present distributions are displayed in Figures 1a and 1b.

The great one-horned rhinoceros is the least threatened of the Asian species. Populations have increased and rhino have been successfully translocated to re-establish populations in areas where the species had been exterminated. The total estimated number is about 1,700 animals (see Table 1). There are about 75 in captivity.

The species has been intensely protected by the Indian and Nepalese wildlife authorities and the situation until recently seemed under control. However, the expanding population pressure adjacent to these rhino areas, coupled with the great value of its horn, has recently resulted in

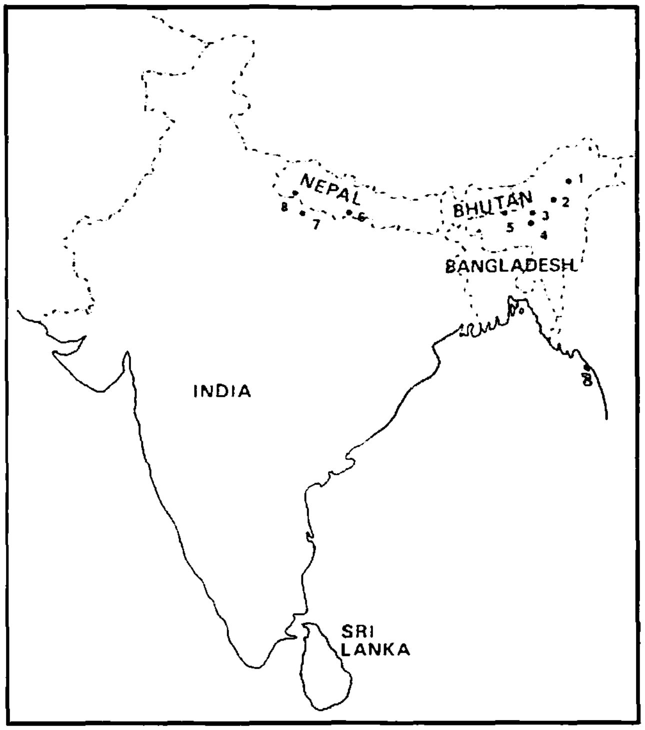


Figure 1b Current distribution of the great one-horned rhinoceros. 1: Kaziranga; 2: Laokhowa; 3: Orang; 4: Pobitora; 5: Manas; 6: Chitawan; 7: Dudhwa; 8: Bardia. Note: tiny pockets also exist elsewhere in Assam and in West Bengal, but are not mapped.

Great one-horned rhinoceros (Photo: Peter Jackson)

significant losses to poachers. Recent reports indicate that 238 rhinos were lost in India between 1982 and 1985, though this rate of attrition has now been slowed down considerably.

In both these countries the programmes of protection and translocation should be continued. This is particularly so in

Table 1. Population estimates of the great one-horned rhinoceros

Country	Location	No of Rhino	Habitat Availability Presently (Km²)	Habitat Availability Potentially (Km²)	Protection Status	Potential Carrying Capacity
Bhutan/India	Manas	80	391	391	Wildlife Sanctuary	>100
India	Dudhwa	7	490	490	National Park	>100
India	Kaziranga	1,080	430	?500	National Park threatened by railway	1,080
India	Laokhowa	5	70	70	Wildlife Sanctuary	?
India	Orang	65	76	76	Wildlife Sanctuary	>100
India	Pobitora	40	16	16	Wildlife Sanctuary	40
India	Pockets in Assam	25	?	?	Insecure	?
India	Pockets in West Bengal	32	?	?	Insecure	?
Nepal	Royal Bardia	13	968	968	Wildlife Reserve	?400
Nepal	Royal Chitawan	375	92	?1,200	National Park	?400
Pakistan	Lal Sohanra	2	?	?	National Park	?
TOTAL		1,724				2,200 +

Table 2. Population estimates of the Javan rhinoceros

Country	Location	No of Rhino	Habitat Availability Presently (Km²)	Habitat Availability Potentially (Km²)	Protection Status	Potential Carrying Capacity
Indonesia	Ujung Kulon	50-54	761	761	National Park	?<100
Cambodia	Various	?	?	?	Not known	?
Laos	Various	?	?	?	Not known	?
Vietnam	Nam Cat Tien	Small numbers	350	?	National Park	?
Vietnam	Bugiamap	Small numbers	160	?	Reserve	?
Vietnam	Various	?	?	?	Not known	?
TOTAL		50-54 +				?

India where there remain many areas which historically had rhino populations. These areas should be protected and new populations established in them through translocations from areas where populations now exist in sufficient numbers to be unaffected by animals being taken out of them.

2.2 The Javan Rhinoceros

Javan rhinoceros (Photo: Alain Compost)

The principle surviving population of the Javan rhinoceros is located on the Ujung Kulon peninsula, which forms the westernmost extremity of the island of Java. An estimated 50 animals now live in the area. The species was once widespread throughout the Oriental Realm from Bengal eastward to include Burma, Thailand, Cambodia, Laos, Vietnam and southwards to the Malay Peninsula and the islands of Sumatra and Java. About 150 years ago the species occurred as three discrete populations. The first, belonging to the subspecies *inermis* (now almost certainly extinct) was found from Bengal to Assam and eastwards to Burma. The second subspecies *annamiticus* occurred in Vietnam, Laos, Cambodia, and the easternmost part of Thailand. The third subspecies, the nominate form, was found from Tenasserim, through the Kra Ithmus into the Peninsula and Sumatra and in the western half of Java. All these populations have disappeared, except for in Ujung Kulon and some scattered remnants surviving in Indochina. The Javan rhino has the distinction of being the rarest large mammal in the world. Population estimates are given in Table 2, and the past and present distributions are displayed in Figures 2a and 2b.

The 50 or so Javan rhinos in Ujung Kulon are in a national park and the population size is probably limited to the

Figure 2a Approximate former distribution of the Javan rhinoceros (shaded area).

effective carrying capacity of the area. One danger to these animals comes from disease, which could potentially wipe out the entire population. In 1981-1982, this threat became a reality when an unknown disease actually killed at least five animals in Ujung Kulon. In addition, any such small population of rhinos faces a permanent threat from poachers. There are no Javan rhinos in captivity.

Figure 2b Current distribuition of the Javan rhinoceros. 1: Ujung Kulon; 2: Nam Cat Tien; 3: Bugiamap. Note: the records mapped in Laos and Kampuchea refer to scattered sightings, and it is not clear whether any of these constitute substantial populations.

It is suggested that the situation facing this species be looked at very closely to see if recommendations to translocate some animals into other areas, such as Way Kambas or southern part of Bukit Barisan Selatan National Park in Sumatra should not be seriously considered. A single small population is always extremely vulnerable. It must be kept in mind that the Ujung Kulon peninsula is on the Sundaic edge volcanic line and that during the Krakatau eruption in 1883, the entire peninsula was affected by tidal waves and ash rains which destroyed much of its terrestrial life.

A second approach is that the Indonesian authorities should also consider bringing some animals into a captive breeding project to be based at least partly in Indonesia.

Better exploration of the situation in Vietnam, Laos and Cambodia also needs to take place, with the option of captive breeding again being considered. Such information might become available as fieldwork on the kouprey *Bos sauveli* conservation programme get underway.

2.3 The Sumatran Rhinoceros

The Sumatran rhinoceros was once found from the foothills of the Himalayas in Bhutan and eastern India, through Burma, Thailand, and the Malay Peninsula, and on the islands of Sumatra and Borneo. There have also been unconfirmed reports of the species in Cambodia, Laos and Vietnam. The past and present distributions are displayed in Figures 3a and 3b and population estimates are given in Table 3. In general this species has survived much better in its native habitats than the Javan rhino. This may be partly because it mainly inhabits the mountains and forests of higher elevations which were not so subject to development and logging. In contrast the Javan rhino is a species of the coastal plains and river valleys.

At present the species survives in pockets in Burma, Thailand, the Malay Peninsula, Sumatra and Borneo. Little is known of its status in Burma which holds the subspecies *lasiotus*. The nominate subspecies *sumatrensis* is now represented by animals in Thailand, Peninsula Malaysia and in Sumatra. There has been little recent news of animals in Thailand and its continuing occurrence there is now in doubt. In the Peninsula there are an estimated 100 animals surviving in several isolated pockets of which perhaps only two are in protected areas of sufficient size to guarantee long term viability. All these animals have to be closely protected.

The largest number of the subspecies *sumatrensis* now survives on the island of Sumatra and it is possible that several hundred animals still exist. However, the island is now in a phase of intense development resulting from Indonesia's transmigration programme and the habitat available to the species is being rapidly reduced. In addition the sheer size of the island, compared to the available staff for protecting the species, makes adequate protection almost impossible. Even in areas where there is a strong presence of protection staff, poaching is active. This is evidenced by the fact that in a project to capture animals for a captive breeding programme in an area where numerous wildlife staff are positioned, animals are being caught with fresh snare wounds on their legs.

The rhinos in Sumatra are too widespread and in too many pockets for all of them to be protected adequately in the ranges where they still survive. As a result, they are subject to

Table 3. Population estimates of the Sumatran rhinoceros

Country	Location	No of Rhino	Habitat Availability Presently (Km²)	Habitat Availability Potentially (Km²)	Protection Status	Potential Carrying Capacity
Burma	Schwe-u-daung	Perhaps survives	207	?	Game sanctuary	?
Burma	Tamanthi	Perhaps survives	2,150	?	Game sanctuary	?
Burma	Lassai tract	6-7	?	?	Unknown	?
Indonesia (Kalimantan)	near Sabah border	Perhaps survives	?	?	Unclear	?
Indonesia (Sumatra)	Gunung Leuser	130-200	1,400	8,000	National Park but disturbance & poaching	140-800
Indonesia (Sumatra)	Gunung Patah	Numbers unknown	400	500	No information	40-50
Indonesia (Sumatra)	Kerinci Seblat	250-500	5,000	10,000	Little protection proposed National Park	500-1,000
Indonesia (Sumatra)	Gunung Abong-abong and Lesten-Lukup	15-25	?	?	Not protected	?
Indonesia (Sumatra)	Berbak	Perhaps extinct	?	?	Nature Reserve	?
Indonesia (Sumatra)	Torgamba	Very few	?	?	Being deforested	?
Indonesia (Sumatra)	Barisan Selatan	25-60	700	3,600	National Park, deforestation occurring	70-360
Malaysia (Peninsula)	EndauRompin	10-25	1,600	1,000-1,600	Reserve, National Park proposed	110-160
Malaysia (Peninsula)	Taman Negara	22-36	4,400	4,400	National Park	220-440
Malaysia (Peninsula)	Sungai Dusun	3-4	40	140+	State Wildlife Reserve	15
Malaysia (Peninsula)	Gunung Belumut	3-5	230	230	Wildlife Reserve proposed	23
Malaysia (Peninsula)	Mersing Coast	5-6	?	Probably none	Being deforested	0
Malaysia (Peninsula)	Sungai Depak	2-4	?	Probably none	Being deforested	0
Malaysia (Peninsula)	Sungai Yong	3-5	?	Probably none	No information	0
Malaysia (Peninsula)	Kuala Balah	2-4	?	Probably none	Being deforested	0
Malaysia (Peninsula)	Bukit Gebok	2	?	None	Being deforested	0
Malaysia (Peninsula)	Krau Reserve	1	500	500	Insecure	50
Malaysia (Peninsula)	Sungai Lepar	2	1,000	0	Unprotected and being deforested	0
Malaysia (Peninsula)	Ulu Atok	1	?	?	No information	?
Malaysia (Peninsula)	Ulu Selama	6-7	?	?	Unprotected	?
Malaysia (Peninsula)	Ulu Belum	2-4	?	?	Insecure	?
Malaysia (Peninsula)	Bubu Forest	2	?	?	No information	?
Malaysia (Peninsula)	Kedah	1	?	?	Insecure	?
Malaysia (Sabah)	Tabin Reserve	20+	1,200	1,200	Perhaps protectable	120
Malaysia (Sabah)	Kretam/Dent Peninsula	8	1,000	0	Being converted to agriculture	0
Malaysia (Sabah)	Danum Valley	10	2,000	2,000	Perhaps protectable	200
Malaysia (Sarawak)	Limbang	5-15	600	600	Protection proposed	60
Thailand	Phu Khieo	Perhaps survives	1,560	?	Protected area	?
Thailand	Tenasserim Range	6-15	?	?	Insecure	?
Thailand	Khao Soi Dao Reserve	Perhaps survives	745	?	Protected area	?
TOTAL			536-962			1,548-3,278

Figure 3a Approximate former distribution of the Sumatran rhinoceros (shaded area).

Figure 3b Current distribution of the Sumatran rhinoceros. 1: Lassai tract; 2: Tamanthi; 3: Schwe-u-daung; 4: Phu Khieo; 5: Khao Soi Dao; 6: Tenasserim Range; 7: Kedah; 8: Ulu Selama; 9: Bubu Forest; 10: Kuala Balah; 11: Sungai Depak; 12: Sungai Yong; 13: Taman Negara; 14: Sungai Lepar; 15: Ulu Atok; 16: Ulu Belum; 17: Sungai Dusun; 18: Krau Reserve; 19: Bukit Gebok; 20: Endau Rompin; 21: Mersing Coast; 22: Gunung Belumut; 23: Lesten Lukup; 24: Gunung Abongabong; 25: Gunung Leuser; 26: Torgamba; 27: Berbak; 28: Kerinci Seblat; 29: Gunung Patah; 30: Barisan Selatan; 31: Limbang; 32: Kretam; 33: Tabin; 34: Danum Valley; 35: Sabah border.

Sumatran rhinoceros
(Photo: Department of Wildlife and National Parks, Malaysia)

heavy poaching pressure both from hunters with firearms and from trappers who use wire snares and other traps that maim and kill animals. The total world population is now thought to be between 500 and 900 animals (see Table 3) and the annual loss may be as much as 10 percent of that population. There is evidence that breeding in the wild is taking place but the rate of such recruitment to the population is not known. Presently, there are 16 animals in captivity.

The subspecies *harrissoni* is possibly the most endangered of the subspecies and now exist in a few rapidly dwindling pockets in eastern Sabah. There may be less than thirty animals still surviving in the state and the rate of poaching is believed to be high. The Sabah state is at present engaged in a programme to capture these high risk animals and put them into the safety of a captive breeding programme. Recently it was discovered that a small group of this subspecies survives in the upper Limbang catchment in Sarawak. Efforts are now being made to monitor this group and protect them from poachers. It is also possible that populations remain in eastern Kalimantan.

An extensive international cooperative programme for the conservation of this species is already being implemented. There are ongoing efforts to establish captive breeding centres for the species in Indonesia and in Malaysia (both the Peninsula and in Sabah) where the active trapping of animals is now being carried out. Captive breeding is also being planned in the United States and the United Kingdom, using animals of Indonesian origin. The Peninsular Malaysian programme also calls for the setting up of "gene pools" where the species will be allowed to breed in semi-wild conditions in large fenced areas.

All of these efforts are components of a global captive propagation programme being developed for this species under the general guidelines of the Singapore Proposals (see Appendix 2) adopted by the Asian Rhino Specialist Group (ARSG) and IUCN in 1984 and in accordance with the specific provisions of the national plans and bilateral agreements that have been formulated. A major guideline of note is that no mixing of animals from the four major regions of their range (Burma, Peninsula, Sumatra, and Borneo) be undertaken until there has been adequate genetic investigation of any significant differences between these geographically disjunct populations.

2.4 Conclusion

Finally, it should be emphasised that members of the IUCN/SSC Asian Rhino Specialist Group should work together for the maximum benefit of all these species, and should carry out their tasks and agreements in a manner that will encourage and engender future and long-term cooperation. The importance of respecting absolutely the authority in each country that is responsible for the conservation of wildlife in general, and the rhino species in particular, cannot be overemphasised.

Great one-horned rhinoceros (Photo: Peter Jackson)

5. The Asian Two-horned or Sumatran Rhinoceros: An Action Plan

5.1 Introduction

The Sumatran rhinoceros is a species of rainforest in hilly and mountainous areas. It is much more widely scattered, often in tiny inviable populations, than the other two species. As a result, it is more difficult to make decisions as to the most appropriate priorities for its conservation, especially since a number of national and state governments are involved. Although not yet as critically threatened as the Javan rhinoceros, this species is probably experiencing the most serious level of poaching for its horn of all the Asian rhinos. In some areas it is also threatened by habitat destruction. In view of these complexities, it has been felt best to handle the specific recommendations for each country in a slightly different way from the previous two species.

Development of captive populations in North America and England, as well as in the countries of origin, is considered important for several reasons:

1. There are significant risks (e.g. disease epidemics, natural disasters, etc) of having all the rhinos in only a few places. To ensure maximum security, the population should be distributed as widely as possible.

Sumatran rhinoceros
(Photo: Department of Wildlife and National Parks, Malaysia)

2. For long-term viability, the captive population needs to be larger than existing South-east Asian facilities can reasonably accommodate.

3. There are appreciable resources and expertise in North American and British zoos that can be utilized to expedite the expansion of the captive population.

However, it should also be noted that for a variety of reasons the mortality among animals that have been transported beyond the borders of their countries is extremely high. Of the five animals moved so far three have died, a 60 percent mortality. This does not compare well with the overall mortality of the capture programme in which five animals have died out of 17 captures (29.4 percent). In fact the mortality falls to 15.4 percent (two mortalities out of 13 animals) if the mortalities of exported animals are excluded from the calculations.

Therefore, it is essential that certain conditions be satisfied when animals are to be transported to foreign destinations. These are:

1. There must be accurate and as complete information on the animal/animals as possible. This should include complete veterinary records.

2. The animals should not only be in excellent health but should be free from any significant physical deformities or injuries. As far as possible the animals should be in perfect condition.

3. The animals should be physically prepared for their new homes and should be preconditioned, at least partially, to the new diet regime before they are moved.

5.2 Objectives

1. To develop populations of at least 700-1,000 rhinos in each of the major regions of its range: Sumatra, Borneo, Peninsular Malaysia and adjacent mainland, and northern Burma.

2. To preserve, manage and where appropriate expand all populations that have the potential to increase to 100 animals or more.

3. To determine if the populations in each major part of its range (listed under objective 1 above) constitute valid subspecies or evolutionary significant units (ESUs), justifying preservation as separate entities by conservation programmes.

4. To locate or establish additional viable populations, especially on the mainland and Borneo..

5. To develop a captive population of 150 rhinos distributed in zoos worldwide: South-east Asia, North America, and Europe. Establish this captive population with at least 20 pairs of founders from the wild.

6. To experiment with the gene pool concept.

7. To continue efforts to close down the trade in rhino products.

5.3 General Recommendations

1. Concentrate initial *in situ* conservation efforts on the seven, or so, populations considered to be reasonably viable according to current information and analysis (see Table 3).

2. Calculate the resources currently available and additionally required to provide adequate protection for these populations.

3. Ensure improved legal protection status of all areas with viable, or potentially viable, populations (particular attention to be given to Kerinci-Seblat in Sumatra and Endau Rompin in Peninsular Malaysia).

4. Conduct biochemical genetic studies, initially using blood and tissue from captive animals, to investigate if there is more than one ESU in this species.

5. Organise surveys as soon as possible in Kalimantan (highest priority), Thailand, and northern Burma to ascertain whether appreciable populations of rhino survive there.

6. Continue the capture of "doomed" animals to provide founders for the captive population and the gene pool experiments, as well as stock for possible translocation after sufficient animals have been obtained for the *ex situ* programmes.

7. Develop an experimental "gene pool" in order to learn as much as possible about the management of the animals (initially at Sungai Dusun in Peninsular Malaysia).

8. Manage the captive animals as part of the overall conservation programme for the species, and discourage all movements of captive rhinos (including as gifts), unless this is endorsed by IUCN. Details on how the animals should be managed in captivity are available from the ARSG. Guidelines for captive management are given in Appendix 3.

9. Improve the effectiveness of law enforcement throughout the species' range with respect to anti-poaching measures and trading in Sumatran rhinoceros products. The strictest possible penalties should be applied to offenders.

5.4 Indonesia: Specific Recommendations

The total population of the Sumatran rhinoceros in Indonesia is estimated to be between 420-785, all in Sumatra, with the possibility of a few existing in Kalimantan (see Table 3).

In Indonesia this species has been legally protected since 1931. A number of reserves have been set aside for the conservation of wildlife, including this species, notably the Gunung Leuser, Kerinci-Seblat, and Barisan Selatan National Parks in Sumatra. These are all managed by the PHPA (Perlindugan Hutan dan Pelestian Alam), a Directorate General which comes under the Ministry of Forestry.

A programme of bringing animals into captivity is currently underway for doomed rhinos in Sumatra. This is being organised by the American Association of Zoological Parks and Aquaria (AAZPA), and the Howletts and Port Lympne Zoo in Britain. This programme is still in an early Phase, but it is envisaged to include captive breeding in Indonesia, Britain and the United States.

The goal is to ensure the survival of viable populations of the Sumatran rhino in Indonesia in its natural habitat.

1. Protection

Better protection is needed of the known viable rhino populations in Kerinci-Seblat, Gunung Leuser and Barisan Selatan National Parks in Sumatra. Such improved protection should include the following aspects:

- an increase in anti-poaching efforts;

- appropriate forms of sustainable development in the buffer-zones around these parks, to enable people to derive economic benefits from the protected areas;

- a public education programme on the importance of these national parks and their rhinos;

- a training programme for all levels of staff working in wildlife and protected area management. This should include training in captive management of rhino;

- formal gazettment of the national park at Kerinci-Seblat.

2. Monitoring

Monitoring should be done on as many rhino populations as possible on a regular basis to assess the trends, distribution, movement and habitat preferences of the species. Censusing should preferably be carried out annually by teams of people following standardised methods. Surveys also need to be carried out to determine the distribution and abundance of the species outside the protected areas. In particular, surveys should be carried out to assess the status of rhino, if any, in Gunung Patah, Gunung Abongabong, Lesten-Lukup, and in Kalimantan (along the border with Sabah, and northern Sarawak opposite the upper Limbang catchment).

3. Capture and translocation

It is important to identify areas that are destined to be converted to other land uses incompatible with wildlife conservation, and hence determine whether it is necessary to translocate rhinos to another, safer area or into the captive population. The target area must have adequate habitat to sustain a viable population of rhino. For the management of captive animals in Indonesia, the principles outlined for Malaysia, and in Appendix 3, apply.

4. Research

Research on rhino populations in the national parks and other protected areas should be carried out with a view to determining their number, breeding performance and habitat requirements. It is also necessary in order to determine the threats to the animals in each area and to devise appropriate conservation action.

5. Trade

It is clear that an illegal trade exists in Sumatran rhino horn, from Sumatra to Singapore and possibly other countries. It is recommended that the governments concerned make a concerted effort to bring the situation under control. This trade is probably the most serious threat to the species at the present time.

5.5 Malaysia: Specific Recommendations

The management of wildlife in Malaysia is governed by three different legislative measures. In the Peninsula, the Wildlife Protection Act of 1972 provides wildlife protection for the 11 states. In Sabah and Sarawak, the Fauna Conservation Ordinance and the Wildlife Protection Ordinance make necessary provisions for wildlife administration respectively. The Sumatran rhino is protected by law throughout Malaysia. Of 20 known populations in Malaysia, 16 are considered inviable and only four (Taman Negara, Endau Rompin, Tabin and Danum Valley) are considered reasonably viable for long-term genetic management. Habitat destruction through logging, agricultural development, human settlement, and shifting cultivation are the main causes of the population decline. Poaching has been brought under control in the Peninsula but remains a serious problem in Sabah.

The goal is to maintain viable populations of the Sumatran rhinoceros in the wild in Malaysia. The objectives of the action plan for Malaysia are:

- to protect and manage the rhino and its habitat;
- to gather information on the viability of the populations and exact habitat requirements for rhinos;
- to promote scientific research and dissemination of information on captive individuals;
- to build up the captive population so as to make animals available for reintroduction.

1. Sabah

a. Wildlife conservation and management in the state of Sabah is the responsibility of the Wildlife Division of the Forestry Department. The current strength of the Division is inadequate for effective protection and research to be conducted for the rhino in particular and wildlife in general. As a long-term measure, the Wildlife Division should be strengthened in terms of staffing, funding and logistical support.

b. The Fauna Conservation Ordinance 1963 is the wildlife legislation for the state of Sabah. Current penalties for poaching of rhinos and relevant provisions are considered inadequate to deter poaching or to ensure that offenders are brought to book. It is therefore recommended that the ordinance be reviewed to provide for heavier penalties for poaching of rhinos, and the powers of wildlife officers be reviewed to enable them to carry out their duties effectively.

c. Currently, only three breeding populations of the Sumatran rhino are known in Sabah, in the Tabin Wildlife Reserve, the Danum Valley Conservation Area, and the Kretam area (although there are other scattered records from south-eastern Sabah). The status of these three areas needs to be reviewed to determine how much land and habitat needs to be protected. In addition, sufficient manpower and facilities should be assigned to these two areas. Public education programmes should be instigated around these areas, and appropriate forms of buffer-zone development should be considered.

d. At least two of the known populations are considered to be reasonably viable for long-term genetic management (Tabin has approximately 20, and Danum about 10 individuals). It is recommended that surveys be conducted to determine whether further breeding populations exist, and to locate other isolated individuals.

e. It is recommended that the capture of isolated or threatened rhinos be continued for captive breeding or translocation purposes. Breeding between individuals from different geographical regions (e.g. Peninsular Malaysia and Sabah) should be avoided (unless further studies show that there are no appreciable genetic differences between these areas).

2. Sarawak

a. A detailed study of the rhino population is needed in order to demonstrate that the area should be declared a national park or a rhino reserve.

b. Constant monitoring of the Ulu Limbang population is needed to determine its true extent, and its protection requirements.

3. Taman Negara and Endau Rompin (Peninsular Malaysia)

a. These are the two viable populations in Peninsular Malaysia. Constant surveillance should be carried out on these populations. As a matter of the highest priority, the state governments of Pahang and Jahare should be encouraged designate Endau Rompin as a National Park.

b. Extensive habitat evaluation should be carried out to determine the carrying capacity of the areas. This information is important to determine whether these are suitable sites for the future release of animals translocated from doomed populations.

4. Sungai Dusun Wildlife Reserve (Peninsular Malaysia)

a. The "gene pool" concept, in which rhinos would be managed in a semi-wild state, should be implemented at this site. The founder population may consist of five breeding females and at least two sexually mature bulls.

5. Malacca Zoo (Peninsular Malaysia)

a. A captive breeding stock of at least two males and four females should be established.

b. The ARSG should pool all essential data from attempts at captive breeding of the species (including from attempts outside Malaysia) in order to ensure that maximum possible use is made of the limited supply of animals. Such data would include aspects of physiology, pathology, parasitology, feeding, growth and reproduction. The computer database facility at Malacca needs to be upgraded for this purpose. This database would be of use to other breeding facilities at Sungai Dusun, Tabin, Ragunan Zoo, Los Angeles Zoo and Howletts and Port Lympne Zoo. In this way, Malacca Zoo would act as a reference centre for the overall captive breeding programme.

6. Other areas in Peninsular Malaysia

a. Rhinos in isolated and threatened areas will be captured for the "gene pool" and captive breeding programme at Malacca zoo. When these facilities have reached the maximum holding capacity, the newly captured animals could be relocated in Taman Negara and Endau Rompin. It is also proposed that the Malaysian animals largely be kept within the country for the time being for the following reasons:

- That no mixing of animals from the four major regions of their range (Burma, Peninsula, Sumatra and Borneo) be undertaken until there has been adequate genetic investigation of any significant differences between these geographically disjunct populations.

- That all the animals now currently being caught are prioritised for the captive breeding and gene pool programme, which will require between 10 and 20 animals. Once sufficient animals are available for the breeding programmes in the Peninsula, and if it can be shown that they are genetically similar to animals from other areas, then further animals, if caught, could be considered for overseas captive breeding programmes.

5.6 Thailand

The current status of the species in Thailand is obscure, and requires investigation. If any animals survive, it is most unlikely that they do so in viable populations. As such, any animals would best be captured for a captive breeding programme (perhaps in conjunction with Peninsular Malaysia), pending reintroduction to a suitable site at a later date.

Rhino products, almost entirely of imported origin, are still available in Thailand. Although rhinos are strictly protected in Thailand, there is currently insufficient legal capacity to control the importation of rhino products. The government of Thailand is strongly urged to take action on this.

5.7 Burma

That the isolated subspecies *lasiotus* survives in northern Burma is confirmed by the continuing appearance of rhino products of Burmese origin in northern Thailand. As the situation permits, the status of the species in northern Burma should be investigated to determine the necessary *in situ* and *ex situ* conservation requirements.

5.8 Conclusion

The Sumatran rhino is an instance of a species where there is still time to act to reverse the current rapid decline in the population. Current efforts at all levels must therefore be intensified if a "Javan rhino" type crisis is to be avoided.

6. Action Plan Summary

This chapter summarises Chapters 3, 4, and 5 on the great one-horned, Javan and Sumatran rhinoceroses respectively. The goals for each of the action plans are highlighted as the following:

1. Preserve and manage the great one-horned, Javan and Sumatran rhinos as species and as components of their ecosystems.

2. Therefore, maintain viable populations *in situ* of all Evolutionary Significant Units (ESUs) of the three species against the pressure of habitat destruction and poacher activity.

3. To achieve this goal, develop populations of 2,000-3,000 individuals of each species. Ensure that for each species their populations are distributed across at least five separate sanctuaries, each of which should be capable of accommodating a minimum of 100 rhinos, preferably more. It is highly desirable to have two or more sanctuaries that can accommodate at least 400-500 rhinos each, though this might no longer be feasible for two of the species.

4. For Javan and Sumatran rhino in particular, Goal 3 will entail substantially expanding the existing population and establishing additional sanctuaries. For all three species, a total population larger than the minimum (i.e. 2,000), and additional sanctuaries capable of accommodating reasonably viable populations (>100), are highly desirable.

5. "Doomed" rhino (i.e. individuals which are outside populations of reasonable viability and which cannot be protected with available or acceptable levels of resources) should be used for captive propagation, "gene pools", or be translocated to other natural sanctuaries where they may be part of viable and protectable populations.

6. Develop captive populations of at least 150 rhinos for each of the three species to reinforce the populations in the wild.

7. Encourage and assist efforts to reduce further the trade in rhino horn. Specifically:

   - There needs to be more enforcement of laws against internal trade in rhino horn and products, particularly in Singapore, Thailand, China, Hong Kong, and Taiwan. Use of substitutes for rhino horn needs to be promoted.

   - Efforts to prevent the illegal international commerce in rhino horn. Export of horn from India and Sumatra needs particular attention;

   - The internal trade of horn in Laos needs to be prohibited.

8. Implement public awareness and education campaigns in the vicinity of *in situ* rhino populations, to draw the attention of local communities to the importance and rarity of the rhinos, and thereby to mobilise public opinion in support of their conservation.

9. Continue wildlife management training programmes with a particular emphasis on developing an indigenous capacity to monitor and manage wild rhino populations, to capture, translocate, and reintroduce rhinos, and to maintain and breed them in captivity.

10. Continue protected area management training programmes, with an emphasis on survey techniques, anti-poaching measures, and village extension work. Devise methods whereby villagers can derive economic benefits from the protected areas.

11. As the situation permits, investigate the status of the Javan rhino in Indochina, and the Sumatran rhino in northern Burma, with a view to assessing what, if any, conservation activities should be undertaken.

Preface

This appendix is an attempt to apply principles of conservation biology to Asian rhinos. As such it concentrates on the genetic and demographic problems of small and fragmented populations. The science of conservation biology is in early stages of evolution. Many aspects are still controversial or unvalidated. Moreover, genetics and demographics are only two of the factors that must be considered in developing conservation strategies and programmes. Thus the conclusions of this appendix should not be considered as absolute or definitive. However, it is important to be aware that these genetic and demographic problems may very well exist and to adhere to principles as discussed in this appendix as far as possible.

Introduction

Protection of both animals and their habitat is necessary for conservation programmes for Asian rhino. However, such protection may not be sufficient. The combined pressures of habitat destruction and poacher activity are both reducing and fragmenting rhino populations in the wild. When populations become small and fragmented, they become vulnerable to extinction for genetic and demographic reasons (Figure 4) in addition to the problems with habitat and from poachers. Moreover, the smaller the population, the greater these genetic and demographic threats become.

As a consequence, it becomes essential to maintain some minimum viable population (MVP) size or sizes to preserve the species against the genetic and demographic problems. Determination of what MVP is required is a central problem for the emerging science of conservation biology. This section of the Asian Rhino Action Plan is intended as an initial attempt to apply the principles of conservation biology to strategies and programmes for preservation of Asian rhino.

It is possible through appropriate population viability analyses (PVA) to prescribe the size of the population that will be required to achieve some level of genetic and demographic security. As explained more fully below, preliminary analyses suggest that minimum populations of 100 may be required for each separate wild population of rhino to be genetically and demographically viable over the next 150-200 years.

However, it should be emphasised that a recommended MVP is not necessarily the actual population now existing in a defined area of the natural range of the species. Instead, the MVP represents a minimum number that the area currently occupied by a given population must ultimately be able to sustain, assuming the rhinos can be protected and hence permitted to grow in number to the carrying capacity of the habitat. Thus, the MVP will by extension prescribe a minimum viable area required by this number of rhinos for each *in situ* population. Obviously, the size of this area will depend upon the density of rhinos that an area can accommodate.

Problems of Small Populations

Small populations lose genetic diversity rapidly at both the population and the individual level. At the population level, genetic diversity is vital to permit adaptation to continually changing environments. At the individual level, genetic variation is required to maintain the "vigor" of animals; loss of diversity in individuals is known as inbreeding and the phenomenon of decline in "vigor" (i.e., survival and fecundity) is inbreeding depression.

Conservation biologists have recommended that genetically effective populations of 50 are necessary for the shorter-term (5-10 generations), mainly to counteract inbreeding depression. Genetically effective populations of 100 to 500 may be necessary over the longer term (10 or more generations) to maintain adaptability.

However, the population size of relevance is not merely the census number. Rather it is the genetically effective size (N_e) which depends on how the animals are actually reproducing to transmit genes to the next generation. Very generally, the genetically effective size of a population depends on:

- the number of animals actually reproducing;
- the sex-ratio of the reproducing animals;
- the relative lifetime number of offspring (i.e. family size) of animals in the population.

For example, animals that do not reproduce at all do not contribute and thereby reduce the genetically effective size of the population below the census number. Alternatively, if a few animals do most of the breeding, again the genetically effective size is reduced. In natural populations, N_e is almost always only a fraction (25-75%) of the census number (N). Thus, to achieve an N_e of 50, 70-200 actual animals might be required.

A preliminary analysis of the population biology of Asian rhinos suggests that the N_e/N ratio for this species in the wild might be of the order "0.5". Therefore, an MVP of 100 would be required to achieve an N_e of 50 for each separate population of Asian rhino.

Demographically, small populations are very vulnerable to natural disasters, disease epidemics, distortions of sex ratios (i.e., all animals born to the small number in the population being of one sex) and other ecological vicissitudes. Conservation biology models suggest that populations smaller than 25-50 total individuals are seriously at risk due to demographic problems of this nature.

Minimum Viable Population

Recognising the significance of these genetic and demographic problems, the concept of Minimum Viable Populations (MVP) has become central to modern conservation biology and strategies. MVPs are critical to populations in the wild or in captivity. In the wild, MVPs are important for the size, shape, number, interaction and security of reserves. In captivity, MVPs relate to the carrying capacity that is developed for the captive population and the number of founders needed to establish it.

MVPs depend on both the genetic and demographic objectives of a conservation strategy and on biological characteristics of the species under consideration. Genetic and demographic objectives of relevance are: the nature and amount of genetic diversity that is to be preserved and the length of time over which this variation is to be maintained.

1. The kind and level of genetic diversity to be preserved. Obviously, the optimal objective is to retain all or as much of the diversity as possible. However, with the restricted populations possible (in the wild or captivity) and limited resources for conservation, something less than all may have to be accepted at least for some period of time, e.g. "the demographic winter". This term has been created to denote that period of the next 200 to 500 years when human population growth and development will continue and intensify its devastation of wildlands, destruction of wildlife, and general disruption of ecological systems and balances on the planet. In any case specifying the kind and level of diversity to be preserved will prescribe MVPs required. Preserving rarer alleles (i.e. specific varieties of genes) will

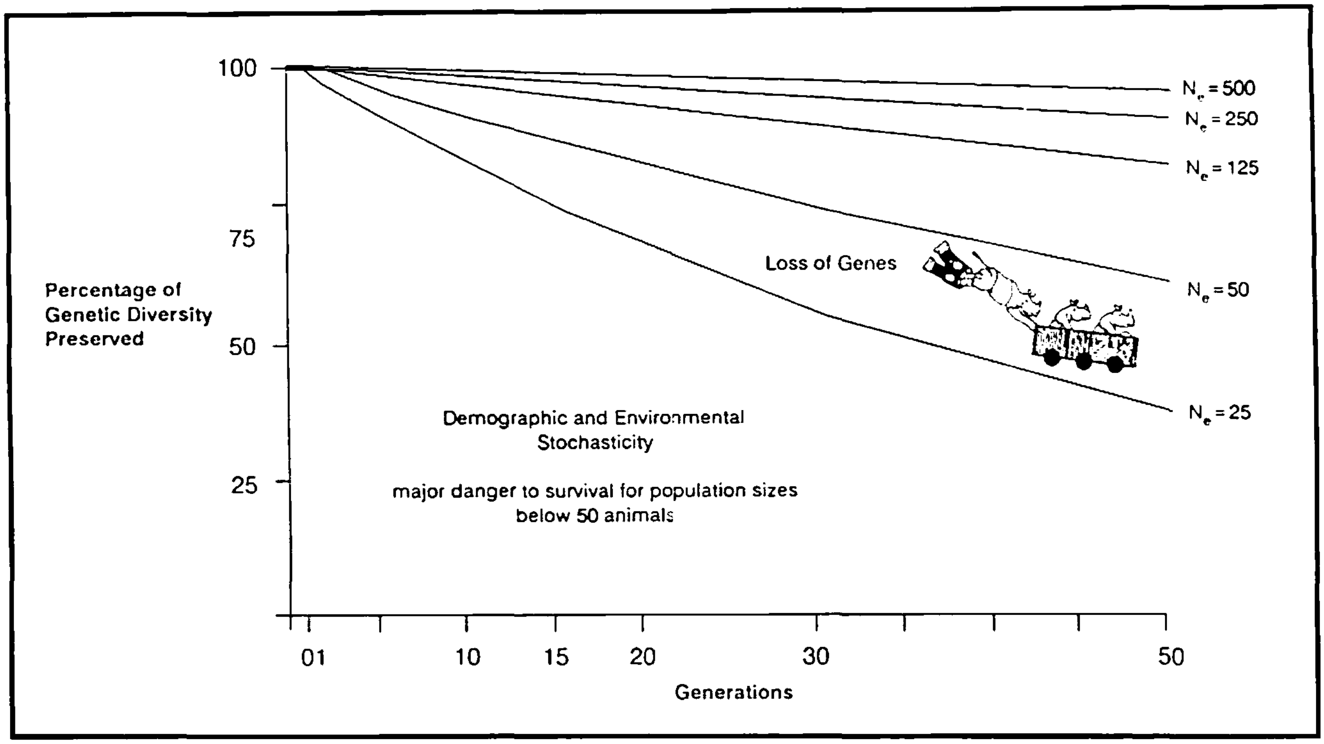


Figure 4. Decline of genetic diversity for various effective population sizes (N_e) possible for a total population (N) of 250.

require larger MVPs than merely maintaining average heterozygosity (some variation of any, non-specific kinds). Preserving 95% of average heterozygosity will require an MVP twice as large as 90% will. Unfortunately, population geneticists are not certain or agreed how much diversity is enough but levels of at least 90% of average heterozygosity have been strongly suggested.

2. How long must this level of genetic diversity be preserved? The optimal answer is indefinitely, i.e. the species will have enough variation to continue to evolve as environments change and to maintain adequate levels of vigor. But again, there may have to be compromises. Hopefully, intensive programmes will be needed only through the "demographic winter", which may in general continue for 200 to 500 years. However, the winter may vary on a species-by-species and area-by-area basis. Several reintroduction projects using captive stock of species extinct in the wild are in progress even now. But these opportunities are likely to be limited and often transient over the next century or two.

Biological characteristics of importance are: the generation time of the species; the N_e/N ratio of the populations; the number of founders that establish a population; the reproductive rate or recovery potential; and the degree of subdivision of the overall population.

1. The generation time of the species. Genetic diversity is lost generation by generation, not year by year. Thus some given period of time, e.g. 200 years, represents more generations, hence more opportunity to lose diversity, for a species like a tarsier than it does for a species like a rhino.

2. The N_e/N of the population. Loss of diversity depends on population size. However as discussed above, the population size of relevance is not simply the census number. Rather, loss of diversity depends on the way in which members of the population breed with one another to transmit their genes to the next generation. Such factors as animals not reproducing at all, uneven numbers of the males and females reproducing, or some animals having many more offspring than others can greatly reduce the genetically effective size far below the actual census number of a population. Normally N_e is less, sometimes much less, than N; and hence MVPs must be larger than the population size prescribed by genetic calculations since these prescriptions are always in terms of N_e.

3. The number of founders that establish a population. Founders are animals out of the wild population that are used to establish a captive or a new (including recovering) wild population; conversely, they could be animals from captivity that are used to re-establish a species in the wild. In general, the larger the number of founders, the smaller the MVP needed for some genetic objectives. However there is a point of diminishing returns so that usually 20-30 effective founders may be adequate. To be effective, a founder must reproduce. Thus, if capture programmes are planned carefully, source (e.g. wild) populations do not have to be decimated to create new (e.g. captive) ones.

4. The reproductive rate or recovery potential of the population. Much genetic diversity can be lost either as a population grows from its foundation size to its carrying capacity or during recovery from periodic reductions. In general, the higher the reproductive rate and hence growth or recovery to carrying capacity, the less genetic diversity is lost.

5. The degree of subdivision or fragmentation in the population. If a species population is fragmented into a number of subdivisions which are isolated from one another, animals may not be able to move around for breeding and hence exchange of genetic material. Such situations can cause loss of genetic diversity. On the other hand some subdivision may assist retention of some kinds of genetic diversity. The important point is that conservationists must analyse the genetic processes in the species under

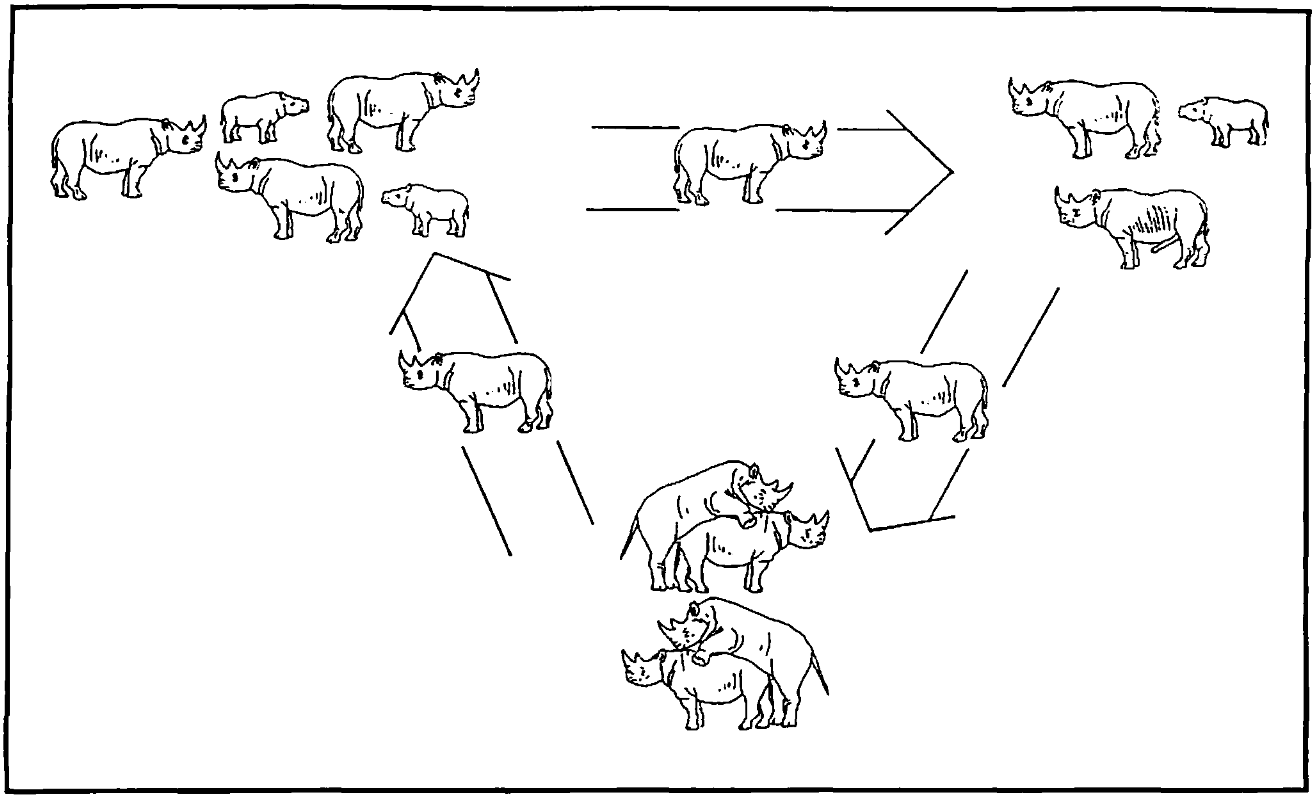


Figure 5. Managed migration among populations of rhino.

consideration and develop an appropriate management plan that may include artificial movement or manipulation of animals thus synthesising many separate smaller populations into a so-called metapopulation capable of greater long-term viability.

Finally, it must be emphasised that there is no single minimum viable population that applies to all species or to all situations for any given species. Rather, MVPs will vary depending on the objectives of the programme and circumstances of the species. Indeed, some conservation biologists are recommending that the term MVP be replaced by simply viable population (VP). But all conservationists agree that the kind of population viability analysis (PVA) described in this section is critical to successful conservation strategies and programmes for endangered species.

Population Viability Guidelines for Asian Rhino in the Wild

Based on considerations of conservation biology, habitat destruction, and poacher activity, it actually seems useful to distinguish three categories of Asian rhino populations in developing action plans:

1. **Reasonable Viability**

A minimum number of 100 rhinos seems to be indicated by PVA for a population be genetically and demographically viable for periods of time in the order of 150 years. To maintain such populations, areas of 100 km^2 or less will be required in the productive riverine habitats frequented by the great one-horned rhinoceros, and of 1000 km^2 or more in the mid-montane zones inhabited by the Sumatran rhinoceros. Naturally, area requirements may also vary somewhat depending on the actual carrying capacity of a particular habitat. Longer term viability (>10 generations) will then require that enough of the separate populations of 100 be maintained to achieve a metapopulation with an N_e of perhaps 500 for each species. Because of N_e/N ratio effects, such metapopulations for each species will need to be 2,000 to 3,000 rhinos.

2. **Limited or Uncertain Viability**

Populations with fewer than these numbers of rhinos, actually or potentially, may have shorter-term viability and value for the preservation of the species. Artificial migration (i.e., managed movement) of rhinos periodically between smaller populations may effectively render them a single larger population and would thereby enhance the viability of such remnant rhino populations, as discussed further below (Figure 5). However, the cost of such operations will be high and their success uncertain.

There may be other factors that render a population smaller than the MVP guidelines for long-term viability worthy of attempted preservation. Uniqueness may be a consideration, e.g. the Sarawak or Thai populations of Sumatran rhino. Indeed, the entire matter of subspecies or better "evolutionarily significant units" (ESUs) must be considered when developing action plans. Smaller populations may also provide important research, educational or other opportunities. The Sungai Dusun Reserve for Sumatran rhino in Peninsular Malaysia is a case in point.

However, realistic cost-benefit analyses need to be performed on each of the rhino populations of limited viability to determine if intensive and interactive management is feasible in both logistic and economic terms. This cost-benefit analysis should above all else demonstrate that attempts to preserve these smaller remnants of rhinos do not divert or dissipate resources needed to protect the larger, reasonably viable populations.

3. **Inviable or "Doomed"**

A "doomed" rhino is defined as an animal that is considered to have no possibility of contributing to the survival of the species in its current situation because:

a. It is not part of a population large enough to be viable in genetic and demographic terms, and/or

b. The animal cannot be protected from habitat destruction or poacher activity with acceptable or available levels of resources.

Single animals or isolated groups that do not satisfy the MVP criteria and which cannot be protected from habitat destruction or poacher activity with available or acceptable levels of conservation resources are "doomed".

Protectability of Rhinos and their Habitat

Assessment of risks to viability from habitat destruction and poacher activity have been discussed previously in van Strien (1985b). Factors that need to be considered in evaluating the protectability of rhinos and their habitat include:

- ecological situation, including the location of the area in relation to other places occupied by rhino;
- legal status, i.e. whether or not the area has been gazetted as a protected area;
- land use plans and the stage of their development;
- pressure to use the area;
- alternatives available to use of land and their cost;
- level of poaching;
- type of poaching: trappers in Sumatra versus Dyaks in Borneo; it will be cheaper to protect in Sumatra;
- accessibility of the area;
- present and future manpower to protect the rhinos;
- cost of protection in relation to other demand on resources.

Viable Populations of Asian Rhinos

Currently, five populations of great one-horned rhino, seven populations of Sumatran rhino and possibly one population of Javan rhino seem to satisfy the criteria for minimum viable size, as well as probable protectability (see Table 4).

Table 4. Viable populations of the Asian rhino

Species	Country/State	Population
Great One-horned Rhino	India	Kaziranga
		Manas
		Orang
	Nepal	Chitawan
		Bardia
Sumatran Rhino	Peninsular Malaysia	Taman Negara
		Endau Rompin
	Sabah	Tabin
		Danum Valley
	Indonesia	Gunung Leuser
		Kerinci Seblat
		Barisan Selatan
Javan Rhino	Indonesia	Ujung Kulon

Table 5. Population viability analyses (PVA) for captive populations of Sumatran rhino.

A. Example of PVA software output

Effective population size (N_e) and carrying capacity necessary for maintaining the specified amount of genetic diversity for a specified time period.

Years per generation:	15	No. generations during period:	15
Yearly % growth rate:	1.03	Gen. growth rate:	1.56
Effective no. of founders:	20	Gen. expon. growth:	0.44
Estimated N_e/N ratio:	0.5		
Desired % heterozygosity retained	90		
Length of time period:	225 years		

Effective Size required to maintain desired amount of original variation for the specified length of time: 118

Carrying Capacity necessary to maintain desired amount of the original variation over this time: 236

B. Actual captive population sizes required to preserve 90% average heterozyosity for indicated number of years commencing with indicated number of effective founders

Generation time = 15 years
Population growth rate = 1.03
N_e/N ratio = 0.5

Effective Founders	Years 75	150	225	300	375
10	-	-	-	-	-
15	73	275	516	857	1226
20	62	131	236	367	477
25	50	121	189	273	362
30	30	103	170	241	316

C. Actual captive population sizes required to preserve 90% average heterozygosity for 225 years with indicated N_e/N ratios commencing with indicated number of effective founders (assuming slow population growth rate)

Generation time = 15 years
Population growth rate = 1.03
N_e/N ratio = 0.5

Effective Founders	N_e/N 0.3	0.4	0.5	0.6	0.7
10	-	-	-	-	
15	861	645	516	430	369
20	393	295	236	196	168
25	315	236	189	158	135
30	283	212	170	141	121

D. Actual captive population sizes required to preserve 90% average heterozygosity for 225 years with indicated N_e/N ratios commencing with indicated number of effective founders (assuming faster population growth rate)

Generation time = 15 years
Population growth rate = 1.05
N_e/N ratio = 0.5

Effective Founders	N_e/N 0.3	0.4	0.5	0.6	0.7
10	1758	1318	1055	879	753
15	449	337	270	225	193
20	323	242	194	161	138
25	288	216	173	144	123
30	270	202	162	135	116

There is also the possibility that there are other populations that can satisfy long-term viability criteria: e.g. Gunung Abongabong and Lesten-Lukup in Central Aceh (Sumatra) or on Borneo in Kalimantan-Sarawak for Sumatran rhino; in Dudhwa for the great one-horned rhino; in Indochina for Javan rhino. But more surveys must be conducted to secure information on these possibilities.

Rhinos outside populations and areas that do not satisfy the minimum viable size criteria will be of limited or uncertain viability and should be subjected to cost-benefit analyses to determine if they should be designated as inviable or "doomed".

Options for Doomed Animals

Two options seem possible to attempt redemption of "doomed" rhinos:

1. **Translocation**
   There are two variations of this option:

a. One-time movement of the animal to a larger and/or safer situation.

b. Periodic movement of animals among population remnants which are too small to be viable by themselves but which might be managed by such artificial migration of genetic and demographic material to constitute a single larger population which could be viable.

The latter variation has been proposed for black rhinos in Africa and great one-horned rhinos in both Nepal and India. However, the option may be much less applicable to Sumatran or Javan rhino. This kind of intensive management and artifical migration requires considerable information on the subpopulations, i.e. sexes, parentage, etc. Such information will be much more difficult to collect on forest-dwellers like the Sumatrans than on largely savanna animals like the black rhino.

The cost of moving many animals among a large number of very small populations and indeed of trying to protect numerous fragments also argues for a minimum size for such subpopulations. Although theoretically small populations of any size might be interactively managed to create larger metapopulations, the limited resources available for protection and manipulation of animals in the wild can be extended only so far.

Many problems are perceived and have already been observed with translocations of rhinos and other vertebrates.

a. New animals may be disruptive to the social organization of resident populations.

b. Translocated animals may be disoriented in the new habitat and actually try to repatriate themselves.

c. Translocated animals may introduce diseases and parasites.

d. The habitats to which animals are translocated may already be saturated under prevailing conditions, e.g. poaching pressures as well as non-human aspects of the environment.

e. It may still not be possible to protect animals from poachers.

2. **Captive Propagation**
   A number of clear advantages can be recognised for captive propagation.

a. Protection from poachers.

b. Moderation of environmental stochasticity or vicissitudes.

c. Management to maximise preservation of genetic diversity.

Considering these factors, it appears that establishment of a viable captive population should have priority over attempts at translocation of "doomed" rhinos. Once a viable foundation for a captive population is established, if there are more "doomed" rhinos that need to be rescued, perhaps translocation experiments can be attempted if adequate habitat and resources are available.

Population Guidelines for Asian Rhino in Captivity

Because of the limited space and resources available in *ex situ* facilities, MVPs may have to be, and probably can be, even more precisely defined for captive than for wild populations. An objective for captive propagation of attempting to preserve 90% of average heterozygosity for 200 years are common recommendations of conservation biologists considering carefully principles of population genetics (e.g. inbreeding) and demography, as well as the likely period of time that human pressures will be most intense on wildlife.

To achieve the objectives of preserving a significant fraction (90%) of the wild gene pool for an appreciable period of time (e.g. 200 years), a number of combinations of ultimate carrying capacity, initial founder numbers, and population growth rates will produce the desired results. Table 5 provides some examples of the kinds of calculations that can generate guidelines (using the Sumatran rhino as an example). Despite some flexibility, the constraints imposed by the biological characteristics of the species will prescribe a critical minimum for the number of founders (i.e., animals out of the wild) that will be needed to establish the captive population.

Considering these factors for Asian rhino, a minimum of 20 pairs out of the wild over the entire range of the species (e.g., in the case of Sumatran rhino, 11 pairs out of Sumatra, 5 out of Peninsular Malaysia, and 4 out of Borneo) seems necessary as a viable foundation for the captive population, which itself will be distributed over Peninsular Malaysia, Sabah, Indonesia, Great Britain, and the United States.

If and where subspecies are validated so that they should be preserved as separate entities, then a larger number of founders may be needed to achieve the same genetic and demographic objectives.

Mechanics for Designation of Animals as Doomed

- It will be the responsibility of the countries of origin to provide the information and the initial recommendations to decide which animals should be considered doomed and hence candidates for capture.

- The IUCN/SSC Asian Rhino Specialist Group should review and ratify these decisions using the criteria delineated in this Appendix.

- Each country with Asian rhinos should systematically analyse all known populations and submit recommendations for "doomed" or "not doomed" as soon as possible. Tables 1-3 represent the kind of compilation of population and habitat sizes that can serve as the basis for analysis. Such a systematic and comprehensive analysis will in essence constitute the nucleus of a global masterplan for conservation of all three species.

- In the meantime, urgent cases that represent both a need and an opportunity for capture to found the captive population should receive immediate attention by the countries of origin and then the IUCN/SSC Asian Rhino Specialist Group.

Appendix 2: The Singapore Proposals on the Sumatran Rhinoceros Conservation Programme

1. The primary goal is long-term survival of the Sumatran rhino as a species and a component of natural ecosystems.

2. A comprehensive masterplan for conservation of the species will be developed, which will be collaborative and multinational in nature and which will identify and integrate all of the actions necessary to achieve the primary goal.

3. Development and oversight of the masterplan will be the responsibility of the IUCN/SSC Asian Rhino Specialist Group.

4. The conservation programme will include to following three fundamental activities:

   a. Development of an education programme to enhance public awareness and support for the Sumatran rhinoceros.

   b. Provision of primary support for a programme of conservation for the Sumatran rhinoceros as viable populations in sufficiently large areas of protected habitat.

   c. Establishment of a captive breeding programme for the preservation of the genetic divesity of the Sumatran rhinoceros in the countries of origin, including Indonesia, Malaysia and Thailand, and in North America and Europe, using animals with no hope of survival in the wild. The parties are committed to contribute to each of these in each country as mutually agreed, with details subsequently recorded in a bilateral memorandum of understanding or similar document.

5. The following principles and actions are to be observed in the captive propagation programme:

   a. Animals selected for capture in the wild are to be "doomed" individuals or come from "doomed" populations or habitats; that is, those whose future long-term viability or contribution to the survival of the species is determined to be unsatisfactory as measured by objective criteria subject to continuing refinement.

   b. Currently presumed subspecies stocks will not be mixed, either in captive breeding or in the wild translocation, until further work is done on their taxonomy.

   c. The zoo communities will provide support and technical assistance in field capture and transfer operations.

   d. Bilateral agreements will provide for captive breeding programmes in the countries of origin as well as in the United States and United Kingdom.

   e. Animals sent abroad will be on breeding lone from the countries of origin, or under some similarly equitable ownership agreement of sufficient time span to protect all interests.

   f. All animals placed in captivity and their future progeny will be managed cooperatively as part of a "world population" in the light of the primary overall goal of the programme. Decisions will be taken by consultation among the owners and interested parties with oversight provided by the IUCN/SSC Asian Rhino Specialist Group.

   g. Bilateral agreements will provide for appropriate support, training and technical assistance in captive breeding in the countries of origin.

Appendix 3: Captive Management Guidelines for the Sumatran Rhino

Because of the limited supply of animals, every possible step must be taken to minimise mortality. The following aspects should be taken into consideration:

1. Basic requirements. There should be large enclosures, and public access should be strictly limited. The paddock area must have plenty of shade, and it is essential that the animals have a place where they can wallow in mud. A holding pen should be connected to the paddock, constructed in such a way as to give the animals shelter from adverse weather conditions. The holding pen should also have facilities that permit veterinary care to be performed. The diet should be kept as similar as possible to that in the wild; the species is a browser and needs large amounts of food, rich in fibre.

2. Breeding loans should take place within the same ESU (in this respect, taxonomic studies are urgently required). The reproductive rate is slow, and so it is therefore recommended that females be considered for long-term loans, and males for short-term loans, taking into account the necessary genetic and demographic requirements.

3. Training is an important aspect of the programme, and should include all aspects of veterinary care and genetic analysis. The trained personnel should follow standardised procedures for the physical examination of animals; in particular, body measurements and growth rates should be recorded; and all appropriate records should be sent on a yearly basis to the International Studbook Keeper.

References

Andau, M.P. 1987. Conservation of the Sumatran rhinoceros in Sabah, Malaysia. Proceedings of the Fourth IUCN/SSC Asian Rhino Specialist Group Meeting. *Rimba Indonesia* 21(4): 39-45.

Andau, M.P. and Payne, J. 1982. The plight of the Sumatran rhinoceros in Sabah. Report presented at the 8th Malaysian Forestry Conference, Sandakan, Sabah, August 1982.

Andau, M.P. and Payne, J. 1986. Conservation of the Sumatran rhincoceros in Sabah, Malaysia. Report presented at the Meeting of the IUCN/SSC Asian Rhino Specialist Group meeting in Jakarta, Indonesia, October 1986.

Blouch, R.A. 1984. Current status of the Sumatran rhino and other large mammals in southern Sumatra. A World Wildlife Fund report.

Borner, M. 1979. A field study of the Sumatran rhinoceros: Ecology, behaviour and conservation situation in Sumatra. Ph.D. Dissertation, Philiosophisch-Naturwissenschaftlichen, Fakultat of the University of Basel, Switzerland.

Caldecott, J.O. and Kavanagh, M. 1984. Guidelines for the use of translocation in the management of wild primate populations. In: *The barbary macaque: a case study in conservation*. Plenum, New York and London.

Flynn, R.W. and Abdullah, M.T. 1984. Distribution and status of the Sumatran rhinoceros in Peninsular Malaysia. *Biological Conservation* 28: 253-273.

Foose, T.J. and Thomas, W. 1985. Captive propagation as part of a conservation strategy for Sumatran rhino. Report presented at public forum on conservation of Sumatran rhino, sponsored by the Sabah Society, Kota Kinabalu, Sabah, November 1985.

Groves, C.P. 1967. On the rhinoceroses of Southeast Asia. *Saugetierkunde Mitt.* 15: 221-237.

Groves, C.P. and Kurt F. 1972. *Dicerorhinus sumatrensis. Mammalian Species* 21: 1-6. The American Society of Mammalogists.

Khan, M. 1987. Distribution and population of the Sumatran rhinoceros in Peninsular Malaysia. Proceedings of the Fourth IUCN/SSC Asian Rhino Specialist Group meeting. *Rimba Indonesia* 12(4): 75-81.

Martin, E.B. and Martin, C. 1987. Combatting the illegal trade in rhinoceros products. *Oryx* 21: 143-148.

Martin, E.B., Martin, C.B. and Vigne, L. 1987. Conservation crisis - the rhinoceros in India. *Oryx* 21: 212-218.

Reynolds, R.J. 1961. Asian rhinos in captivity. *International Zoo Yearbook* 2: 17-42.

Rookmaaker, L.C. and Reynolds, R.J. 1985. Additional data on rhinoceroses in captivity. *Der Zoologische Garten* 55: 129-158.

Van Strien, N.J. 1974. *The Sumatran or two-horned Asiatic rhinoceros: a study of the literature.* H. Veenman & Zonen, Wageningen, Netherlands.

Van Strien, N.J. 1985a. *The Sumatran rhinoceros in the Gunung Leuser National Park, Sumatra, Indonesia: its distribution, ecology, and conservation.* Privately published by the author, Doorn, Netherlands.

Van Strien, N.J. 1985b. Report on a preparatory mission for the implementation of the "Singapore Proposals" for captive breeding of Sumatran rhinoceros *(Dicerorhinus sumatrensis)* as part of a conservation strategy for the species. IUCN, Gland, Switzerland.

Vigne, L. and Martin, E.B. 1987. The North Yemen government and the rhino horn trade. *Swara* 10(4): 25-28.

SUMATRAN RHINO

POPULATION AND HABITAT

VIABILITY ANALYSIS WORKSHOP

BRIEFING BOOK

SECTION 6: OVERVIEW OF SUMATRAN PROTECTED AREAS AND GIS ANALYSIS

19 Indonesia

Land area 1,811,570 sq. km†, 1,918,663 sq. km (official)
Population (1989) 184.6 million
Population growth rate (1987–2000) 1.7 per cent
Expected maximum population (2150) 355 million
Gross national product (1987) US$450 per capita
Rain forest (see maps) 1,148,400 sq. km
Monsoon forest (see maps) 30,740 sq. km
Closed broadleaved/coniferous forest (1980)† 1,138,950 sq. km
Annual deforestation rate (1981–5)† 6000 sq. km
Annual deforestation rate (late 1980s) up to 12,000 sq. km
Roundwood production* 173,598,000 cu. m
Roundwood exports* 1,131,000 cu. m
Fuelwood and charcoal production* 133,989,000 cu. m
Sawlog and veneer log production* 36,690,000 cu. m
Sawlog and veneer log exports* 3000 cu. m
* 1988 data from FAO (1990)
† FAO/UNEP (1981); FAO (1988)

Indonesia is a huge archipelago extending for 4500 km between the Asian and Australian continents. Once more or less completely covered in tropical rain and monsoon forests, Indonesia still retains well over one million square kilometres of such forests, more than any other nation in the region. Worldwide, only Brazil has more rain forest than Indonesia. There are major biogeographical differences between the different parts of Indonesia, of which the most important are between the western and the eastern ends. This difference is most clearly seen in the animals, which form two groups, divided by Wallace's Line, which lies east of Borneo at the edge of the Sunda continental shelf and is one of the sharpest zoogeographical frontiers in the world. The single most important family of tropical timber trees, the Dipterocarpaceae, is found almost entirely in the lowland rain forests west of Wallace's Line, but in general this frontier is much less important for plants than for animals.

Major exploitation of the Indonesian rain forests for timber began in the 1960s and is continuing today. The lowland rain forests of Sumatra and Kalimantan have been particularly heavily logged and now, although very large areas of forest cover remain, very little is pristine. Exploitation has often been destructive because Forest Department rules have been widely ignored. Moreover, once roads have given access to formerly inaccessible areas, farmers have often moved in after the timber companies and then cleared the relict, regenerating forest for either permanent or shifting cultivation. An exceptionally long and severe drought in 1982–3 was followed in Kalimantan by forest fires, mostly started inadvertently by these farmers. Over thirty thousand sq. km were burned, mostly comprising logged forest containing a lot of dry debris, but there are reports of widespread regeneration. Forests have also been lost through conversion of land to plantation agriculture and to transmigration schemes (see chapter 5).

In recent years the government has progressively tightened enforcement of regulations concerning forest exploitation and timber processing. Indonesia prohibited log exports in 1980; all exported timber is now either sawn or converted to plywood, of which Indonesia is a major world supplier. Export of raw rattan was banned in 1986.

Indonesian forests are fabulously diverse and rich in species. Serious damage, however, has been done over the past quarter century by the rampant timber industry, especially to the west Indonesian dipterocarp rain forests. Some wildlife is known to have been seriously affected, for example clouded leopard, Sumatran rhinoceros and elephant in Sumatra. Exploitation is now starting to focus on the east Indonesian forests. In the late 1970s, FAO and IUCN collaborated on a major review of the requirements for adequate conservation. Reserves which exist, or were proposed following this review, cover 10 per cent of the land area and if effectively implemented should conserve most of the nation's heritage of species. In Indonesia there is now a need to implement existing conservation plans and this will necessitate the strengthening of conservation institutions and a greater conservation awareness amongst decision makers and the public.

Introduction

Indonesia comprises a 4500 km long chain of islands stretching from Sumatra in the west to Irian Jaya, the western half of the island of New Guinea, in the east. This archipelago of 13,667 islands, of which about 1300 are habitable, forms the greater part of the phytogeographic region technically termed Malesia.

The three islands of Sumatra, Borneo and Java, together with intervening smaller ones, lie on the Sunda continental shelf and formed part of mainland Southeast Asia until geologically recent times. To the west of Sumatra, however, lie the Mentawai Islands separated from it by a deep ocean trench. New Guinea lies on the Sahul continental shelf and has had a land connection with Australia. In contrast Sulawesi and many of the Moluccan islands appear to have had no recent connection with either continent and to have been islands for a very long time.

The long arc of Sumatra, Java and the Lesser Sundas has a spine of high mountains which in Sumatra runs close to the western coast and which contains many extinct and a few active volcanoes. The island of Borneo is mountainous in the centre and to the north, and has a main range separating Kalimantan from Sarawak and Sabah. Sulawesi is mountainous virtually throughout. New Guinea contains some of the highest country in the southern hemisphere, with most of its mountain ranges lying just to the north of the island's north-west/

south-east axis. Much of this high country exceeds 4000 m and it culminates in Irian Jaya, in the 5039 m Gunung Jaya (Mount Carstenz). In contrast the eastern half of Sumatra, southern and eastern Borneo, and south-western New Guinea are low-lying and in parts swampy.

The peoples of Indonesia are diverse in racial origin, and the nation contains a rich mixture of languages, cultures, religions and customs. There is a central government based in Jakarta (which as Batavia was capital of the former Dutch East Indies), but the country is divided for many administrative purposes into provinces.

The Forests

Indonesia was once clothed in tropical rain forests except for the southern islands of eastern Java, Madura, Bali and the lesser Sunda islands which had tropical monsoon forests. This belt of seasonally dry climate and forests extends into southern Irian Jaya, and northwards into parts of southern Sulawesi.

Indonesia contains more tropical rain forest than any other nation in the Asia–Pacific region. All the different tropical rain forest formations found in Malesia occur in Indonesia, and in fact form their greatest extent here, as is described in the next section.

There are major regional differences in the floristics of the forests. The most important is that lowland rain forests of the Sunda shelf islands, Sumatra and Borneo, have an abundance of Dipterocarpaceae. Animals show even stronger regional differences between western and eastern Indonesia, bounded by Wallace's line. Some key features of the original forest cover may be summarised by islands and island groups as follows:

Sumatra (Sumatera)

- Lowland evergreen rain forest, dominated by dipterocarps, once occurred throughout the lowlands.
- Peat swamp forest and mangroves are extensive along the eastern coast.
- The major mountain spine has extensive montane rain forest, much of it still intact.
- In parts of the slightly dry central intermontane valley and in the far north occur the only natural pine (*Pinus merkusii*) forests in Indonesia (FAO, 1982; Whitten *et al.*, 1984).

Java

- Rain forests were probably originally found in south-western Java and in montane areas, but are now restricted to isolated montane patches.
- Teak, probably introduced by man, is extensively planted in the seasonal lowlands in the centre and east.
- Natural monsoon forests, formerly extensive in northern and eastern Java, are now all heavily disturbed.
- Where fire is excluded the forest begins to change to lower montane forest, subalpine forests and, on the highest mountains, temperate herbaceous formations. Extensive montane grassland have resulted from forest destruction by fire.
- Limestone karst occurs on the southern and north-eastern coasts, most of which are now planted with teak.
- Freshwater swamp forests and mangroves occur in a few small patches.

Lesser Sunda Islands (Nusa Tenggara)

- Savanna woodland with *Casuarina* and *Eucalyptus* now cover most of these islands.
- Evergreen rain forest was never extensive and only survives in isolated patches in steep valleys on south-facing sides of mountain ranges; elsewhere, there are monsoon forests and extensive grass lands.
- Timor once had extensive natural sandalwood (*Santalum album*) forests (FAO, 1982).
- The montane rain forests are not luxuriant and are characterised by an absence of swathing bryophytes, although some have beards of the lichen *Usnea*.

Kalimantan

- Lowland evergreen rain forests occur up to about 1000 m; above them occur montane forests which, as is the case everywhere in the region, have abundant Fagaceae, Lauraceae and Myrtaceae.
- Kalimantan has massive areas of lowland rain forest as well as extensive mangroves, peat and freshwater swamp forests, and the largest heath forests (kerangas) in Southeast Asia.
- Degradation is extensive, and there are now large areas of secondary forest, and *Imperata cylindrica* grasslands on land degraded by shifting cultivation and excessive forest exploitation.

The Toraut River in Dumoga-Bone National Park, Sulawesi, provides water for irrigation schemes in the valley below. N. M. Collins

Sulawesi

- Extensive tracts of montane rain forests still occur.
- Tracts of lowland rain forests, except in the southwest peninsula, also occur extensively.
- There are few dipterocarps; the main timber species include *Agathis dammara* and ebony *Diospyros* spp. and the flora is less rich than on islands to the west.
- Sulawesi has the biggest tracts of forest over ultrabasic rocks in the tropics (at the head of the Gulf of Bone) with their distinctive forest formation, and also has large areas of karst limestone (especially in the south-west).
- There are only small areas of inland swamp forests.
- Mangroves occur in isolated patches in the south.
- Seasonal climates which once supported monsoon forests occur, mainly in the south (Whitten *et al.*, 1987a).

Moluccas (Maluku)

- The Moluccan archipelago is partly perhumid and partly seasonal so has both rain and monsoon forests, both lowland and montane.
- Other formations include small areas of mangroves and freshwater swamps with extensive stands of sago (*Metroxylon sagu*).

Irian Jaya

- Apart from a belt of monsoon forest and savanna woodland in the far south, the vegetation is one of the largest expanses of pristine tropical rain forest in Southeast Asia.
- Timber trees include *Calophyllum* and *Intsia* in the lowlands and *Agathis* and *Araucaria* in the hills, where they occur as dense stands.
- Lower montane rain forests are found at 1400–3000 m, upper montane forests up to 3400–3600 m, above which subalpine forest and alpine heathland are found.
- Freshwater swamp forests with sago palm and extensive mangrove forests are present, as well as huge tracts of peatswamp forest on the west coast, only discovered in the 1980s.
- In the south is monsoon forest, savanna woodland with much *Eucalyptus*, and grassland.
- The Fak Fak Mountains have limestone forest and large areas of anthropogenic grassland.
- Beach forests have a typical Indo-Pacific strand flora and are better preserved than elsewhere in Malesia.

Forest Resources and Management

Land-use planning in Indonesia depends upon a process of land-use classification at provincial level. This process resulted in the publication of an account of Indonesian forest resources in 1985 (Table 19.1). The *Consensus Forest Land Use Plan* reveals that about 1.13 million sq. km of permanent forest has been identified, and that a further 0.3 million sq. km of forest land is suitable for conversion to non-forest use. This is in addition to 0.49 million sq. km already alienated. Since this assessment was undertaken, there have been improvements in the availability of data on slope, soil, climate and vegetation coverage that have enabled some fine-tuning. The Regional Physical Planning Programme for Transmigration (RePPProT), funded by a loan from the World Bank and bilateral aid from the UK, has undertaken a complete reclassification of Indonesia, based on available satellite imagery, aerial photography and local information. At the time of writing, the data are being drawn together and cannot be presented in detail (RePPProT, 1990), but the general conclusions are clear. There has been considerable agricultural encroachment into forest reserved for conservation or timber production purposes, and there is an urgent need for enforcement of conservation laws. At the same time, the new review of land use potential is likely to recommend that substantial areas of land previously classified as production forest is in fact suitable for alienation (i.e. conversion to other uses), particularly to agricultural tree-crops.

Table 19.1 Indonesian forest resources

	Area (sq. km)	*% of land area*
Permanent forest		
Protection forest	303,160	16
Nature conservation forest	175,213	9*
Production forests		
Permanent	338,660	18
Limited	305,250	16
Sub totals	1,122,283	58
Other land		
Forests for alienation	305,370	16
Alienated	491,010	26
Sub totals	796,380	42
Total	1,918,663	

(Adapted from Departamen Kehutanan (1985), Burgess (1988) and RePPProT (1990))

* This figure includes gazetted terrestrial reserves (see Table 19.3), but not marine reserves. It differs slightly from the figure of 187,250 sq. km given by Burgess (1988), which cannot be reconciled with data available for this atlas.

The official statistics resulting from the RePPProT study are as yet unpublished, but the RePPProT team has generously released a set of 1:2.5 million scale forest cover maps for use in the preparation of this atlas (see Map Legend). Using GIS techniques it has been possible to estimate forest cover statistics, detailed in Table 19.2. It must be emphasised that these data are for use only until the official RePPProT report is available, but the data on these maps are expected to be accurate within fairly narrow limits.

Table 19.2 indicates 1,179,140 sq. km of tropical moist forest in Indonesia, of which 1,148,400 sq. km are rain forest. Rain forests occur throughout the archipelago but the greatest extents are in Kalimantan and Irian Jaya, each with over a third of a million sq. km, and Sumatra with almost a quarter of a million. Monsoon forests are much less extensive, only found in the Lesser Sundas, Sulawesi and the Moluccas, with a total of just 30,740 sq. km.

FAO/UNEP (1981) estimated the closed broadleaved and coniferous forest cover of Indonesia in 1980 at 1,138,950 sq. km. In 1987 FAO in Bangkok published a slightly adjusted figure of 1,134,970 sq. km for 1980, a figure of 1,134,730 sq. km for 1985 and a projected figure of 1,132,590 sq. km for 1990 (FAO, 1987).

As so often is the case, the mapped information is slightly more generous in terms of forest cover than data from FAO would suggest. Nevertheless, the difference between the two sets of figures is small, only 4 per cent. It is encouraging to know that the RePPProT project has been able to produce a set of reliable forest maps for one of the largest and most important rain forest areas of the world.

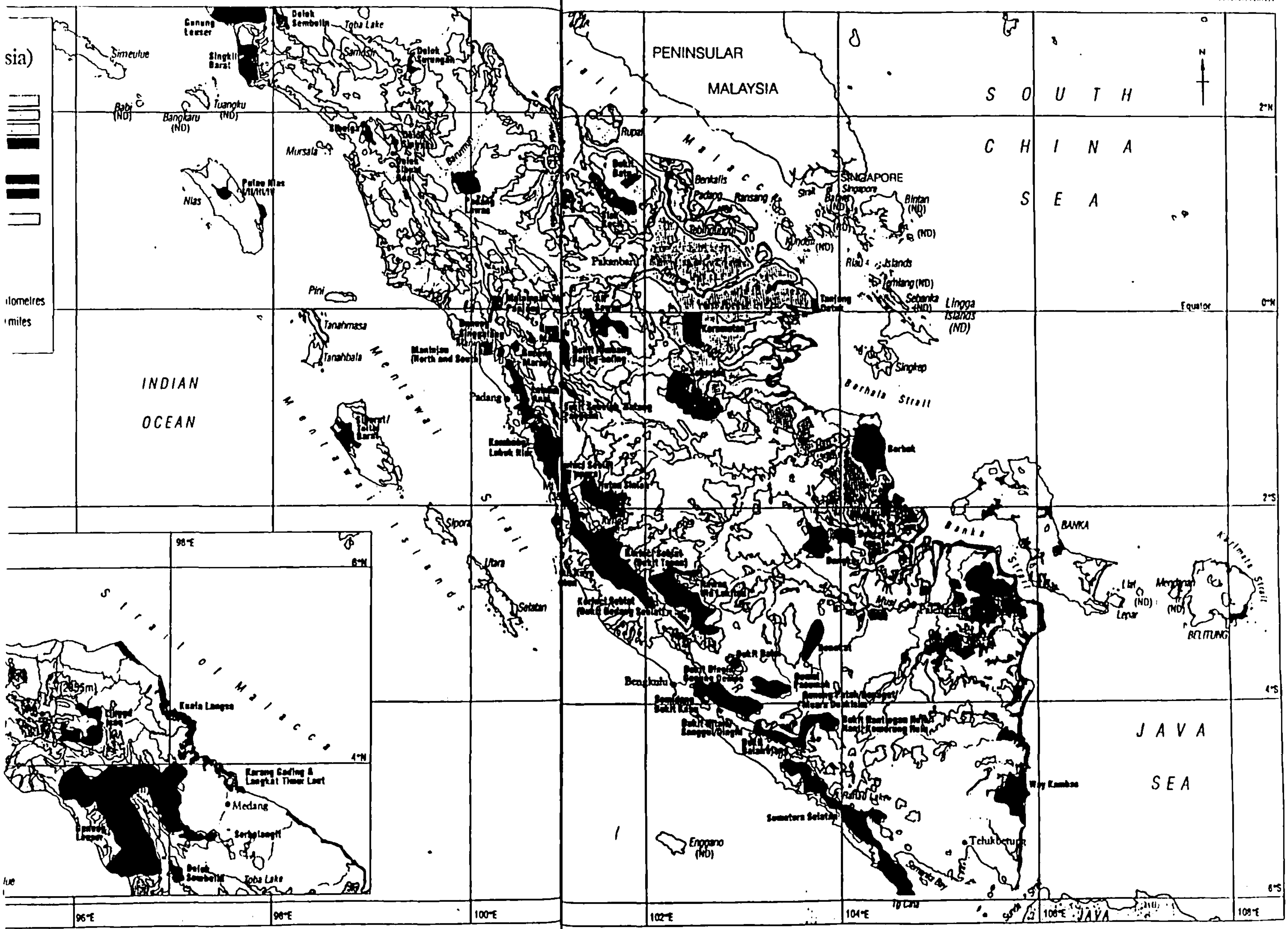
The present extent of unlogged productive forest remains in doubt. Large-scale logging began in 1967 and production figures show that some 435 million cu. m of timber were removed over the following 20 years. Burgess (1988) estimated that this represents the produce from about 120,000 sq. km of production forest and that 524,000 sq. km of unlogged production forest remains as operable production forest and forest for alienation (Table 19.1). This figure does not include the 305,000 sq. km of limited production forest which is at present inaccessible and assumed to be unlogged, although some will have been affected by shifting cultivation.

Table 19.2 Estimates of forest extent

	Area (sq. km)	% of land area
SUMATRA (472,610 sq. km)		
Rain forests		
Lowland	123,150	26.1
Montane	32,190	6.8
Inland swamp	65,310	13.8
Mangrove	10,010	2.1
Sub totals	230,660	48.8
JAVA and BALI (138,580 sq. km)		
Rain forests		
Lowland	7,370	5.3
Montane	5,450	3.9
Inland swamp	70	0.1
Mangrove	850	0.6
Sub totals	13,740	9.9
LESSER SUNDAS (89,770 sq. km)		
Rain forests		
Lowland	130	0.1
Montane	210	0.2
Inland swamp	70	0.1
Mangrove	490	0.5
Sub totals	900	1.0
Monsoon forests		
Lowland	12,590	14.0
Montane	1,100	1.2
Sub totals	13,690	15.2
KALIMANTAN (534,890 sq. km)		
Rain forests		
Lowland	298,070	55.7
Montane	25,540	4.8
Inland swamp	62,210	11.6
Mangrove	11,500	2.1
Sub totals	397,320	74.3
SULAWESI (184,840 sq. km)		
Rain forests		
Lowland	77,680	42.0
Montane	21,920	11.9
Inland swamp	2,510	1.4
Mangrove	2,170	1.2
Sub totals	104,280	56.4
Monsoon forests		
Lowland	8,120	4.4
Sub totals	8,120	4.4
MOLUCCAS (69,230 sq. km)		
Rain forests		
Lowland	44,160	63.8
Montane	1,310	1.9
Inland swamp	60	0.1
Mangrove	1,610	2.3
Sub totals	47,140	68.1
Monsoon forests		
Lowland	8,820	12.7
Montane	110	0.2
Sub totals	8,930	12.9
IRIAN JAYA (410,650 sq. km)		
Rain forests		
Lowland	232,610	56.6
Montane	54,660	13.3
Inland swamp	49,590	12.1
Mangrove	17,500	4.3
Sub totals	354,360	86.3
INDONESIA (1,918,663 sq. km)[1]		
Rain forests		
Lowland	783,170	40.8
Montane	141,280	7.4
Inland swamp	179,820	9.4
Mangrove	44,130	2.3
Sub totals	1,148,400	59.9
Monsoon forests		
Lowland	29,530	1.5
Montane	1,210	0.1
Sub totals	30,740	1.6
GRAND TOTALS[1]	1,179,140	61.5

Based on analyses of Maps 19.1 to 19.7. See Map Legend for details of sources.

[1] The areas of the regions are estimated from the maps and are not official statistics. The total area of the country by this method is 1,900,570 sq. km, but for calculating the percentage forest cover for the whole nation we have adopted the official figure for total land area, i.e. 1,918,663 sq. km.

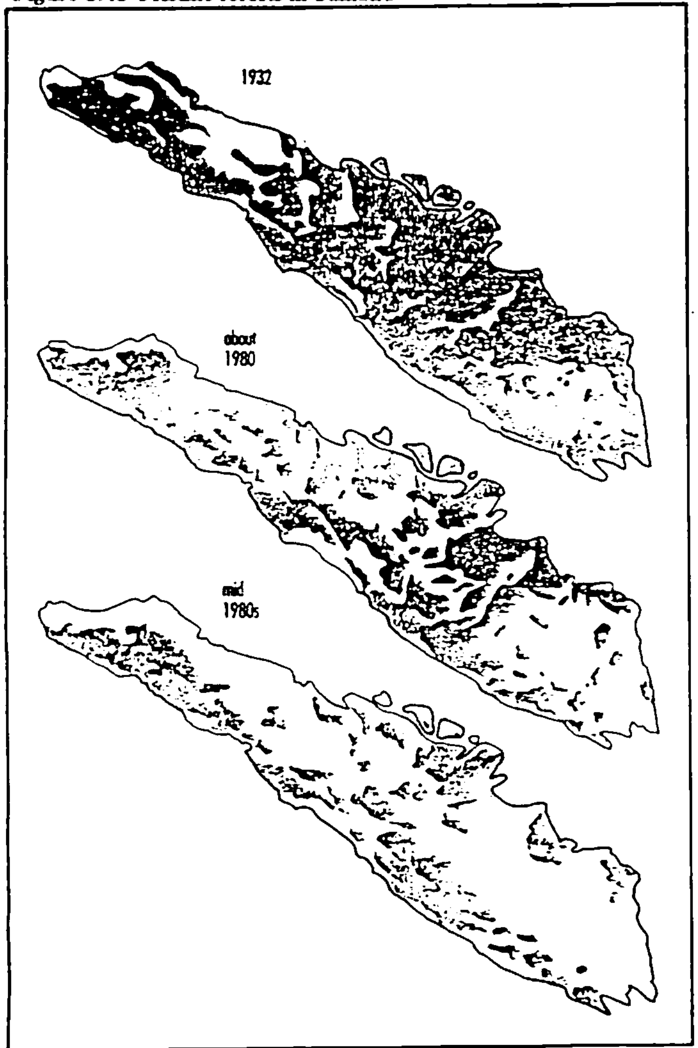

sia)
ilometres
miles
PENINSULAR
MALAYSIA
SOUTH
CHINA
SEA
INDIAN
OCEAN
JAVA
SEA
Strait of Malacca
Mentawai
Mentawai Islands
Berhala Strait
Banka Strait
Karimata Strait
SINGAPORE
Singapore
Simeulue
Babi (ND)
Bangkaru (ND)
Tuangku (ND)
Gunung Leuser
Singkil Barat
Dolok Sembelin
Toba Lake
Samosir
Mursala
Nias
Pulau Nias
Pini
Tanahmasa
Tanahbala
Siberut/Taitai Barat
Sipora
Utara
Selatan
Padang
Pakanbaru
Bengkalis
Padang
Rangsang
Bintan (ND)
Riau Islands
Lingga Islands (ND)
Sebangka (ND)
Singkep
Berbak
BANKA
BELITUNG
Lepar
Liat (ND)
Mendanau (ND)
Bengkulu
Enggano (ND)
Way Kambas
Sumatera Selatan
Teluk Betung
Semangka Bay
Rupat
Kuala Langsa
Karang Gading & Langkat Timur Laut
Medang
Serbalanggit
Dolok Sembelin
Toba Lake
Equator
2°N
0°N
2°S
4°S
6°S
6°N
4°N
96°E
98°E
100°E
102°E
104°E
106°E
108°E
N

Regional Resources

Sumatra

- The population density on Sumatra (59 people per sq. km in 1980) is relatively high and large areas of rain forest have been cleared for agriculture or industrial plantations (Whitten *et al.*, 1984). On the flat lowlands of southern Sumatra, for example, the great stands of ironwood *Eusideroxylon zwageri*, a species of great commercial importance producing an exceptionally durable timber, have been almost entirely destroyed.
- Relatively large areas of the shallower peat swamp forests along the Malacca Strait are being drained to provide farmland for new transmigrants (see chapter 5).
- About 230,660 sq. km, or 49 per cent, of the original forest cover remains (Table 19.2 and Map 19.1), but there is no doubt that large areas are degraded.
- In recent years there has been heavy logging in the lowlands east of the main mountain spine. Estimates from 1975 indicated that 42 per cent of Sumatra was covered with primary forest at that time (FAO/UNEP, 1981), but the figure is certainly much lower now.
- Figure 19.1 dramatically illustrates the rapid depletion of pristine lowland tropical rain forest in Sumatra (Map 19.1 shows logged as well as pristine forest).
- Sumatra probably continues to lose its natural vegetation faster than any other part of Indonesia.

Figure 19.1 Pristine forests in Sumatra



This is based on data from 1932 (Whitten *et al.*, 1984), about 1980 (Whitmore, 1984a) and the mid-1980s (Laumonier *et al.*, 1986). Note that logged forests are excluded from this overview, but are included in Map 19.1, which therefore shows more extensive cover.

Java and Bali

- Java, one of the most densely populated islands in the world, has lost more than 90 per cent of its natural vegetation.
- Primary forests remain only in mountainous regions at elevations above 1400 m.
- Virtually all lowland rain forests have been replaced by farms or plantation forests.
- At the end of 1980 closed broadleaved forest cover was estimated to be only 8 per cent, 11,800 sq. km (FAO/UNEP, 1981), although Map 19.2 indicates slightly more, 13,740 sq. km or 9.9 per cent.

Lesser Sunda Islands

- Tropical rain forests were never extensive and survive only in small isolated patches, usually in steep valleys. Map 19.3 indicates 900 sq. km remaining.
- Seasonal monsoon forests were more widespread, and still cover 13,690 sq. km (15 per cent of land area).
- Closed broadleaved forests were estimated by FAO to cover 25,250 sq. km (28 per cent) at the end of 1980 (FAO/UNEP, 1981), over 10,000 sq. km more than our maps suggest.
- Much of the original forest cover has been degraded by human activity to open savanna woodlands or converted to agriculture.

Kalimantan

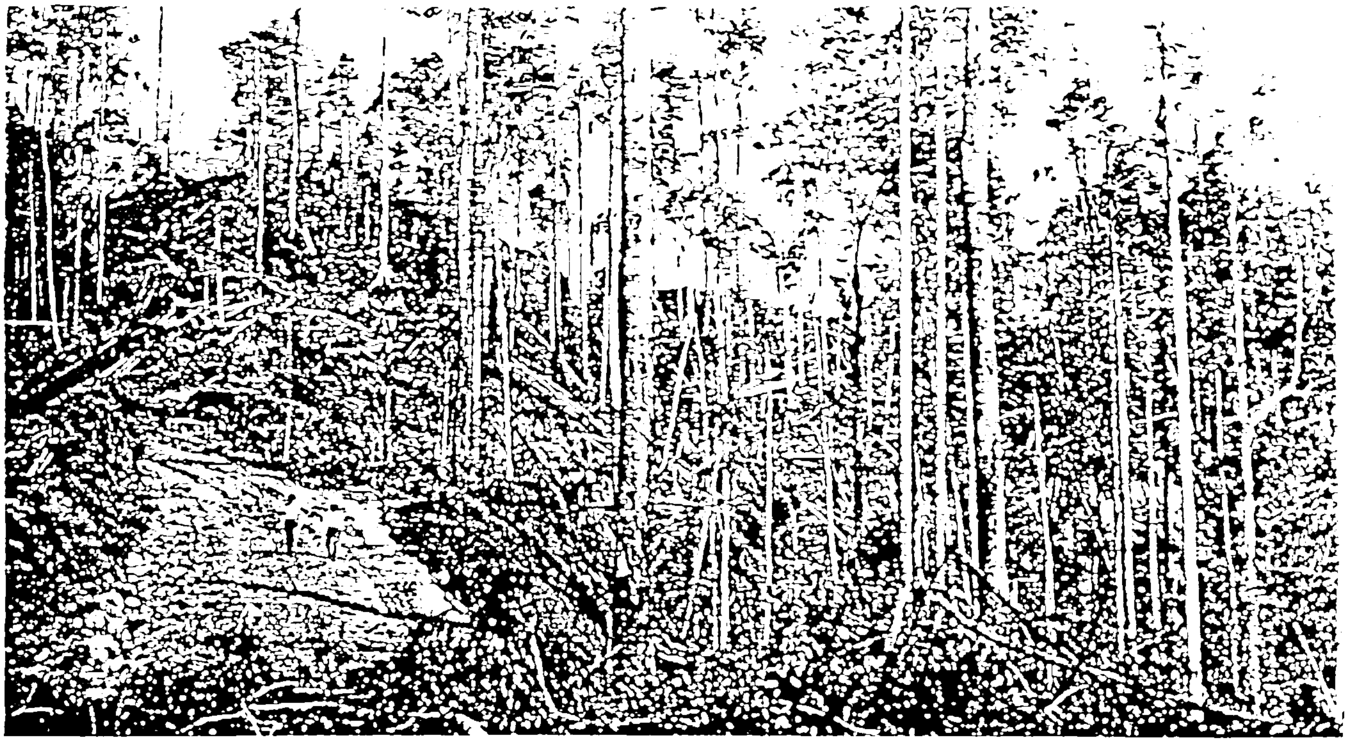
- Kalimantan supports the largest expanse of tropical rain forest in Southeast Asia. It is less densely populated than other parts of the archipelago and our data indicate that almost three-quarters of the land surface was still under natural vegetation in the second half of the 1980s, an estimated 397,320 sq. km (Map 19.4 and Table 19.2).
- FAO estimated only 353,950 sq. km of closed forest in 1980, so there is some discrepancy between the data-sets (FAO/UNEP, 1981).
- The lowland forests have been heavily logged since the late 1960s.
- In 1983 a huge area (over 30,000 sq. km) of Kalimantan, including 8000 sq. km of primary forest, was destroyed by fire or drought (Malingreau *et al.*, 1985) (see case study).
- Much of the land officially classed as forest is seriously degraded and huge areas of *Imperata* grassland exist.

Sulawesi

- Sulawesi has extensive tracts of primary rain forest although large areas in the south and some parts of the centre and north of the island have been cleared for permanent and shifting cultivation. Table 19.2 and Map 19.5 indicate forest cover over about 60 per cent of the island, virtually all of this being rain forest.
- The forest cover per inhabitant is greater than in Sumatra, Java, Bali, or the Lesser Sundas. This is partly due to the high proportion of land on steep slopes which are unsuitable for agricultural development (Whitten *et al.*, 1987a).

Moluccas

- The Moluccas comprise an archipelago of hundreds of islands ranging in size from Seram and Halmahera, *c.* 18,000 sq. km each, to small, mostly uninhabited islets with an area of only a few ha.
- The largest tracts of tropical rain forest occur in Halmahera and Seram.
- The small areas of freshwater swamp forest have been partly replaced by stands of sago palm introduced from Irian and cultivated as an important source of starch.
- The Moluccas have an estimated 56,070 sq. km of moist forest, covering over 80 per cent of the land area.
- Although Map 19.6 indicates monsoon forest on Batjan Island and southern Halmahera, recent reports indicate that this may in fact be rain forest.



Logged-over and heavily degraded forest on Obi Island in the Lesser Sundas, Indonesia. D. Laurent

Irian Jaya

- Irian Jaya, the eastern-most province of Indonesia, shares a common 736 km long border with Papua New Guinea.
- The freshwater swamp forests include huge stands of native sago palm, managed and utilised as their staple food by the indigenous people.
- The mangrove forests are second in extent only to those of the Sundarbans forest of India and Bangladesh. They have recently come under threat of exploitation, and possible destruction, to provide wood chips (Petocz, 1985).
- About 86 per cent (354,360 sq. km) of Irian Jaya remains forested and relatively undisturbed, because the population is low and concentrated mainly in some parts of the mountains.
- Extensive logging concessions have now been granted and there are plans for substantial transmigration schemes.

Deforestation

The annual rate of deforestation in Indonesia was estimated at 5500 sq. km per year for the years 1976–80, and 6000 sq. km per year for 1981–5. More recently rates of 7000 sq. km per year have been quoted (Repetto, 1988), but 11,000 sq. km per year (Gillis, 1988) and even 12,000 sq. km per year (Myers, 1989) have been feared. Such deforestation rates place Indonesia second in the world only to Brazil. Despite the high rate of deforestation in the Indonesian archipelago, however, tropical rain forests still occur extensively on all the large islands. Nevertheless, the area of the original vegetation cover has been considerably reduced, and much of the remaining forest has been seriously disturbed by logging and shifting agriculture.

Agricultural settlement Traditional swidden agriculture within large expanses of rain forest is relatively harmless, in contrast to small-holder agricultural settlement, which gradually makes inroads at the forest margins. Where the latter is unplanned, it has become a major factor contributing to the degradation of Indonesia's forests. All too often spontaneous agricultural settlement (shifting cultivation) along the forest margins employs crude and exploitative agricultural t niques which, combined with inappropriate soils, inevitably lea forest and soil degradation (see chapter 4).

Shifting cultivation is far more extensive than traditional swid and is now the dominant form of land-use in most of Kalimantan Irian Jaya, and frequently in Sumatra, Sulawesi and the Le Sundas. Indonesian Forestry Department Statistics (1985–6) i cate that approximately one million families are practising shif cultivation on 73,000 sq. km of land. However, the number of p time shifting cultivators in Indonesia undoubtedly far exceeds figure, and the national Land Resources Development Centre e mates the area under shifting cultivation in Kalimantan alone to 112,000 sq. km. Furthermore, the area of forests affected by shif agricultural activities in the Indonesian archipelago is increas possibly by as much as 5000 sq. km per year (chapter 5). Ther some local resistance to suggestions that shifting cultivators responsible for forest degradation, particularly from people v believe that the response will be attempts to relocate families from forest without providing them with an alternative means of supp This is a valid concern because a number of such initiatives wl were sponsored by Indonesian agencies in the past (e.g. vil ment programmes), have failed because they involved forced rel tion or because they provided insufficient land to main productivity.

In addition to the enormous spread of unplanned smallhol agricultural settlement, Indonesia has undertaken a substan planned settlement programme within the rain forests. This 'Tra migration Programme', and its impact on the forests, is describe detail in chapter 5.

Substantial areas of Indonesia's lowland forests have been c verted, or are scheduled to be converted, to industrial tree c plantations such as oil palm and rubber. The recent reassessmen land use potential throughout the archipelago has indicated t many more areas currently under natural forest are suitable for s conversion (RePPProT, 1990). Deforestation to accommodate th crops is likely to accelerate rapidly in years to come.

Logging The logging industry has developed from almost nothing since about 1967, soon after President Suharto came to power, though the groundwork had been laid several years earlier. The new government awarded generous timber concessions to foreign companies eager to exploit the vast, untapped stands of valuable hardwoods. By 1988 concessions had been established over approximately 534,000 sq. km (Burgess, 1988), slightly in excess of Indonesia's potentially productive lowland forests (see Forest Resources and Management, page 143). There has been progressive replacement of foreign by local companies and an increase in local processing of the timber so that, instead of logs, sawn timber and plywood have been exported since 1980.

Timber concessions are granted by the Forestry Department for 20 years, which is substantially shorter than the harvest cycle of 35 years. This encourages some timber companies to take a short-term view because they believe it is not likely that they will be able to take advantage of a second harvest. Dipterocarp forests are exploited on a selection system with a minimum felling diameter of 50 cm dbh, but enforcement of concession terms has been difficult as there are insufficient staff to monitor harvesting in remote areas. Felling below the legal girth limit is apparently rarely practised, but the residual stand is very badly damaged because of poor techniques (Burgess, 1988). Concessions tend to be creamed for the best trees so that the whole forest is logged long before the expiry of the cycle; this is then followed by requests to relog before the cycle period has elapsed (Burgess, 1988). The Forest Department has progressively tightened enforcement of the regulations, but huge areas of forest have been destructively exploited and these degraded areas pose a serious future challenge. A completely unexpected hazard of logging is that the rain forest becomes vulnerable to fires (see case study below).

THE GREAT FOREST FIRE OF BORNEO, 1982–3

At the end of an uncommon (but not unprecedented) 18-month long drought in 1982–3 the largest forest fire in recorded history burned a huge area of East Kalimantan. The total area destroyed either by fire or by the drought itself was *c.* 33,000 sq. km, equal in size to the whole of Taiwan or the Netherlands (Figure 19.2), 17 to 20 times the area of the much publicised Australian bush fires of 1982, or about 1500 times the size of the area burned by forest fires which raged in France at the end of 1984. In East Kalimantan, the province which makes the greatest contribution to Indonesia's timber production, the area affected included approximately 8000 sq. km of unlogged dryland primary rain forest, 5500 sq. km of peat swamp forest, 12,000 sq. km of selectively logged forest and 7500 sq. km of shifting cultivation and settlements (Malingreau *et al.*, 1985). In the Malaysian state of Sabah a further 10,000 sq. km of forest lands were severely damaged.

The drought was associated with the 1982–3 El Niño Southern Oscillation Event. The fire started during the drought in the fields of farmers who had moved in after logging, in many cases illegally. It was able to spread quickly in logged forest where dead, dry remains of trees littered the forest floor and also in peat swamp forest, where the dry surface peat burned fiercely, destabilising trees which were then toppled by the wind. In the peat swamps near the Mahakam River coal seams at the surface also caught alight and assisted the fire's progress.

Besides damage to the forests, other consequences of the Great Forest Fire of Borneo included:

- Significant increases in erosion (with associated damage to fisheries and reduced navigability of rivers).
- Disruption of the traditional lifestyles of local inhabitants through loss of forest products.
- Destruction of wild animal populations.

The same drought also resulted in fires in Sumatra and Halmahera (Moluccas). Another lesser drought in 1987 was followed by fires in Sumatra and in south Kalimantan.

Figure 19.2 The location of forest areas killed by drought and fires in Borneo, 1982–3 (*Source:* after Malingreau *et al.*, 1985)

Logging in Indonesia leaves behind large quantities of debris that represent a serious fire risk during periods of drought. WWF/A. Compost

There is little or no published information about the regeneration of the drought-stricken and burnt forests; indeed there was little information made available at the time of the drought itself. There are now reports that over 600 sq. km of former natural forest land is being turned over to industrial timber plantations, mainly of *Albizia*, *Gmelina* and *Eucalyptus*. At the height of the drought vast areas of forest appeared to be dead. Only the biggest trees, such as *Koompassia excelsa*, remained in leaf. By 1989, however, P. Burgess, a forester working in the region, noted that many of the dipterocarps were turning green once more. The areas affected by drought and fire have not been excised from Map 19.4 partly because of a lack of detailed data, but also because regeneration appears to be quite possible if the forest is given an opportunity to recover.

Consequences of deforestation Loss of Indonesia's tropical rain forests has had severe biological, social and physical consequences. In Indonesia, as elsewhere, careless forest exploitation with cynical disregard of the rules laid down for log extraction and road construction, has led to substantial soil erosion, with consequent silting of rivers and irregularity of river flow. In the uplands of Java dense populations, continually advancing into steeper upper watersheds and more marginal environments, have had significant and destructive effects on nutrient outflow, total water yield, peak stormflows and stream sedimentation (see also Bengkulu case study for Sumatra). On Java, particularly extensive erosion has occurred, notably in areas under annual cropping systems where the soil is disturbed and left exposed during critical periods (e.g. during the transition from the dry to the wet seasons). A variety of government projects and programmes seek to promote changes in farming systems and land use in order to limit environmental degradation, but in many upland communities soil and water conservation practices have been adopted only to the extent that they serve to improve yields in the short term.

Erosion can also make a serious and expensive impact on irrigation schemes. For example, in 1973 the Gumbara irrigation scheme was initiated in the Palu valley (Sulawesi) with the intention of supplying water for the development of 115 sq. km of rice fields. Twenty-three years later, however, only 50 sq. km were being irrigated and the irrigation canals now have to be dredged every year when about 30,000 cu. m of soil is removed. This excessive siltation results largely from the activities of a logging company which has been active since 1978 (Whitten *et al.*, 1987a).

HEAVY FLOODS FOLLOW FOREST DESTRUCTION IN BENGKULU PROVINCE, SUMATRA

The conversion of forest into agricultural holdings, some of which have proved ephemeral and been abandoned, is a particularly serious cause of conservation problems in Sumatra. It is estimated that between 65 and 80 per cent of the forests in the lowlands of Sumatra have already been lost (see Figure 19.1). The mountain areas have so far been less seriously affected, but the disruption of continuous cover is already substantial in some cases (see Kerinci-Seblat case study), and perhaps 15 per cent of their total area has already been removed.

The lowland forests that are so rich in both plants and animals are being destroyed indiscriminately in Bengkulu Province and this has led to serious environmental problems affecting thousands of villages. The loss of lowland forests is nowhere more serious than on either side of the main road running north from Bengkulu to Muko-Muko. The scale of deforestation of such rich wildlife habitat is enormous, and their destruction had been carried out with international involvement in replacing tropical rain forest by monocultures of oil palm and cocoa. These activities were directly responsible for floods which in 1988 in Bengkulu province destroyed the possessions of thousands of people. Deforestation was followed by soil erosion and massive landslides and floods when the rains finally arrived. In the absence of forests, flood control measures have proved both expensive and rather ineffective.

Source: Charles Santiapillai

Mangroves

Mangroves are estimated to cover 44,130 sq. km in Indonesia (Table 19.2), representing a major increase over an earlier estimate of 21,700 sq. km (IUCN, 1983). They are most extensive in Irian Jaya, particularly around Bintuni Bay in the north-west, but large tracts and many smaller formations occur scattered throughout the archipelago (Koesoebiono *et al.*, 1982; Soegiarto and Polunin, 1982; Petocz, 1985 and Subagjo, 1987).

Indonesian mangroves were little affected by large-scale forest exploitation until 1975 (IUCN, 1983), but they are probably now the most threatened forests in the archipelago (Petocz, 1985). Some destruction of mangroves has occurred as a result of over-exploitation by traditional users, but most destruction results from conversion of the land for agriculture, brackish water fishponds, salt ponds, and human settlement (Hanson and Koesoebiono, 1987). Fishponds are particularly extensive in Sulawesi, Java and Sumatra, extending to about 1850 sq. km by 1982 (Soemodihardjo, 1984).

Since the mid-1970s mangrove forests in Indonesia have also been utilised for wood chips, exported to Japan for the production of cellulose or paper. There is no evidence that the care necessary to exploit the mangroves in a non-destructive manner is being taken, and in consequence forest regeneration is poor.

Biodiversity

No other country has responsibility for more diverse and unique species than does Indonesia. Although Indonesia occupies only 1.3 per cent of the land surface of the globe it contains an estimated 10 per cent of all plant species, 12 per cent of mammals, 16 per cent of reptiles and amphibians and 17 per cent of birds. This is partly because it is situated at the heartland of the Asia–Pacific humid tropics, but also spreads into large areas of seasonal climate, so that both rain forest and monsoon elements occur. Indonesia's wildlife is influenced by both the geological supercontinents of Gondwanaland and Laurasia, each of which has contributed a rich and distinctive biota, fairly sharply delimited (especially for animals) at Wallace's Line. The small geologically isolated islands west of Sumatra, particularly the Mentawai Islands, have developed a suite of endemic species, including four primates. New Guinea and Borneo are probably the individual islands with greatest richness and diversity. Information on the non-Indonesian parts of these great islands may be found in chapters 21 and 24 respectively.

Indonesia's flora is one of the richest in the world, encompassing most of the Malesian floristic region, which has over 25,000 species of flowering plants including about 10,000 trees (FAO, 1982). About 40 per cent of plants are endemic at the generic level. Western Malesia is the centre of diversity of dipterocarps, which form the basis of the logging industry. About 262 of 386 species of dipterocarps are found in Kalimantan, which is being heavily logged as a result. On small plots of about one hectare Bornean rain forests are uniquely rich in tree species, only equalled by parts of Amazonia (Whitmore, 1990).

About 430 of Indonesia's 1500 species of birds, almost 200 of its 500 mammals, and a large proportion of the 1000 reptiles and amphibians and unknown numbers of invertebrates are found nowhere else. Even within Indonesia many are very localised. The parts of Indonesia lying on the Sunda Shelf, i.e. Sumatra, Java, Bali and Kalimantan, include some of the large placental mammals, such as tiger, rhinoceros, elephant, orang utan, serow and banteng. In contrast, the mammalian fauna of Irian Jaya, on the Sahul Shelf, is

The consequences of total deforestation are disastrous for soils. Even on gentle slopes, gulley erosion can occur, as here in Sulawesi. N. M. Collins

characterised by marsupial cuscuses (*Phalanger* spp.), tree kangaroos (*Dendrolagus* spp.), and bandicoots (*Echymipera* spp.), and the monotreme long-nosed echidna (*Zaglossus bruijni*). Other than man, there are no primates in Australia and New Guinea. Between these Sunda and Sahul groups of islands lies Wallacea, a biogeographical zone that includes Sulawesi, the Lesser Sundas and the Moluccas, which contain a curious mixture of Asian and Australian fauna including bizarre forms such as the babirusa and the anoas (*Bubalus* spp.), as well as macaques, tarsiers, squirrels and cuscuses. Rodents and bats are numerous and include a wealth of endemic forms such as the true giant rats and water rats of Irian Jaya as well as smaller nectar-eating bats upon which many fruit trees are dependent for pollination.

The bird life is extraordinary in its richness and range of form and habitat. Among the endemics are the birds of paradise and bower birds, the flightless cassowaries, diverse families of honeyeaters, kingfishers, pigeons, and various parrots. The megapodes are large ground-nesting birds that incubate their eggs in soil warmed by hot springs or rotting organic matter. Other spectacular species include hornbills, many raptors and a wealth of forest specialists such as barbets, pittas, pheasants, flycatchers and whistlers.

Four species of crocodiles occur in swampy and coastal areas, some of which are bred in special ranches that bring revenue to rural people. The small islands off Flores are home to the world's largest lizard, the Komodo dragon *Varanus komodoensis*. Flying and frilled lizards, freshwater turtles, skinks, geckos and tree frogs form rich assemblages of species.

Insect life is spectacular, and includes the birdwings (*Troides* and *Ornithoptera* spp.), which are the largest butterflies in the world and some of the rarest (Collins & Morris, 1985). Several species are being reared in butterfly farms to supply zoos in Europe and North America.

There have already been extinctions, of which the Bali and Java subspecies of tiger (*Panthera tigris balica* and *P. tigris sondaica*) are probably best known. Unfortunately Indonesia has the world's longest list of vertebrates threatened with extinction, including 126 birds (Collar and Andrew, 1988), 63 mammals and 21 reptiles (IUCN, 1988). Most species are threatened because they cannot survive rain forest clearance. A few examples may be given here:

1 The most serious threat to the clouded leopard and other large mammals in Sumatra is clear felling of forests for conversion to agriculture or human settlements. At the turn of the century when much of Sumatra was principally covered with primary rain forest, the clouded leopard probably maintained continuous populations throughout the island. Today this species, although still found in the eight provinces of Sumatra, occurs only in a few isolated areas (Santiapillai, 1986).

2 Forest clearance has also adversely affected the status of some bird populations. The last recorded sighting of the Caerulean paradise-flycatcher took place in 1978 on the upper slopes of Mount Awu on Sangihe, an island located off the northern tip of north Sulawesi (White and Bruce, 1986). Virtually all of Sangihe has now been converted to coconut and nutmeg plantations or else is covered by patches of secondary forest. Some primary forest remains on Mount Sahendaruman in the south of Sangihe, but even if a few flycatchers remain in this small area it is unlikely to be large enough to ensure the survival of the species (Whitten *et al.*, 1987b). The Javan wattled lapwing (*Vanellus macropterus*) is already believed to be extinct (MacKinnon, 1988).

To those who appreciate Indonesia's incredible natural wealth, little more needs be said to warrant its preservation and protection. To the vast number of rural Indonesian citizens, whose lives are closely tied to the forests or depend upon the sea for their subsistence and livelihood, conservation of natural resources has become a growing imperative, so that the benefits they now enjoy can be sustained into the future. Those who seek to exploit the natural resources on an industrial scale remain to be persuaded that the long-term wealth of the archipelago, and perhaps the welfare of the world, is linked with sustainable utilisation of this biological diversity.

Conservation Areas and Initiatives for Conservation

Conserving the nation's biological heritage presents an exceptional challenge to Indonesia, but one that can be met. The Government has recognised the urgent need for conservation and, in view of the progressive loss of its natural vegetation, is planning to increase substantially the area of forest estate under protection by the end of the century. With the present rate of change, any areas left unprotected by that time are not likely to remain intact.

At present the archipelago has over 320 conservation reserves covering some 175,000 sq. km or 9.1 per cent of land area (Table 19.3). In addition to these gazetted areas, there are several major sources of proposals for new protected areas and extensions to existing areas.

1 A further 185 areas encompassing almost 30,000 sq. km have been recommended by PHPA, and await a decision by the Ministry of Forestry. Many of these areas have been chosen because of their water catchment functions as well as to protect areas of biological richness (FAO, 1982; IUCN/UNEP, 1986).

2 Additional proposals have been made in an eight-volume National Conservation Plan produced in 1982 by the government of Indonesia with FAO assistance (FAO, 1982). Objectivity to ensure conservation of all species and habitats was a major tenet of the Plan. However, practical considerations were also taken into account and the candidate sites were evaluated by quantifying the relationship between three factors: importance in preserving genetic diversity, socio-economic justification, and management viability.

3 Proposals in the Conservation Plan have been supplemented by the identification of key conservation sites in the Marine Conservation Plan (Salm and Halim, 1984), the Irian Jaya Conservation Development Strategy (Petocz and Raspado, 1984) and the Indonesian wetland inventory (Silvius *et al.*, 1987).

These proposals together recommend an additional 200 areas which have yet to be approved. They total 212,530 sq. km (11.1 per cent of land area).

The existing and proposed protected area system of the country offers excellent coverage of all habitat types. If the Government implements in addition most of the recommendations included in the National Conservation Plan it will have one of the finest and most comprehensive protected area networks in Southeast Asia (IUCN/UNEP, 1986). There is no need for further surveys to identify more new protected areas; the priority must now be the implementation of existing proposals and management plans (IUCN/UNEP, 1986). These have recently been further refined by the identification of key reserves for priority action (RePPProT, 1990).

One of the major constraints to implementation, however, is a lack of trained and motivated personnel. Staff recruited from the forestry service are usually not trained in the theory or practice of protected area management, and forest guards and park wardens lack motivation and are poorly paid. There is therefore an urgent need for manpower development before conservation work can begin. Increased funding is also needed. The total budget and revenues provided by the Ministry of Forestry for conservation in Indonesia's fourth Five Year Plan (1984–9) were about US$12 million. Less than US$2 million were allocated for protected area management. This is not sufficient to ensure that the country's reserves are efficiently managed. Increased financial resources must be mobilised if Indonesia's network of parks is to provide any meaningful protection to a biological heritage that is of major global significance.

HUMAN ENCROACHMENT IN SUMATRA'S CONSERVATION AREAS

The Kerinci–Seblat National Park (Figure 19.3) is situated along the Barisan mountain range in the southern half of Sumatra. With a total area of 14,847 sq. km it is the largest conservation area in Sumatra. The importance of Kerinci–Seblat lies in the fact that the forests protect the watersheds of two of Sumatra's most important rivers, the Musi and Batang Hari. Its strength so far has been its sheer size, but, given the current rate of deforestation, as a result of human encroachment both from within and outside the park, it is one of the most seriously threatened parks in Indonesia. The main conservation problem is the conversion of forest to agriculture by shifting and shifted cultivators resident in the enclave, whose area is 1460 sq. km. This enclave is inhabited by a population of about 273,000 people that is growing at an annual rate of 3.6 per cent.

Given the richness of the volcanic soil, the principal activity of the human population in the enclave is agriculture. Paddy is cultivated extensively on the plateau and Kerinci Province is self-sufficient in rice. Recent immigrants into Kerinci have extended their activities beyond the border of the enclave well into the park, clear felling forests to cultivate paddy. When soil fertility decreases, other cash crops such as cinnamon, cloves and coffee are grown. Large areas of forests have so far been replaced by cinnamon plantations. Misuse of land is the most serious conservation problem in Kerinci and already the hills that border the enclave have been completely deforested.

The buffer-zone in Kerinci covers about 500 sq. km and consists of denuded hills and abandoned clearings. The most important conservation measure that needs to be adopted here is a complete ban on any further encroachment and the relocation of all illegal settlers to areas outside the park. Hand in hand with this must be the restoration of all the derelict lands through reforestation programmes using Indonesian species such as *Paraserianthes (Albizia) falcataria*, *Pinus merkusii* and surian (*Toona sureni*). The development of the buffer zone and the regulation of the land-use activities of the settlers is vital to such measures. The current trends are likely to result in the gradual but certain destruction of Sumatra's most important conservation area.

Source: Charles Santiapillai

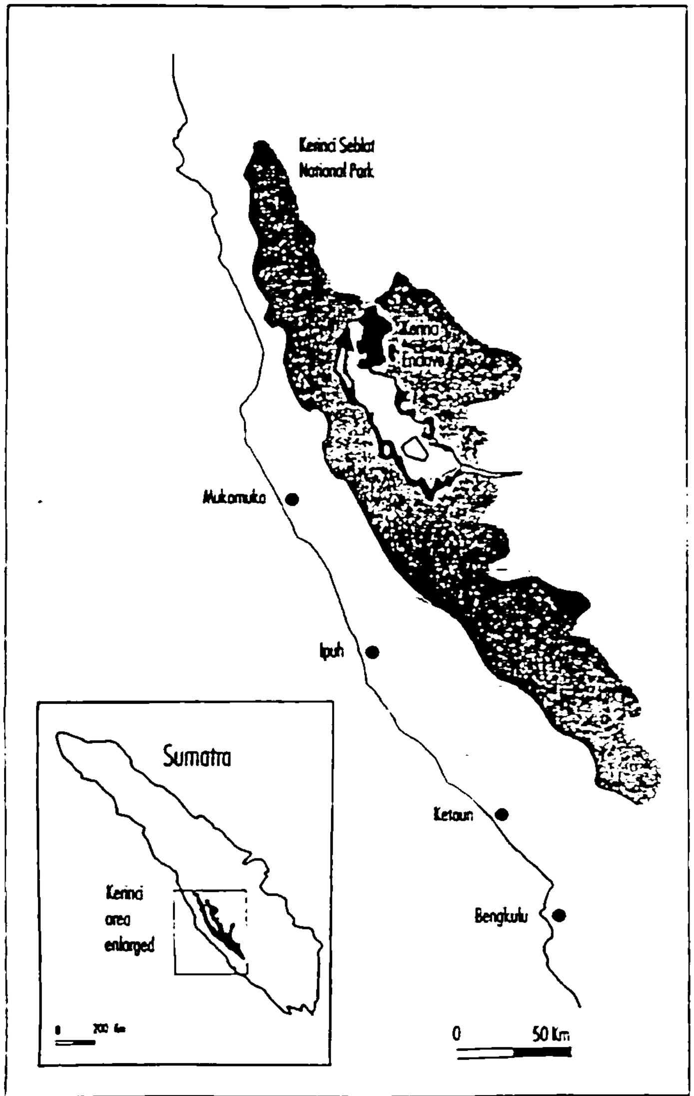
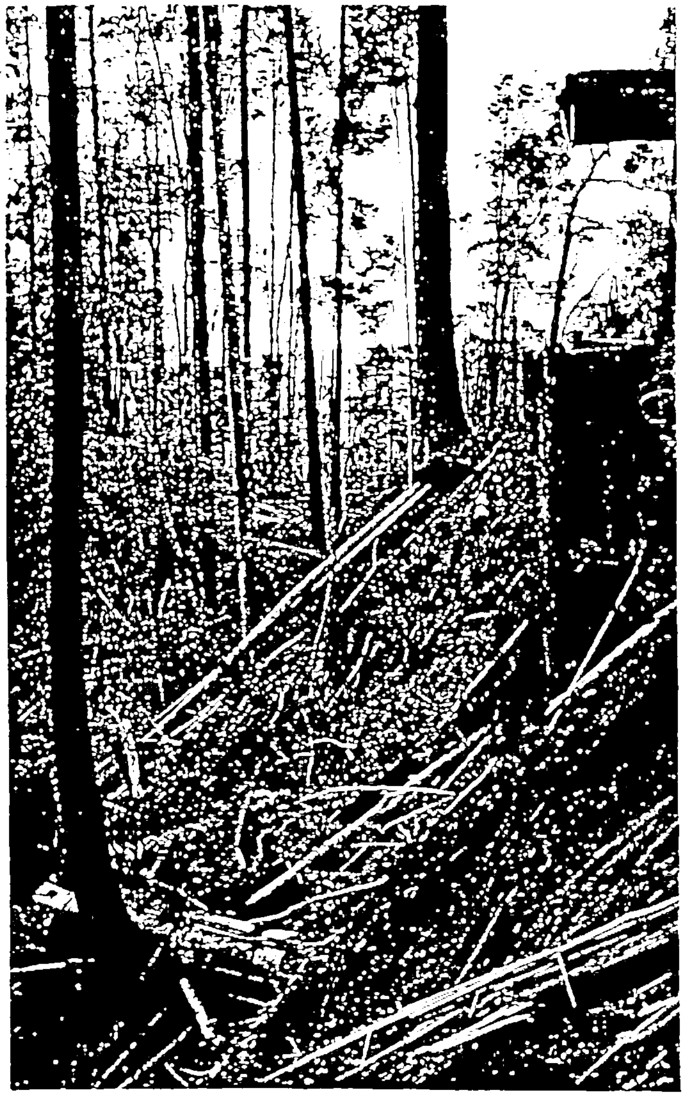


Figure 19.3 The Kerinci Seblat National Park, Sumatra
(*Source*: Charles Santiapillai)



On Obi Island in the Lesser Sundas, logging on 45° slopes has led to severe damage to the forest cover, resulting in erosion and loss of fertility. D. Laurent

Table 19.3 Conservation areas of Indonesia

Existing and proposed areas, 50 sq. km and over and for which we have location data, are listed below. The remaining areas are combined in a total under Other Areas. Protected forests are included, but Forest Reserves have been excluded. For data on ASEAN sites and Biosphere reserves see chapter 9.

	Existing area (sq. km)	*Proposed area (sq. km)*
INDONESIA – Sumatra		
National Parks		
Gunung Leuser	8,097	600 (ext)
Kerinci Seblat*	14,847	
Nature Reserves		
Bukit Balai*		136
Bukit Rimbang Baling-baling*		1,360
Bukit Sebelah Batang Pangean*		328
Bukit Tapan* (Part of Kerinci Seblat)	665	
Dolok Sembelin*		339
Dolok Sibual Bual*	50	
Dolok Sipirok*	70	
Gian Duri*		400
Gunung Sago Malintang*		50
Gunung Salawah Agam*		120
Indrapura* (Part of Kerinci Seblat)	2,367	
Kuala Langsa*		70
Lembah Anai*		960
Malampah Alahan Panjang*		369
Maninjau (North and South)*		221
Seberida*		340
Siak Kecil*		1,200
Siberut/Taitai Balti*	965	560 (ext)
Sibolga*		201
Singkil Barat*		650
Tanjung Datuk*		288
Game Reserves		
Air Sawan*		1,400
Bentayan*	193	
Berbak*	1,900	
Bukit Batu*		180
Bukit Gedang Seblat* (Part of Kerinci Seblat)	488	
Bukit Kayu Embun*	1,060	
Dangku*	291	
Dolok Surungan*	238	
Gumai Pasemah*	459	
Karang Gading & Langkat Timur Laut*	158	
Kerumutan*	1,200	
Pulau Nias I/II/III/IV*		480
Rawas Ulu Lakitan*	2,134	
Sumatera Selatan*	3,568	
Way Kambas*	1,300	
Hunting Reserves		
Benakat	300	
Lingga Isaq*	800	
Padang Lawas*		687
Semidang Bukit Kabu*	153	
Recreation Parks		
Serbolangit		544
Protected Forests		
Bukit Balairejang*	167	
Bukit Dingin/Gunung Dempo*	381	
Bukit Hitam/Sanggul/Dingin*	694	
Bukit Nantiogan Hulu/Nanti Komerung Hulu*	362	
Gunung Merapi*	97	
Gunung Patah/Bepagut/Muara Duakisim*	917	
Gunung Singgalang*	97	
Hutan Sinlah*		810
Kambang/Lubuk Niur*	1,000	
Sub totals	45,018	12,293
Other Areas	c. 18,419	c. 26,730
INDONESIA – Java		
National Parks		
Baluran	250	
Bromo-Tengger-Semeru*	576	
Dataran Tinggi Yang (Yang Plateau)*		142
Gunung Gede Pangrango*	140	
Merapi Merbabu*		100
Meru Betiri*	495	
Ujung Kulon*	761	
Nature Reserves		
Gunung Halimun*	400	
Gunung Kawi/Kelud*		500
Gunung Lawu*		60
Gunung Masigit*		90
Gunung Muria*		120
Gunung Raung*		600
Gunung Sumbing*		100
Gunung Tilu*	80	
Gunung Unggaran*		55
Kawah Kamojang*	75	
Nusa Barung*	61	
Nusa Kambangan Perluasan*		221
Pegunungan Pembarisan*		130
Segara Anakan*		153
Tanjung Sedari		82
Teluk Lenggasana*		160
Waduk Gede/Jati Gede		105
Game Reserves		
Banyuwangi Selatan (Blambangan)*	620	
Cikepuh*	81	
Gunung Sawal*	54	
Cikamurang		55
Gunung Liman Wilis*		450
Gunung Perahu*		250
Karimunjawa		1,100
Hunting Reserves		
Gunung Pangasaman		340
Masigit Kareumbi*	124	
Recreation Parks		
Gunung Ciremai*		120
Sub totals	3,717	4,933
Other Areas	c. 1,729	c. 1,902

INDONESIA – Lesser Sunda Islands

National Parks		
Bali Barat*	777	
Komodo Island	407	
Nature Reserves		
Gunung Ambulombo*		50
Gunung Diatuto (East Timor)		150
Gunung Muna (Alor Is.)		150
Gunung Olet Sangenges (Sumbawa Is.)*		350
Ruteng (Flores Is.)*	300	
Game Reserves		
Danau Ira Lalora-Pulau Yaco (East Timor)*		250
Gunung Talamailu (East Timor)		200
Gunung Wanggameti (Sumba Is.)*	60	
Hutan Dompu Complex (Sumbawa Is.)		100
Lore (East Timor)*		102
Pulau Moyo (Sumbawa Is.)*	188	
Pulau Panjang		100
Pulau Sangiang (Sumbawa Is.)		160
Rinjani (Lombok Is.)*	410	
Sungai Clere (East Timor)		300
Tambora Utara (Sumbawa Is.)*		800
Tanjung Kerita Mese		150
Tanjung Rukuwatu		60
Timolar (East Timor)		50
Hunting Reserves		
Dataran Bena*	114	
Tamboka Selatan (Sumbawa Is.)	300	
Protected Forests		
Egon-Iliwuli (East Flores)*	149	
Gunung Mutis (West Timor)*	100	
Gunung Timau (West Timor)	150	
Hadekewa-Labelakang (East Flores)	125	
Manupeu (Sumba Is.)*	120	
Selah Legium Complex (Sumbawa Is.)*	500	
Recreation Parks		
Danau Sano		55
Sub totals	3,027	3,027
Other Areas	c. 2,925	c. 845

INDONESIA – Kalimantan

National Parks		
Kutai*	2,000	
Tanjung Puting*	3,550	
Nature Reserves		
Apar Besar*		900
Apu Kayan*		1,000
Bukit Baka*	705	
Bukit Raya*	1,100	
Gunung Bentuang dan Karimun*		6,000
Gunung Beratus*		1,300
Gunung Berau*		1,100
Gunung Lumut*		300
Gunung Palung*	300	
Hutan Kapur Sangkurilang*		2,000
Karimata*		1,500
Long Bangun*		3,500
Meratus Hulu Barabai*		2,000
Muara Kaman Sedulang*	625	
Muara Kayan*		800
Muara Kendawangan*		1,500
Muara Sebuku*		1,100
Muara Uya*		250
Pamukan*		100
Pantai Samarinda*		950
Pararawen I/II*	62	
Sungai Kayan Sungai Mentarang*	16,000	
Tanjung Dewa Barat*		163
Tanjung Penghujan*		400
Ulu Kayan*		8,000
Ulu Sembakung*		5,000
Game Reserves		
Danau Sintarum*		800
Gunung Penrisen/Gunung Niut*	1,800	
Kelompok Hutan Kahayan*		1,500
Pleihari Martapura*	364	
Pleihari Tanah Laut	350	
Sungai Mahakam Danau Semayam Kutai (Perluasan)*		2,000
Protected Forests		
Bukit Perai*	1,000	
Bukit Rongga*	1,100	
Gunung Asmansang*	280	
Gunung Tunggal*	508	
Sub totals	29,744	42,000
Other Areas	c. 21,008	c. 28,353

INDONESIA – Sulawesi

National Parks		
Dumoga-Bone*	3,000	
Lore Lindu*	2,310	
Nature Reserves		
Bulusaraung*	57	
Gunung Ambang*	86	
Gunung Soputan*		80
Kelompok Hutan Buol Toli-toli*		5,000
Lamiko-miko*		50
Lasolo-Sampara*		450
Morowali*	2,250	
Pegunungan Peruhumpenai*	900	
Tangkoko-Dua Saudara*	89	
Game Reserves		
Buton Utara*	820	
Danau Tempe		94
Gunung Manembo-Nembo*	65	
Lambu Sango*		200
Mambuliling*		100
Mamuja/Tapalang*		125
Marisa Complex*		940
Pegunungan Morowali/Pelantak*		5,000
Pegunungan Palu dan Sekitarnya*		6,000
Polewai (Tenggara)*		80
Rangkong*		590
Rawa Opa*		1,500
Tanjung Batikolo*	55	
Tanjung Peropa*	380	
Hunting Reserves		
Gunung Watumohai*	500	
Rompi*		150

Recreation Parks		
Danau Matado/Mahalano*	300	
Danau Towuti*	650	
Protected Forests		
Gunung Kelabat*	57	
Gunung Lompobatang*	200	
Gunung Sojol*		70
Pegunungan Latimojong*	580	
Tamposo-Sinansajang	150	
Sub totals	12,458	20,429
Other Areas	*c.* 11,110	*c.* 19,097

INDONESIA – Moluccas

National Parks		
Manusela Wai Nua/Wai Mual*	1,890	
Nature Reserves		
Ake Tajawi*		1,200
Aru Tenggara*		800
Gunung Arnau*		450
Gunung Sahuai*		300
Gunung Sibela*		400
Kai Besar*		370
Pulau Nuswotar*	75	
Pulau Obi*		450
Saketa*		1,040
Taliabu*		700
Waya Bula*		600
Yamdena*		600
Game Reserves		
Gunung Gamkonora*		320
Gunung Kelapat Muda*		1,450
Lolobata*		1,890
Pulau Baun*	130	
Pulau Kobroor*		1,700
Wayabula*		450
Sub totals	2,095	12,720
Other Areas	110	8,885

(*Sources:* IUCN, 1990 and WCMC *in litt.*)

* Area with moist forest within its boundary.
(ext) = extension

INDONESIA – Irian Jaya

National Parks		
Gunung Lorentz*		1,675
Mamberamo-Pegunungan Foja*		14,425
Nature Reserves		
Gunung Wagura-Kote*		150
Kumbe-Merauke*		1,268
Lorentz*	21,500	
Pegunungan Arfak*		450
Pegunungan Cyclops*	225	
Pegunungan Fak Fak*		510
Pegunungan Kumawa*		1,180
Pegunungan Tamrau Selatan*		2,479
Pegunungan Tamrau Utara*		2,657
Pegunungan Wandamen Wondiwoi*		795
Pegunungan Weyland*		2,230
Pulau Batanta Barat*	100	
Pulau Biak Utara*	110	
Pulau Misool*	840	
Pulau Salawati Utara*	570	
Pulau Superiori*	420	
Pulau Waigeo Barat*	1,530	
Pulau Yapen Tengah*	590	
Sungai Kais*		1,220
Teluk Bintuni*		4,500
Game Reserves		
Pegunungan Jayawijaya*	8,000	
Pulau Dolok*	6,000	
Danau Bian*		500
Sungai Rouffaer*		819
Teluk Cenderawasih*		825
Wasur*	3,040	
Recreation Parks		
Beriot*		124
Klamono*		100
Sub totals	42,925	35,907
Other Areas	3,102	1,338
GRAND TOTALS	*c.* 198,060	*c.* 218,459

References

Burgess, P. F. (1988) *Natural Forest Management for Sustainable Timber Production in the Asia/Pacific region.* Report to ITTO. 97 pp. Unpublished.

Collar, N. J. and Andrew, P. (1988) *Birds to Watch.* The ICBP world checklist of threatened birds. *Technical Publication* No. 8. International Council for Bird Preservation, Cambridge, UK. 303 pp.

Collins, N. M. and Morris, M. G. (1985) *Threatened Swallowtail Butterflies of the World. The IUCN Red Data Book.* IUCN, Cambridge, UK, and Gland, Switzerland. vii + 401 pp. + 8 pls.

Departamen Kehutanan (1985) *Draft Long-term Forestry Plan.* Jakarta, Indonesia.

FAO (1982) *National Conservation Plan for Indonesia.* 8 vols. FAO, Bogor, Indonesia. (1–Introduction; 2–Sumatra; 3–Java and Bali; 4–Lesser Sundas; 5–Kalimantan; 6–Sulawesi; 7–Maluku and Irian; 8–General topics.)

FAO (1987) *Special Study on Forest Management, Afforestation and Utilization of Forest Resources in the Development Regions. Asia-Pacific Region. Assessment of Forest Resources in Six Countries.* FAO, Bangkok, Thailand. 104 pp.

FAO (1988) *An Interim Report on the State of Forest Resources in the Developing Countries.* FAO, Rome, Italy. 18 pp + 15 tables.

FAO (1990) *FAO Yearbook of Forest Products 1977–88.* FAO Forestry Series No. 23. FAO Statistics Series No. 90. FAO, Rome.

FAO/UNEP (1981) *Tropical Forest Resources Assessment Project.* Vol 3 of 3 vols. FAO, Rome, Italy. 475 pp.

Gillis, M. (1988) Indonesia: Public Policies, Resource Management, and the Tropical Forest. In: *Public Policies and the Misuse of Forest Resources.* Repetto, R. and Gillis, M. (eds). World Resources Institute/Cambridge University Press, UK. 432 pp.

Hanson, A. J. and Koesoebiono (1977) *Settling Coastal Swamplands in Sumatra: A Casestudy for Integrated Resource Management.* Research report No. 4. Center for Natural Resource Management and Environmental Studies. Bogor Agricultural University, Indonesia.

IUCN (1983) *Global Status of Mangrove Ecosystems.* Commission on Ecology Papers No. 3. IUCN, Gland, Switzerland. 88 pp.

IUCN (1986) *Plants in Danger. What do we Know?* IUCN, Gland, Switzerland, and Cambridge, UK. 461 pp.

IUCN (1988) *1988 IUCN Red List of Threatened Animals.* IUCN, Gland, Switzerland, and Cambridge, UK. 154 pp.

IUCN (1990) *1989 United Nations List of National Parks and Protected Areas.* IUCN, Gland, and Cambridge, UK.

IUCN/UNEP (1986) *Review of the Protected Areas System in the Indo-Malayan Realm.* MacKinnon, J. and Mackinnon, K., consultants. IUCN, Gland, Switzerland, and Cambridge, UK. 284 pp. + maps section.

Koesoebiono, Collier, W. L. and Burbridge, P. R. (1982) Indonesia: resource use and management in the coastal zone. In: Soysa *et al.* (eds) *Man, Land and Sea* (1982), Bangkok. pp. 115–34.

Laumonier, Y., Purnadjaja and Setiabudhi (1986) *Sumatra* (Map in 3 sheets). Institut de la Carte Internationale du Tapis Végétal/ SEAMEO-BIOTROP.

MacKinnon, J. (1988) *Field Guide to the Birds of Java and Bali.* Gadjah Mada University Press, Yogyakarta. 390 pp.

Malingreau, J. P., Stephens, G. and Fellows, L. (1985) Remote Sensing of Forest Fires: Kalimantan and North Borneo in 1982–83. *Ambio* 14: 314–21.

Myers, N. (1989) *Deforestation Rates in Tropical Forests and their Climatic Implications.* Friends of the Earth, London, UK. 116 pp.

Petocz, R. G. and Raspado, G. (1984) *Conservation and Development in Irian Jaya: a Strategy for Rational Resources Utilisation.* WWF/IUCN Report. PHPA, Bogor, Indonesia.

Petocz, R. G. (1985) *Irian Jaya, the other side of New Guinea: Biological Resources and Rationale for a Comprehensive Protected Area Design.* Paper presented at the Third South Pacific National Parks and Reserves Conference and Ministerial Meeting. Apia, Western Samoa, 24 June–3 July, 1985. 11 pp + maps.

Repetto, R. (1988) *The Forest for the Trees? Government Policies and the Misuse of Forest Resources.* World Resources Institute, Washington, DC, USA.

RePPProT (1990) *National Overview of the Regional Physical Planning Programme for Transmigration.* Overseas Development Natural Resources Institute (ODNRI), Chatham, UK.

Salm, R. V. and Halim, M. (1984) *Marine and Coastal Protected Areas in Indonesia.* IUCN/WWF Report. WWF Indonesia Programme, Bogor, Indonesia.

Santiapillai, C. (1986) *The Status and Conservation of the Clouded Leopard* (Neofelis nebulosa diardi) *in Sumatra.* Report to WWF and IUCN. 13 pp.

Silvius, M. J., Steeman, A. P. J. M., Berczy, E. T., Djuharsa, E. and Taufik, A. W. (1987) *The Indonesian Wetland Inventory.* 2 vols. PHPA, AWB and EDWIN, Bogor, Indonesia.

Soemodihardjo, S. (1984) Impact of human activities on mangrove ecosystems in Indonesia: An overview. In: *Proceedings of the MAB/ COMAR Regional Seminar*, November 13–16, 1984, Tokyo, Japan, pp. 15–19.

Soemodihardjo, S. (1987) Indonesia. In: Umali R., Zamora, P. M., Gotoera, R. R., Jara, R. R. and Camacho, A. S. *Mangroves of Asia and the Pacific.* Ministry of National Resources, Manila. pp. 89–130.

Soegiarto, A. and Polunin, N. (1982) *The Marine Environment in Indonesia.* Report for the Government of the Republic of Indonesia sponsored by IUCN and WWF. University of Cambridge: Department of Zoology, UK.

White, C. M. N. and Bruce, M. D. (1986) *The Birds of Wallacea (Sulawesi, The Moluccas and Lesser Sunda Islands, Indonesia).* British Ornithologists' Union, London, UK. 524 pp.

Whitten, A. J. (1987) Indonesia's transmigration program and its role in the loss of tropical rain forests. *Conservation Biology* 1: 239–46.

Whitten, A. J., Damanik, S. J., Anwar, J. and Hisyam, N. (1984) *The Ecology of Sumatra.* Gadjah Mada University Press, Yogyakarta, Indonesia.

Whitten, A. J., Muslimin Mustafa and Henderson, G. S. (1987a) *The Ecology of Sulawesi.* Gadjah Mada University Press, Yogyakarta, Indonesia. 777 pp.

Whitten, A. J., Bishop, K. D., Nash, S. V. and Clayton, L. (1987b) One or more extinctions from Sulawesi, Indonesia? *Conservation Biology* 1: 42–8.

Whitmore, T. C. (1984a) A vegetation map of Malesia at scale 1:5 million. *Journal of Biogeography* 11: 461–71.

Whitmore, T. C. (1990) *An Introduction to Tropical Rain Forests.* Clarendon Press, Oxford, UK.

Authorship

Roger Cox in London, Mark Collins at WCMC, with contributions from Tony Whitten in Cambridge, Adam Messer in Bogor, D. Kretosastro of the Transmigration Department in Jakarta, John Makin in Chatham, UK, J. R. D. Wall in Jakarta, Genevieve Michon of BIOTROP in Bogor, Russell Betts and Charles Santiapillai of WWF in Jakarta, Sinung Rahardjo and Effendy Sumardja of the Forest Protection and Nature Conservation Department, Ministry of Forestry in Jakarta.

Maps 19.1–7 Forest cover in Indonesia

The Regional Physical Planning Programme for Transmigration (RePPProT) began work in 1984 in association with the National Centre for Coordination of Surveys and Mapping (BAKOSURTANAL). The programme has now completed a rapid reconnaissance of Indonesia using existing reports, air photographs and satellite or radar imagery with selective field checking. Reviews for each of the eight regions have been published with complete map coverage at 1:250,000 scale in three map themes: land systems and land suitability, land use and land status. A total of 693 thematic maps have been prepared.

Remote sensing imagery for Indonesia used in preparing the maps included air photography, Landsats 2, 3, 4 and 5, SPOT, and radar, including SAR and SLAR. Dates, scales and areas covered varied greatly and full details are available from BAKOSURTANAL and RePPProT's regional reviews.

The RePPProT team is now preparing a *National Overview of Land Resources of Indonesia for Physical Land Use Planning*, which will summarise the results from the eight regions. This *Overview* will include 32 compiled maps at scales of 1:2 million or 1:4 million showing geology, agro-climatic zones, hydrological zones, landforms, soils, land cover, land status, environmental hazards, population distribution and areas of potential development.

Data used in the preparation of the maps of Indonesia's forest cover and protected areas in this atlas were generously provided by the RePPProT team in the form of hand-coloured draft maps at 1:2.5 million scale. The legend included eight forest and eight non-forest categories. The forest categories were harmonised with the scheme used in this atlas in the following way (category in brackets is RePPProT title): lowland rain forest (lowland moist forest), inland swamp forest (swamp forest), mangrove (mangrove and other tidal forests), montane rain forest (submontane and montane forest). RePPProT appear to have taken 1000 m as the upper limit of lowland rain forest, over most of the region. Seasonal (monsoon) forests have been delineated from data published in Whitmore (1984a). .

In this atlas, forest logged but left to regenerate either with or without silvicultural treatment is not distinguished from pristine forest. Thus, in Indonesia the atlas does not distinguish separately the areas of recently logged forest which were identified by RePPProT. Areas which RePPProT showed as converted from forestry to other land uses are of course clearly identified.

Some notes on the origin and interpretation of Maps 19.1 to 19.7 are given below. In each case the date of origin of the bulk of the information is given in brackets (these being the publication dates of RePPProT's Regional Reviews), but since a wide variety of sources make up the whole series, it is important to refer to the original RePPProT regional reviews or BAKOSURTANAL itself if detailed information is needed.

Map 19.1: Sumatra (1988)

The RePPProT maps included no data for Singkil Barat or for the islands of Simeuluë, and Enggano, nor for the Riau and Lingga groups. Whitmore (1984a) shows some lowland rain forest on northern Simeuluë and central Singkilbaru, but none on Enggano, Riau and Lingga, which are believed to be largely deforested.

Map 19.2: Java and Lesser Sundas (1989)

The climate becomes increasingly seasonal from Java along the Lesser Sunda Islands. Remaining forests on Java are marked as rain forests since they are on mountain slopes and peaks, but much of the island was probably originally clothed in monsoon forest.

Map 19.3: Lesser Sundas (1989)

No data are available for the island of Roti. Whitmore (1984a) indicates some monsoon forest in the south-west of the island. No data are available for the Babar Islands between Tanimbar and Leti, nor for the southernmost island in the Tanimbar group. The latter is believed to be deforested, but Babar and Leti have some monsoon forest (Whitmore, 1984a).

Map 19.4: Kalimantan (Central, 1985; South, West and East, 1987)

The main point to note here is that substantial areas of forest in the southeast were killed or degraded by drought and fire in 1982–3. The area affected is indicated in Figure 19.2, but much is now believed to be regenerating. There are no data for the Anambas and Bunguran (Natuna) Islands in the South China Sea, but Whitmore (1984a) indicated small areas of lowland rain forest in the centres of the main islands.

Map 19.5: Sulawesi (1988)

The now deforested Talaud and Sangihe Islands have been omitted from this map to enable a larger scale to be used. No data are available for the southernmost Banggai Islands. Banggai itself is deforested, but Bangkulu and Labobo are believed to have small patches of lowland rain forest (Whitmore, 1984a).

Aopa swamp, in the southeast arm of Sulawesi, is the best known area of peatswamp forest on the island, forming part of a national park. It has been overlain onto the RePPProT data.

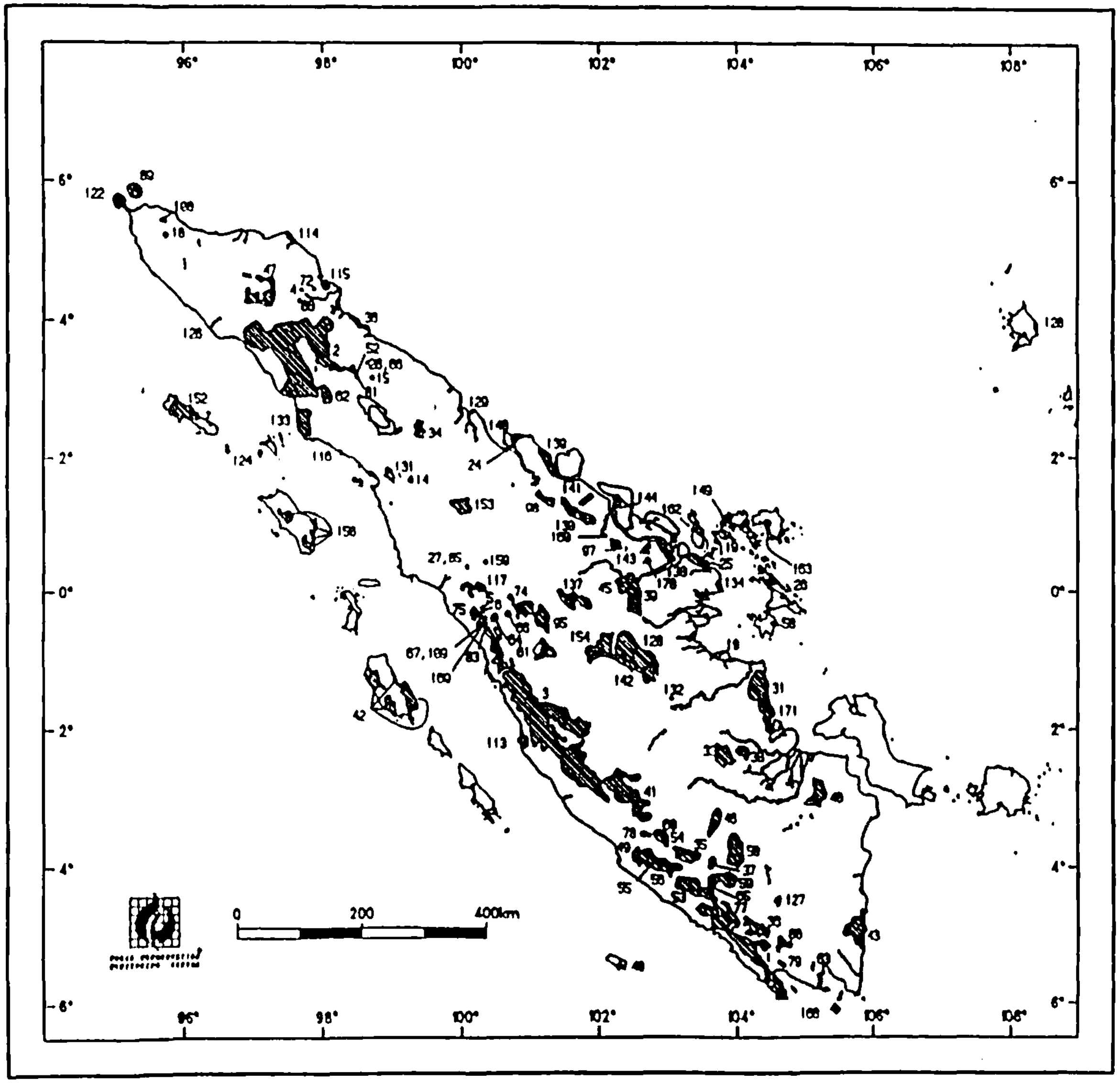
Map 19.6: Moluccas (1989)

See the note on Banggai Islands above. In Seram some areas marked by RePPProT as swamp forest are believed to be cultivated land and have been marked as such (after Whitmore 1984a). The island of Bacan is labelled as monsoon forest after Whitmore (1984a). Recent reports indicate that the island in fact bears rain forest (T. C. Whitmore, personal communication).

Map 19.7: Irian Jaya (1986)

Monsoon forest indicated in the southeastern corner of Irian Jaya by Whitmore (1984a) is adjudged by RePPProT to be open savanna woodland and is therefore labelled as non-forest on this map.

The editors are especially grateful to the Director General of Settlement Preparation, Ir. Djatijanto Kretosastro for use of data from the RePPProT project; to BAKOSURTANAL for their support; and to Dr David Wall, the RePPProT team leader, and his cartographers, for their cooperation in providing draft maps.


96°
98°
100°
102°
104°
106°
108°
6°
4°
2°
0°
2°
4°
6°
0
200
400km

INDONESIA – Sumatra

** Not yet legally gazetted
* Not mapped

National Parks**			
1. Barisan Selatan NP	II	365,000	1982
2. Gunung Leuser NP	II	792,675	1980
3. Kerinci Seblat NP	II	1,484,650	1981
43. Way Kambas NP	II	130,000	
Nature Reserves			
4. Aceh Rafflesia I/II Serbojadi NR	I	300	1936
5. Baringin Sati NR	I	1	1921
6. Batang Palupuh NR	I	3	1930
7. Batu Gajah NR*	I	1	1924
8. Batu Ginurit NR*	I	1	1934
3. Bukit Tapan NR	I	66,500	1978
9. Bungamaskikim NR*	I	1	1919
10. Cawang I/II*	I	1	1932
11. Despatah I/II*	I	1	1932
12. Dolok Saut NR	I	39	1924
13. Dolok Sibual Bual NR*	I	5,000	1982
14. Dolok Sipirok NR	I	6,970	1982
15. Dolok Tinggi Raya NR	I	167	1924
16. Dusun Besar NR*	I	441	1936
17. Gua Ulu Tiangko NR*	I	1	1919
3. Gunung Indrapura NR	I	70,000	1980
3. Indrapura NR	I	221,136	1929
18. Jantho NR	I	8,000	1984
19. Kelompok Hutan Bakau Timur Jambi NR	I	6,500	1981
20. Konak NR*	I	1	1932
168. Krakatau NR	I	2,500	1919
169. Lembah Anai NR	I	221	1922
21. Liang Balik NR*	I	1	1936
22. Manua NR*	I	1,500	
23. Pager Gunung I/II/III NR*	I	1	1932
24. Pulau Berkeh NR	I	500	1968
25. Pulau Burung NR	I	200	1968
26. Pulau Laut NR	I	400	1968
27. Rimbo Panti NR	I	2,830	1934
28. Sibolangit NR	I	90	1934
29. Toba Pananjung NR*	I	1,235	1932
Game Reserves			
30. Bentayan GR*	IV	19,300	1981
31. Berbak GR	IV	175,000	1935
3. Bukit Gedang Seblat GR	IV	48,750	1981
3. Bukit Kayu Embun GR	IV	106,000	1980
32. Danau Pulau Besar/Danau GR*	IV	25,000	1980
33. Dangku GR	IV	29,080	1981
34. Dolok Surungan GR	IV	23,800	1974
35. Gumai Pasemah GR	IV	45,883	1976
36. Gunung Raya GR	IV	39,500	1978
37. Isau-Isau Pasemah GR	IV	12,144	1978
2. Kappi GR	IV	8,000	1976
138. Karang Gading & Langkat Timur Laut GR	IV	15,765	1980
39. Kerumutan GR	IV	120,000	1979
2. Kluet GR	IV	23,425	1936
40. Padang Sugihan GR	IV	75,000	1983

3. Rawas Ulu Lakitan GR	IV	213,437	1979
2. Sekundur and Langkat GR	IV	218,440	1939
1. Sumatera Selatan GR	IV	356,800	1935
42. Tai-tai Batti GR	IV	56,500	1976
43. Way Kambas GR	IV	130,000	1937
<u>Marine Parks</u>			
44. Pulau Weh MP*	IV	2,600	1982
<u>Forest Parks</u>			
45. Dr. Moch. Hatta Grand FoP*	V	70,000	1986
<u>Hunting Reserves</u>			
46. Benakat HR	VI	30,000	1980
47. Lingga Isaq HR	VI	80,000	1978
48. Nanuua HR	VI	10,000	1978
49. Semidang Bukit Kabu HR	VI	15,300	1973
50. Subanjeriji HR	VI	65,000	1980
<u>Protected Forests</u>			
3. Bajang Air Tarusan PFo	VI	81,865	
52. Bandar Baru PFo	VI	250	
3. Batang Marangin Barat/Menjuta Hulu PFo	VI	64,600	1926
3. Batang Marangin Timur PFo	VI		1926
30. Bentayan PFo	VI	19,300	1981
53. Bukit Balairejang PFo	VI	16,700	1926
54. Bukit Balal PFo	VI	13,583	1926
55. Bukit Dingin/Gunung Dempo PFo	VI	38,050	1926
56. Bukit Hitam/Sanggul/Dingin PFo	VI	69,395	1932
57. Bukit Kaba PFo*	VI	13,490	1926
58. Bukit Mancung dan Sei Gemuruh PFo	VI	1,500	
59. Bukit Nantiogan Hulu/Nanti Komerung Hulu PFo	VI	36,200	1936
60. Bukit Raja Mandara/Kaur (North) PFo	VI	77,180	1935
3. Bukit Reges/Hulu Sulup PFo	VI	41,060	1926
61. Bukit Sebelah & Batang Pangean PFo*	VI	22,803	
62. Dolok Sembelin PFo	VI	33,910	
63. Gunung Betung PFo	VI	22,244	
64. Gunung Merapi PFo	VI	9,670	
65. Gunung Patah/Bepagut/Muara Duakisim PFo	VI	91,655	1936
66. Gunung Sago/Malintang/Karas PFo	VI	5,486	
67. Gunung Singgalang PFo	VI	9,658	
3. Gunung Sumbing/Masurai PFo	VI	300,000	
68. Gurah Serbolangit PFo*	VI	9,297	
69. Hulu Bintuanan Complex PFo*	VI	76,745	1939
70. Hutan Sinlah PFo*	VI	81,000	
3. Kambang/Batanghari I/Bayang	VI	100,000	
71. Krui Utara/Bukit Punggur PFo*	VI	34,861	
72. Langsa Kemuning PFo	VI	2,000	
73. Lembah Anai (Extension) PFo*	VI	96,002	1922
74. Lembah Harau PFo	VI	23,467	1933
75. Maninjau (North and South) PFo	VI	22,106	1920
76. Merangin Barat dan Nunjuta Ulu PFo*	VI	64,600	1926
77. Paraduan Gistana & Surroundings PFo	VI	70,000	1936
78. Punguk Bingin PFo	VI	2,400	
3. Sangir Ulu /Batang Tebo/Batang Tabir PFo	VI	61,200	1926
79. Tanggamus PFo	VI	15,660	1941
80. Tangkitebak/Kota Agung Utara/Way Waya PFo	VI	140,600	1941

Recreation Parks			
81. Lau Debuk-Debuk RP	V	7	1980
82. Lembah Harau RP*	V	28	1979
83. Mega Mendung RP	V	13	1974
84. Pulau Weh RP*	V	1,300	1982
85. Rimbo Panti RP	V	570	1979
86. Sibolangit RP	V	25	1980
Biosphere Reserves			
2. Gunung Leuser National Park	IX	946,400	1981
42. Siberut (Tai-tai Batti) Game Reserve	IX	56,500	1981
Proposed National Parks			
31. Berbak NP	PRO	(100,000)	
87. Siak Dua NP	PRO	(100,000)	
42. Siberut NP	PRO	(56,000)	
Proposed Nature Reserves			
88. Alur Melidi NR	PRO	(250)	
89. Aneuk Laut NR	PRO	(1,000)	
51. Bajang Air Tarusan (Utara) NR*	PRO	(81,865)	
52. Bandar Baru Sibayak NR*	PRO	(250)	
90. Bukit Balai NR*	PRO	(13,585)	
91. Bukit Gabah NR*	PRO	(4,200)	
92. Bukit Jambul NR*	PRO	(2,151)	
58. Bukit Mancung /Sei Gemuruh NR*	PRO	(1,500)	
93. Bukit Nanti Komering Ulu*	PRO	(22,483)	
94. Bukit Rancing NR*	PRO	(8,640)	
95. Bukit Rimbang/Baling-baling NR	PRO	(136,000)	
96. Bukit Sabarung Komering NR*	PRO	(1,523)	
61. Bukit Sebelah & Batang Pangean NR	PRO	(32,803)	
97. Danau Bawah dan Pulau Besar NR	PRO	(25,000)	
3. Danau Gunung Tujuh NR	PRO	(6,200)	
62. Dolok Sembelin NR	PRO	(33,910)	
98. Giam Duri NR	PRO	(40,000)	
99. Gunung Batan NR*	PRO	(3,430)	
100. Gunung Dempo Utara dan Selatan NR*	PRO	(3,750)	
101. Gunung Duren NR*	PRO	(14,900)	
102. Gunung Kubing NR*	PRO	(3,480)	
103. Gunung Manumbing NR*	PRO	(1,150)	
104. Gunung Maras NR*	PRO	(12,950)	
105. Gunung Parimisan NR*	PRO	(3,095)	
106. Gunung Raja Basa NR*	PRO	(5,000)	
107. Gunung Ratah NR*	PRO	(13,583)	
66. Gunung Sago/Malintang NR	PRO	(5,486)	
108. Gunung Salawah Agam NR*	PRO	(6,000)	
109. Gunung Singgalang NR	PRO	(9,658)	
110. Gunung Sulasih Talang NR*	PRO	(6,150)	
111. Gunung Tayam NR*	PRO	(3,350)	
112. Kalianda NR*	PRO	(1,000)	
3. Kambang/Batanghari I/ Bayang NR	PRO	(100,000)	
113. Kompleks Hutan Lunang NR	PRO	(17,700)	
114. Kuala Jambu Aye/Air NR	PRO	(3,000)	
115. Kuala Langsa NR	PRO	(7,000)	
72. Langsa Kemuning NR	PRO	(1,000)	
116. Laut Tapus NR*	PRO	(8,000)	
73. Lembah Anai (Extension) NR	PRO	(96,002)	

117. Malampah Alahan Panjang NR	PRO	(36,919)
75. Maninjau (North and South) NR	PRO	(22,106)
118. Mere Kakau NR*	PRO	(10,950)
42. Muara Siberut NR	PRO	(12,000)
119. Muara Sungai Guntung NR	PRO	(26,000)
120. Natuna Besar NR	PRO	(6,000)
121. Pantai Seluma NR*	PRO	
122. Perairan Pulau Weh & P. Beras NR	PRO	
123. Pulau Barut dan Pulau Terang NR*	PRO	
124. Pulau Bengkaru NR	PRO	(400)
125. Pulau Jemur NR*	PRO	
78. Punguk Bingin*	PRO	(5,400)
126. Rantau Pala Gajah NR	PRO	(1,600)
127. Rebang NR	PRO	(13,500)
128. Seberida NR	PRO	(120,000)
129. Sei Prapat Simandulang NR	PRO	(2,900)
130. Siak Kecil NR	PRO	(35,000)
131. Sibolga NR	PRO	(20,100)
132. Singkati Kehidupan NR	PRO	(5,000)
133. Singkil Barat NR	PRO	(65,000)
134. Tanjung Datuk NR	PRO	(28,800)
135. Pantai Krueng Raya MR*	PRO	
136. Pulau Breuh MR*	PRO	

<u>Proposed Game Reserve</u>

137. Air Sawan GR	PRO	(140,000)
138. Bakau Muara Kampar GR	PRO	(70,000)
139. Bakau Selat Dumai GR	PRO	(60,000)
140. Bukit Baka (Sumatra) GR	PRO	
141. Bukit Batu GR	PRO	(18,000)
142. Bukit Besar GR	PRO	(200,000)
143. Danau Belat/Besar Serkap GR	PRO	(10,000)
144. Danau Tanjung Padang GR	PRO	(2,500)
145. Kerumutan Lama GR	PRO	(55,000)
71. Krui Utara/Bukit Punggur GR*	PRO	(34,861)
146. Merangin dan Menjuto Ulu GR*	PRO	(80,815)
147. Perluasan Leuser (Bengkong) GR*	PRO	(70,320)
148. Pulau Alang Besar/ Sinebu GR	PRO	(15,000)
149. Pulau Bulan GR	PRO	(12,000)
150. Pulau Nias I/II/III/IV GR	PRO	(47,949)
151. Pulau Selat Dumai	PRO	(60,000)
152. Pulau Simeulue GR	PRO	(26,750)
3. Sangir Ulu /Batang Tebo/Batang Tahir GR	PRO	(189,050)
3. Sangir Ulu GR	PRO	(361,200)
170. Sarang Barung GR	PRO	
171. Sembilang GR	PRO	(180,000)
42. Siberut II (Perluasan)GR*	PRO	(107,303)

<u>Proposed Hunting Reserve</u>

153. Padang Lawas HR	PRO	(68,700)
154. Peranap HR	PRO	(120,000)
155. Pulau Bulan HR*	PRO	(12,000)

<u>Proposed Protection Forest</u>

3. Batang Bungo PFo	PRO	(80,000)
3. Bukit Gedang Seblat (Southern extension) PFo	PRO	(40,000110)
110. Gunung Sulasih Talang PFo*	PRO	(6,150)
157. Selawah Agam PFo*	PRO	(9,110) 1932

Proposed Recreation Park

158. Air Kelebat/Danau Tees RP*	PRO	(3,230)
57. Bukit Kaba RP*	PRO	(25,000)
159. Candi Muara Takus RP	PRO	(5)
160. Istana Sultan Siak RP	PRO	(5)
161. Komplek Hutan Way Curup RP*	PRO	(20)
162. Pulau Pasir Panjang RP	PRO	(10)
163. Pulau Penyengat RP	PRO	(10)
164. Pulau Tikus dan perairannya RP*	PRO	(300)

Proposed Category Unknown

165. Lunang	PRO	(17,500)
166. Muara Dua Kisam*	PRO	(91,665)
167. Sinlah*	PRO	(81,000)

ANNEX 1 Definitions of protected area designations, as legislated, together with authorities responsible for their administration

---

Title (English title):
Basic Forestry Act

Date: 1967

Brief description:
Provides for protection, management and exploitation of forest lands

Administrative authority:
Ministry of Forestry

Designations:

Hutan Produksi (Production forest)

- Forests which, because of their natural condition or their capacity, can give benefits in the form of timber and other forest products. The removal of forest products is regulated in such a way that it can be continued permanently.

Hutan Lindung (Protection forest)

- Forests whose natural condition is such that they exert a good influence upon soil, the surrounding environment and water control, and so must be maintained and protected. Among forests classified as protective forest, there are some from which, because of their natural condition, products can still be removed within certain limits, without detracting from/diminishing their protection.

NATURE SANCTUARY

Cagar Alam (Nature reserve)

- No management or human interference is permitted that changes the character of soil, flora or fauna in any way or affects its pristine condition. Access is for scientific purposes only and is subject to written permission of the Directorate of Forest Protection and Nature Conservation (PHPA) (MacKinnon, 1982).

Suaka Margasatwa (Game reserve)

- No activities are permitted that damage the flora, fauna or landscape or that could detract from the value of the reserve. Provision is made, however, for hunting in such an area, subject to written permission of the Minister of Forestry, and also for development of forest industries subject to a permit issued by the provincial governor for collection of forest produce, grazing of livestock and fishing (FAO, 1977; MacKinnon, 1982; Scott, 1989).

TOURIST FOREST

Taman Buru (Hunting park)

- Managed specifically for hunting and fishing (MacKinnon, 1982).

Taman Wisata (Recreation park)

- Maintained for outdoor recreation purposes (MacKinnon, 1982).

Title (English title):
Conservation of Living Resources and their Ecosystems Act

Date: August 1990

Brief description:

Concerned with the maintenance of biodiversity and ecosystem function in the context of the sustainable utilisation of living natural resources

Administrative authority:

Directorate General of Forest Protection and Nature Conservation (Director of Nature Conservation)

Designations:

NATURE SANCTUARY
- A specific terrestrial or aquatic area having protection as its main function to preserve biodiversity of plants and animals, as well as their ecosystems which also act as life support systems.

Cagar Alam (Nature reserve)
- A nature sanctuary which, because of its characteristic plants, animals and/or ecosystems, must be protected and allowed to develop naturally. Activities permitted are research and the development of science, education and other activities protecting breeding stock. Management shall be by the government in an effort to preserve the species diversity of plants and animals and their ecosystems.

Suaka Margasatwa (Game reserve)
- A nature sanctuary having high species diversity and/or unique animal species, in which the habitat may be managed, in order to assure the continued existence of these species. Management shall be implemented by the government in an effort to preserve the diversity of plant and animal species and their ecosystems.

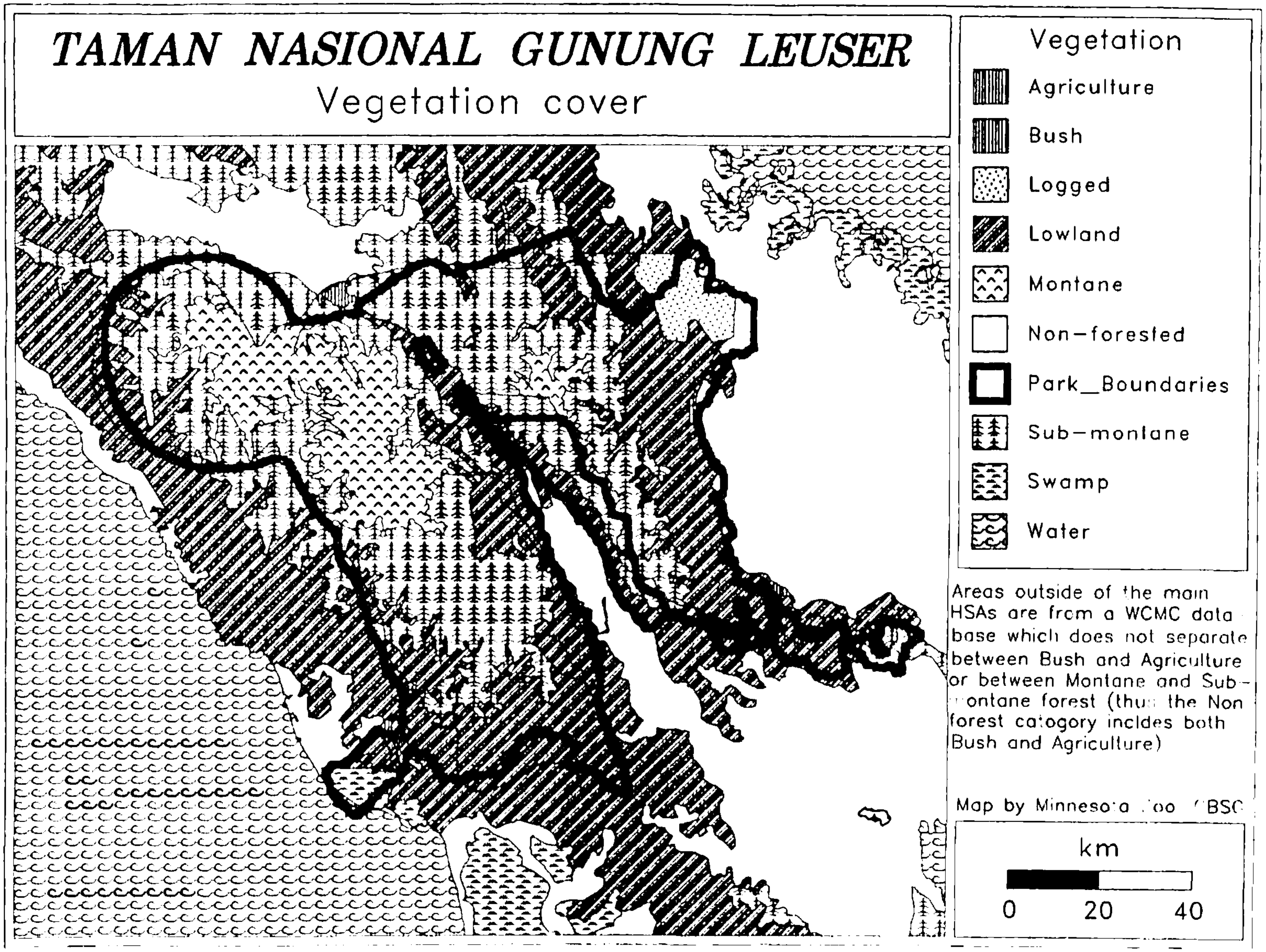
BIOSPHERE RESERVE
- An area of unique and/or degraded ecosystems, which need to be protected and conserved for their research and education value. Within the framework of international conservation and for those activities defined in Article 17, "sanctuary reserves" and other specified areas can be established as biosphere reserves.

KAWASAN PELESTARIAN ALAM (NATURE CONSERVATION AREA)
- A specific terrestrial or aquatic area where the main functions are to protect life support systems, to preserve diversity of plant and animal species, as well as to conserve living natural resources and their ecosystems for sustainable utilisation

Taman Nasional (National park)
- A nature conservation area which possesses natural ecosystems, and which is managed through a zoning system for research, science, education, supporting cultivation, recreation and tourism purposes

Taman Hutan Agung (Grand forest park)
- A nature conservation area created to provide a collection of indigenous and/or introduced plants and animals for research, science, education, support cultivation, culture, recreation and tourism purposes

Taman Wisata Alam (Nature recreation park)
- A nature conservation area mainly intended for recreation and tourism purposes


TAMAN NASIONAL GUNUNG LEUSER
Vegetation cover
Vegetation
Agriculture
Bush
Logged
Lowland
Montane
Non-forested
Park_Boundaries
Sub-montane
Swamp
Water
Areas outside of the main HSAs are from a WCMC data base which does not separate between Bush and Agriculture or between Montane and Sub-montane forest (thus the Non forest category inclides both Bush and Agriculture)
km
0
20
40

GUNUNG LEUSER NATIONAL PARK

Area: 586,500 ha
Elevation range: 0 - 3419 m
Status: Suaka Margasatwa/Taman Nasional
ZB No. 122/AGR 26-10-36
ZB No. 317/35 3-7-34
SK Mentan 697/Kpts/Um/12/1976
Location: Kabupatens Aceh Selatan, Aceh Tenggara, Aceh Timur

Description: Superb undisturbed forests from sea level to bare mountain peaks with wide range of habitat types on volcanic and limestones in wet and moist agriclimatic regions. The reserve contains the widest known range of animals and plants in Sumatra including many rare species such as elephants, rhinoceros, orangutan, tigers, serow, etc. The reserve is one of the most important in Southeast Asia with great potential for nature tourism, research, genetic resources conservation, species conservation and watercatchment protection.

Reasons for Protection:
- Protection of flora and fauna
- Hydrological protection forests
- Nature tourism and research

Threats:
- Logging pressures on adjacent lowland forests
- Agricultural encroachment and growing enclaves
- Hunting and collection of rattan

Recommendations: Retain as Taman Nasional. Revise western boundaries as per Management Plan and continue to try to add Bengkong extension.

References:
van Strien, N.J. 1978. Draft Proposed Gunung Leuser National Park Management Plan 1978/79 - 1982/83. lUCN/WWF Report of Project 1514.
Hoogerwerf, A. 1937. Verslag van een Reis door de Gajoe en Alas-Landen.
PPA. 1975. Laporan Survey Inventarisasi Suaka Alam Kluet.
IPB. 1976. Telaah Kemungkinan Pengembangan dan Pembinasn Taman Nasional Gunung Leuser Selama Pelita II. Bogor.
IPB. 1978. Preliminary Management Plan Taman Nasional Leuser.

GUNUNG LEUSER NATIONAL PARK

Table 1. Amount of protected and non-protected land under the grid.

	Amount of Forest (Km^2)	Amount of Non-forest
HSA	8511.3 km^2	354 km^2
Other HSA	3.6 km^2	0 km^2
Adjacent HL	2008.9 km^2	292.5 km^2
Other HL	3.4 km^2	175.8 km^2
Non-protected	1880.1 km^2	4317.3 km^2

Table 2. Vegetation cover within protected areas (HSA/HL).

A. HSA

Vegetation type	Total areas	Total Area
Montane	7	1461.04 km^2
Sub-montane	13	3613.69 km^2
Lowland	30	3412.53 km^2
Swamp	4	24.05 km^2
Bush	9	44.66 km^2
Agriculture	11	41.04 km^2
Logged	1	268.3 km^2

B. HL

Vegetation type	Area (km^2)
Sub-montane	820.1 km^2
Lowland	1188.8 km^2
Non-forest	292.5 km^2

... 1 0 1991

RHINO POACHING IN THE UPPER MAMAS VALLEY OF GUNUNG LEUSER NATIONAL PARK

By: Michael Griffiths

This report is based largely on the experiences and observations of the writer, who has spent almost one and a half years photographing for the WWF Indonesia Programme in the Upper Mamas area. Additional information was obtained from discussions with assistants of Nico van Strein, who worked on a rhino research project in the valley from 1975 through 1980. These assistants have subsequently made trips to the area, and their observations on poaching are incorporated here. Use also has been made of van Strein's monograph on "The Rhinos of Gunung Leuser National Park".

Rhino poaching in the upper Mamas began almost 40 years ago, so we really have no indication of what the original population in the area might have been. During the five years that van Strein was carrying out his research in the upper Mamas, rhino poaching was effectively eliminated. In the early 1980s, however, rhino poaching once again became rampant. Initially, poaching activities were concentrated around the salt springs in the southern headwaters, but as the rhinos there were hunted out, the poachers began moving downstream and trapping in areas around other salt licks. Intermittent poaching continued in the southern headwaters, however, particularly by armed hunters.

By the late 1980s, the rhino populations in the upper regions of the upper Mamas had been decimated, falling from an estimated twelve animals to about five.

At the same time, poachers began using a norther entrance route into the Upper Mamas valley, and for at least two years they were able to trap rhinos there without interruption. During that period, they effectively wiped out the best rhino population in the valley.

Around the beginning of 1990, the poachers moved upstream and to the west, and began to trap the last known unmolested group of rhinos in the Mamas. Four of their traps were discovered and triggered by the author's party, but at least one rhino was killed -- a female with a calf.

In addition to trapping, several groups of armed hunters have entered the valley with the intention of killing rhinos. At least three parties of armed hunters entered the valley in 1990.

When van Strein did his studies, there were an estimated 39 rhinos in the Upper Mamas. Today, there are only 13 at most. This is significant because it means the chances of the population building again are becoming increasingly remote. If the present rate of poaching goes unchecked, then we can expect to lose at least another three rhinos by the end of 1991 - almost 25 percent of the remaining population.

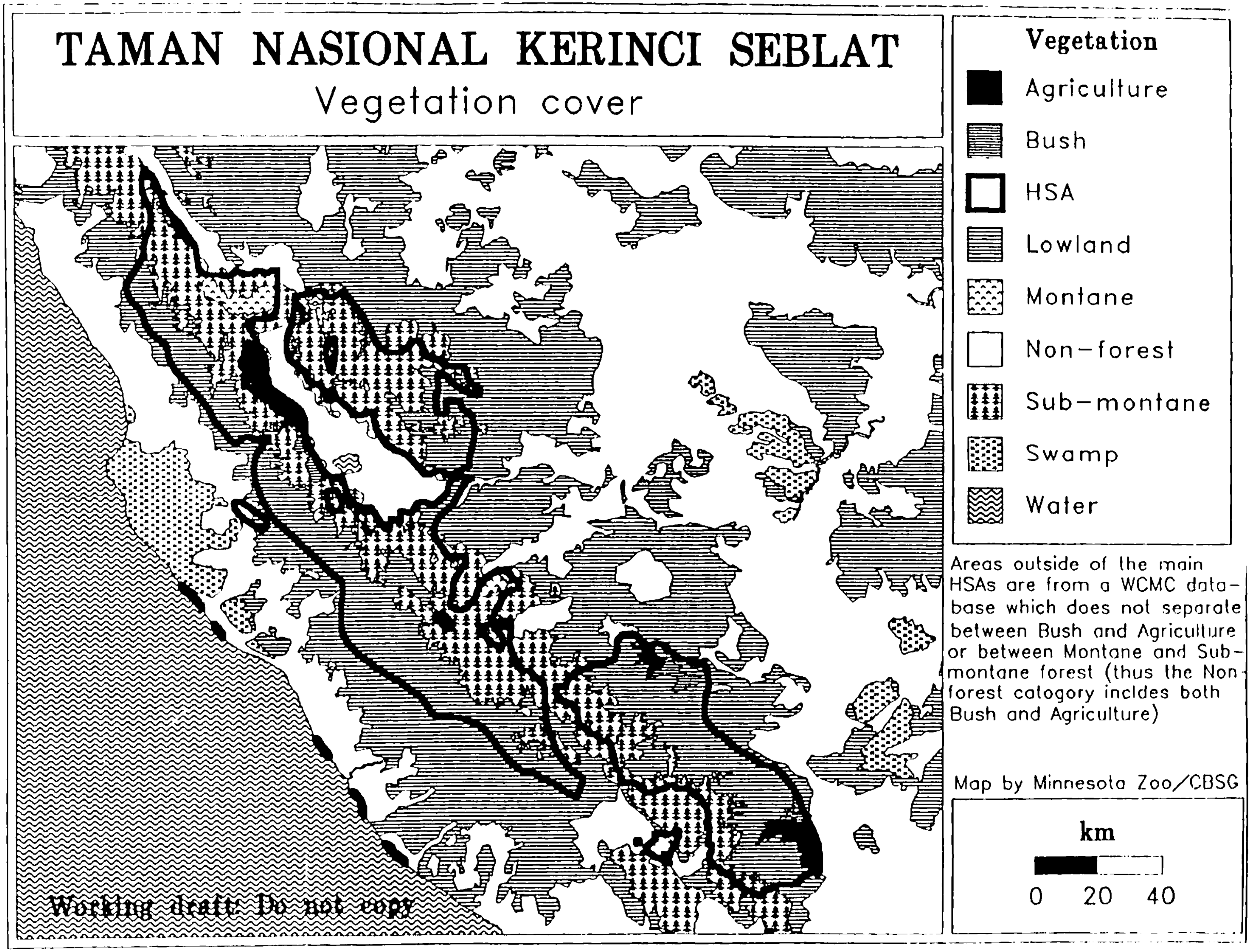
Conclusion

Very few people derive a living from hunting rhinos (perhaps six men in the west of the Alas). Therefore, it is not a significant social problem, but rather an ecological one. Armed hunters are not considered to be dependent on rhinos for making their living. In fact, they may represent a class rather better off than most.

If it is desired to stop rhino poaching, it is also necessary to catch the perpetrators of these acts. These man are a storehouse of information, and if poaching is merely suspected through a series of fear campaigns, then in time the poachers will return and carry on with their business. To be caught, there must be proof of their activities, and perhaps here a person's illegal presence in the valley would be proof enough, since there appears to be no other source of wealth (such as rotan, birds nests, or fish) other than rhinos that might attract people to the valley.

Careful monitoring of who enters and leaves the valley would ultimately bring dividends, but ideally evidence of man actively hunting in the valley would be more convincing.

Finally, if all the pawangs (master hunters) are known and their activities stopped, then in time the knowledge they have gained of both the land and the techniques of trapping will be lost. With no trained apprentices to carry on, this vicious cycle of death and ultimately extinction could be broken.


TAMAN NASIONAL KERINCI SEBLAT
Vegetation cover
Vegetation
Agriculture
Bush
HSA
Lowland
Montane
Non-forest
Sub-montane
Swamp
Water
Areas outside of the main HSAs are from a WCMC data-base which does not separate between Bush and Agriculture or between Montane and Sub-montane forest (thus the Non-forest catogory incldes both Bush and Agriculture)
Map by Minnesota Zoo/CBSG
km
0 20 40
Working draft: Do not copy

KERINCI-SEBLAT NATURE RESERVE (27)

Location: 1°30'-2'40'S, 101''00'-10''-50'E; part of the Bukit Barisan mountain chain. Sumatra Barat, Jambi, Bengkulu and Sumatra Selatan Provinces, Sumatra.
Area: Area of wetlands unknown; Nature Reserve 1,484,600 ha.
Altitude: 50-3,000m (including the highest peak in Sumatra).
Biogeographical Province: 4.21.12.
Wetland type: 11, 12, 14 & 22.

Description and site: The Kerinci-Seblat Nature Reserve is situated in the Bukit Barisan mountain range between Bengkulu and Padang. It incorporates the undisturbed forests in the main water catchment areas for the extensive settled region of southern Sumatra. The reserve includes some of the most outstanding scenery in Sumatra, including a 3,000m high volcano (Indrapura), numerous rivers, many lakes and extensive montane and lowland forests. It is characterized by alternating high massifs and alluvial plains, producing steep slopes with broad alluvial fans at their base. Many large rivers, including the Batang, Musi and Teba, have their headwaters in this region. The largest lake in the reserve is Kerinci Lake. This lies in a flat-bottomed valley at an elevation of 783m; it is about 9.5 km long by 6 km wide, and 110m deep. The lake lies within the Kerinci Enclave, a cultivated area of 140,000 ha inside the reserve. Gunung Tujuh Lake, a crater lake at 1,996m elevation, is one of the last undisturbed mountain lakes in Sumatra. It is approximately 1,000 ha in area and 8-40m deep. Other lakes include Danau Lamkat, Danau Sati, Danau Ladeh Panjang, Danau Dua, Danau Kecil, Danau Pauh and Danau Dipatjampat. Danau Bentu (Sangir Hulu), a high altitude forested bog, is of considerable botanical interest.

Climatic conditions: Humid tropical to temperate climate, depending on altitude. In the western part of the reserve, the rainfall reaches a peak in April and again in November. The average temperature in the lowlands is 28°C.

Principle vegetation: The main vegetation types within the reserve are lowland rain forest, sub-montane rain forest, montane rain forest, cloud forest, riverine forest, swamp forest and highland bog forest.

Land tenure: The site is state owned (PHPA); surrounding areas are owned by the local people and the Indonesian Government.

Conservation measures taken: The site has been afforded some protection since 1929, and was designated as a Nature Reserve (Cagar Alam) in 1980.

Conservation measures proposed: A proposal has been made to upgrade the reserve to the status of National Park; (Taman Nasional). A buffer zone management plan will be developed for the Kerinci Enclave.

Land use: Nature reserve; rice is cultivated in the Kerinci Enclave. There are numerous small settlements around the perimeter of the reserve.

Disturbances and threats: The most serious threat is continuing expansion of the Kerinci Enclave, as agricultural land encroaches further and further into the forest. There are seven other settlements with a total population of over 1,100 people within the area of the proposed National Park. Logging is a problem in the west coast lowlands, and the present levels of wardening and law enforcement are inadequate. The introduced aquatic weed *Eichhornia crassipes* has become a pest in Kerinci Lake.

Economic and social values: The reserve is of considerable geological, botanical and zoological interest and has considerable potential for outdoor recreation and tourism. It is extremely important for watershed protection, and constitutes an important gene pool, particularly for commercial timber species and rattans.

Fauna: No information is available on the fishes. The reserve supports an extremely rich avifauna, including six species of kingfishers (Alcedinidac), five species of hornbills (Bucerotidae), and several very rare species such as Salvadori's Pheasant *Lophura inornata* and the scops owl *Otus stresemanni* (known from only one specimen collected in this area). The reserve is, however, of only limited importance for waterfowl; species known to occur include *Egretta intermedia, Gallinula chloropus* and *Callinago gallinago.* The mammalian fauna is also very rich. The reserve contains probably the world's largest continuous population of the Asian Two-horned Rhinoceros *Dicerorhinus sumatrensis,* estimated at between 250 and 500 individuals. Other vulnerable or rare mammals include tiger, Asian elephant, tapir, clouded leopard, siamang, dark-handed gibbon and serow *(Panthera tigris, Elephas maximus, Tapirus indicus, Neofelis nebulosa, Symphalangus syndactlus, Hylobates agilis* and *Capricornis sumatrensis).* The Sumatran Hare *Nesolagus netscheri* (endemic to Sumatra) may have its last refuge in the reserve. Reptiles include *Varanus salvator, Python reticulatus* and *Dryophis prasinnus.* Frogs are common everywhere in the reserve.

Special floral values: The forested bog at Danau Bentu (Sangir Hulu) is claimed to be the highest forested marsh in western Indonesia. Unfortunately, much of the bog has been destroyed for rice cultivation during the last decade. The exceptionally rich flora of the Nature Reserve includes the world's largest flower, *Rafflesia arnoldi,* and the world's tallest flower, *Amorphophallus titanum.*

Research and facilities: Various brief faunal and floral surveys have been carried out in the Nature Reserve, e.g. by Frey-Wyssling in 1933, Jacobs in 1958, Borner in 1973, Meyer in 1977, and Ohsawa and Suharto in 1979. The reserve has been selected as a study area for a long term research programme under the "Tropenbos-programme", a joint effort between several Dutch research institutes and universities. The programme was scheduled to begin in 1987.

References:
Blouch, 1985; IUCN (in prep); MacKinnon and Artha, 1982a.

Criteria for inclusion: la, Ib, le, 2a, 2b.
Source: Marcel J. Silvius.

KERINCI-SEBLAT NATIONAL PARK

Table 1. Amount of protected and non-protected land under the grid.

	Amount of Forest (Km^2)	Amount of Non-forest
HSA	9160.1 km^2	784.9 km^2
Other HSA*	94.2 km^2	365.5 km^2
Adjacent HL	3005.7 km^2	461.2 km^2
Other HL	399.4 km^2	100.9 km^2
Non-protected	12446.5 km^2	14113.4 km^2

* This includes several areas along the coast and in the Northeastern corner of the grid which are not part of Kerinci-Seblat N.P.

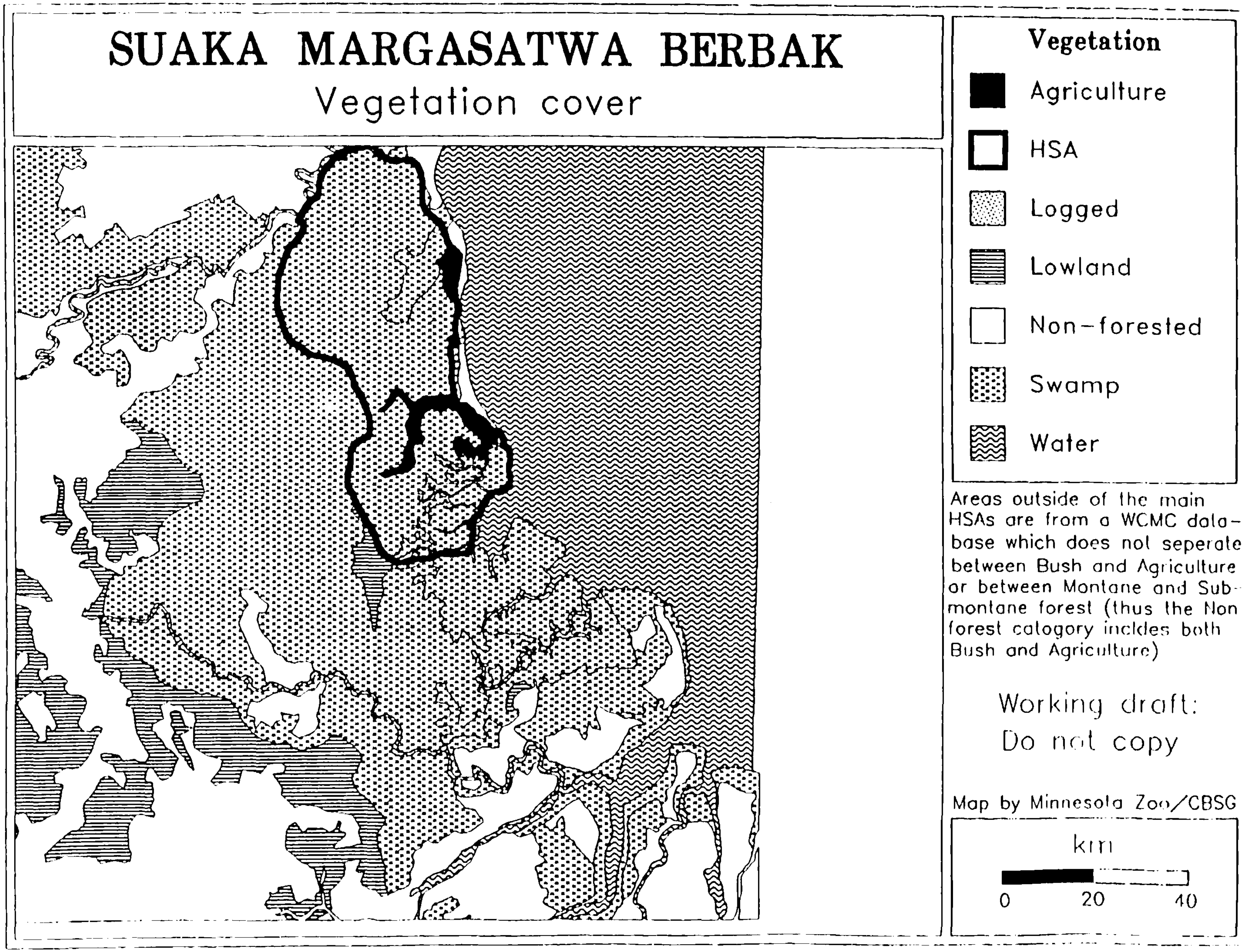
Table 2. Vegetation cover within the protected areas (HSA/HL).

A. HSA

Vegetation type	Total areas	Total Area
Montane	10	248.62
Sub-montane	8	4146.47
Lowland	17	4804.18
Bush	19	224.48
Agriculture	39	565.92
Logged	0	0
Water Bodies	1	10.09

B. Adjacent HL

Vegetation type	Area (km^2)
Sub-montane	869.6 km^2
Lowland	2136.1 km^2
Non-forest	461.2 km^2


SUAKA MARGASATWA BERBAK
Vegetation cover
Vegetation
Agriculture
HSA
Logged
Lowland
Non-forested
Swamp
Water
Areas outside of the main HSAs are from a WCMC data-base which does not seperate between Bush and Agriculture or between Montane and Sub-montane forest (thus the Non forest catogory inclдes both Bush and Agriculture)
Working draft: Do not copy
Map by Minnesota Zoo/CBSG
km
0
20
40

BERBAK GAME RESERVE

Area: 190,000 ha
Elevation range: Sea level - 20 m
Status: Suaka Margasatwa SK GB 29-10-1935 No.18 Stbl. 521
Location: Kabupaten Tanjung Jabung

Description: Berbak is a large coastal reserve consisting mostly of peat swamps and also in the more brackish areas mangrove forest. At present this reserve is the only protected area of peat swamp in Sumatra. Peat swamp is of great botanical interest as well as being of great forestry importance and it is extremely important that this habitat remains included within the reserve system. Mangrove forest too is rare, threatened and underrepresented in reserves and of high conservation value. Unfortunately parts of the reserve have been excised for a) timber concessions and b) rice production. It is vital that no further losses occur and desirable that compensatory extensions are made. A small extension at the northern end of the reserve has been proposed. In addition it may be possible to acquire an adjacent reserve in Sumatera Selatan province to the south. The reserve may still contain a small population of rhinoceros as well as tigers.

Reasons for Protection: Protection of excellent representative example of swamp forests and mangrove typical of east coast.

Threats:
- Illegal Bugis settlements altering drainage and clearing mangrove - Hunting and fishing
- Logging in reserve
- Upstream effluents flowing through rivers

Scoring:
Genetic value: 250
Socio-economic justifications: 13
Management viability: 10
Overall priority: 1

Recommendations: Prevent further incursion by coastal settlers. Mark clear boundaries around existing villages and develop reserve as per existing management plan.

References:

FAO. 1982. Berbak Game Reserve Management Plan FO/INS/78/061, Field Report 38, Bogor.
PPA, Bogor. 1976. Laporan Survey Areal Cadangan Suaka Alam/Xutan Wisata di Hutan Lindung Bukit Tapan dan Orientasi Lapangan di Hutan Bakau Berbak di Propinsi Jambi.
IPB, Bogor. 1976. Telaah Kemungkinan Pengembangan dan Pembinaan Suaka Margasatwa Berbak Selama Pelita II.

BERBAK GAME RESERVE

Table 1. Amount of protected and non-protected land under the grid.

	Amount of Forest (Km^2)	Amount of Non-forest
HSA	2256.8 km^2	191 km^2
Other HSA	97.3 km^2	23.3 km^2
HL*	1178.8 km^2	269.3 km^2
Non-protected	4114.2 km^2	2076.8 km^2

* This is weighted to forest because some water may be included in the amount of forest.

Table 2. Vegetation cover within protected areas (HSA/HL).

A. HSA

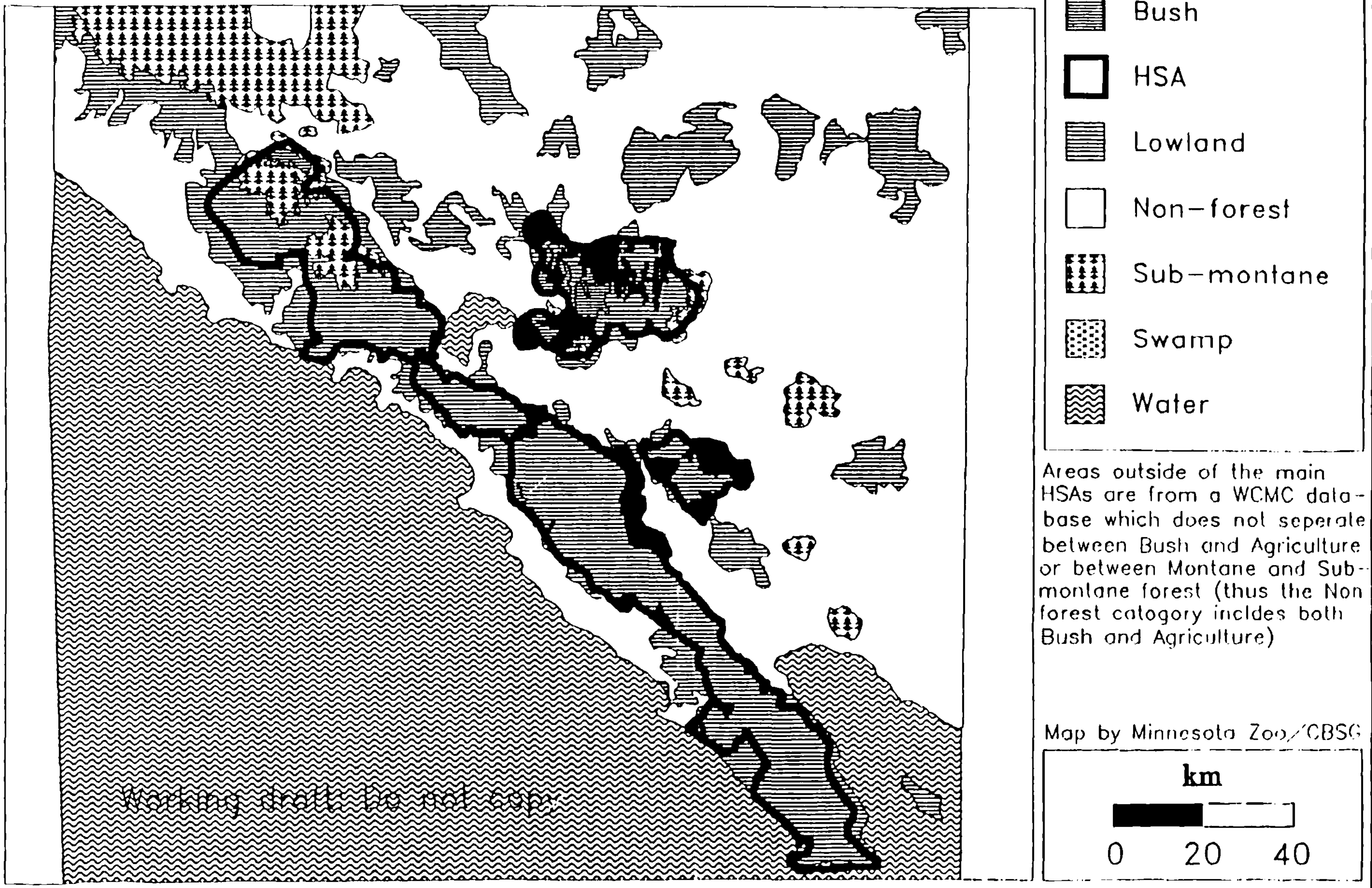
Vegetation type	Total areas	Total Area
Swamp	8	2256.8 km^2
Agriculture	7	186.4 km^2
Logged	1	4.6 km^2

B. HL

Vegetation type	Area (km^2)
Swamp	1178.8 km^2
Non-forest	269.3 km^2

SUAKA MARGASATWA BARISAN SELATAN

Vegetation cover



SUMATERA SELATAN I (PART)

Area: 66,000 ha of total 356,800 ha
Elevation range: 0 - 1811 m
Status: Suaka Margasatwa, SK GB 18-9-1935 No. 391, Proposed National Park
Location: Kabupaten Bengkulu Selatan

Description: This northern portion of the SS I reserve is the largest continuous forest block in the reserve, the most compact in shape, and the least disturbed by human activities and spreading of landangs. The area is rich in wildlife. Elephants are known to be present near Danau Ranau and rhinoceros are also thought to be present. Whilst the rest of SS I appears too heavily damaged and disturbed for consideration as a National Park, this northern portion does meet more of the criteria as a large tract of undisturbed wilderness. The Bengkulu portion of SS I comprises a full range of attitudinal types from sea level to about 1800 m and is certainly an area of high conservation interest.

Reasons for Protection:
- Hydrological protection forest
- Protection of flora and fauna
- Recreation potential

Recommendations: Retain this valuable reserve and manage together with the larger portion in Lampung province in accordance with FAO Management Plan under new name of Barisan Selatan.

Reference:
FAO. 1981. Proposed Kerinci-Seblat National Park, Management Plan 1982-1987, FO/INS/78/061, Field Report 14, Bogor.

SUMATERA SELATAN I (part)

Area: 290,800 ha of a total 356,800 ha
Elevation range: 0 - 1964 m
Status: Suaka Margasatwa, SK GB 18-9-1935 No. 391
Proposed National Park
Location: Kabupaten Lampung Selatan/Lampung Utara

Description: Sumatera Selatan I is the second largest reserve in Sumatra (after Gunung Leuser). It runs down the southern end of the Barisan range of mountains but these are not so high as further north and over 70% of the reserve is classified as lowland forest. Since this is based on rich volcanic strata and in the wettest part of the island, the forest is lush and diverse. The vegetation types include cover, some mangrove and Nypa forest, some swampy grassland, a small area of freshwater swamp forest, much hilly Dipterocarp forest and also montane elements.

Faunistically the reserve contains a very complete coverage of the southern Sumatran fauna. Elephants are not uncommon, a few rhino still occur, bears and tigers are present, wild dogs are common, deer and monkeys well represented, and the forests contain a long list of bird species, including several species of hornbill, argus pheasants, parrots, etc. Feral buffalo have established themselves in the reserve.

In addition the reserve has a long coastline which has a variety of coastal types including sandy, rocky, muddy and coral substrates. There are several turtle nesting areas along the south coast of the reserve.

Again despite the obvious importance of the reserve, it has been much abused in the past few years. Timber companies have operated within the reserve in four places. There are illegal settlements in several areas, boundary pressure by ladang clearance is very high everywhere, roads cut the long thin reserve into many fragments.

Reasons for Protection:
- Protection of large fauna and flora
- Hydrological protection forest
- High visitor potential

Threats:
- Logging
- Road construction
- Shifting agriculture
- Hunting

Recommendations: Follow tho revised FAO Management Plan for development.

References:
IPB, Bogor. 1976. Telaah Kemungkinan Pengembangan dan Pembinaan Taman Nasional Sumatera Seletan I Selama Pelita II. - FAO (1981). Barisan Selatan Game Reserve, Management Plan 1982-1987. FO/INS/78/061.
PPA, Bogor. 1979. Laporan Inventarisasi Flora dan Monitoring Ekosistcm di Suaki Alam Sumatera Selatan I.

BARISAN SELATAN NATIONAL PARK

Table 1. Amount of protected and non-protected land under the grid.

	Amount of Forest (Km^2)	Amount of Non-forest
HSA	3248.4 km^2	796.6 km^2
Adjacent HL	2873.4 km^2	3325.1 km^2
Other HL	17.3 km^2	211.3 km^2
Non-protected	2419.2 km^2	11845.5 km^2

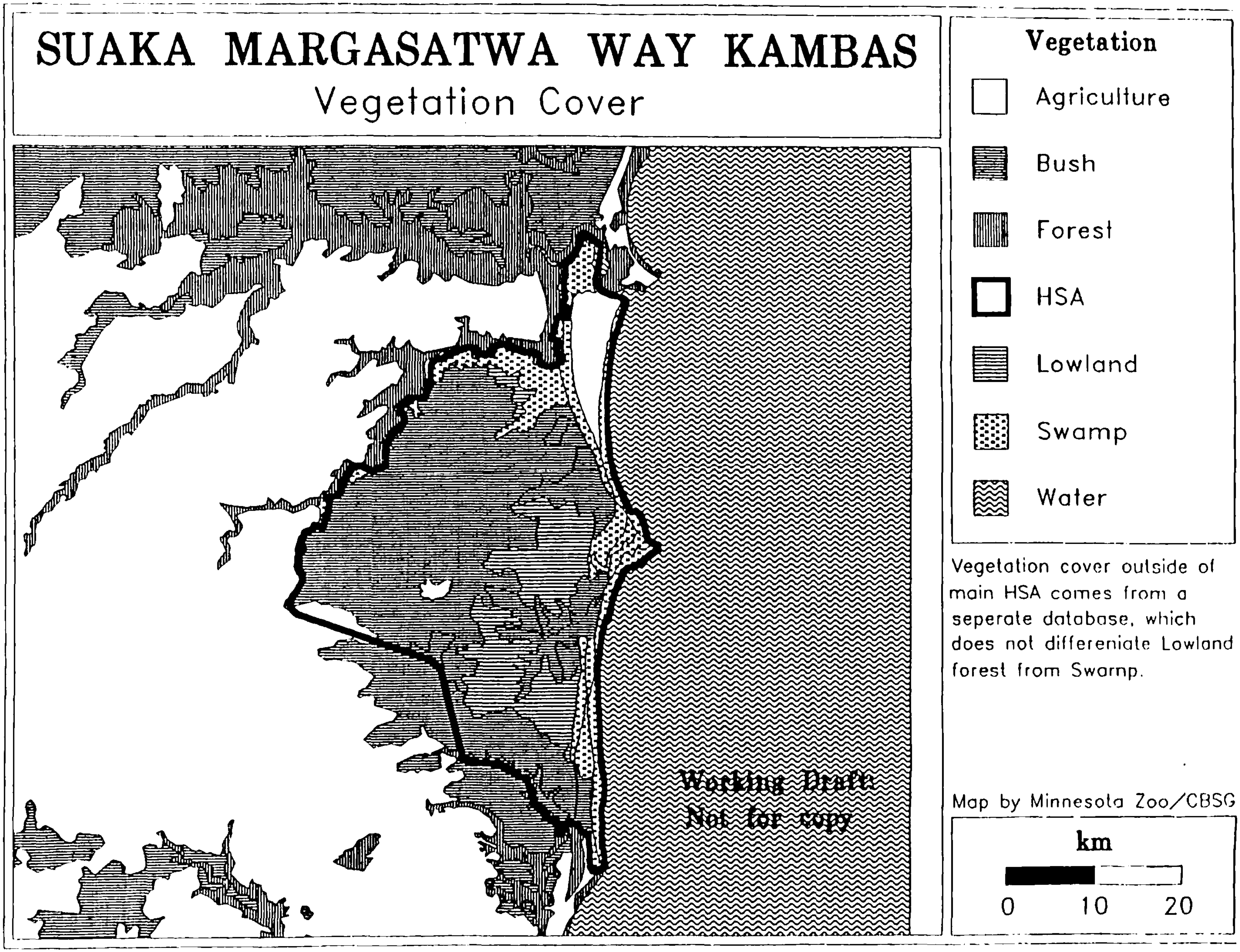
Table 2. Vegetation Cover within protected areas (HSA/HL).

A. HSA

Vegetation type	Total areas	Total Area
Sub-montane	7	308.3 km^2
Lowland	9	2924.3 km^2
Swamp	6	15.8 km^2
Bush	14	167.1 km^2
Agriculture	23	629.5 km^2

B. HL

Vegetation type	Area (km^2)
Sub-montane	1543.9 km^2
Lowland	1329.5 km^2
Non-forest	3325.1 km^2


SUAKA MARGASATWA WAY KAMBAS
Vegetation Cover
Vegetation
Agriculture
Bush
Forest
HSA
Lowland
Swamp
Water
Vegetation cover outside of main HSA comes from a seperate database, which does not differeniate Lowland forest from Swamp.
Working Draft: Not for copy
Map by Minnesota Zoo/CBSG
km
0
10
20

WAY KAMBAS GAME RESERVE

Area: 123,500 ha
Elevation range: 0 - 50 m
Status: Suaka Margasatwa, SK GB 26-1-1937 No.14 LN No. 38.
Location: Kabupaten Lampung Tengah

Description: Way Kambas is a large flat reserve on the east coast of Lampung, established in Dutch colonial times because of its great richness of wildlife including elephants, tapirs, tigers, sunbears, many deer, six species of monkeys, wild dog, crocodiles and ghavials and a wealth of bird species. About 200 species of birds have been recorded in the reserve including some rare and endangered species. Notable is the white-winged wood duck for which this reserve may now be the last known nesting site outside of Assam.

Botanically the area is of great interest as one of the few lowland areas of Dipterocarp forest included in a Sumatran reserve and the largest area of non-peat freshwater swamp in any reserve. The reserve also protects some good examples of accrediting coastal forests with mangrove swamps, Nypa beds, Casuarina forest, Barringtonia and Pandanus formations and swampy Nibung (Oonchosperma sp.)

Despite these obvious conservation values the reserve has been terribly damaged by the issuing of timber concessions inside the reserve heavy poaching and uncontrolled influx of spontaneous transmigrants. Over 75% of the reserve constituting all the dry forest has been selectively logged. Some areas so heavily logged that they have regressed into annually burnt grassland. Although official logging has ceased there are still large numbers of small scale operators removing logs by rafting them down the rivers to the coast. The Javan rhinos which were reported to occur in the area are certainly extinct now, there are very few records of tigers being seen in recent years, bears have become scarce and elephants greatly reduced. Many illegal settlements occur along the coast and particularly in the Way Penet area inside the reserve with a total of about ten thousand people living inside the reserve.

Despite this damage there are still elephants and abundant monkeys and tapirs. There are still some patches of forest which have only been lightly logged and could recover to some semblance of their original form.

Reasons for Protection: Protection of rare fauna and flora.

Threats:
- Logging
- Hunting
- Fires
- Agricultural encroachment

Recommendations: Despite the damage this area still merits very high conservation priority and efforts should be made to redress the disastrous pattern of exploitation of the last two decades and offer firm protection to this valuable area. The existing FAO Management Plan should be followed.

Reference: FAO. 1979. Way Kambas Management Plan 1980-1985. FO/INS/78/061, Field Report 5, Bogor.

WAY KAMBAS GAME RESERVE

Table 1. Amount of protected and non-protected land under the grid.

	Amount of Forest (Km^2)	Amount of Non-forest
HSA	435 km^2	873.9 km^2
HL	10.3 km^2	61.6 km^2
Non-protected	241.3 km^2	839.4 km^2

* This is only UNC totally enclosed by HSA or HL.

Table 2. Vegetation cover within protected areas.

A. HSA

Vegetation type	Total areas	Total Area
Lowland	3	197.19 km^2
Swamp	12	237.81 km^2
Bush	11	800.86 km^2
Agriculture	3	73.07 km^2

B. HL

Vegetation type	Area (km^2)
Forest	10.3 km^2
Agriculture	61.6 km^2

Lingga Isaq

Area: 80,000 ha
Elevation range: c.800 - 2823 m
Status: Taman Buru
Location: Kabupaten Aceh Tengah

Description: The forested hills are less lush than in Gunung Leuser and some natural pine occurs at higher altitudes. The area has excellent and varied scenery suitable for recreation purposes and good numbers of deer, pigs and small birds and mammals as well as some protected species such as elephant and tiger.

Reasons for Protection:
- Originally for hunting purposes
- Hydrological protection forest
- Protection of fauna and flora

Threats: Overhunting

Recommendations: The area is not really ideal for hunting, cannot be properly controlled as a Hunting Reserve and has valuable wildlife resources which should be protected from hunting. Recommend change of status from Taman Buru to Suaka Margasatwa. Develop modest visitor facilities.

References:

- PPA. 1980. Telaah Kemungkinan Pengembangan Taman Buru Lingga Isaq, Daerah Istimewa Aceh.
- PPA. 1981. Studi Blok Buru di Aceh.

Dolok Sembelin

Area: 33,910 ha
Elevation range: 150 - 1604 m
Status: Protection Forest/Proposed Cagar Alam
Location: Kabupaten Dairi

Description: Excellent forested hills on limestone with a wealth of wildlife and some important mineral caves and salt-licks used by elephants and other wildlife. Other protected species include orangutans, siamangs, gibbons, tigers, serows and formerly rhinoceros. The area contains hot water springs, beautiful waterfalls and mineral seeps that attract large numbers of butterflies including Trogonoptera brookiana.

Reasons for Protection:
- Hydrological protection forest
- Preservation of rare fauna and flora

Threats:
- Logging
- Ladangs

Recommendations: This superb area is probably of great important to the elephant populations of South Gn. Leuser and is also the site of former orangutan research. It should be given much better protection than currently and should be raised in status to Cagar Alam.

Reference:
MacKinnon, J. 1974. In search of the Red Ape. Collins, London.

Sibolga

Area: 20,100 ha
Elevation range: 200 - 1230 m
Status: Proposed Suaka Margasatwa
Location: Kabupaten Tapanuli Tengah

Description: Steep forested limestone hills of major importance as a water source for surrounding area but also having interesting wildlife including serow, gibbons, tiger, deer and pigs.

Reasons for Protection:
- Hydrological protection forest
- Preservation of endemic fauna and flora including several protected species

Threats:
- Cutting of firewood
- Hunting
- Peripheral ladang clearance

Recommendations: Survey for suitability as Suaka Margasatwa

Lembah Anai

Area: 96,002 ha
Elevation range: 600 - 1811 m
Status: Protection Forest/Proposed Cagar Alam
Location: Kabupatens Tanah Datar/Padang Pariaman

Description: Hilly protection forests on volcanic hills of Barisan Range. The area is not easily accessible. There are still tigers in the forests which also harbor several primate species and a wealth of birds.

Reasons for Protection:
- Hydrological protection forests
- Protection of flora and fauna

Threats: Hunting of tiger

Recommendation: Although of moderate conservation interest the area is currently not threatened and requires no management or development. It should remain as Hutan Lindung.

Lembah Harah

Area: 23,476 ha
Elevation ranges: 600 - 1256 m
Status: Protection Forest/Proposed Cagar Alam
Location: Kabupaten Limapuluh Kota

Description: Protection forests on the limestone hills along the provincial border with Riau. The forests are scenic of importance as water catchments and contain valuable protected wildlife such as tigers and serow.

Reasons for Protection: Hydrological protection forest.

Threats:
- Ladang encroachment
- Hunting
- Cutting of firewood and timber

Recommendations: Process area as Cagar Alam and combine with extension agar Alam Lembah Harah.

Reference:
PPA, Bogor. 1979. Studi Pengembangan/Rencana Pengelolaan 1980-1984 Cagar Alam dan Wisata Lembah Harah, Sumatera Barat.

D. Maninjau Utara/Selatan

Area : 22,106 ha
Elevation range: 600 - 1724 m
Status: Protection Forest/Proposed Cagar Alam
Location: Kabupatens Agam and Padang Pariaman

Description: Attractive forests on the hills surrounding the beautiful resort lake Danau Maninjau. Siamangs call from the forest over the lake and tigers are still reported to occur.

Reasons for Protection:
- Hydrological protection forests
- Aesthetic value
- Protection of flora and fauna

Threats: Few

Bukit Sebelah and Batang Pangean

Area: 22,803 ha
Elevation range: 600 - 1078 m
Status: Proposed Cagar Alam (Protection Forest)
Location: Kabupaten Sawahlunto

Description: Forested limestone hills on either side of the main road south from Muara and Sijunjung. The forests are rather disturbed with extensive ladang encroachment. Tall forests contain such species as Shorea, Litsea, Scorodocarpus and Koompassia. The forests have a varied wildlife with deer, monkeys, tigers, elephants and many birds.

Reasons for Protection: Hydrological protection forest.

Threats:
- Ladang encroachment
- Hunting
- Logging

Recommendations: The forest shape is so irregular that proper control as a reserve would be very difficult. The area does not score well enough to merit transfer from current status as Hutan Lindung.

Reference:
PPA, Bogor. 1979. Laporan Survey Areal Cadangan Suaka Alan/Hutan Wisata Bukit Sebelah dan Kuantan II (Propinsi Sumatera Barat).

Bajang Air Tarusan Utara

Area: 81,865 ha
Elevation range: 500 - 2000 m
Status: Protection Forest/Proposed Cagar Alam
Location: Kabupaten Padang Pariaman

Description: Hilly lowland and montane forests on volcanic soils with tall diverse forests and a wealth of wildlife including elephants and tigers, many primates and the very rare endemic Sumatran hare *Nesolagus netscheri*. The hills are a vital catchment area for the fertile Padang coastal plain.

Reasons for Protection:
- Hydrological protection forest
- Preservation of rare fauna and flora

Threats:
- Cutting of firewood and timber
- Hunting and trapping of wildlife (primates)
- Ladang encroachment in lowlands

Recommendations: Although of moderate conservation value the current status of Hutan Lindung is probably sufficient to protect this area. If the area continues to be damaged under this status it may eventually be necessary to upgrade it to Cagar Alam.

Kerumutan (Baru)

Area: 120,000 ha
Elevation range: c.20 m
Status: Cagar Alam, SK Mentan 350/Kpts/Um/6/79
Location: Kabupaten Kampar

Description: Extensive peat swamp forests with a small area of dry land forest. The district is rich in wildlife including elephant, tiger, tapirs, bears, gibbons, reptiles, birds, etc. The southern tip of the reserve is opened up with rice sawahs but otherwise the area is fairly undisturbed.

Reasons for Protection: Preservation of fauna and flora. This is the best representative example of inland lowland swamp forests in the province and richest in species due to proximity of dry land forests.

Threats:
- Agricultural expansion in reserve
- Hunting
- Logging potential

Recommendations: Retain as Cagar Alam and try to extend boundaries in the northwest to include the remaining forest in the old Kerumutan reserve (see area 10).

Reference:
PPA, Bogor. 1977. Laporan Penelaahan Areal Kemun-kinan Pengembangen Suaka Margasatwa Kerumutan di Kabupatcn Kampar, Propinsi Riau, Sumatera.

Danau Bawah dan P. Besar

Area: 25,000 ha
Elevation range: Sea level
Status: Cagar Alam
Location: Kabupaten Kampar

Description: The area is peat swamps with two lakes and an island in one of the lakes. The flora is an excellent example of the extensive Shorea and Ramin swamp forests with attractive setting and a rich wildlife including crocodiles, tigers, tapirs, primates and many birds.

Reason for Protection:
- Protection of flora and fauna
- Aesthetic interest

Threats:
- Land clearance for transmigration
- Logging

Recommendation: This is an attractive and interesting example of peat swamps and lakes, well worth keeping.

Reference:
PPA, Bogor. 1980. Laporan Survai Areal Cadangan Suaka Alam/Hutan Wisata Kelompok Hutan Bukit Kembang-Bukit Baling-Baling dan Kelompok Hutan Danau Pulau Besar Danau Bawah (Propinsi Daerah Tingkat I Riau).

Seberida

Area: 120,000 ha
Elevation range: 150-830 m
Status: Proposed Cagar Alam
Location: Kabupaten Indragiri Hulu

Description: Tall forested lowland hills and plains on the southern provincial boundary. The flora is extremely rich and there is also a diverse fauna including tiger, tapir, serow, elephant, crocodiles, primates and many birds. The area is partly encroached upon by ladangs and much of the area is planned for logging.

Reasons for Protection: Protection of flora and fauna.

Threats:
- Ladang encroachment
- Logging plans overlap

Recommendations: This area is very rich and of great conservation interest. Every effort should be made to get as much as possible of this forest block as a Cagar Alam. The original proposed area of only 15,000 ha is too small.

Reference:
PPA, Bogor. (1977). Laporan survai penjajagan wilayah Hutan Seberida di Kabupaten Indragiri Hulu, Propinsi Riau.

Bukit Baling Baling

Area: c.146,000 ha
Elevation range: 200 - 1090 m
Status: Proposed Cagar Alam
Location: Kabupaten Indragiri Hulu

Description: Some of the few hills in the province including some limestone. The original proposal includes large cultivated, occupied or disturbed forest. Only about half of this area is suitable for a reserve. The area contains tiger, tapir, serow, deer, siamangs, gibbons, monkeys and a rich bird fauna.

Reasons for Protection:
- Hydrological protection forest
- Preservation of fauna and flora

Threats:
- Ladang encroachment
- Hunting
- Logging

Recommendations: Much of this area would make a very interesting and valuable reserve. Recommend survey to find more suitable boundaries that exclude the human disturbance.

Reference:
PPA, Bogor. 1980. Laporan Survai Areal Cadangan Suaka Alam/Hutan Wisata Kelompok Hutan Bukit Kembang-Bukit Baling-Baling dan Kelompok Hutan Danau Pulau Besar Danau Sawah (Propinsi Daerah Tindkat I Riau).

Peranap

Area: c.120,000 ha
Elevation range: 120 - 492 m
Status: Proposed Taman Buru
Location: Kabupnten Indragiri Hulu

Description: Forested rolling plains at the southern border of the province of some agricultural potential, some forestry interest and unknown conservation importance. The area presumably harbors the usual lowland fauna including tigers, elephants, tapir, bears, primates and birds.

Reasons for Protection: Protection of flora and fauna.

Threats:
- Logging plans
- Shifting agriculture
- Hunting

Recommendation: The area is clearly of some conservation value but further survey is needed to determine whether these are enough to justify reserve status.

Siak Kecil

Area: c.100,000 ha
Elevation range: c.20 m
Status: Proposed Taman Buru/Suaka Margasatwa
Location: Kabupaten Bengkalis

Description: Very interesting system of small lakes used by false ghavial crocodiles Thomistoma schlegeli. Also good habitat for elephant, tiger, tapir and other wildlife and heavily used by water birds.

Reasons for Protection: Protection of breeding area of rare crocodile species. Protection of flora and fauna including endangered species such as tapir and elephant.

Threats:
- Logging
- Disturbance by oil exploration

Recommendations: This a very interesting area of lakes very important to the survival of false ghavial crocodiles elephants and also used by tigers. It would make an excellent swamp reserve and should be made larger than the original proposed of c.40,000 ha. It should be given Suaka Margasatwa status and not used for hunting.

Air Sawan

Area: c.140,000 ha
Elevation range: 100 - 176 m
Status: Proposed Suaka Margasatwa
Location: Kabupaten Indragiri Hulu

Description: A large almost undisturbed forested area on a belt of impoverished and agriculturally useless soil. The forest is slightly stunted and therefore of reduced timber interest but is botanically interesting and harbors valuable wildlife such as tiger, tapir, elephant and primates.

Reasons for Protection: Preservation of flora and fauna.

Recommendations: Because the area is of low use for agriculture or logging but has a high conservation value, its establishment as a reserve would seem tho most sensible land use. Recommend survey for suitable boundaries and process as Suaka Margasatwa.

Batang Merangin Barat/Menjuta Ulu

Area: 64,600 ha
Elevation range: 1000 - 1931 m
Status: Hutan Lindung SK GB 29-6-1926 No.44
Proposed Suaka Margasatwa
Location: Kabupatens Kerinci/Muara Bungo-Tebo

Description: This area to the south of Danau Kerinci is largely montane but does contain a small area of lowland forest. The proposed area has already been heavily encroached by agricultural clearing though about 30,000 ha of forest remain intact. The area is adjacent to the Bukit Tapan reserve and would also come within the boundaries of the proposed Kerinci National Park. The area is known to support rhinoceros, tapir and tiger, so is clearly valuable for conservation in its own right as well as being an important protection forest.

Reasons for Protection:
- Hydrological protection forest
- Protection of rare fauna including tigers, tapirs and rhinoceros

Threats:
- Agricultural encroachment
- Geothermal potential

Recommendations: Process as Suaka Margasatwa. Cultivated areas inside reserve should be marked and declared buffer zones. The reserve should be included in the proposed Kerinci-Seblat National Park as per existing Management Plan.

References:
FAO. 1981. Proposed Kerinci-Seblat National Park Management Plan 1982-1987. FO/INS/78/061 Field Report 14, Bogor.

Gumai Pasemah

Area: 45,883 ha
Elevation range: 200 - 1776 m
Status: Suaka Margasatwa, SK Mentan No.408/Kpts/Um/6/1976
Location: Kabupaten Lahat

Description: This old colonial protection forest was recently declared a reserve because of its floral, faunal and historic value. About half the reserve is montane but the lower slopes are still fairly well forested though encroached well within the reserve boundaries on the northern side. The area is reported to contain many interesting animal species including elephants, tiger, siamangs, serow, argus pheasants and hornbills. Of botanical interest are the Rafflesia flowers and of historical interest are some carved rocks and statues.

Reasons for Protection:
- Hydrological protection forest
- Protection of fauna and flora
- Aesthetic interest
- Historic sites

Threats:
- Shifting agriculture
- Hunting

Recommendations: Retain as Suaka Margasatwa but improve levels of protection and management.

Isau-Isau Pasemah

Area: 12,114 ha
Elevation range: 500 - 1431 m
Status: Suaka Margasatwa SK Mentan No. 69/Kpts/Um/2/1978
Location: Kabupaten Lahat/LIOT

Description: This is another recently declared reserve that was-formerly a protection forest. The area of the reserve is not large enough to contain such large animals as elephants but is nevertheless an interesting example of wet lowland rainforest and contains many interesting animals such as tigers, bears, tapir, serow, siamangs, argus pheasants and hornbills. The vegetation is dominated by Dipterocarpaceae, Fagaceae, and Lauraceae trees.

Reasons for Protection:
- Hydrological protection forest
- Protection of fauna and flora

Threats:
- Shifting agricultural encroachment
- Hunting
- Cutting of timber

Recommendations: Retain as Suaka Margasatwa and improve protection.

Gunung Raya

Area: 39,500 ha
Elevation range: 300 - 2232 m
Status: Suaka Margasatwa SK Mentan No.55/Kpts/Um/1/197
Location: Kabupaten Ogan Komering Ulu

Description: This area in the southernmost tip of the province again protects both montane and lowland rainforest. The reserve is bordered by agriculture on the western side but is bordered to the south and east by protection forests on the other side of the province boundary in Lampung and thus faces less pressure than other reserves in South Sumatra. The area is again dominated by Dipterocarpaceae, Fagaceae, Lauraceae and reported to contain many interesting orchids. Most of the characteristic fauna of Sumatra have been reported for the area including elephant, tapir, bears, serow, deer, siamang, argus pheasants and several species of hornbill.

Reasons for Protection:
- Hydrological protection forest
- Protection of flora and fauna

Threats: Agricultural encroachment on west side

Recommendations: Retain as Suaka Margasatwa.

Rawas Hulu Lakitan

Area: 213,437 ha
Elevation range: 300 - 2384 m
Status: Suaka Margasatwa SK Mentan No.424/Kpts/Um/7/1979
Location: Kabupaten Rawas Hulu

Description: This large area composed of two old protection forests was recently declared a reserve. The reserve contains a large portion of montane forest but over half of the reserve is lowland, making this a very important and valuable addition to the montane-dominated Sumatran reserve system. The reserve retains its important protection forest functions but is also the home for many endangered species including tigers, elephants and rhinoceros. The reserve forms the southern end of a large continuous block of reserves and protection forests around the valley of lake Kerinci and is planned eventually to be incorporated into a Kerinci National Park that will cover parts of four provinces.

Reasons for Protection:
- Hydrological protection forest
- Protection of rare fauna and flora including elephant, tiger and rhinoceros

Threats:
- Shifting agriculture
- Hunting
- Timber cutting
- Collection of rattan

Recommendations: Retain this superb reserve and include in the proposed Kerinci-Seblat National Park as per existing Management Plan.

References:
PPA, Bogor. 1976. Laporan Survey Reconnaissance Daerah Musi Rawas Ulu Lakitan dsk dan Bentayan Dangku dsk Propinsi Sumatera Selatan.
FAO. 1981. Proposed Kerinci-Seblat National Park Management Plan 1982-1987. FO/INS/78/061, Field Report 14, Bogor.

SUMATRAN RHINO

POPULATION AND HABITAT

VIABILITY ANALYSIS WORKSHOP

BRIEFING BOOK

SECTION 7: OVERVIEW OF VORTEX AND POPULATION AND HABITAT VIABILITY ANALYSIS

Captive Breeding Specialist Group

Species Survival Commission
IUCN -- The World Conservation Union
U. S. Seal, CBSG Chairman

POPULATION and HABITAT VIABILITY ANALYSIS WORKSHOPS

Objectives and Process

The PHVA workshop provides population viability assessments for each population of a species or subspecies as decided in arranging the workshop. The assessment for each species will undertake an in depth analysis of information on the life history, population dynamics, ecology, and population history of the individual populations. Information on the demography, genetics, and environmental factors pertinent to assessing the status of each population and its risk of extinction under current management scenarios and perceived threats will be assembled in preparation for the PHVA and for the individual populations before and during the workshop.

An important feature of the workshops is the elicitation of information from the experts that is not readily available in published form yet which may of decisive importance in understanding the behavior of the species in the wild. This information will provide the basis for constructing simulation models of each population which will in a single model evaluate the deterministic and stochastic effects and interactions of genetic, demographic, environmental, and catastrophic factors on the population dynamics and extinction risks. The process of formulating information to put into the models requires that assumptions and the data available to support the assumptions be made explicit. This process tends lead to consensus building on the biology of the species, as currently known, and usually leads to a basic simulation model for the species that can serve as for continuing discussion of management alternatives and adaptive management of the species or population as new information is obtained. It in effect provides a means for conducting management programs as scientific exercises with continuing evaluation of new information in a sufficiently timely manner to be of benefit to adjusting management practices.

These workshop exercises are able assist the formulation of management scenarios for the respective species and evaluate their possible effects on reducing the risks of extinction. It is also possible through sensitivity analyses to search for factors whose manipulation may have the greatest effect on the survival and growth of the population(s). One can in effect rapidly explore a wide range of values for the parameters in the model(s) to gain a picture of how the species might respond to changes in management. This approach may also be used to assist in evaluating the information contribution of proposed and ongoing research studies to the conservation management of the species.

12101 Johnny Cake Ridge Road, Apple Valley, MN 55124, USA tel. 612-431-9325 fax 612-432-2757
(home) 9801 Pillsbury Ave. S., Bloomington, MN 55420, USA tel. 612-888-7267 fax 612-888-5550

Information and Expertise

Short reviews and summaries of new information on topics of importance for conservation management and recovery of the individual populations are also prepared during the workshop. Of particular interest are topics addressing:

(1) factors likely to have operated in the decline of the species or its failure to recover with management and whether they are still important,

(2) the need for molecular taxonomic, genetic heterozygosity, site specific adaptations, and the effects of seed banks on the rate of loss of heterozygosity,

(3) the role of disease, predation, and competition in the dynamics of the wild population, in potential reintroductions or translocations, and in the location and management of captive populations,

(4) the possible role of inbreeding in the dynamics and management of the captive and wild population(s),

(5) the potential uses of reproductive technology for the conservation of the species whether through genome banking or transfer of genetic material between subpopulations,

(6) techniques for monitoring the status of the population during the management manipulations to allow their evaluation and modification as new information is developed,

(7) the possible need for metapopulation management for long term survival of the species,

(8) formulation of quantitative genetic and demographic population goals for recovery of the species and what level of management will be needed to achieve and maintain those goals,

(9) cost estimates for each of the activities suggested for furthering conservation management of the species.

Preparation and Documentation Needs

Information to be included in briefing book:

1. Bibliography - preferably complete as possible and either on disk or in clean copy that we can scan into a computer file.

2. Taxonomic description and most recent article(s) with information on systematic status including status as a species, possible subspecies, and any geographically isolated populations.

3. Molecular genetic articles and manuscripts including systematics, heterozygosity evaluation, parentage studies, and population structure.

4. Description of distribution with numbers (even crude estimates) with dates of information, maps (1:250,000 or better if needed) with latitude and longitude coordinates.

5. Protection status and protected areas with their population estimates. Location on maps. Description of present and projected threats and rates of change. For example, growth rate (demographic analysis) of local human populations and numerical estimates their use of resources (development plans) from the habitat.

6. Field studies - both published and unpublished agency and organization reports (with dates of the field work). Habitat requirements, habitat status, projected changes in habitat. Information on reproduction, mortality (from all causes), census, and distribution particularly valuable. Is the species subject to controlled or uncontrolled exploitation? Collecting?

7. Life history information - particularly that useful for the modelling. Includes: size - stage information, stage transitions, age of first reproduction, mean seed production and germination rates, occurrence and survival of seed banks, life expectancy, stage mortalities, adult mortality, dispersal, and seasonality of reproduction.

8. Published or draft Recovery Plans (National or regional) for the wild population(s). Special studies on habitat, reasons for decline, environmental fluctuations that affect reproduction and mortality, and possible catastrophic events.

9. Management masterplans for the captive population and any genome banks.

11. Color pictures (slides okay) of species in wild - suitable for use as cover of briefing book and final PVA document.

Plans for the Meeting:

1. Dates and location. Who will organize the meeting place and take care of local arrangements? Should provide living quarters and food for the 3 days in a location that minimizes outside distractions. Plan for meeting and working rooms to be available for the evening as well as the day. Three full days and evenings are needed for the workshop with arrival the day before and departure on the 4th day.

2. Average number of participants about 30 usually with a core group of about 15 responsible for making presentations. Observers (up to 20) welcome if facilities available but their arrangements should be their own responsibility. Essential that all with an interest in the species be informed of the meeting. Participants to include: (1) all of the biologists with information on the species in the wild should be invited and expected to present their data, (2) policy level managers in the agencies with management responsibility, (3) NGOs that have participated in conservation efforts, (4) education and PR people for local programs, (5) botanical garden or herbarium biologists with knowledge of the species, (6) experts in plant population biology and needed areas of biological expertise and (7) local scientists with an interest in the species.

3. Preparation of briefing document.

4. Funding (cost analysis available) - primarily for travel and per diem during the meeting, preparation of briefing document and the PVA report, and some personnel costs. CBSG costs are for preparation of the documents, completion of the modelling and report after the meeting, travel of 3-4 people, and their per diem. We estimate that each PHVA Workshop costs CBSG $10,000 to $15,000 depending upon the amount of work required in preparation and after the workshop to complete the report.

5. Preparation of agenda and securing of commitments to participate, supply information, and make presentations needs to have one person responsible and to keep in close contact with CBSG office on preparations.

6. Meeting facilities need to include meeting room for group, break away areas, blackboard, slide projector, overhead projector, electrical outlets for 3+ computers, printer (parallel port IBM compatible), and photocopying to produce about 200-500 copies per day. Have food brought in for lunches. Allow for working groups to meet at night.

SSC MISSION

To preserve biological diversity by developing and executing programs to save, restore and wisely manage species and their habitats.

PHVA WORKSHOPS

Guidelines

Every idea or plan or belief about the Species can be examined and discussed

Everyone participates & no one dominates

Set aside (temporarily) all special agendas except saving the Species

Assume good intent

Yes and ...

Stick to our schedule ... begin and end promptly

Primary work will be conducted in sub-groups

Facilitator can call 'timeout'

Agreements on recommendations by consensus

Plan to complete and review draft report by end of meeting

Adjust our process and schedule as needed to achieve our goals

POPULATION AND HABITAT VIABILTY ASSESSMENT

_ CBSG/SSC/IUCN thanks the 'Host Agency' for the invitation to participate in this Workshop on the conservation of the 'SPECIES'.

- SSC MISSION: To preserve biological diversity by developing and executing programs to save, restore and wisely manage species and their habitats.

- Captive Breeding Specialist Group (CBSG) works as a part of the IUCN Species Survival Commission (SSC) to assist rescue of species.

- CBSG has conducted **Population and Habitat Viability Assessment** (PHVA) workshops for >50 species in 22 countries at the request of host countries.

- **Values of the Workshops** are in:

  * bringing together all groups responsible for the saving and management of the species to build a consensus on actions needed for the recovery of the species;

  * bringing together experts whose knowledge may assist rescue of the species;

  * assembling current information on status of the species and the threats to its survival;

  * providing an objective assessment of the risk of extinction of the species based upon current information;

  * using simulation models to test alternative management actions for rescue of the species and its recovery;

  * producing an objective report which can be used as a basis for the policy and implementation actions that are needed to save the species.

- These Workshops have helped chart a course for saving of many species; we hope that this Workshop will be a help to our colleagues in their work to save the 'Species'.

PHVA DATA NEEDS

MAP OF POPULATION(S) DISTRIBUTION AND FRAGMENTATION

CENSUS AND CHANGES DURING PAST 10-50 YEARS

AVERAGE AGE OF FIRST REPRODUCTION (FEMALE & MALE)

OLDEST AGE (SENESCENCE)

MONOGAMOUS OR POLYGYNOUS

INBREEDING

CATASTROPHES & THREATS

ALL MALES IN BREEDING POOL?

MAXIMUM YOUNG PRODUCED PER YEAR

PROPORTION OF ADULT FEMALES REPRODUCING PER YEAR

PROPORTION OF YOUNG (LITTER/CLUTCH SIZES)

MORTALITY: 0 - 1
JUVENILES
ADULT

FREQUENCY & SEVERITY OF CATASTROPHES

STARTING POPULATION SIZE (AGE DISTRIBUTION IF KNOWN)

CARRYING CAPACITY AND PROJECTED CHANGES

HARVESTS

SUPPLEMENTATION

ANNUAL RATES AND STANDARD DEVIATIONS IF POSSIBLE

VORTEX

Simulation model of stochastic population change
Written by Robert Lacy
Chicago Zoological Park
Brookfield, IL 60513

Version 5.1, 13 April 1991

Stochastic simulation of population extinction

Life table analyses yield average long-term projections of population growth (or decline), but do not reveal the fluctuations in population size that would result from variability in demographic processes. When a population is small and isolated from other populations of conspecifics, these random fluctuations can lead to extinction even of populations that have, on average, positive population growth. The VORTEX program (earlier versions called SIMPOP and VORTICES) is a Monte Carlo simulation of demographic events in the history of a population. Some of the algorithms in VORTEX were taken from a simulation program, SPGPC, written in BASIC by James Grier of North Dakota State University (Grier 1980a, 1980b, Grier and Barclay 1988). Fluctuations in population size can result from any or all of several levels of stochastic (random) effects. Demographic variation results from the probabilistic nature of birth and death processes. Thus, even if the probability of an animal reproducing or dying is always constant, we expect that the actual proportion reproducing or dying within any time interval to vary according to a binomial distribution with mean equal to the probability of the event (p) and variance given by $Vp = p * (1 - p) / N$. Demographic variation is thus intrinsic to the population and occurs in the simulation because birth and death events are determined by a random process (with appropriate probabilities).

Environmental variation (EV) is the variation in the probabilities of reproduction and mortality that occur because of changes in the environment on an annual basis (or other timescales). Thus, EV impacts all individuals in the population simultaneously -- changing the probabilities (means of the above binomial distributions) of birth and death. The sources of EV are thus extrinsic to the population itself, due to weather, predator and prey populations, parasite loads, etc.

VORTEX models population processes as discrete, sequential events, with probabilistic outcomes determined by a pseudo-random number generator. 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, whether each adult female produces broods of size 0, or 1, or 2, or 3, or 4, or 5 during each year, and which of the two alleles at a genetic locus are transmitted from each parent to each offspring. Mortality and reproduction probabilities are sex-specific. Fecundity is assumed to be independent of age (after an animal reaches reproductive age). Mortality rates are specified for each pre-reproductive age class and for reproductive-age animals. The mating system can be specified to be either monogamous or polygynous. In either case, the user can specify that only a subset of the adult male population is in the breeding pool (the remainder being excluded perhaps by social factors). Those males in the breeding pool all have equal probability of siring offspring.

Each simulation is started with a specified number of males and females of each pre-reproductive age class, and a specified number of male and females of breeding age. Each animal in the initial population is assigned two unique alleles at some hypothetical genetic locus, and the user specifies the severity of inbreeding depression (expressed in the model as a loss of viability in inbred animals). The computer program simulates and tracks the fate of each population, and outputs summary statistics on the probability of population extinction over specified time intervals, the mean time to extinction of those simulated populations that went extinct, the mean size of populations not yet extinct, and the levels of genetic variation remaining in any extant populations.

Extinction of a population (or meta-population) is defined in VORTEX as the absence of either sex. (In some earlier versions of VORTEX, extinction was defined as the absence of both sexes.) Recolonization occurs when a formerly extinct population once again has both sexes. Thus, a population would go "extinct" if all females died, and would be recolonized if a female subsequently migrated into that population of males. Populations lacking both sexes are not considered to be recolonized until at least one male and at least one female have moved in.

A population carrying capacity is imposed by a probabilistic truncation of each age class if the population size after breeding exceeds the specified carrying capacity. The program allows the user to model trends in the carrying capacity, as linear increases or decreases across a specified numbers of years.

The user also has the option of modelling density dependence in reproductive rates. I.e., one can simulate a population that responds to low density with increased (or decreased) breeding, or that decreases breeding as the population approaches the carrying capacity of the habitat. To model density-dependent reproduction, the user must enter the parameters (A, B, C, D, and E) of the following polynomial equation describing the proportion of adult females breeding as a function of population size:

$$\text{Proportion breeding} = A + BN + CNN + DNNN + ENNNN,$$

in which N is total population size. Note that the parameter A is the proportion of adult females breeding at minimal population sizes. A positive value for B will cause increasing reproduction with increasing population sizes at the low end of the range. Parameters C, D, and E dominate the shape of the density dependence function at increasingly higher population sizes. Any of the values can be set to zero (e.g., to model density dependence as a quadratic equation, set D = E = 0). To determine the appropriate values for A through E, a user would estimate the parameters that provide the best fit of the polynomial function to an observed (or hypothetical) data set. Most good statistical packages have the capability of doing this. Although the polynomial equation above may not match a desired density dependence function (e.g., Logistic, Beverton-Holt, or Ricker functions), almost any density dependence function can be closely approximated by a 4th-order polynomial. After specifying the proportion of adult females breeding, in the form of the polynomial, the user is prompted to input the percent of successfully breeding females that produce litter sizes of 1, 2, etc. It is important to note that with density dependence, percents of females producing each size litter are expressed as percents of those females breeding, and the user does not explicitly enter a percent of females producing no offspring in an average year. (That value is given by the polynomial.)

In the absence of density dependence, the user must specify the percent of females failing to breed, and the percents producing each litter size are percents of all breeding age females (as in earlier versions of VORTEX). Read the prompts on the screen carefully as you enter data, and the distinction should become clear. VORTEX models environmental variation simplistically (that is both the advantage and disadvantage of simulation modelling), by selecting at the beginning of each year the population age-specific birth rates, age-specific death rates, and carrying capacity from distributions with means and standard deviations specified by the user. EV in birth and death rates is simulated by sampling binomial distributions, with the standard deviations specifying the annual fluctuations in probabilities of reproduction and mortality. EV in carrying capacity is modelled by sampling a normal distribution. EV in reproduction and EV in mortality can be specified to be acting independently or jointly (correlated in so far as is possible for discrete binomial distributions).

Unfortunately, rarely do we have sufficient field data to estimate the fluctuations in birth and death rates, and in carrying capacity, for a wild population. (The population would have to be monitored for long enough to separate, statistically, sampling error, demographic variation in the number of breeders and deaths, and annual variation in the probabilities of these events.) Lacking any data on annual variation, a user can try various values, or simply set EV = 0 to model the fate of the population in the absence of any environmental variation.

VORTEX can model catastrophes, the extreme of environmental variation, as events that occur with some specified probability and reduce survival and reproduction for one year. A catastrophe is determined to occur if a randomly generated number between 0 and 1 is less than the probability of occurrence (i.e., a binomial process is simulated). If a catastrophe occurs, the probability of breeding is multiplied by a severity factor specified by the user. Similarly, the probability of surviving each age class is multiplied by a severity factor specified by the user.

VORTEX also allows the user to supplement or harvest the population for any number of years in each simulation. The numbers of immigrants and removals are specified by age and sex. VORTEX outputs the observed rate of population growth (mean of N[t]/N[t-1]) separately for the years of supplementation/harvest and for the years without such management, and allows for reporting of extinction probabilities and population sizes at whatever time interval is desired (e.g., summary statistics can be output at 5-year intervals in a 100-year simulation).

VORTEX can track multiple sub-populations, with user-specified migration among the units. (This version of the program has previously been called VORTICES.) The migration rates are entered for each pair of sub-populations as the proportion of animals in a sub-population that migrate to another sub- population (equivalently, the probability that an animal in one migrates to the other) each year. VORTEX outputs summary statistics on each subpopulation, and also on the meta-population. Because of migration (and, possibly, supplementation), there is the potential for population recolonization after local extinction. VORTEX tracks the time to first extinction, the time to recolonization, and the time to re-extinction.

Overall, VORTEX simulates many of the complex levels of stochasticity that can affect a population. Because it is a detailed model of population dynamics, it is not practical to examine all possible factors and all interactions that may affect a population. It is therefore incumbent upon the user to specify those parameters that can be estimated reasonably, to leave out of the model those that are believed not to have a substantial impact on the population of interest, and to explore a range of possible values for parameters that are potentially important but very imprecisely known. VORTEX is, however, a simplified model of the dynamics of populations. One of its artificialities is the lack of density dependence of death rates except when the population exceeds the carrying capacity. Another is that inbreeding depression is modelled as an effect on juvenile mortality only; inbreeding is optimistically assumed not to effect adult survival or reproduction.

VORTEX accepts input either from the keyboard or from a data file. Whenever VORTEX is run with keyboard entry of data, it creates a file called VORTEX.BAT that contains the input data, ready for resubmission as a batch file. Thus, the simulation can be instantly rerun by using VORTEX.BAT as the input file. By editing VORTEX.BAT, a few changes could easily be made to the input parameters before rerunning VORTEX. Note that the file VORTEX.BAT is over-written each time that VORTEX is run. Therefore, you should rename the batch file if you wish to save it for later use. By using data file input, multiple simulations can be run while the computer is unattended. (Depending on the computer used, the simulations can be relatively quick -- a few minutes for 100 runs -- or very slow.) Output can be directed to the screen or to a file for later printing. I would recommend that VORTEX only be used on a 80386 (or faster) computer with a math co-processor. It should run on slower machines, but it might be hopelessly slow.

The program can make use of any extended memory available on the computer (note: only extended, not expanded, memory above 1MB will be used), and the extra memory will be necessary to run analyses with the Heterosis inbreeding depression option on populations of greater than about 450 animals. To use VORTEX with expanded memory, first run the program TUNE, which will customize the program EX286 (a Dos Extender) for your computer. If TUNE hangs up DOS, simply re-boot and run it again (as often as is necessary). This behavior of TUNE is normal and will not affect your computer. After TUNEing the Dos Extender, run EX286, and then finally run VORTEX. TUNE needs to be run only once on your computer, EX286 needs to be run (if VORTEX is to be used with extended memory) after each re-booting of the computer. Note that EX286 might take extended memory away from other programs (in fact it is better to disable any resident programs that use extended memory before running EX286); and it will release that memory only after a re-boot. If you have another extended memory manager on your system (e.g., HIMEM.SYS), you will have to disable it before using EX286.

VORTEX uses lots of files and lots of buffers. Therefore, you may need to modify the CONFIG.SYS file to include the lines

```
FILES=25
BUFFERS=25
```

in order to get the program to run.

VORTEX is not copy protected. Use it, distribute it, revise it, expand upon it. I would appreciate hearing of uses to which it is put, and of course I don't mind acknowledgement for my efforts. James Grier should also be acknowledged (for developing the program that was the base for VORTEX) any time that VORTEX is cited.

A final caution: VORTEX is continually under revision. I cannot guarantee that it has no bugs that could lead to erroneous results. It certainly does not model all aspects of population stochasticity, and some of its components are simply and crudely represented. It can be a very useful tool for exploring the effects of random variability on population persistence, but it should be used with due caution and an understanding of its limitations.

References

Grier, J. 1980a. Ecology: A simulation model for small populations of animals. Creative Computing 6:116-121.

Grier, J.W. 1980b. Modeling approaches to bald eagle population dynamics. Wildlife Society Bulletin 8:316-322.

Grier, J.W. and J.H. Barclay. 1988. Dynamics of founder populations established by reintroduction. Pages 689-701 in T.J. Cade, J.H. Enderson, C.G. Thelander, and C.M. White, eds. Peregrine Falcon

Populations: Their Management and Recovery. The Peregrine Fund, Boise, Idaho.

Lacy, R.C, Flesness, N.R., and Seal, U.S. 1989. Puerto Rican parrot population viability analysis. Report to the U.S. Fish and Wildlife Service. Captive Breeding Specialist Group, Species Survival Commission, IUCN, Apple Valley, Minnesota.

Lacy, R.C. and T.W. Clark. 1990. Population viability assessment of the eastern barred bandicoot in Victoria. Pages 131-146 in T.W. Clark and J.H. Seebeck (eds.), The Management and Conservation of Small Populations. Chicago Zoological Society, Brookfield, Illinois.

Lindenmayer, D.B., V.C. Thomas, R.C. Lacy, and T.W. Clark. 1991. Population Viability Analysis (PVA): The concept and its applications, with a case study of Leadbeater's Possum, *Gymnobelideus leadbeateri* McCoy. Report to the Forest and Timber Inquiry (Resource Assessment Commission), Canberra, Australia. 170 pp.

Maguire, L.A., R.C. Lacy, R.J. Begg, and T.W. Clark. 1990. An analysis of alternative strategies for recovering the eastern barred bandicoot in Victoria. Pages 147-164 in T.W. Clark and J.H. Seebeck (eds.), The Management and Conservation of Small Populations. Chicago Zoological Society, Brookfield, Illinois.

Seal, U.S. and R.C. Lacy. 1989. Florida panther population viability analysis. Report to the U.S. Fish and Wildlife Service. Captive Breeding Specialist Group, Species Survival Commission, IUCN, Apple Valley, Minnesota.

Seal, U.S. and R.C. Lacy. 1990. Florida Key Deer (*Odocoileus virginianus clavium*) population viability assessment. Report to the U.S. Fish and Wildlife Service. Captive Breeding Specialist Group, Species Survival Commission, IUCN, Apple Valley, Minnesota.

Wildl. Res., 1993, 20, 45–65

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,

1035-3712/93/010045$10.00

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,

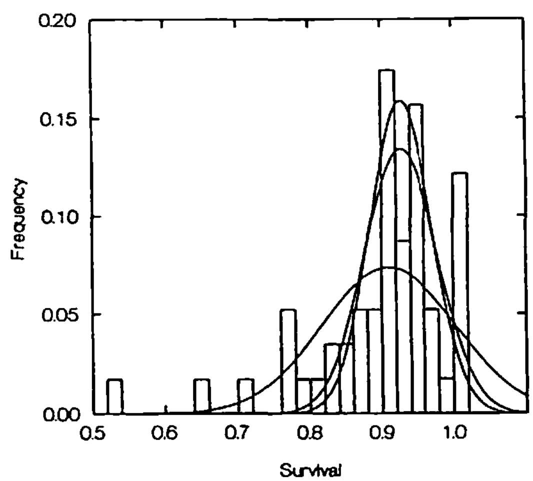


Fig. 1. Frequency histogram of the proportion of whooping cranes surviving each year, 1938–90. The broadest curve is the normal distribution that most closely fits the overall histogram. Statistically, this curve fits the data poorly. The second highest and second broadest curve is the normal distribution 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

$$SE(p) = \sqrt{[p \times (1-p)/n]}\,,$$

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 ($N \pm SD = 151 \pm 123$) 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 $(r) = 0{\cdot}112$ *v.* actual SD $(r) = 0{\cdot}141$]. 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.

Acknowledgments

James W. Grier made available his simulation program, SPGPC, which provided many of the algorithms on which the first version of VORTEX (SIMPOP) was based. I thank Ulysses S. Seal, Thomas J. Foose, Jon Ballou, Nathan R. Flesness, Tim W. Clark, Gary Backhouse, David Lindenmayer, Simon Bennett, and many of the staff of the Department of Conservation and Environment, Victoria, Australia, for many helpful comments on VORTEX and PVA. Tim W. Clark, David Lindenmayer and two anonymous reviewers provided valuable critiques of drafts of this paper.

References

Akçakaya, H. R., and Ferson, S. (1990). 'RAMAS/Space User Manual. Spatially Structured Population Models for Conservation Biology.' (Applied Biomathematics: Setauket, New York.)

Ballou, J. (1983). Calculating inbreeding coefficients from pedigrees. In 'Genetics and Conservation: A Reference for Managing Wild Animal and Plant Populations'. (Eds C. M. Schonewald-Cox, S. M. Chambers, B. MacBryde and W. L. Thomas.) pp. 509–20. (Benjamin/Cummings: Menlo Park, California.)

Belovsky, G. E. (1987). Extinction models and mammalian persistence. In 'Viable Populations for Conservation'. (Ed. M. E. Soulé.) pp. 35–57. (Cambridge University Press: Cambridge.)

Berger, J. (1990). Persistence of different-sized populations: an empirical assessment of rapid extinctions in bighorn sheep. *Conservation Biology* 4, 91–8.

Brewer, B. A., Lacy, R. C., Foster, M. L., and Alaks, G. (1990). Inbreeding depression in insular and central populations of *Peromyscus* mice. *Journal of Heredity* 81, 257–66.

Burgmann, M. A., and Gerard, V. A. (1990). A stage-structured, stochastic model for giant kelp *Macrocystis pyrifera*. *Marine Biology* 105, 15–23.

Clark, T. W. (1989). 'Conservation Biology of the Black-footed Ferret. Special Scientific Report.' (Wildlife Preservation Trust International: Philadelphia.)

Clark, T. W., and Seebeck, J. H. (Eds) (1990). 'Management and Conservation of Small Populations.' (Chicago Zoological Society: Brookfield, Illinois.)

Clark, T. W., Warneke, R. M., and George, G. G. (1990). Management and conservation of small populations. In 'Management and Conservation of Small Populations'. (Eds T. W. Clark and J. H. Seebeck.) pp. 1–18. (Chicago Zoological Society: Brookfield, Illinois.)

Clark, T. W., Backhouse, G. N., and Lacy, R. C. (1991). Report of a workshop on population viability assessment as a tool for threatened species management and conservation. *Australian Zoologist* 27, 28–35.

Crow, J. F., and Kimura, M. (1970). 'Introduction to Population Genetics Theory.' (Harper and Row: New York.)

Doughty, R. W. (1989). 'Return of the Whooping Crane.' (University of Texas Press: Austin.)

Falconer, D. S. (1981). 'Introduction to Quantitative Genetics.' 2nd Edn. (Longman: New York.)

Ferson, S. (1990). 'RAMAS/Stage. Generalized Stage-based Modeling for Population Dynamics.' (Applied Biomathematics: Setauket, New York.)

Ferson, S., and Akçakaya, H. R. (1989). 'RAMAS/Age User Manual. Modeling Fluctuations in Age-structured Populations.' (Applied Biomathematics: Setauket, New York.)

Fisher, R. A. (1958). 'The Genetical Theory of Natural Selection.' 2nd Edn. (Dover: New York.)

Foose, T. J., Lacy, R. C., Brett, R., and Seal, U. S. (1992). Kenya black rhinoceros population and habitat viability assessment. (Captive Breeding Specialist Group, SSC, IUCN: Apple Valley, Minnesota.)

Gilpin, M. E. (1987). Spatial structure and population vulnerability. In 'Viable Populations for Conservation'. (Ed. M. E. Soulé.) pp. 125–39. (Cambridge University Press: Cambridge.)

Gilpin, M. E. (1989). Population viability analysis. *Endangered Species Update* 6, 15–18.

Gilpin, M. E., and Soulé, M. E. (1986). Minimum viable populations: processes of species extinction. In 'Conservation Biology: the Science of Scarcity and Diversity'. (Ed. M. E. Soulé.) pp. 19–34. (Sinauer: Sunderland, Massachusetts.)

Goodman, D. (1987). The demography of chance extinction. In 'Viable Populations for Conservation'. (Ed. M. E. Soulé.) pp. 11–34. (Cambridge University Press: Cambridge.)

Grier, J. W. (1980*a*). A simulation model for small populations of animals. *Creative Computing* 6, 116–21.

Grier, J. W. (1980*b*). Modeling approaches for bald eagle population dynamics. *Wildlife Society Bulletin* 8, 316–22.

Harris, R. B., Metzger, L. H., and Bevins, C. D. (1986). 'GAPPS. Version 3.0.' (Montana Cooperative Research Unit, University of Montana: Missoula.)

Hill, F. A. R. (1991). A research recovery plan for the brush-tailed rock wallaby *Petrogale pencillata* (Gray 1825). Report to Australian National Parks and Wildlife Service. (Department of Conservation and Environment: Melbourne.)

Kirkpatrick, S., and Stoll, E. (1981). A very fast shift-register sequence random number generator. *Journal of Computational Physics* 40, 517.

Lacy, R. C. (1993). Impacts of inbreeding in natural and captive populations of vertebrates: implications for conservation. *Perspectives in Biology and Medicine.* (In press.)

Lacy, R. C., and Clark, T. W. (1990). Population viability assessment of eastern barred bandicoot. In 'The Management and Conservation of Small Populations'. (Eds T. W. Clark and J. H. Seebeck.) pp. 131-46. (Chicago Zoological Society: Brookfield, Illinois.)

Lacy, R. C., Flesness, N. R., and Seal, U. S. (1989). 'Puerto Rican Parrot Population Viability Analysis.' (Captive Breeding Specialist Group, SSC, IUCN: Apple Valley, Minnesota.)

Lacy, R. C., Petric, A. M., and Warneke, M. (1993). Inbreeding and outbreeding depression in captive populations of wild species. In 'The Natural History of Inbreeding and Outbreeding'. (Ed. N. W. Thornhill.) (University of Chicago Press: Chicago.) (In press.)

Lande, R. (1988). Demographic models of the northern spotted owl (*Strix occidentalis caurina*). *Oecologia* 75, 601-7.

Latour, A. (1986). Polar normal distribution. *Byte* August 1986, 131-2.

Lindenmayer, D. B., Clark, T. W., Lacy, R. C., and Thomas, V. C. (1993). Population viability analysis as a tool in wildlife management: a review with reference to Australia. *Environmental Management.* (In press.)

Mace, G. M., and Lande, R. (1991). Assessing extinction threats: toward a reevaluation of IUCN threatened species categories. *Conservation Biology* 5, 148-57.

Maguire, L. A., Lacy, R. C., Begg, R. J., and Clark, T. W. (1990). An analysis of alternative strategies for recovering the eastern barred bandicoot. In 'The Management and Conservation of Small Populations'. (Eds T. W. Clark and J. H. Seebeck.) pp. 147-64. (Chicago Zoological Society: Brookfield, Illinois.)

Maier, W. L. (1991). A fast pseudo random number generator. *Dr. Dobb's Journal* May 1991, 152-7.

Mirande, C., Lacy, R. C., and Seal, U. S. (1993). Whooping crane conservation viability assessment workshop. (Captive Breeding Specialist Group, SSC, IUCN: Apple Valley, Minnesota.)

Morton, N. E., Crow, J. F., and Muller, H. J. (1956). An estimate of the mutational damage in man from data on consanguineous marriages. *Proceedings of the National Academy of Sciences, U.S.A.* 42, 855-63.

O'Brien, S. J., and Evermann, J. F. (1988). Interactive influence of infectious diseases and genetic diversity in natural populations. *Trends in Ecology and Evolution* 3, 254-9.

Possingham, H., Davies, I., and Noble, I. R. (1991). 'An Evaluation of Population Viability Analysis for Assessing the Risk of Extinction.' (Resource Assessment Commission: Canberra.)

Possingham, H. P., Davies, I., Noble, I. R., and Norton, T. W. (1992). A metapopulation simulation model for assessing the likelihood of plant and animal extinctions. *Mathematics and Computers in Simulation* 33, 367-72.

Ralls, K., Ballou, J. D., and Templeton, A. R. (1988). Estimates of lethal equivalents and the cost of inbreeding in mammals. *Conservation Biology* 2, 185-93.

Resource Assessment Commission (1991). Forest and timber inquiry. Draft report. Vol. 2. July 1991. (Australian Government Publishing Service: Canberra.)

Ricklefs, R. E. (1979). 'Ecology.' 2nd Edn. (Chiron: New York.)

Robertson, A. (1960). A theory of limits in artificial selection. *Proceedings of the Royal Society of London* 153B, 234-49.

Seal, U. S., and Foose, T. J. (1989). Javan rhinoceros population viability analysis and recommendations. (Captive Breeding Specialist Group, SSC, IUCN: Apple Valley, Minnesota.)

Seal, U. S., and Lacy, R. C. (1989). Florida panther population viability analysis. (Captive Breeding Specialist Group, SSC, IUCN: Apple Valley, Minnesota.)

Seal, U. S., Ballou, J. D., and Padua, C. V. (1990). *Leontopithecus* population viability analysis workshop report. (Captive Breeding Specialist Group, SSC, IUCN: Apple Valley, Minnesota.)

Seal, U. S., Lacy, R. C., Medley, K., Seal, R., and Foose, T. J. (1991). Tana River Primate Reserve Conservation Assessment Workshop. (Captive Breeding Specialist Group, SSC, IUCN: Apple Valley, Minnesota.)

Selander, R. K. (1983). Evolutionary consequences of inbreeding. In 'Genetics and Conservation: A Reference for Managing Wild Animal and Plant Populations'. (Eds C. M. Schonewald-Cox, S. M. Chambers, B. MacBryde and W. L. Thomas.) pp. 201–15. (Benjamin/Cummings: Menlo Park, California.)
Shaffer, M. L. (1981). Minimum population sizes for species conservation. *BioScience* 31, 131–4.
Shaffer, M. L. (1987). Minimum viable populations: coping with uncertainty. In 'Viable Populations for Conservation'. (Ed. M. E. Soulé.) pp. 69–86. (Cambridge University Press: Cambridge.)
Shaffer, M. L. (1990). Population viability analysis. *Conservation Biology* 4, 39–40.
Simberloff, D. A. (1986). The proximate causes of extinction. In 'Patterns and Processes in the History of Life'. (Eds D. M. Raup and D. Jablonski.) pp. 259–76. (Springer-Verlag: Berlin.)
Simberloff, D. A. (1988). The contribution of population and community biology to conservation science. *Annual Review of Ecology and Systematics* 19, 473–511.
Soulé, M. E. (Ed.) (1987). 'Viable Populations for Conservation.' (Cambridge University Press: Cambridge.)
Thomas, C. D. (1990). What do real population dynamics tell us about minimum population sizes? *Conservation Biology* 4, 324–7.
Wright, S. (1977). 'Evolution and the Genetics of Populations. Vol. 3. Experimental Results and Evolutionary Deductions.' (University of Chicago Press: Chicago.)

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)

Manuscript received 4 March 1992; revised and accepted 13 August 1992

SUMATRAN RHINO

POPULATION AND HABITAT

VIABILITY ANALYSIS WORKSHOP

BRIEFING BOOK

SECTION 8: ASIAN RHINO LIFE HISTORY CHARACTERISTICS

NOTE: THIS DATA FORM IS FOR THE JAVAN RHINO

Captive Breeding Specialist Group

Species Survival Commission
International Union for the Conservation of Nature and Natural Resources
U. S. Seal, CBSG Chairman

POPULATION VIABILITY ANALYSIS DATA FORM - MAMMALS

Species: Rhinoceros sondaicus (Desmarest). Javan Rhinoceros.

Species distribution: *Ujung Kulon National Park (Java)*;
Vietnam - 1989; Cambodia, Malaya, Burma? Historically in Malaya, Burma, Thailand, Indochina, Java, Sumatra, parts of northern India. Most unconfirmed until sightings in Vietnam.

Study taxon (subspecies): *R. s. sondaicus*
R. s. annamiticus in Vietnam, Cambodia, Laos. R. s. inermis in Assam.

Study population location: *Ujung Kulon National Park. 30,000 hectares = 300 km².*

Metapopulation - are there other separate populations? Are maps available?: (Separation by distance, geographic barriers?)
Only one population known in Indonesia.

Specialized requirements (Trophic, ecological):
Browser. Prefers coastal forest zones and swamps in the park. 190 plants (179 dicots) with 4 comprising 44% of diet (Spondia pinnata, Amomum sp, Leea sambucina, & Dillenia excelsa).

Age of first reproduction for each sex (proportion breeding):

a)Earliest: *Female - 7 yrs; Male - 7;*
55 M in captivity. (Both Indian)

b)Mean: *Females 8 yrs in captivity (up to 20 yrs)*
Males 10 yrs

Gestation period (days or weeks): *16 months*

Litter size (N, mean, SD, range)(at birth?, weaning?): *1*

Birth Season: *Unlikely. None for Indians.*

Birth frequency (interbirth interval): *4-9 years for Javan.*
8 - 9 years suggested by Amman. Very long. 3-4 years for Indian with one at 18 months following loss of calf at a few days.

Reproductive life-span (Male & Female, Range):
30 yrs? G = 16 yr (F); = 19 yr (M) (Indians in captivity).
(G = generation time)

Life time reproduction (Mean, Male & Female): *4 - 8.*

Adult sex ratio: *.64 : 1 based upon 17 sexed animals (6:11).*

Adult body weight of males and females: *1500 kg.*

Social structure in terms of breeding (random, pair-bonded, polygyny, polyandry, etc; breeding male and female turnover each year?):

Solitary, females with young to about 3 years. No pair bonding. Male territory may overlap several females.

Proportion of adult males and females breeding each year:
? .113 of adult females (4 calves per year; assuming 70 animals, 83% adults and sex ratio 0.64:1.0. Estimated from footprints - difficult and little validation. If this age structure is correct, this is a dying population.

Dispersal distance (mean, sexes): *May move 15-20 km in a day.*

Migrations (months): *Move between feeding areas. Area with 5 deaths reoccupied by a male and female.*

Territoriality (home range, season): *Said to not have a stable home range. Female territory said to be 2.6-13.4 km2 and males 12.5 to 21 km2.*

Birth sex ratio: *1:1*

Birth weights (male and female):

Ovulation - induced or spontaneous: *Probably spontaneous.*

Implantation - immediate or delayed (duration): *Probably immediate. (About 3 weeks).*

Estrous cycles (seasonal, multiple or single, post partum):
Probably multiple and non-seasonal. Post partum possible but inhibited by lactation.

Duration of lactation: *About 12-18 months (Indian).*

Post-lactational estrus: *Probably at about 18 months postpartum.*

Age of dispersal: *Males 39.4 ± 4.8 months; Females 34.1 (Indian). This would be shortly before birth of next calf.*

Maximum longevity: *35 - 40 years.*

Population census - most recent. Date of last census. Reliability estimate.:
About 50 (census)-70 (extrapolation) in Ujung Kulon. April 1984. 10-15%?
See attached tables. Census and extrapolation methods.

1989: 57 (52 - 62) with no young detected. (Santiapillai, Widodo, & Bambang).

Projected population (5, 10, 50 years).: *Population has been stable for about 10 years.* Would be difficult to detect a change of 10% in any one year (± 5 animals). No calves were detected this year.

Past population census (5, 10, 20 years - dates, reliability estimates):

1955 30-35 (Hoogerwerf, 1970). 13 killed 1955-65.
1967 21-28 (Schenkel)
1980 54-70 (PHPA: Ammann). 1984 50-54 (Sadjudin).

Population sex and age structure (young, juvenile, & adults) - time of year.:

Alternate scenarios:				
	0 - 1 =	2.2	0.0	1.1 (2.2)
	1 - 6 =	6.10	6.6	6.6
	Adult =	12.16	18.26	18.26

Fecundity rates (by sex and age class):
Adult females - 0.11 calf per year. This implies greatly reduced reproductive rates (about 1 calf per 8 years) as compared to the Indian and other rhinos protected and in good habitat. Capable of 1 calf every 3 years. An alternative scenario is 1 calf per 4 years but a high infant mortality rate.

Mortality rates and distribution (by sex and age) (neonatal, juvenile, adult);
Uncertain but: Infant = 5 - 20%
Juvenile = 2 - 4 %
Adult = 8 - 9%

Population density estimate. Area of population. Attach marked map.:
50 animals in 30,000 hectare (300 km²) Ujung Kulon Park. 1 per 600 hectare. However perhaps only 1/3 of habitat is suitable.

Sources of mortality-% (natural, poaching, harvest, accidental, seasonal?).:
Disease.
Poaching. 1 in 1985 and 1 in 1987.

Habitat capacity estimate (Has capacity changed in past 20, 50 years?).:
Banteng (Bos javanicus) population increasing.
Vegetation changes occurring.

Present habitat protection status.:
National Park.

Projected habitat protection status (5, 10, 50 years).:
Park to remain protected?

Environmental variance affecting reproduction and mortality (rainfall, prey, predators, disease, snow cover ?).:
5 bodies (4 adults and 1 calf) found in 1982. Diagnosis uncertain. Data on sex and ages?
Volcano activity. Poaching. Disease. Rainfall?

Is pedigree information available?:
NO

Attach Life Table if available. *See attached tables.*

Date form completed: June 6, 1989

Correspondent/Investigator:

Name: U. S. Seal

Address: CBSG c/o Minnesota Zoo
12101 Johnny Cake Road
Apple Valley, Minnesota 55124
USA

Telephone: 612-431-9325

Fax: 612-432-2757

References:

Nardelli, F., W.S. Ramono, & T. Foose. 1987. Project to conserve the Javan rhinoceros - Rhinceros sondaicus Desm.
Sadjudin, . 1987.

Schnekel, R. and H. Schnekel. 1969.

Amman, Hartman. 1985.

Laurie, A. 1982.

Indian Rhino SSP Analyses. Rockwell, R. 1989.

C. Santiapillai, S. R. Widodo, and P. D. Bambang. 1989.

Comments:

10 animals recorded in captivity during past 150 years (Reynolds, 1961). None now or in recent past. One lived 21 years.

Protected since the turn of the century in Ujung Kulon. Poachers and hunters took 16 in 1935-36, perhaps 20-25 in 1937. Estimated that 42 animals taken between 1930 and 1970, i. e. about 1 per year.

Population appears to have been stable in numbers for past 10 years. Interbirth interval is suggested to be about 8 years (would be 3 years in growing pop.),. Growth rate perhaps 4% now but was 10% from 1967 to 1974. Deaths in 1981-82 were in one area suggesting disease. These observations suggest that the population may be at carrying capacity of about 60 animals.

SUMATRAN RHINO

POPULATION AND HABITAT

VIABILITY ANALYSIS WORKSHOP

BRIEFING BOOK

SECTION 9: TRAFFIC: WORLD TRADE IN RHINO HORN--REVIEW

SPECIES IN DANGER

THE WORLD TRADE IN RHINO HORN: A REVIEW

Nigel Leader-Williams

A TRAFFIC NETWORK REPORT

TRAFFIC
International

This report was published
with the kind support of

WWF

National Westminster Bank

Published by TRAFFIC International,
Cambridge, United Kingdom.
With financial support from
WWF UK (World Wide Fund For Nature).

ISBN 0 947613 86 2

Cover drawing by Bryan Poole.

Printed on recycled paper.

THE WORLD TRADE IN RHINO HORN: A REVIEW

Nigel Leader-Williams[1]

The People's Trust for Endangered Species provided financial support for the compilation of the data presented in this publication.

[1]Large Animal Research Group
Department of Zoology
Cambridge University

ACKNOWLEDGEMENTS

The author would like to thank the People's Trust for Endangered Species for their financial support while this review was compiled and John Beddington for his encouragement. Richard Luxmoore of WCMC and Jorgen Thomsen of TRAFFIC kindly provided access to data and reprints. The manuscript was reviewed constructively by Jorgen Thomsen, Esmond Bradley Martin, Kristin Nowell, Tom Milliken and Martin Brooks. Alison Rosser provided much support while the manuscript was prepared. Finally, the author would like to acknowledge Esmond Bradley Martin's pioneering work in unravelling the intricacies of the trade in rhino horn.

INTRODUCTION

Rhinos are amongst the world's most endangered large mammals. Two species of rhinos in Asia (Javan *Rhinoceros sondaicus* and Sumatran *Dicerorhinus sumatrensis*) and one sub-species in Africa (northern white *Ceratotherium simum cottoni*) teeter on the edge of extinction. Over the past two decades, the formerly numerous black rhino *Diceros bicornis* has plummeted from an estimated 65,000 to 3,000 and has become locally extinct over large areas of Africa. By contrast the southern white rhino *C. s. simum* is currently well conserved in limited areas of its range in southern Africa, as is the Indian rhino *Rhinoceros unicornis* in India and Nepal. However, with total world populations in only the low thousands, the continued survival of southern white and Indian rhinos is by no means guaranteed (Cumming *et al.* 1990; Khan 1989).

WWF International

White Rhinos in Kruger National Park. One of the few rhino populations not in decline.

Rhino numbers have declined for two main reasons. First, loss of rhino habitat has been especially serious in the rainforests and floodplains of Asia, but is less of a problem in African savannas. Second, rhino horns are used in medicines and as dagger handles, and other rhino products such as skin and blood are used to a lesser extent. As a result of high demand for rhino horns, unprotected populations of rhinos have been exploited unsustainably and the trade in their products has largely been responsible for reducing rhinos to their presently endangered status. Therefore, when the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) entered into force in 1975, rhinos were among the first species included on the CITES Appendices. In July 1975, three species (Sumatran, Javan and Indian) and one sub-species (northern white) were placed on Appendix I, while one species (black) was placed on Appendix II. In February 1977, both the black and southern white rhino were placed on Appendix I, therefore prohibiting international commercial trade in the whole family of rhinos and their products.

This review has two aims. The first is to collate the available information on volumes and prices of rhino horn on world markets and to determine if the quality of the available data on the rhino horn trade is comparable to that on ivory. Recently, the Ivory Trade Review Group (ITRG) has been very successful in documenting volumes and prices of ivory on world markets as part of the international effort to achieve more successful conservation of African and Asian elephants (Cobb 1989). Indeed, the data on volumes of ivory traded over time are more complete than data on elephant numbers, due largely to the difficulties of censusing elephants in rainforests. Estimates of world rhino numbers are even less complete and less accurate than those of elephants. Three species of rhino (Javan, Sumatran and black) are primarily solitary and live in forested or wooded habitats which make accurate total counts difficult. The main conclusion from this section of the review, unfortunately, is that data on volumes and prices of rhino horn on world markets are much less complete than data for ivory. Two major factors are responsible for the difference in data quality between rhino horn and ivory. First, rhino horn has not been differentiated from other types of horn and animal products in the customs statistics of most producing, entrepôt and consuming nations even when the trade was legal, whereas ivory appears as a separate commodity. Second, by 1977 all species of rhinos and their products were placed on CITES Appendix I, and many of the producing and consuming nations had instituted their own trade bans or became parties to CITES. Thus, most trade in rhino horn became illegal, so by definition should not have appeared in declared customs statistics (though it does in one case, as discussed below).

The second aim of the review is to compile our present knowledge on the extent of the rhino horn trade, in order to question whether policies attempting to halt the rhino horn trade, followed over the last 15 years, have succeeded, or are likely to succeed. Since CITES was formulated and all species of rhinos were placed on Appendix I, it has been hoped that successful conservation of rhinos would be achieved most cost-effectively by halting the trade in horn. While being afforded the supposed benefit of an international trade ban, unprotected populations of the most widely distributed sub-species of black rhino have continued to be over-exploited for their horns, to the extent that black rhinos have the dubious distinction of showing the fastest known rate of decline of any species of large mammal. The fate of the widely distributed Sumatran rhino in Asia has been less well documented. However, successes in rhino conservation have been achieved or consolidated, for example, the continued increase in numbers of southern white and Indian rhinos in southern Africa, and India and Nepal, respectively. Other efforts have begun to show signs of success, for example, the initial recovery of two of the four sub-species of black rhinos in Kenyan and in South African and Namibian sanctuaries, respectively and of northern white rhinos in Zaire. The recipe for success of these endeavours has involved the rounding up of stragglers, concentrating resources in small areas, and once the population has built up sufficiently, making translocations to unoccupied habitats in areas of former range (reviewed in Leader-Williams 1992). Affording protection to rhinos costs money and the crucial questions are whether rhinos could contribute to the costs of their conservation through a legal trade in horn, and whether a legal trade in horn would reduce the considerable pressures on unprotected populations of rhinos that have resulted from the illegal trade in their horn. If this review stimulates further informed debate on this topic, then it will have achieved its second aim.

RESEARCH FOR THE REVIEW

Most of the available information on the rhino horn trade has been gathered as a result of the pioneering work of E.B. Martin and his colleagues since 1979, and their results have been presented in numerous articles and several books. During the course of this review all the articles and books in the reference list were read, the files of the World Conservation Monitoring Centre and TRAFFIC were examined, and the rather qualitative information on volumes and prices of rhino horn in world trade were collated. Many of the articles in the reference list re-circulate the same information but in a slightly different form. This approach has presumably been adopted to canvas support amongst different audiences for attempts to halt the trade in rhino horn, but it means that many of the articles read have not been quoted in the body of this report.

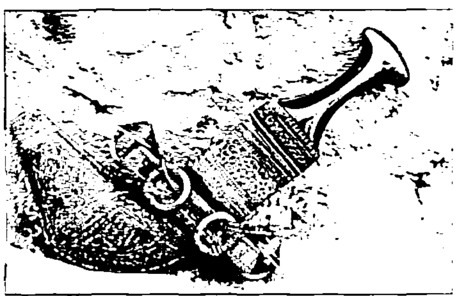
The available data that have been compiled for this report are all shown in terms of volume in kg and price in US$/kg, not corrected for inflation. Some price data has been corrected for inflation where indicated in various Figures, with a base of 100% in 1980 (as was done for the Japan data set shown in Leader-Williams *et al.* 1990). Where the terms wholesale and retail price appear, Martin's definitions for his own work have been followed. Namely, **wholesale price** is that paid by dealers and large pharmacy shops and **retail price** is that charged to the consumer. Volumes of horn can be converted to approximate numbers of rhino supplying that horn using the following mean weights: black rhino: 2.88kg; white rhino: 4.00kg; Indian rhino: 0.72kg; Javan rhino: 0.68kg; Sumatran rhino: 0.27kg (Martin 1983e), making the assumption that horn weights have not changed over time.

THE USES AND HISTORY OF THE TRADE IN RHINO HORN

WWF / J Mallwitz

The use of rhino horn in traditional medicines is widespread and continuing in the Far East

The rhino horn trade has a long history. One of the earliest records of use of rhino horn as a medicine was by the Chinese during 200 B.C - 200 A.D. (Martin and Martin 1982, But *et al.* 1990). During the Ming and Ching dynasties, the Chinese carved rhino horns into beautiful cups, plates, bowls and figurines. Rhino horn drinking vessels had the added advantage of being able to detect alkaloid poisons, in an age when such poisons were a major means of treachery. However, westerners long believed that rhino horn was used primarily as an aphrodisiac, but this myth was exploded in the early 1980s (Parker and Martin 1979, Martin and Martin 1982). Some rhino horn is indeed consumed as an aphrodisiac, but this is limited to use by the Gujaratis in India. Rhino horn has had two far more important uses in terms of volume traded in recent times. First, horn and other rhino products such as blood, skin and urine, are an important constituent in traditional medicines and potions used to reduce fevers, headaches and other illnesses in the Far East. Such medicines are used primarily by the Chinese, but also by Burmese, Thais and Nepalis. In contrast, the Japanese and Koreans also learned to use rhino horn in medicines through early cultural links with the Chinese, but do not use other rhino products. Rhino horn is generally sold in the Far East in one of two forms: first as "raw" horn by traditional pharmacists who make up the medicine for individual customers from horns held in their shops, and second as a constituent in manufactured medicines. An important point is that "Fire" (Asian) horn is believed more efficacious than "Water" (African) horn and that Asian horn is considerably more expensive (Nowell *et al.* 1992). Thus both African and Asian rhino horn is used widely throughout the Far East both by indigenous people but particularly by the resident Chinese communities found in most Far Eastern countries (Martin 1983d). In addition, confiscations in Los Angeles, San Francisco and Brussels attest to the use of rhino horn by Chinese communities in Western countries. Second, Yemenis have used African rhino horn since at least the eighth century to make handles for traditional daggers (*jambias*). Daggers are important status symbols in the cultural life of Yemeni men. In contrast to other materials used for dagger handles such as water buffalo *Bubalus bubalis* horn, rhino horn handles improve in appearance and lustre with age. Therefore, it is the quality of rhino horn that interests the makers of daggers rather than any fascination with rhinos per se (Varisco 1987, 1989a, 1989b).

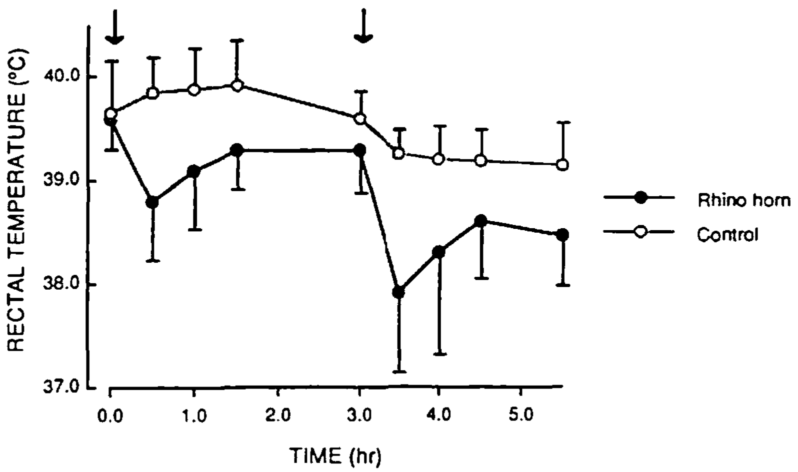


WWF / Hartmut Jungius

Traditional daggers or jambias are produced with rhino horn handles in Yemen

The beauty of carved rhino horn, whether as cups or dagger handles, cannot be disputed. The pharmacological efficacy of rhino horn as an aphrodisiac can, as with all other types of aphrodisiac, only be guessed at. However, its psychological value may well be all important and has some basis both in the shape of rhino horns and in the long courtship and staying power of copulating rhinoceroses, which take upwards of one hour from intromission to ejaculation (Goddard 1966; Laurie 1982). An early study suggested, too, that rhino horn had no pharmacological efficacy as an anti-pyretic, using doses of 100-300mg kg-1 administered orally in rats (Hoffmann-La Roche *in litt.* 1980), and that its use must therefore rest on traditional belief. However, a more recent study shows that African rhino horn has an anti-pyretic effect at much higher doses of 4,000-20,000mg kg-1 administered intra-peritoneally, also in rats (Figure 1). The latter represents a dose some one hundred times higher than would be taken by a human, and experimental protocols between the studies differed, not only with respect to the route of administration, but also with respect to the experimental means used to induce the initial pyrexia (But *et al.* 1990). However, the recent study shows that traditional Chinese beliefs may have some pharmacological basis, but this conclusion needs further substantiation (But *et al.* 1990). In addition, a study of the supposed difference in the efficacy of African and Asian horn would be well-merited.

Figure 1: The anti-pyretic effect of two intra-peritoneal injections (marked with arrows) of rhino horn at doses of 2.5g/ml in rats (after But *et al.* 1990).



Whatever the situation with pharmacology versus traditional beliefs, trade in rhino horn has occurred along well established routes for centuries. An early record of rhino horn leaving Azania (ancient East Africa), together with ivory and tortoise-shell, for southern Arabia dates from 50 A.D. (Sutton 1990). However, historical and contemporary information on actual volumes and prices of rhino horn in world trade are generally lacking. To illustrate this point, the five living species of rhinos formerly ranged in historic times in at least 44 countries, some 29 in Africa and 15 in Asia. Rhino horn used to be imported into at least 40 different countries from East Africa alone (Parker and Martin 1979), ranging through North and South America, Europe, the Middle and Far East. Until the mid-1970s, when CITES entered into force, there were no legislative barriers to trade between nations. Yet there are only long series of data over time for three producing and four consuming nations, with additional less complete or anecdotal data from a few other countries.

LEGAL EXPORTS FROM PRODUCING NATIONS

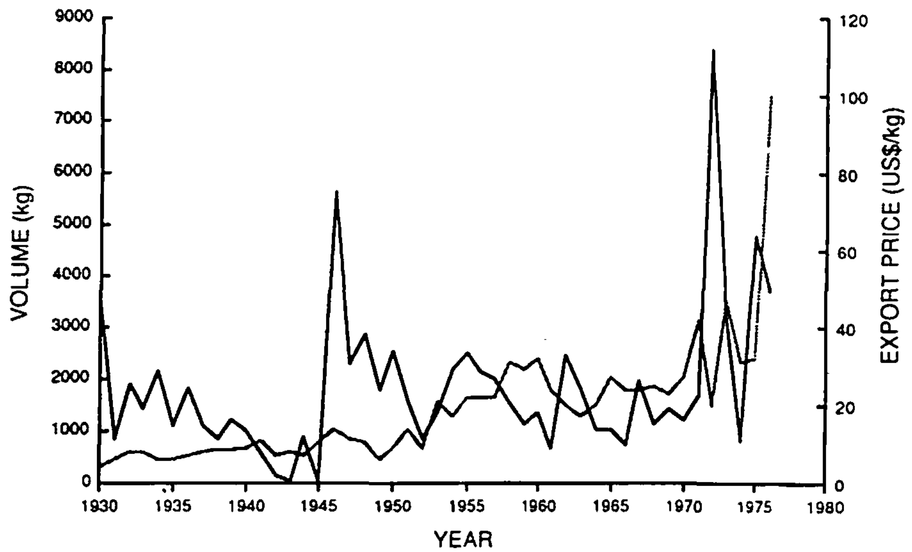
Africa

There is little evidence of domestic consumption of rhino horn produced in Africa (see Martin and Ryan 1990), yet there are only runs of export data in terms of volume and price for three countries, and one short run of data on volumes for a fourth country.

East Africa

The longest time series of data on exports in terms of volume and price of rhino horn derives from the three East African countries of Kenya, Uganda and Tanganyika (later Tanzania after independence in 1964). The declared exports of rhino horn from East Africa were compiled from customs statistics from 1926-1976, three years before Kenya became a party to CITES in 1979 (Parker and Martin 1979). For most years from 1929-1976 there are data on volumes and prices declared to have been exported from each country. The relationship between the average price and the total volume of rhino horn sold from the East African auction rooms is shown in Figure 2. Declared exports from East Africa averaged 1,600kg/year (or the death of 555 black rhinos/year) during the 1930s, dropped to 500kg/year (174 rhinos/year) during World War II, rose to 2,500kg/year (or 868 rhinos/year) immediately after the war, dropped to 1,800kg/year and 1,300kg/year (625 and 451 rhinos/year) during the 1950s and 1960s, before rising to 3,400kg/year (1,180 rhinos/year) in the 1970s. During this period average prices increased steadily until the early 1970s when they showed a more rapid increase (Figure 2; Table 1).

Figure 2: The volume (solid line) and price (dashed line) of East Africa's declared exports from 1929-1976 (data from Parker and Martin 1979).



This data set, acquired from one consistent source, can be combined with some more anecdotal information for earlier years (Table 2). This suggests that far larger volumes of horn were traded from East Africa during 1840-1900 (Martin and Martin 1982). From these figures, it was estimated that East Africa as a whole may have traded 11,000kg/year from 1849-1895. This represents the death of around 170,000 black rhinos over this period (Martin and Martin 1982), assuming there has not been a marked decline in horn weight. Even if mean horn weight was higher than the present 2.88kg (Martin 1983e), say 4kg, this would still represent the death of around 100,000 black rhinos.

Table 1: Declared volume (kg) and average price (US$/kg) of exports from East Africa (Kenya, Uganda and Tanganyika/Tanzania before/after 1964) during 1949-1976 to countries of destination (data from Parker and Martin 1979).

YEAR	Hong Kong	Aden/ S Yemen	Zanzibar	China	USA	UK	Japan	Others	Total volume	Average price
1949	1,067		508		152	51			1,778	6
1950	965		1,423		102	51			2,540	9
1951	1,372		203						1,575	14
1952	508		356						864	19
1953	965		203		51	102		51	1,372	21
1954	1,422	51	508		51	152			2,184	17
1955	1,361		862		91	91		91	2,496	22
1956	1,134	45	544		182	227			2,132	22
1957	227	363	953		272	182			1,997	22
1958	182	136	726		408	91			1,543	31
1959	45		817		227	45			1,134	29
1960	91	45	907		181	136			1,360	32
1961	136	136	45		182	181			680	24
1962	1,588	771			45	46			2,450	20
1963	1,270	136	46		227	136			1,815	17
1964	259	604			88	45		36	1,032	19
1965	178	682			58	70		35	1,023	27
1966	331	196			78	48	38	43	734	24
1967	1,068	668			50	24	142	3	1,955	24
1968	101	342		465	56	5	9	151	1,129	25
1969	994	396			35			20	1,445	23
1970	249	829			12	3	113	4	1,210	27
1971	187	882		364	16		231	4	1,684	42
1972	2,718			4,554	33		1,068	16	8,389	20
1973	846			2,125	25			216	3,212	47
1974	676			111	20			31	838	31
1975	3,912	779						92	4,783	32
1976		1,946						1,393	3,339	100
Total	23,852	9,007	8,101	7,619	2,642	1,686	1,601	2,186	56,694	

Table 2: Historical estimates of rhino horn exports from East Africa, shown as estimated quantities either in kg for individual years or as kg/year over a run of years, and price in US$/kg (from Martin and Martin 1982).

Year	Place and activity	Quantity	Price
1840s	Mafia and Bagomoyo received	c. 5,500-8,000kg/year	
1863/64	Zanzibar imported	c. 6,350kg	0.63
1867/68	Zanzibar imported	c. 9,700kg	0.73
1873	Zanzibar imported	c.12,700kg	0.79
1870s	Mombasa exported	c. 1,590kg/year	0.94
1893	Tanganyika exported	c. 7,000kg	1.10
1894	Tanganyika exported	c. 9,000kg	1.10
1895	Tanganyika exported	c.13,400kg	1.10
1914	East African exports		3.15
1926	East African exports		11.69
1929	East African exports		22.68

The statistics from 1949-1976 include the countries to which the horn from East Africa was declared to have been exported (Table 1). In the 1950s most horn from East Africa went to Hong Kong and the then independent Zanzibar, both of which acted as entrepôts for trade to the Far East. In the 1960s an increasing proportion of horn was taken by Aden/South Yemen, and in the late 1960s and 1970s Hong Kong, South Yemen and China all took relatively even shares of East Africa's declared horn (Figure 3a).

Figure 3: The countries of (a) destination and (b) origin of East Africa's declared rhino horn exports from 1947-76 (data from Parker and Martin 1979).

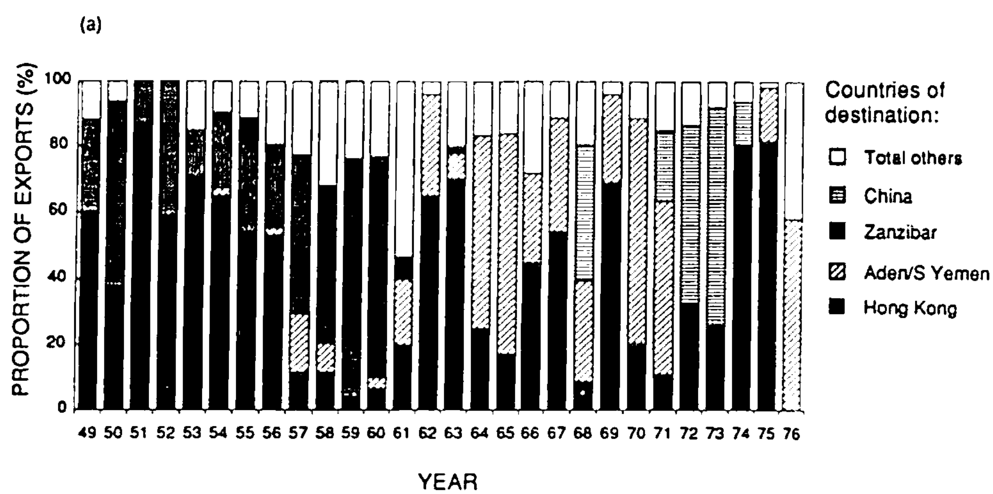
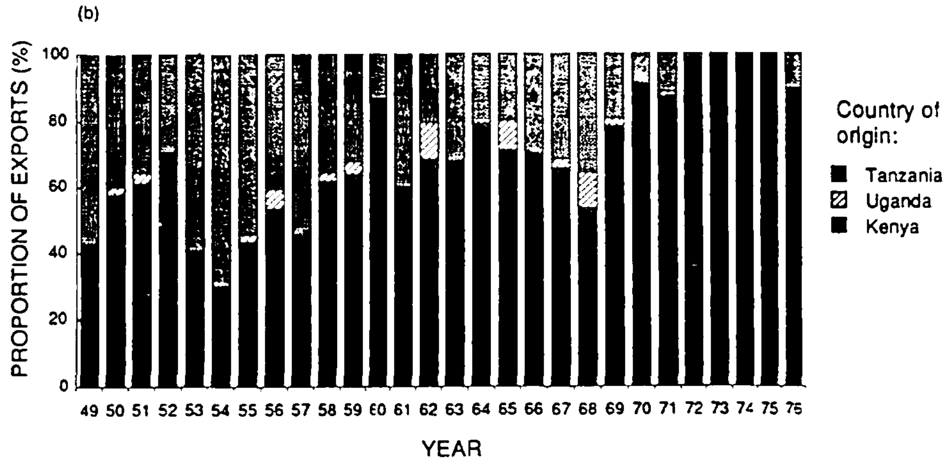


Figure 3 continued



The rest of Africa

Data on exports from other African countries are largely anecdotal and fragmentary (Martin 1983d). The only other time series is for South Africa, but is for volumes only (see Table 8c), and this is discussed in another context below.

Asia

In contrast to African producers, many of the producing nations in Asia use horn for domestic consumption and export it. There are, however, even fewer runs of data from Asia than from Africa. From 1919-1927, 344kg of horn was exported from Sumatra to Singapore and China, and from 1912-1922, 210kg of Sumatran horn was exported from Borneo. For this period, the trade from these two states averaged 90kg (or the deaths of 350 Sumatran rhinos)/year (Martin 1983d).

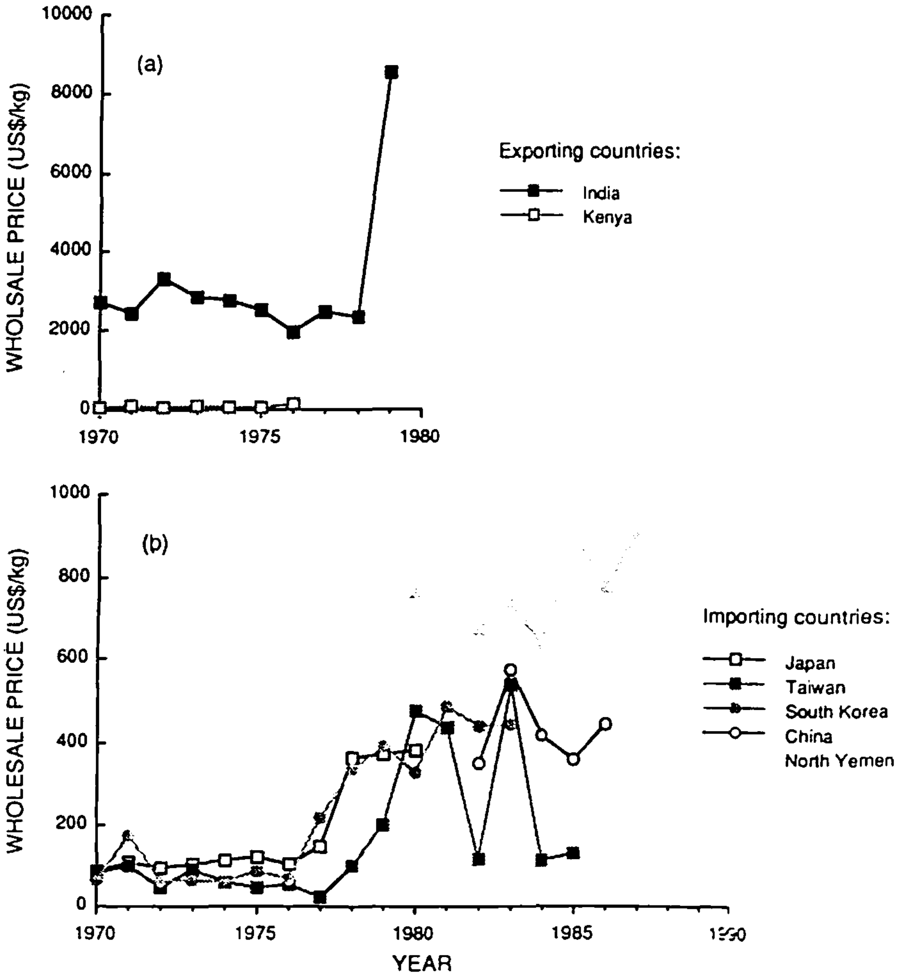
The only time series comparing volumes and prices is from the horns recovered from Indian rhinos dying in Assamese reserves. Between 1965 and 1979 this horn was put up for tender legally (but probably exported illegally). The auctioning of horn ceased from 1979/80 and onwards due to pressure from conservationists, and the recovered horn was instead stockpiled (Martin and Ryan 1990). The quantities available for tender fell from 1965 to a low in 1972 but then increased again (Table 3). The average price increased steadily until a rapid price increase in 1979, and this increase is clear even when average prices are corrected for inflation. This rise mirrors events in Africa, but the wholesale value of Indian rhino horn is considerably higher (Figure 4a).

The appearance of Asian countries such as India as major exporters to other Asian countries (see below in Tables 4-6) occurs in large part because they acted as entrepôts for African horn (Martin 1983d).

Table 3: The volume and price (in kg and US$/kg) of horn recovered from dead Indian rhinos and put up for tender in Assam. Some of the horn was defective, but for consistency the price of sound horn only is shown (data from Martin 1983d).

Year	Volume	Price	Year	Volume	Price
1965	29.34	931	1973	17.03	1,650
1966	22.04	1,161	1974	31.60	1,750
1967	14.39	1,104	1975	16.13	1,760
1968	Nil		1976	18.06	1,454
1969	12.72	1,269	1977	30.04	1,950
1970	10.44	1,333	1978	45.33	1,957
1971	21.90	1,269	1979	39.49	7,800
1972	7.10	1,800			

Figure 4: The wholesale price of rhino horn, corrected for inflation, from two exporting countries and five importing countries, showing (a) prices of African and Asian horn and (b) of African horn only (data from Tables 1, 3, 4, 5, 6, 7, 12).



IMPORTS TO CONSUMING AND ENTREPOT NATIONS

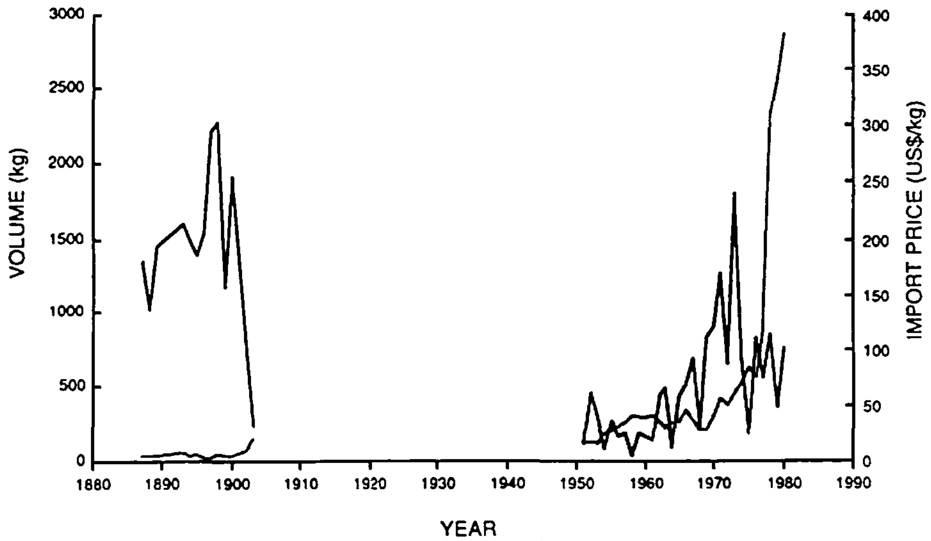
Far East

Rhino horn has been traded and consumed in the Far East for centuries, yet there are only reasonable time series of declared imports to three consuming countries.

Japan

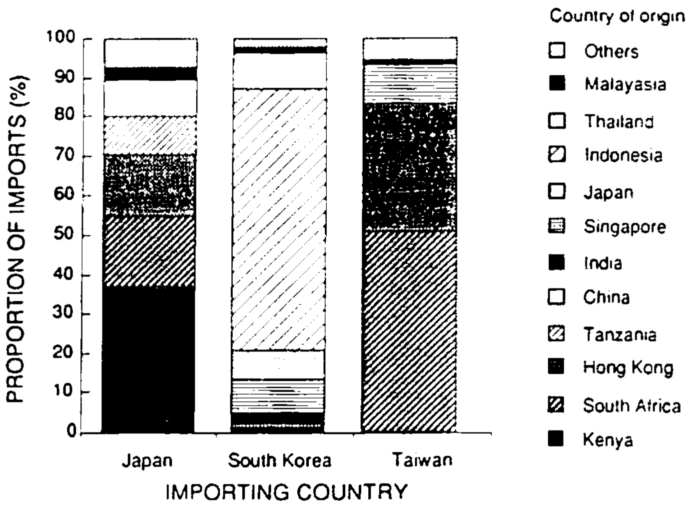
Japan has the longest series of data on horn volumes and prices covering 1882-1903 and 1951-1980 (Figure 5). The volume of imports to Japan was high (1,283kg/year) during 1882-1889 and rose higher still (1,697kg/year) during 1893-1900. Between 1882 and 1887, most horn was imported from Siam (Thailand) and East Indies (Indonesia), from Sumatran and Javan rhinos. The level of imports during this period represents the deaths of around 2,000 rhinos/year depending on the mix of horn from the two species. In 1888, the Japanese turned both to Indian traders who supplied them, not with Indian horn which was then used for domestic consumption, but with East African horn, and to the Chinese. African horn continued to be exported into Japan between 1904 and 1940 when World War II interrupted supplies, but no records were kept.

Figure 5: The volume (solid line) and price (dashed line) of Japan's declared imports from 1882-1903 and 1951-1980 (data from Martin 1983d).



After the War, Japan declared the greatest volume of horn imports of the three Far Eastern nations with statistics, at an average of 488kg/year during 1951-1980. From 1951-1959 imports were low (196kg/year) but increased in the 1960s (404kg/year) and 1970s (806kg/year). The price of horn climbed steadily from the nineteenth century to the 1970s and then increased rapidly (Figure 5). Thus, the relationship between volume and price for Japan shows similarities to the export data from East Africa (c.f. Tables 1, 2, 4; Figures 2, 5). The declared countries of origin of the horn imported to Japan have also been recorded from 1951-1980 (Table 4). Kenya (37%), South Africa (18%), Hong Kong (18%) and Tanganyika/Tanzania (10%) provided the bulk of Japan's declared imports (Figure 6).

Figure 6: The declared origin of rhino horn imported to three Far Eastern consuming nations (data from Tables 4, 5, 6).



Taiwan

A shorter series of declared imports are available for Taiwan from 1968-1985 (Table 5). Over this period, declared imports were similar to Japan's at an average of 476kg/year. The average price of horn remained steady until the late 1970s, increased rapidly between 1978 and 1982, but then dropped, rose and dropped from 1983-1985 (Table 5). The early part of Taiwan's data set has two problems. First, from 1968-1971 horn volumes included some antelope horn (Martin 1980b). Second, from 1968-1978, the declared countries of origin of 67% of the horn were not specified, but the major source during this period was Hong Kong (51%). Sources of origin were better specified during 1979-1985, when most of Taiwan's declared horn came from South Africa (51%), Hong Kong (32%) and Singapore (10%) (Figure 6).

Table 4: Declared volume (kg) and average price (US$/kg) of imports to Japan during 1951-1980 from countries of origin (*Tanganyika/Tanzania before/after 1964) (data from Martin 1983d; Martin and Barzdo 1984).

YEAR	Kenya	South Africa	Hong Kong	Tanga-nyika*	Tan-zania*	China	India	Others	Total volume	Average price
1951		80				36			116	16
1952		137	58			112		150	457	17
1953		83	18			174			275	15
1954		48				30			78	25
1955	48		56			157		5	266	27
1956	48					120			168	31
1957	18	18				120		30	186	34
1958	30			6					36	41
1959	25		50	18		51	20	18	182	39
1960	61					94	5		160	39
1961	10					132	2		144	40
1962	160	25	20			75	151	15	446	34
1963	92	215		69		6	112		494	29
1964		10	79				8		97	35
1965	38	39	68	10		53	62	160	430	34
1966	91	43	49	146		75		115	519	45
1967	59		162		261	20	86	100	688	36
1968	9	25	106		49			50	239	28
1969	295	11	274		85			160	825	28
1970	203	37	353		262	10		28	893	41
1971	447	121	197		414		31	60	1,270	56
1972	588	15	45						648	50
1973	1,016	462	265					49	1,792	60
1974	409	164	27		84				684	70
1975	143	22	16						181	84
1976	704	64	55						823	75
1977	304	25	229					3	561	116
1978	367	350	120					16	853	308
1979	234	68						55	357	341
1980	7	587	15			106		48	763	383
Total	5,406	2,649	2,262	249	1,155	1,371	477	1,062	14,631	

Table 5: Declared volume (kg) and average price (US$/kg) of imports to Taiwan during 1966-1985 from countries of origin (data from Martin 1980b; Martin and Barzdo 1984; Anon. 1985).

YEAR	South Africa	Hong Kong	Singapore	Japan	Indonesia	Others	Total volume	Average price
1966		326				48	374	35
1967		226				268	494	27
1968		1,077		10		394	1,481	20
1969		242				119	361	38
1970		122		4		85	211	39
1971		119				11	130	50
1972		216				725	941	24
1973		153		3		189	344	51
1974						1,600	1,600	37
1975						1,098	1,098	32
1976						681	681	40
1977		200				24	224	17
1978	166	84	12			643	905	82
1979	11	170				38	219	184
1980	55			2			57	477
1981	47						47	476
1982	71				4		75	136
1983	117						117	654
1984		50	70				120	142
1985	43						43	168
Total	510	2,984	82	19	4	5,923	9,522	

South Korea

The third series of declared imports is for South Korea and spans 1970-1983 (Table 6). Declared imports were the lowest of the Far East nations at 204kg/year and remained fairly constant during this period, but import prices rose rapidly in the 1970s. Most horn imported to South Korea was declared to have come from Indonesia (67%), with lesser amounts from Thailand (9%), Singapore (9%) and Japan (7%) (Figure 6). However, this appears unlikely because Indonesian dealers did not re-export their African horn, and it seems likely that most of South Korea's horn came from Hong Kong (Martin 1983d).

Table 6: Declared volume (kg) and average price (US$/kg) of imports to South Korea during 1970-1983 from countries of origin (data from Martin 1983d; Martin and Barzdo 1984; Anon. 1985).

YEAR	Indonesia	Thailand	Singapore	Japan	India	Malaysia	Hong Kong	Kenya	Others	Total volume	Average price
1970				1			2			3	30
1971			50	2						52	91
1972			197	31					20	248	34
1973	214			9	30					253	37
1974	97	81		6			30			214	38
1975	200			12						212	58
1976	204	65		8						277	49
1977	207	66		15	19					307	172
1978	51									51	284
1979	208	40			20	30			20	318	355
1980	93	4		89		21			10	217	326
1981	127						5		10	142	530
1982	200			28				35		263	516
1983	300									300	537
Total	1,901	256	247	201	69	51	37	35	60	2,857	

Middle East

It is probable that the wish to own a *jambia* is not restricted to Yemeni men, and indeed *jambias* are found in at least Saudi Arabia (Martin 1990b). However, Yemen appears the major user of rhino horn and it is only from there that information on the rhino horn trade exists. Because rhino horn improves in appearance with age, it is the preferred material for dagger handles.

Yemen

Yemen used to comprise two countries. Aden or South Yemen was under British control from 1839-1967 and imported rhino horn from East Africa that appears under the East African export statistics (Table 1). Increasing volumes were recorded as leaving for Aden: 51kg (7kg/year) from 1949-1955; 725kg (120kg/year) from 1956-61, 3,795kg (474kg/year) from 1962-69 and 4,436kg (634kg/year) from 1970-1976 (Table 1, Figure 3a). From 1967-1990 South Yemen was a communist state and import of luxury goods such as rhino horn has been discouraged. North Yemen, by contrast, remained isolated until it underwent a long civil war between 1962-1969. North Yemen then replaced South Yemen as the major consumer of rhino horn, so it can be assumed that South Yemen acted as an entrepôt for its northern neighbour in East Africa's customs statistics from 1969-1976. During 1969-1977, official statistics show that North Yemen imported at least 22,645kg (3,235kg/year) of horn (Table 7a), and it was believed most horn imported to North Yemen at this stage was from East Africa.

Table 7a: Total declared imports and estimates of the total volume of horn entering North Yemen (since 1990 the Republic of Yemen), the purchases of and wholesale price paid by the main merchant in Sanaa (all in kg or US$/kg)(after Martin 1984a, 1985b, 1987; Vigne and Martin 1987a, b, 1991b).

Declared imports		Estimated imports		Merchant's purchases		
Year	Volume	Year	Volume	Volume	Price	Events
1969-70	233					
1970-71	131	1970	c.3,000	c.3,000		
1971-72	1,445	1971	"	"		
1972-73	2,139	1972	"	"		
1973-74	3,544	1973	"	"		
1974-75	Nil	1974	"	"		
1075-76	8,310	1975	"	"		
1976-77	6,843	1976	"	"		
		1977	"	"		
		1978	"	"		
		1979	c.1,675	"		
		1980	"	1,050	764	
		1981	"	1,320	764	
		1982	"	1,585	786	Imports banned
		1983	"	1,120	891	
		1984	"	1,058	796	Reduced smuggling
		1985	c.1,000	475	1,159	
		1986	c. 500	100	1,032	
		1987				Further restrictions
		1990	c. 120		1,360	Further restrictions
Total	22,645		43,000	36,708		

Table 7b: Change in the rate of manufacturing dagger handles from rhino horn by the main merchant in Sanaa.

		Rhino horn handles	
Year	No daggers/year	No/year	%
1970s	6,000	6,000	100
1986	24,000	2,400	10

Table 7c: Price of horn shavings in Sanaa for export (in US$/kg).

Year	Price
1985	139
1986	227
1987	253
1990	340

The declared statistics cease well before North Yemen first banned imports in 1982. However, the main rhino horn trader in Sanaa, the capital of North Yemen, kept records of the volumes and wholesale prices of horn that he bought spanning the end of the period when horn could be imported legally and the start of the supposed import ban (Table 7a). Both his colleagues and the main trader claimed that he monopolised two thirds to four fifths of Yemen's trade (Martin 1987). The trader's records are exact from 1980-1986 and estimated from the 1970s to 1980. With an approximate total import of 36,000kg from 1970-1986, and multiplying up from the trader's claimed rate of monopolisation, the volume of the horn trade was estimated for North Yemen from 1970-1986 by Martin (1987), as shown in Table 7a. However, it was also claimed that there was considerable smuggling of horn (and most other consumer goods) into North Yemen in order to avoid import tax, to the approximate tune of 70% of total imports (Martin 1985b). As it was only after 1983 that more rigorous customs checks were instituted to save the country large amounts of revenue (Martin 1985b), the estimated volumes for North Yemen most probably only represent minimum values. Even so, the Yemeni trader's claimed total volume of 36,000kg of horn represents the death of a minimum of 12,750 black rhinos.


WWF / Mark Boulton / ICCE

The black rhinos have been subject to the worst decline experienced by any land mammal in recent time. The main reason: poaching for their horns.

COMPARISONS BETWEEN EXPORT AND IMPORT STATISTICS

Under-reporting in Declared Statistics

Large mis-matches are evident between the declared statistics of exporting and importing nations (Tables 8a, b, c). If the assumption that South Yemen acted as entrepôt for its northern neighbour in East Africa's customs statistics from 1969-1976 is correct, then there is an almost five-fold difference between the declared exports from East Africa to South Yemen and the declared imports to North Yemen (Table 8a).

Similarly, the declared exports from Kenya and Tanzania during 1955-1980 are between four and 12 times lower than the declared imports to Japan over the same period (Table 8b). Furthermore, the proportion of horn that Tanzania contributed to East Africa's declared statistics dropped significantly after independence in 1964 (Figure 2b), but this was clearly not due to a lack of rhinos to supply the horn. Instead, it appears that in the declining economy of an extreme socialist state, entrepreneurs were illegally converting increasing quantities of horn into hard currency (Parker and Martin 1979). Furthermore, the official exports from South Africa during 1966-1978 are lower than the minimum total imports to the three consuming and entrepôt countries of Japan, Taiwan and Hong Kong, even though the data for Taiwan and Hong Kong (South Africa's two most important consumers: see Figure 6) are missing from almost the entire run of data (Table 8c). One further example comes from an entrepôt for a single year. In 1978, South Korea declared that it had exported 28kg of horn to Japan, which itself recorded 133kg of imports from South Korea (Song and Milliken 1989).

Table 8a: Mis-match between declared exports of horn from East Africa to South Yemen and declared minimum imports to North Yemen during 1969-1977, all in kg (data from Parker and Martin 1979). The data for North Yemen represent a minimum because the lack of imports in 1974-1975, which is probably due to lack of recording rather than to lack of imports (Varisco 1987).

Year	Volume	Years	Volume
1969	396	1969-1970	233
1970	829	1970-1971	131
1971	882	1971-1972	1,445
1972		1972-1973	2,139
1973		1973-1974	3,544
1974		1974-1975	Nil
1975	779	1975-1976	8,310
1976	1,946	1976-1977	6,843
Total	4,832		22,645

Table 8b: Mis-match between declared exports of horn from East Africa and declared imports from Japan, all in kg (data from Parker and Martin 1979; Martin 1983d).

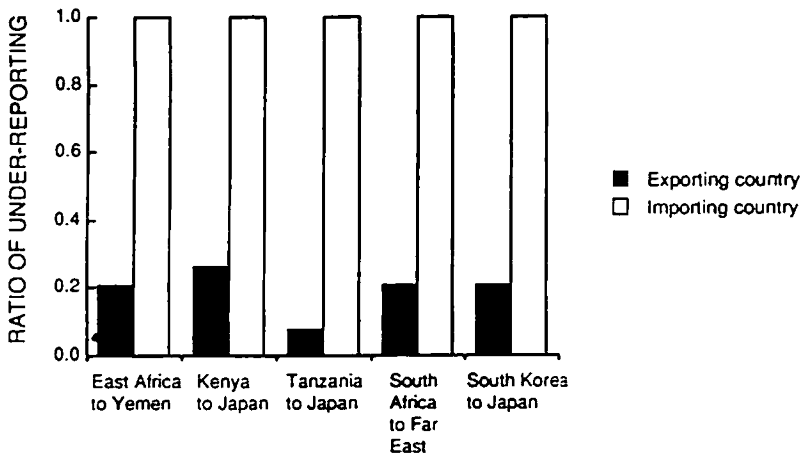
Year	Kenyan exports to Japan	Japanese imports from Kenya	Tanganyikan/ Tanzanian exports to Japan	Japanese imports fromTanganyika/ Tanzania
1955		48		
1956		48		
1957		18		
1958		30		
1959		25		18
1960		61		
1961		10		
1962		160		
1963		92		69
1964				
1965		38		10
1966	11	91	27	146
1967	142	59		261
1968	9	9		
1969		295		85
1970	67	203	46	262
1971	128	447	91	414
1972	1,062	558	6	
1973		1,016		
1974		409		84
1975		143		
1976		704		
1977		304		
1978		367		
1979		234		
1980		7		
Total	1,419	5,376	107	1,349

Table 8c: Mis-match between the official exports of horn from South Africa and the declared imports to various countries from South Africa (data from Martin 1983d).

Year	South African official exports	Japanese declared imports	Taiwan declared imports	Hong Kong imports	Minimum total imports
1966	605	43	NA	NA	
1967			NA	NA	
1968		25	NA	NA	
1969		11	NA	NA	
1970		37	NA	NA	
1971		121	NA	NA	
1972		15	NA	NA	
1973	389	462	NA	NA	
1974	304	164	NA	NA	
1975		22	NA	NA	
1976	126	64	NA	NA	
1977		25	NA	NA	
1978	177	350	166	345	
Total	1,601	1,339	166	345	1,850

Therefore, even when rhino horn could be traded legally, it appears that there was a flourishing illegal trade. The difference of around four to 12 times between the trade figures of exporting and importing nations (Figure 7) would appear to be due primarily to the latter recording illegal exports from producing nations. The size of the difference between exporting nations may not be a fully accurate estimate of the size of the illegal trade. On the one hand, it may be an overestimate, at least in the case of Japan. Studies of the ivory trade show that some Kenyan ivory re-exported from Hong Kong to Japan appeared in the Japanese statistics under Kenya, but in the Kenya statistics under Hong Kong (Milliken 1989), and the same may be true for rhino horn. On the other hand, the difference may be an underestimate for it takes no account of the under-reporting by the importing country. This cannot be easily quantified because there are no other sets of figures for comparison. However, smuggling into importing countries was believed to be considerable even when the horn trade was legal, in order to avoid import taxes, for example into South Korea and Yemen (Martin 1983d, 1985d).

Figure 7: The extent of under-declaring of exports relative to declarations of imports from the same country, for a range of years (East Africa) and the single year of 1978 (South Africa, South Korea).



Usefulness of Trade Statistics

Despite their various shortcomings, the legal and declared trade statistics make several points. For example, comparisons between African and Asian trade and exports (Tables 1, 3) show that there were considerable differences in volumes and prices produced legally by the two continents in the 1970s. The volume of legal trade was much higher from East Africa than from India, but the average price of Asian horn at source was much higher (Figure 4a). As will be shown when discussing the illegal trade, this difference also translates through to retail prices charged in pharmacies (see later in Table 11). The price of African and Asian rhino horn differs for two main reasons, first, because there are far fewer Asian rhinos and, second, because Asian horn is considered much more effective as a medicine (Martin 1980b; Martin and Martin 1982; Nowell *et al.* 1992).

The legal trade statistics also show that a sharp increase in the price of horn was seen in all producing and consuming countries in the late 1970s (Tables 1, 3, 4, 5, 6, 7a). This difference still holds when prices are corrected for inflation (summarised in Figure 4b for countries consuming African rhino horn). This price rise has been attributed to two main factors (Martin 1980b; Martin and Martin 1982). First, many Yemeni workers migrated to Gulf States with oilfields after the end of the civil war in North Yemen in 1969 and, with high wages, were able to afford *jambias*.

Second, new buyers, mainly Africans, entered the markets in the now independent African countries and broke the monopoly of Indian traders. The price rise was not due to reduced supplies because an increasing amount of horn entered the market in the 1970s (Figures 2. 5). A third possible factor has not been considered (Martin and Martin 1982), namely that the formulation of CITES and the placing of horn from all species of rhino on Appendix I by 1977 meant that continued trade would be illegal, thereby causing the price of horn to rise.

Finally, with the move into the era of illegal trade, the declared trade statistics are useful, ironically, in showing the ineffectiveness of CITES and other bans in controlling the trade in rhino horn. Several producing countries had their own bans in place before CITES. For example, India abolished rhino hunting in Bengal and Assam in 1910, Indonesia's rhino populations have been protected nominally since 1931, Malaysia's have been protected since 1955, whilst Thailand's have been protected since 1960. Thus exports made by these four countries since the dates of their bans and that appear in the declared imports of other countries (Tables 4-6) were already illegal. Even after many producing and entrepôt countries became a party to CITES, they still continued to export rhino horn that appeared in the legal imports of consuming countries until they in turn became a party to CITES (Table 10). South Africa was a major offender with its illegal exports to Japan and Taiwan, as was Hong Kong with its exports to Japan, Taiwan and South Korea (Martin and Martin 1989; Vigne and Martin 1989a). Even though Indonesia appears a major offender with its exports to South Korea, it seems to appear incorrectly as a guise for Hong Kong, further swelling the volume of Hong Kong's illegal traffic (Martin 1983d; Song and Milliken 1990). Obviously these figures represent minimum levels of contravention of CITES because they exclude horn not declared by the importing nation. However, these figures show clearly the ineffectiveness of CITES and other bans in controlling the supply of horn by producer and entrepôt nations, as will be discussed further below.

HOW MUCH HORN HAS COME ONTO INTERNATIONAL MARKETS?

Incompleteness of Trade Statistics

The good quality of data on volumes of ivory in world trade has recently enabled a model to be formulated that matches changes in ivory volumes to changes in elephant numbers (Milner-Gulland and Mace 1991). One of the aims of this review was to determine if the data on volumes of rhino horn would permit a similar model for rhinos. Unfortunately, the available statistics for trade in rhino horn are very incomplete, even when the horn trade was legal, for two main reasons. One reason has been discussed already, namely the under-representation of trade in declared statistics (Figure 7). The other reason is that the statistics for rhino horn cover only a short period and very few producing or consuming countries (Tables 1, 3, 4, 5, 6, 7a, 12). It is therefore not even possible to sum the total declared world trade in rhino horn for any single year.

Attempts to Match Horn Volumes Traded and Changes in Rhino Numbers

Despite the incompleteness of trade statistics, an attempt has been made to quantify the total volume of horn traded during the 1970s. Using annual average volumes from declared statistics for Yemen, Taiwan, Japan and South Korea, it was estimated that a minimum of around 8,000kg/year of rhino horn was traded during the 1970s (Martin 1980b: Table 9). Because this was mainly supplied by black rhinos, this volume represented the deaths of around 2,800 rhinos/year during this period. A crude attempt was made to match this assumed loss to the actual loss in rhino numbers, which from the African Elephant and Rhino Specialist Group (AERSG) best estimates, was calculated to have been 2,660 rhinos/year during the same period (Martin 1980b). The volume of trade in the 1980s was estimated to have dropped to 3,000kg/year, based on the loss of Yemen from the marketplace (Table 7a) and from estimates of change in rhino numbers (Martin 1983d).

Table 9: Minimum estimates of rhino horn imports into main consumer countries, taking into account declared volumes per year during 1971-1977 (North Yemen) and during 1972-1978 (Japan, Taiwan and South Korea) and educated guesses for other countries (taken from Martin 1980b). The figures in brackets are re-calculated by the author on the basis of the same data used by Martin. The figures can be verified in Tables 4-7.

Country	Volume (kg/yr)		Approx. volume
North Yemen	2,972	(2,828)	3,000
Taiwan	943	(827)	
Japan	792		2,000
South Korea	223		
China:			
Chippings from North Yemen	750	(407)	1,750
Other imports	1,000		
Others	1,000		1,000
Total			7,750

Table 10: Minimum levels of contravention of CITES regulations by producer and entrepôt nations exporting rhino horn, as shown by declared imports of consumer countries, all in kg (data from Tables 4, 5 and 6).

Producer/entrepôt	Enforcement of CITES	Japan until 1980	S Korea until 1983	Taiwan until 1983
South Africa	1975	1,094	—	344
India	1976	—	49	—
Hong Kong	1976	364	5	170
Malaysia	1978	—	51	—
Kenya	1979	7	35	—
Indonesia	1979	—	720	4
Japan	1980	NA	28	—
China	1981	NA	—	—

The volumes of horn on world markets were then questioned and believed to have been great underestimates (Western 1989). It was argued that the earlier analysis (Martin 1980b), using only losses of rhinos between censuses, had taken no account of recruitment and the subsequent loss of these additional rhinos. Using corrections for the proportion of rhinos believed poached (90%, based on evidence from Amboseli, Kenya in Western 1982) and for the loss of orphan calves (20%) that would contribute nothing to the horn trade, it was estimated that only 45-51% of the horn actually going on to international markets was picked up in trade surveys, and that this shortfall went undetected (Western 1989). Given that China declared that it alone imported 2,124kg/year of African rhino horn during 1982-1986 (see later in Table 12) and that other importing countries, especially South Korea and Yemen, were known to under-report the volumes they imported (Martin 1983d, 1985b), this argument appears to have some basis (Western 1989). It was also recognised that the best estimates of rhino numbers produced by AERSG are also likely to be under-estimates, and could cause an even greater disparity between detected and undetected horn volumes (Western 1989).

The criticism that much trade went undetected was subsequently refuted (Martin and Ryan 1990). It was acknowledged that recruitment needed to be taken into account, but the two studies then differed on the proportion of horn that would reach international markets. While one side estimated that 90% of deaths were due to poaching (Western 1989), the other side believed that only 50% of adult deaths arose from poaching and that only 14% of horn was recovered from natural deaths (Martin and Ryan 1990). Corrections were also made for the amount of horn that would never have reached international markets because (a) rhinos were shot on license in various countries until 1979, (b) recovered and confiscated horns were being stockpiled (see later in Table 13), (c) storage of stockpiles was inefficient and resulted in damage to horns, and (d) a small amount of domestic use within Africa (see Martin and Ryan 1990). After making these assumptions and corrections, it was estimated that volumes of 8,000kg/year in the 1970s and 3,000kg/year in the 1980s left little horn unaccounted for (Martin and Ryan 1990).

Some of the corrections have merits, especially with regard to the proportion of horn recovered from natural deaths. However, the basis for their major assumption that only 50% of rhino deaths arose from poaching was not explained (Martin and Ryan 1990), when carcass ratios from major populations such as Luangwa Valley, Zambia that were heavily exploited in the 1980s were in fact around 70% (Leader-Williams 1988; Leader-Williams *et al.* 1990). In addition, only minimum values of traded volumes can be estimated both because horn volumes are under-reported and because rhino numbers are under-counted to unknown extents. Furthermore, estimates of horn volumes made from population estimates lack independence. It seems likely, therefore, that the actual volumes of horn that have entered the trade will remain open to speculation, and that a model of horn volumes against rhino numbers could not be approached with the same degree of confidence as a model of ivory volumes against elephant numbers (Milner-Gulland and Mace 1991).

MONITORING THE ILLEGAL TRADE

Producing and Entrepôt Nations

Reductions in rhino numbers and distribution, especially of black rhinos, provide evidence of continued trade in rhino horn in producing countries. However, apart from evidence cited above (Table 10), horn volumes have been impossible to monitor in producing and entrepôt nations.

Consuming Nations in the Far East

Since import statistics in consumer nations of the Far East ceased to be recorded, the illegal trade in horn has been monitored largely through the continuing work of E.B. Martin and his colleagues, who have conducted interviews with pharmacists since 1979. These interviews have provided a short time series on the availability of rhino horn products for sale and their price in Far Eastern consumer nations. These data have at least two major drawbacks. First, the general problem of whether changes in the proportion of shops stocking horn (an index of 'consumer' demand) and in its retail price can be equated to changes in demand in terms of volume. Second, the specific problem of the reliability of interviews conducted openly by a westerner accompanied by an interpreter as compared with undercover interviews by nationals without a westerner present. The reliability of the former approach has been questioned recently for South Korea (Song and Milliken 1989, 1990). As a Korean, Song pretended to be buying medicines for a sick relative, and their survey showed that more pharmacies were selling horn and at a higher price in 1988, in contrast to a 1986 survey which suggested that South Korea's 1984 import ban had been successful in reducing consumer demand because fewer pharmacies were stocking horn and its retail price had dropped (Martin 1986c). Furthermore, a recent survey in Taiwan was conducted by local college students (Nowell *et al.* 1992) and its results followed the same pattern as the Korean survey. While these increases may reflect a real difference between years, methodological differences cannot be discounted. Despite these reservations, most data that are available to monitor the illegal trade in consumer nations over time come from E.B. Martin's interviews (Table 11). A profile of each consumer nation now follows, and at this stage all data on prices remain uncorrected for inflation.

Table 11: Consumer demand for rhino horn in some major cities of eastern Asia, as measured by the number of traditional pharmacies stocking horn and by the average retail price. All data were collected by E.B. Martin apart from those marked with *† (from Martin and Vigne 1987b; Martin 1989a, b; *Song and Milliken 1990; Martin and Martin 1991; Milliken *et al.* 1991; † Nowell *et al.* 1992).

Country	City	Year	Selling %	Horn (N)	Retail price African	Retail price Asian	Restrictions
Hong Kong		1976					CITES
		1979	73	15	11,103		Imports banned
		1982	46	50	15,700		
		1985	41	80	14,282		
		1986					Exports banned
		1987	32	60	20,751		
		1990	5	65	16,240		
China	Guangzhou	1981					CITES
		1985	17	12	18,722		
		1987	15	13	16,304		
Taiwan	Taipei	1979	100	9	1,596	17,090	
		1985	76	34	1,532	23,929	Imports/exports banned
		1988	73	60	4,660	40,558	
		1989					Internal trade banned
		1990	51	79	4,221	54,000	
		1991†	71	167	8,148	62,455	
	Kaohsiung	1985	90	20	2,007	21,365	
		1988	87	15	3,347	42,880	
		1990	50	14	3,737	40,404	
		1991†	84	197	5,107	42,495	
Singapore		1979	53	15	11,615		
		1983	35	46	11,804		
		1986	39	33	14,464		Imports/exports banned
		1987					CITES
		1988	23	43	17,327		
Japan	Tokyo	1980	44	18	1,620		CITES
		1986	17	29	3,417		
	Osaka	1980	90	10	2,230		CITES
		1982	60	5	2,516		
		1986	76	41	3,771		
S Korea	Seoul	1980	63	30	1,436		
		1982	62	76	1,797		
		1983					Medicines banned
		1986	51	108	1,771		Imports banned
		1988*	86	59	4,410		
Peninsula Malaysia	Kuala Lumpur	1978					CITES
		1981	58	26	19,801		
		1983	21	29	17,280		
		1986	10	41	11,636		
		1988	4	45	23,810		
						14,697	
Sabah Malaysia	Kota Kinabalu	1986	11	18		20,350	
		1988	10	21	4,070		
						20,851	
Brunei		1978					Sumatran trade banned
		1982	40	5	6,895		
		1987	14	7	3,797		
		1988	12	8	6,614		
Macau		1979	78	9	4,127		
		1982	64	14	7,797		
		1986	80	20	8,644		CITES
		1987	65	22	8,407		
		1988					Internal trade banned
		1990	7	28	15,285		
Thailand	Bangkok	1972					Trade banned
		1979	52	23	3,654		
		1983					CITES
		1986	34	44		11,629	
		1988	33	52		13,111	
	Hat Yai	1988	50	4		20,910	

India

Domestic consumption of rhino horn as an aphrodisiac by Gujaratis seems largely to have ceased, and few pharmacies stock horn. This may be for two reasons. First, rhino horn imports from Africa were banned in 1972, causing the price of horn to rise beyond the means of most Indians (Vigne and Martin 1987c). Second, it has paid to export all the available Indian rhino horn to more lucrative markets, and the high prices commanded for Asian rhino horn in Taiwan (Table 11) are probably responsible for the poaching of at least 489 Indian rhinos during 1979-1989 (Martin *et al.* 1987; Vigne and Martin 1991a).

Hong Kong

Customs statistics show that Hong Kong took 42% of East Africa's declared exports from 1949-1976 (Table 1). Hong Kong became a party to CITES under the United Kingdom's ratification in 1976, but a short run of import statistics showed that Hong Kong imported 445kg of horn on license between June 1978 and February 1979 (Martin 1983d). Ivory traders, however, requested the government to take direct action against the trade and the first step in this process was the registration of existing stocks in 1978-1979, and the banning of all imports of horn in February 1979. Only existing stocks, totalling 696 kg of horn, were eligible for re-export (Milliken 1991). This continued 'legal' trade made it easier for illegal trade to continue and, in April 1986, Hong Kong agreed to stop exports of old stocks (Martin and Martin 1987). Internal trade continued after 1979 but fewer pharmacies stocked horn products in 1987. However, the retail price of horn doubled between 1979 and 1987 (Table 11). Internal trade in rhino horn was banned in August 1988, and a ban on the import, export and local sale of medicines claiming to contain rhinoceros ingredients was enacted in May 1989 (Milliken 1991; Milliken *et al.* 1991). Hong Kong therefore provides a successful model of the steps necessary to bring many aspects of the trade in rhino horn under control, and recent surveys show that very few pharmacies now stock horn (Table 11). However, the extent to which these measures have succeeded in controlling Hong Kong's role as an entrepôt remains uncertain. For example, 1,000kg of horn was said to have been purchased by Hong Kong businessmen in 1987/88 for export to China (Martin and Martin 1991), and exports from Hong Kong to Taiwan continue (Milliken *et al.* 1991). Given Hong Kong's traditional role as go-between for trade with Taiwan and China, and Taiwan's lack of trade links with Africa, apart from South Africa, Hong Kong may still remain an important deal-making centre for trade in rhino horn.

China

Customs statistics show that China directly imported 13% of East Africa's declared exports from 1949-76 (Table 1), and no doubt imported more via entrepôts. China became a party to CITES in 1981, and some domestic use of rhino horn also continues (Table 11). However, even though China has banned the use of rhino horn in new medicinal products, it has continued to be the major manufacturer of medicines containing rhino horn for re-export, and uses 600-700kg of horn annually (Martin 1990a). Intriguingly, as it was then a party to CITES, a short run of statistics was collected by ITRG, which showed that China imported 10621kg of African horn and 433kg of Asian horn during 1982 to 1986 (Table 12). The origin of this horn was not declared, but it was believed mainly to be from North Yemen (in the form of chips left over from carving dagger handles), Hong Kong, Macau and Taiwan, with smaller quantities smuggled in from Singapore and Thailand (Martin 1990a). In 1988, stocks of horn in China were registered and this produced a total of 9,874kg in the various medicine corporations, but excluded stocks in retail medicine shops, museums and private ownership. At current rates of use, this should provide sufficient stocks to last 15 years, but even valuable carved rhino horn antiques are now being stored up for pulverisation and inclusion in medicines (Martin 1990a).

Table 12: Rhino horn imports to China during 1982-1986, shown as volumes (kg), total price (US$x10⁴) and average price (US$/kg)(data from WCMC and TRAFFIC files).

	Rhino horn (African)			Rhino horn (Asian)		
Year	Volume	Total price	Price/kg	Volume	Total Price	Price/kg
1982	6,651	274	412	54.5	65	11,927
1983	517	36	696	76	101	13,289
1984	705	37	525	92	108	11,739
1985	2,274	106	466	149	171	11,476
1986	474	28	591	61	101	16,557

Taiwan

Taiwan was a major importer of horn from 1979-1985, and was supplied mainly by South Africa, Hong Kong and Singapore (Table 5). Taiwan cannot become a party to CITES because it is not recognised by the United Nations. However, Taiwan banned imports and exports of horn in 1985 but internal trade continued, itself to be the subject of a further ban in June 1989. The effect of these bans had apparently been to reduce those stocking horn products from 100% of pharmacies in 1979 to 50% in 1990. However, the retail price of African horn tripled from 1979-1988, but fell by 10% between 1988 and 1990. The retail price of Asian horn has also tripled but continued to rise between 1979 and 1990 (Table 11). Evidence suggests that most African horn during this period continued to originate from South Africa and its supplying countries, while supplies of Asian horn continue to come in from Hong Kong, Indonesia and India. Taiwan is also believed to be stockpiling horn and acting as an entrepôt since Macau and Singapore imposed, and apparently successfully enforced, bans on imports and exports of horn in 1985 and 1986, respectively (Martin and Vigne, 1986; Vigne and Martin, 1989a). A legally mandated registration of rhino horn was completed in November 1990, supposedly covering all importers, wholesalers, retailers and private owners, and produced a total stock of 1,465kg from 410 registrants. However, a survey in 1991 showed that a total of 1,800 pharmacies throughout Taiwan stocked horn and suggested current stockpiles of at least 3,712kg and possibly as high as 8,943kg (Nowell *et al.* 1992).

Singapore

Singapore took only a negligible fraction of East Africa's declared horn exports during 1949-1976 (Parker and Martin 1979). During the late 1970s and early 1980s, however, Singapore replaced Hong Kong as a major entrepôt, especially of horn from Sumatran rhinos in Sabah and Indian rhinos in Assam (Martin and Martin 1987; Martin 1989a). It took considerable pressure for Singapore to ban imports and exports of rhino horn in 1986 (Anon. 1986c) and in 1987 Singapore became a party to CITES. An 'undercover' survey conducted on behalf of CITES by local university students in 1985 showed that only 7% of 30 pharmacies examined sold horn (Sheeline 1987), but this survey is believed unreliable and is not included in Table 11. Instead, the proportion of pharmacies stocking rhino horn has declined from 53% in 1979 to 23% in 1988, while the retail price of African horn has increased from US$ 11,615 to 17,327/kg over the same period (Table 11). In 1991, ten horns were seized in a consignment from Indonesia, and were believed to be from Javan or Sumatran rhinos (TRAFFIC International *in litt.* 1992).

Japan

Before its accession to CITES in 1980, Japan imported large volumes of horn (Table 4). Pre-CITES stocks of horn remain legal, but pharmacists are being encouraged to use substitutes such as saiga. Fewer pharmacies now stock horn in two major cities, but the retail price of horn doubled between 1980 and 1986. There has been no recent survey of the extent of present sales of either raw horn or manufactured medicines in Japan.

South Korea

Customs statistics show that South Korea was a major importer of horn during 1970-1983, and suggested it was mainly supplied by Indonesia, Thailand, Singapore and Japan. However, it was estimated that actual imports were twice those declared due to high customs taxes which encourage smuggling (Martin 1983d) and that imports came mainly from Hong Kong (Martin and Barzdo, 1984; Sheeline 1987). The use of rhino horn in medicines was banned in 1983 and the import of horn was banned totally in 1986, but South Korea is not yet a party to CITES. By 1986, smuggling of horn was believed to have dwindled (Martin 1986c), fewer pharmacies were stocking horn and its retail price appeared to have fallen (Table 11). In contrast, a survey in 1988 showed that many more pharmacies were stocking horn products and that retail prices had more than doubled (Song and Milliken 1989, 1990). South Korea therefore remains a major consumer of rhino horn, but further surveys and/or registration of horn stocks are badly needed to determine the extent of South Korea's use in relation to China and Taiwan, and to investigate North Korea as a possible market.

Malaysia

The number of shops in Peninsula Malaysia stocking rhino horn products are few and declining, and prices too have not risen dramatically (Table 11). Rhino products are not in great domestic demand and little smuggling is believed to occur (Martin 1989a). However, a recent seizure from a medicine shop in the state of Penang included 13 rhino horns, 34 rhino hoofs and seven kg of rhino skins, all believed to be from Sumatran rhinos (R. Samsudin *in litt.* to TRAFFIC International 1992).

Sabah

The Chinese community in Tawau export Sumatran rhino horn from Sabah and Kalimantan to Singapore, and some pharmacies stock Sumatran rhino horn (Table 11).

Brunei

Although Brunei only joined CITES in 1990, export of Sumatran horn was banned in 1978. However, Brunei still imports some Sumatran horn from Singapore, and some horn is used in pharmacies (Table 11). Fears that it could become an entrepôt for African horn have not been realised (Martin 1989b).

Macau

Rhino horn has been imported to Macau for many years to supply Chinese pharmacies. However, in 1984 and 1985 traders found Macau to be a convenient entrepôt after other Asian countries had banned the trade in horn. Around 500kg of horn in several shipments were seized or declared en route to Hong Kong in 1984 and 1985 (Martin and Vigne 1987b). Even though supposedly a party to CITES since 1981 when Portugal joined, the Macau government officially agreed to conform to CITES only in 1986. Most pharmacies continued to sell horn and the retail price of horn doubled between 1979 and 1987 (Table 11). A ban on internal trade was announced in March 1988 (Anon. 1989a), and appears to have been very successful in greatly reducing the proportion of pharmacies stocking horn in 1990 (Table 11).

Thailand

Trade in Thailand seems largely to be in Asian rhino horn (Table 11). Even though Thailand instituted a trade ban in 1972 and became a party to CITES in 1983, internal consumption of horn continues and threatens Sumatran rhino populations in neighbouring countries (Martin 1989a).

Consuming and Entrepôt Nations in the Middle East

The illegal trade in the Middle East has been monitored by interviews with horn carvers in North Yemen (Martin 1987; Vigne and Martin 1987a, 1991b).

North Yemen

When North Yemen's economy was booming as a result of migrant workers bringing home big salaries from the Saudi oilfields in the 1970s, only rhino horn dagger handles were made (Table 7b). As black rhinos in Africa became depleted, and when it was realised that well organised trade routes were established from East Africa, Zambia and Central African Republic via Burundi, Somalia, Sudan, Djibouti and United Arab Emirates to Yemen, pressure was put on Yemen by conservationists to control their trade. North Yemen has not become a party to CITES but instead banned the import of rhino horn in 1982. The ban was not strictly enforced and horn continued to be imported, but at reduced volumes. The main trader reduced his purchases of horn from over 1,000kg annually during 1980-1984 to 475kg in 1985 to 100kg in 1986 (Table 7a). However, this reduction in trade may have been due also to the downturn in the North Yemen economy. While the total production of daggers had increased in North Yemen, far more were being made with other cheaper materials such as water buffalo horn and fewer were being made with rhino horn (Table 7b). Further pressure to impose bans and curtail the rhino horn trade (including on its export of horn chippings left over from making dagger handles: Table 7c), was put on North Yemen by conservationists and diplomats in 1987. In May 1990, North and South Yemen united to form the Republic of Yemen. The total volume of rhino horn now reaching Yemen appears to have become greatly reduced, to perhaps 120kg annually (Vigne and Martin 1991b: Table 7a).

United Arab Emirates

The trade route to Yemen has been known to involve various Gulf States, and this was dramatically confirmed by the recent burning of around 2,000kg of rhino horn in Dubai in 1992 (TRAFFIC International *in litt.* 1992: see Table 13 below). The exact origin of this horn is not known, nor its relationship to the reduced demand in Yemen. The role of Gulf States as entrepôts needs further investigation.

TRADE BANS AND THE CONSUMPTION OF RHINO HORN

Has CITES Affected the Consumption of Rhino Horn?

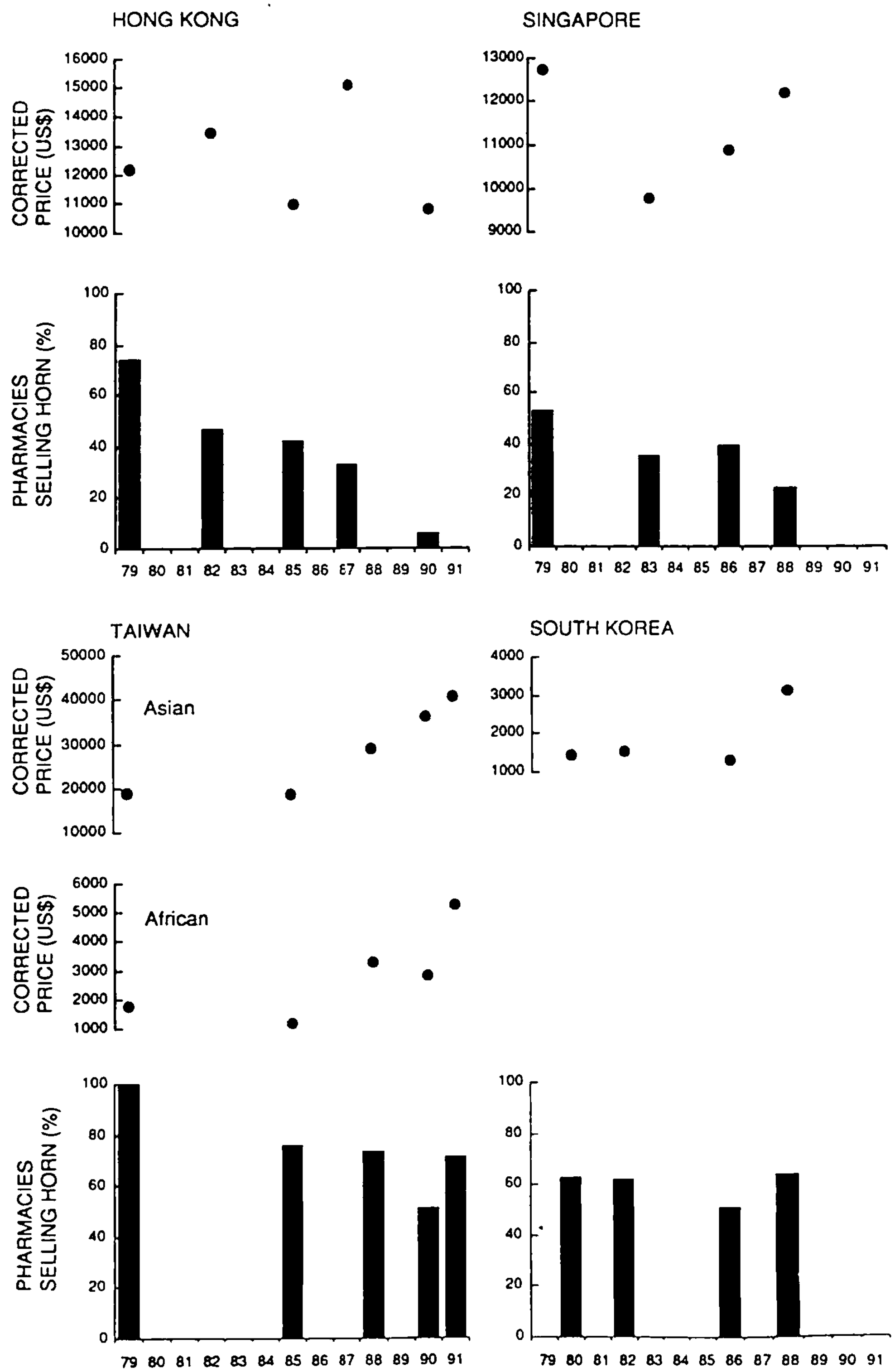
Since 1977, CITES has prohibited commercial international trade in all rhinoceros parts, derivatives or products. However, actual demand for horn, as evidenced by continued loss of rhinos in the wild, is a function both of the degree to which speculators are stockpiling horn and consumers are using horn. Control of domestic possession and sale of rhino parts and products is beyond the specific mandate of CITES and still remains unregulated in most consuming nations in Asia. Since the 1980s, therefore, the main approach by conservationists wishing to halt the serious declines seen in unprotected populations of endangered rhinos has been to attempt to halt the trade and encourage the use of substitutes within individual consuming nations. This option was seen as a more cost-effective approach than providing protection for rhinos throughout their range (e.g. Martin 1980b, 1987, 1988b; Cumming and Jackson 1984; Western 1987; WWF 1991).

It has been argued from survey data collected on the rhino horn trade that demand for rhino horn has decreased (Martin and Martin 1987), and that the battle to control the trade is being gradually won, using the following reasoning. First, only three tonnes/year of horn came onto world markets from 1980-1985 (see above), in contrast to the eight tonnes/year during the 1970s (Table 9). Second, even with this reduced supply, wholesale prices have remained the same since 1979, and retail prices actually fell from 1980 to 1986 in several cities (Table 11). Third, had the demand for horn remained constant, the prices would have soared because less horn was available (Martin and Martin 1987). Demand was believed to have fallen due to acceptance of substitutes such as water buffalo and saiga antelope *Saiga tatarica* horn in traditional medicines (indeed recent findings suggest that substitutes like water buffalo horn are as efficacious as anti-pyretics in traditional medicines (But *et al.* 1990)). Yet results from South Korea and Taiwan caution against accepting results from such surveys as evidence of reduced demand (Song and Milliken 1990; Nowell *et al.* 1992). By the mid-1980s there was evidence of reduced consumption only in Japan, India and North Yemen. In the case of Japan, this appeared due to the voluntary acceptance of substitutes (Martin 1983d) but, as noted above, the use of rhino horn medicines by the Japanese was learned from the Chinese and may not be as firmly ingrained a traditional belief. In the case of India, it was because it is more economically viable to export horns to lucrative markets (Martin 1983d; Martin *et al.* 1987). In the Yemen the reduced use of rhino horn can be attributed to the fact that substitutes and synthetic materials of suitable quality are acceptable for dagger handles, especially in times of economic stringency, in contrast to medicines (Vigne and Martin 1991b). This makes the point quite clearly that it is easier to halt the trade in animal products in luxury than in consumer goods.

Since the earlier optimism that demand for horn was slowing, the retail prices of horn have again risen in the data collected from 1988 and onwards (Table 11). A further look at the survey data on the illegal trade in rhino horn is merited because the retail prices charged in pharmacies (Table 11) have not previously been corrected for inflation, and have therefore not reflected real prices. It is unfortunate that only average retail prices are available for correction, rather than the full range of prices, because the few data points give little chance for statistically significant trends in changes of price to be detected. That aside, such correction appears to provide a slightly clearer picture of the success of efforts of a sample of consuming nations to control their trade in rhino horn (Figure 8). In Hong Kong, a significantly and consistently lower proportion of pharmacies have stocked rhino horn during 1979-90 and the real average retail price of rhino horn has shown no trend of increase, and possibly even decreased (Figure 8). By contrast, in South Korea (1980-1988) and Taiwan (1979-1991) the proportion of pharmacies stocking horn varied significantly but showed no consistent decline, and in Singapore (1979-1988) there was no significant change in the proportion of pharmacies stocking horn. However, even with the limited price data, there was a close to significant increase in the real price of Asian rhino horn in Taiwan and weaker trends of increase in the real price of African rhino horn in South Korea, Taiwan and Singapore (Figure 8). The even fewer data for Thailand (1976-1986) more resemble the situation in South Korea, Taiwan and Singapore. In contrast, the data for Kuala Lumpur, Malaysia (1981-1988) and Brunei (1982-1988) more closely resemble the Hong Kong situation, where prices may have even fallen. The situation in Macau (1979-1990) is somewhat equivocal because a lower proportion of pharmacies stock rhino horn, but the real price of horn has tended to increase. The two or fewer data points for China, Japan and much of Malaysia do not permit any reasonable conclusions.

The sale of rhino horn medicines is widespread in Taiwan. The horns are "shaved" (see horn on right) and mixed with a large number of other natural ingredients according to ancient recipes.

Figure 8: Change in numbers of pharmacies selling rhino horn and in retail price, corrected for inflation, of African horn (except where indicated), in four Far Eastern countries (data from Table 11).



Demand, in terms of stocking frequency and real price, for horn has declined, as far as the analysis of these limited data permit, in only Hong Kong, Peninsula Malaysia and Brunei (plus North Yemen and India for reasons discussed above). In the remaining points of sale surveyed over the past decade or so, there is suggestive evidence that demand, in terms of real price has increased. Thus it appears clear that CITES, other national bans and most other efforts may have succeeded in slowing, but not in halting, the rhino horn trade for medicines in the Far East. Control of domestic possession and sale of rhino parts and products, however, is beyond the specific mandate of CITES and still remains unregulated in most consuming nations in Asia. The regulatory model developed in Hong Kong has involved successive steps, of acquiring the broad legal scope to deal with all rhinoceros commodities, of registration of stocks and issuance of possession licences, of import and export/re-export bans, of total bans on domestic trade and of instituting penalties for offenders (Milliken 1991). This regulatory model is being adopted in Taiwan and could be promoted as the way forward in other flourishing markets like South Korea and Thailand. However, after two decades of unsustainable exploitation of the black rhino and its local extinction in many of Africa's protected areas, it is being increasingly questioned whether the policy of attempting to halt the trade in rhino horn, followed for the last 15 years or so, should be reversed. Therefore, proposals were made to the March 1992 meeting of the Conference of the Parties to CITES in Kyoto, Japan to transfer the rhino populations of Zimbabwe (black and white rhinos) and South Africa (white rhinos) to Appendix II, thus providing for a limited legal trade in rhino horn.

Towards a Legalised Trade in Rhino Horn?

Several arguments are made in favour of a legalised horn trade. The first and most important is that rhinos do not have to be killed to produce a harvest of horn, even though poachers certainly kill rhinos. Horns continue to grow throughout life to counteract wear on their tips, although growth rates are slower in older animals (Mentis 1972; Pienaar *et al.* 1992). Horns that have been lost in fights or removed regrow, but in a slightly deformed shape (Bigalke 1945; Ritchie 1963). Rhino horns can be cut off without discomfort as they comprise compressed hair and are not enervated (Ryder 1962), though it will usually be necessary to restrain the rhino by immobilisation. The second argument is that considerable quantities of confiscated and found horn are now building up in warehouses (Table 13), and future dehorning operations of rhinos will produce increasing quantities of horn that would otherwise be added to these stockpiles. Dehorning as means of protecting rhinos has been discussed since the 1950s, but was first attempted in 1989 in Namibia (Leader-Williams 1989). It is now being carried out as a routine measure on all translocated rhinos in Zimbabwe. The third main argument is the economic consideration that selling such a valuable product legally would produce a much greater income per unit area of wildlife land for re-investment in rhino conservation than many alternatives available to state and private land-owners (Anderson 1983; 't Sas-Rolfe 1990a, 1990b).

Table 13: Stockpiles of rhino horn (all in kg) held by six producer nations, including three parks authorities in South Africa, and two consuming nations (data from different sources).

Country/Authority	Year	Volume	Action	Source
Kenya	1987	247		Martin & Ryan (1990)
	1990	350	Burnt	Anon. (1990b)
Tanzania	1987	31		Martin & Ryan (1990)
Zambia	1985	55		"
Zimbabwe	1987	750		"
Natal Parks Board	1987	1,692		"
	1990	1,900		Armstrong (1990)
National Parks Board	1987	100		Martin & Ryan (1990)
Bophutaswana	1981	35	Burnt	"
Namibia	1987	173		"
Assam	1984	236		Martin *et al* (1987)
China	1989	9,874	Medicines	Martin (1990a)
Taiwan	1990	3,712–8,943	Medicines	Nowell *et al.* (1992)
Dubai (UAE)	1992	2,000	Burnt	TRAFFIC in litt. (1992)

Many of these arguments will founder on the philosophy, whether rational or not, of individual conservationists, range states and other parties to CITES. In the recent debate on whether African elephants should be transferred to Appendix I of CITES, the African continent became polarised between a group of southern African countries that favoured sustainable trade in ivory versus the rest of Africa that saw rampant and illegal over-exploitation and wished for a total ban on trade. Most parties to CITES sided with the majority of the range states and the majority of Africa's elephant populations, and voted for a ban and its continuance in 1989 and 1992. In one sense, therefore, a discussion on the possible opening of a legal rhino horn trade could not be started at a more inopportune time, given that the majority of world opinion is in favour of international trade bans as the method for saving Africa's endangered pachyderms. However, the situation with respect to rhinos differs markedly from that of elephants for two reasons. First, the southern countries now possess most of Africa's rhinos (Cumming *et al.* 1990), and therefore the southern countries' views on how they see best to conserve their rhinos merit wider attention than they were granted in the ivory debate. Second, if the ivory trade ban is indeed working, this is most probably because of a voluntary reduction in demand by users of a luxury commodity in response to the publicity surrounding the plight of elephants and the "ivory ban", rather than the ban per se. In contrast, Chinese users of traditional medicines appear unwilling to cease including rhino horn in their potions (Nowell *et al.* 1992), even though substitutes like water buffalo horn are as effective pharmacologically (But *et al.* 1990). Therefore the much longer-standing trade bans for rhino horn have been ineffective because they appear not to have caused a voluntary reduction in demand.

Aside from the philosophical arguments, what evidence is there to suggest that a legalised trade could benefit rhino conservation? Theoretical economic models suggest that the sales of confiscated and harvested horn will alter the supply curve and depress the equilibrium price (see Bergstrom 1990). Assuming that the number of animals killed by poachers is an increasing function of the price of horn (which it is in part, see Milner-Gulland and Leader-Williams 1992), then legal sales should be a preferred option to destroying or stockpiling confiscated material, or not harvesting horn (Bergstrom 1990). Clearly more empirical work is needed on the relationship between commodity prices and demand under legal and illegal trade regimes, but these theoretical models on the economics of crime and confiscation point the way forward. More empirical models show that it would be profitable to dehorn secure populations of rhinos on private land, but suggest it would be necessary to dehorn rhinos for their protection very regularly to make poaching unprofitable on state land (Milner-Gulland *et al.* 1992). Further work is also necessary here, but these models again point the way forward. Whatever, the economic arguments, however, any proposals to re-open a legal trade in rhino horn must be translated into successful policies.

The South African proposal for transferring its white rhino population to Appendix II notes that the transfer of one species to a different appendix should not lead to a reduction in controls for other species. It is for this reason that proposals to open up trade in African rhino horn need further consideration. At this stage it would appear that there is insufficient knowledge of the following:

a) the dynamics of the trade in African and Asian rhino horn and the extent to which the trades may differ. To date it is known that "Fire" (Asian) horn is more efficacious than "Water" (African) horn and that Asian horn is considerably more expensive (Nowell *et al.* 1992). However, until we know more about the differences and similarities in the trade in the two types of horn, it cannot be said with certainty that a southern African trade would not have serious repercussions for the highly endangered Javan and Sumatran rhinos. The situation with Indian rhino horn also merits investigation, for it is building up into stockpiles (Table 13) while rhinos in Assam are being poached by such new methods as electrocution (Vigne and Martin 1991a).

b) the volumes of horn traded and demanded by world markets. There are educated guesses of the approximate volumes of horn traded over the past two decades which have been justified on various grounds and disputed on others (see above). This parameter needs better estimation in order to assess the potential supply available from aspiring producers and its effect upon present price structures and demand for illegal horn. The recent study in Taiwan breaks new ground in having counted the total number of pharmacy shops and estimated the number of medicinal outlets in a particular country (Nowell *et al.* 1992). With a large sample of shops having been surveyed also for stocking horn, this has enabled an estimate to be made of the total stocks of horn held in the country (Table 13). Further unpublished work by Nowell and her colleagues has shown that a sample of pharmacists and doctors prescribe and sell on average around 45g of rhino horn annually. When multiplied by the total number of pharmacies and clinics selling horn (Nowell *et al.* 1992), this suggests the consumption of a total of 486kg annually. Hopefully Nowell's approach can be extended to provide an estimate of annual demand in other consuming nations.

c) the likelihood that the trade will continue in its present form for the foreseeable future. The argument has been made that the trade in horn is traditional and will continue. However, there are no published data on the age structure of users of traditional medicines, and whether younger people, now more subjected to western ideas and conservation appeals, are coming on stream as consumers of traditional medicines or turning to aspirins.

d) the role of stockpiling in influencing illegal demand for rhinos in the wild, and the role that legalising a trade in rhino horn might have on reducing speculation and demand for rhino horn. Investigations of demand have centred mainly on quantifying trends in consumption. Economic studies of the role of stockpiling on influencing volumes demand, using case studies for other commodities, would seem a good starting point for examining whether or not a legalised trade in rhino horn would reduce the demand side that is driven by speculators.

In summary, the question of whether or not a legalised trade in rhino horn should be re-opened is a complex issue, and this review has not provided the answer, one way or another. However, it is hoped that the review will provide the basis for a rational debate on the issue before the next Conference of the Parties to CITES, and that it highlights areas where further research is needed. If it achieves this aim, then this review will have served its purpose.

BIBLIOGRAPHY

References cited in this publication are marked with an asterisk (*).

* Anderson, J.L. 1983. Bestandsaufname und Zukuenftige Entwicklung des Breitmaulnashorns. In *International Studbook of African Rhinoceroses*, edited by H-G. Klos and R. Frese, pp. 46-52. Berlin Zoological Gardens, Berlin.

Anon. 1982a. Extinction is forever. *Asiaweek*, July 9: 24-29.

Anon. 1982b. North Yemen bans importation of rhino horn. *TRAFFIC Bulletin*, 4: 39.

Anon. 1982c. Rhino horn smuggling operation uncovered. *TRAFFIC Bulletin*, 4: 6.

Anon. 1982d. Zambia bans ivory and rhino horn exports. *TRAFFIC Bulletin*, 4: 7.

Anon. 1983 Sale of rhino horn. *TRAFFIC Bulletin*, 5: 49.

Anon. 1984. Rhino horn imports into Korea. *TRAFFIC Bulletin*, 6: 28.

* Anon. 1985. Rhino horn update. *TRAFFIC Bulletin*, 7: 1.

Anon. 1986a. Asian rhino horn imports. *TRAFFIC Bulletin*, 8: 12.

Anon. 1986b. Singapore halts rhino horn trade. *TRAFFIC Bulletin*, 8: 33.

* Anon. 1986c. Zimbabwe hits rhino/elephant poachers. *TRAFFIC Bulletin*, 8: 35.

* Anon. 1989a. Macao prohibits internal trade in rhino horn and musk. *TRAFFIC Bulletin*, 10: 30.

Anon. 1989b. Rhino horn smugglers arrested in the USA. *TRAFFIC Bulletin*, 10: 30.

Anon. 1990a. India: poachers killing rhinos by electrocution. *Animal Kingdom*, 93:

* Anon. 1990b. Kenya burns rhino horn. *TRAFFIC Bulletin*, 11: 19.

Anon. 1990c. Rhino horn on sale in UK. *TRAFFIC Bulletin*, 11: 19.

* Armstrong, S. 1990. Taking the case by the horns. *World Magazine* 3, February 1990: 60-66.

* Bergstrom, E. 1990. On the economics of crime and confiscation. *Journal of Economic Perspectives*, 4: 171-178.

* Bigalke, R. 1945. The regeneration of the anterior horn of black rhinoceros (*Diceros bicornis* L.). *Proceedings of the Zoological Society of London*, 115: 323-326.

But, P.P-H., Lung, L-C. and Tam, Y-K. 1988. Profiles of Chinese medicines, 4. Rhinoceros horn. *Abstracts of Chinese Medicines*, 2: 351-360.

* But, P.P-H., Lung, L-C. and Tam, Y-K. 1990. Ethnopharmacology of rhinoceros horn. I: Antipyretic effects of rhinoceros horn and other animal horns. *Journal of Ethnopharmacology*, 30: 157-168.

* Cobb, S. 1989 (Editor). *The Ivory Trade and the Future of the African Elephant*. Ivory Trade Review Group, Oxford, United Kingdom.

Cohn, J. 1988. Halting the rhino's demise. *Bioscience*, 38: 740-744.

Cumming, D.H.M. 1987. Zimbabwe and the conservation of black rhino. *Zimbabwe Science News*, 21: 59-62.

* Cumming, D.H.M., du Toit, R.F. and Stuart, S.N. 1990. *African Elephants and Rhinos: Status Survey and Conservation Action Plan*. IUCN, Gland, Switzerland.

* Cumming, D.H.M. and Jackson, P. 1984. *The Status and Conservation of Africa's Elephants and Rhinos*. IUCN, Gland, Switzerland.

Eltringham, S.K. 1984. *Wildlife Resources and Economic Development*. John Wiley, Chichester and New York.

Fiske, S. 1988. Rhinos: by the horn? *Effective Farming*, January 1988: 21.

* Goddard, J. 1966. Mating and courtship of the black rhinoceros. *East African Wildlife Journal*, 4: 69-75.

Groves, C.P. 1971. Species characteristics in rhinoceros horns. *Zeitschrift für Säugetierkunde*, 36: 238-252.

Hillman, A.K.K. and Martin, E.B. 1978. Will poaching exterminate Kenya's rhinos? *Oryx*, 15: 131-132.

* Khan, M.K.M. 1989. *Asian Rhinos: an Action Plan for their conservation*. IUCN, Gland, Switzerland.

* Laurie, W.A. 1982. Behavioural ecology of the greater one-horned rhinoceros (Rhinoceros unicornis). *Journal of Zoology*, 196: 307-341.

* Leader-Williams, N. 1988. Patterns of depletion in a black rhinoceros population in Luangwa Valley, Zambia. *African Journal of Ecology*, 26: 181-187.

* Leader-Williams, N. 1989. Desert rhinos dehorned. *Nature*, 340: 599-600.

* Leader-Williams, N. 1992. Theory and pragmatism in the conservation of rhinos. In *Proceedings of International Rhino Conference, San Diego, May 1991*, edited by O.A. Ryder, in press.

• Leader-Williams, N., Albon, S.D. and Berry, P.S.M. 1990. Illegal exploitation of black rhinoceros and elephant populations: patterns of decline, law enforcement and patrol effort in Luangwa Valley, Zambia. *Journal of Applied Ecology*, 27: 1055-1087.

• Martin, C.B. and Martin, E.B. 1991. Profligate spending exploits wildlife in Taiwan. *Oryx*, 25: 18-20.

Martin, E.B. 1979. Trade in African rhino horn. *Oryx*, 15: 157.

Martin, E.B. 1980a. International trade in rhinoceros products. *WWF Yearbook*, 1979-80: 75-81.

• Martin, E.B. 1980b. *The international trade in rhinoceros products*. IUCN/WWF, Gland.

Martin, E.B. 1980c The international trade in rhinoceros products. *Africa Rhino Group Newsletter*, 1: 3-5.

Martin, E.B. 1980d. Selling rhinos to extinction. *Oryx*, 15: 322-323.

Martin, E.B. 1981a. Conspicuous consumption of rhinos: Part I. *Animal Kingdom*, February/March: 11-19.

Martin, E.B. 1981b. Conspicuous consumption of rhinos: Part II. *Animal Kingdom*, April/May: 20-29.

Martin, E.B. 1983a. Follow-up to stop trade in rhino products in Asia. *Pachyderm*, 1: 9-12.

Martin, E.B. 1983b. Halting the rhino horn trade. *WWF Monthly Report*.

Martin, E.B. 1983c. North Yemen bans the importation of rhino horn. *Pachyderm*, 1: 14.

• Martin, E.B. 1983d. *Rhino Exploitation: the trade in rhino products in India, Indonesia, Malayasia, Burma, Japan and South Korea*. WWF, Hong Kong.

• Martin, E.B. 1983e. Rhino horn weights. *TRAFFIC Bulletin*, 5: 23.

Martin, E.B. 1983f. The decline in the trade of rhinoceros horn. *Swara*, 6: 10-15.

• Martin, E.B. 1984a. North Yemen and the rhino horn trade today. *Swara*, 7: 28-33.

Martin, E.B. 1984b. They're killing off the rhino. *National Geographic*, 165: 404-422.

Martin, E.B. 1984c. The Japanese and Korean trade in rhinoceros horn. In *The Status and Conservation of Africa's Elephants and Rhinos*, edited by D.H.M. Cumming and P.Jackson, pp.119-143. IUCN, Gland, Switzerland.

Martin, E.B. 1985a. Religion, royalty and rhino conservation in Nepal. *Oryx*, 19: 11-16.

• Martin, E.B. 1985b. Rhinos and daggers: a major conservation problem. *Oryx*, 19: 198-201.

Martin, E.B. 1986a. Halting the rhino horn trade. *IUCN Bulletin*, 17: 100.

Martin, E.B. 1986b. The rhino horn trade 1985-86. *WWF Monthly Report*.

• Martin, E.B. 1986c. South Korea stops rhino horn imports. *TRAFFIC Bulletin*, 8: 28.

• Martin, E.B. 1987. The Yemeni rhino horn trade. *Pachyderm*, 8: 13-16.

Martin, E.B. 1988a. Taiwan and the African rhino horn trade. *Swara*, 11: 26-27.

• Martin, E.B. 1988b. *Testimony and Statement of Esmond Bradley Martin at the Hearing before the Subcommittee on Natural Resources, Agriculture Research and Environment of the Committee on Science, Space and Technology, US House of Representatives, 100th Congress, 2nd Session, June 2nd, 1988 (No. 133)*. US Government Printing Office, Washington DC, pp. 40-52.

• Martin, E.B. 1989a. Report on trade in rhino products in eastern Asia and India. *Pachyderm*, 11: 13-22.

• Martin, E.B. 1989b. The rhino product trade in northern and western Borneo. *Pachyderm*, 12: 38-41.

Martin, E.B. 1989c. Status of rhino populations and associated trade in rhino products. *Proceedings of the Sixth Meeting of the Conference of the Parties, Ottawa, Canada, July 12-24, 1987*, CITES Secretariat, Doc. 6.25, Annex 1.

• Martin, E.B. 1990a. Medicines from Chinese treasures. *Pachyderm*, 13: 12-13.

• Martin, E.B. 1990b. Survey of wildlife products for sale in Saudi Arabia, with particular emphasis on rhino horn. *TRAFFIC Bulletin*, 11: 66-68.

Martin, E.B. 1991. Rhino horn in China: a problem for conservation.... and the world of art. *Wildlife Conservation*, 94, 24-25.

• Martin, E.B. and Barzdo, J. 1984. The volume of the world's trade in rhino horn. *TRAFFIC Bulletin*, 6: 3-4.

• Martin, E.B. and Martin, C.B. 1982. *Run Rhino Run*. Chatto and Windus, London, United Kingdom.

Martin, E.B. and Martin, C.B. 1985. Horns of a dilemma. *BBC Wildlife*, 3: 127-131.

• Martin, E.B. and Martin, C.B. 1987. Combatting the illegal trade in rhinoceros products. *Oryx*, 21: 143-148.

• Martin, E.B. and Martin, C.B. 1989. The Taiwanese connection: a new peril for rhinos. *Oryx*, 23: 76-81.

• Martin, E.B., Martin, C.B. and Vigne, L. 1987. Conservation crisis-the rhinoceros in India. *Oryx*, 21: 212-218.

* Martin, E.B. and Ryan, T.C.I. 1990. How much rhino horn has come onto international markets since 1970? *Pachyderm*, 13: 20-25.

* Martin, E.B. and Vigne, L. 1986. Rhino poaching and conservation. *Swara*, 9: 25-27.

Martin, E.B. and Vigne, L. 1987a. Clamp-down on rhino-horn trade in North Yemen. *Species*, 9: 21-23.

* Martin, E.B. and Vigne, L. 1987b. Recent developments in the rhino horn trade. *TRAFFIC Bulletin*, 9: 49-53.

Martin, E.B. and Vigne, L. 1988. Abetting the rhino horn trade. *Quagga*, 24: 23-24.

* Mentis, M.T. 1972. A review of the life history features of the large harbivores of Africa. *Lammergeyer*, 16: 1-89.

* Milliken, T. 1989. The Japanese ivory trade: tradition, CITES and the elusive search for sustainable utilisation. In *The Ivory Trade and the Future of the African Elephant*, edited by S. Cobb. Ivory Trade Review Group, Oxford, United Kingdom.

* Milliken, T. 1991. The evolution of legal controls on rhinoceros products in Hong Kong: an Asian model worth considering. *Oryx*, 25: 209-214.

* Milliken, T., Martin, E.B. and Nowell, K. 1991. Rhino horn trade controls in East Asia. *TRAFFIC Bulletin*, 12, 17: 17-21.

* Milner-Gulland, E.J., Beddington, J.R. and Leader-Williams, N. 1992. Dehorning African rhinos: a model of optimal frequency and profitability. *Proceedings of the Royal Scociety, B*, in press.

* Milner-Gulland, E.J. and Leader-Williams, N. 1992. A model of incentives for the illegal exploitation of black rhinos and elephants: poaching pays in Luangwa Valley, Zambia. *Journal of Applied Ecology*, 29: in press.

* Milner-Gulland, E.J. and Mace, R. 1991. The impact of the ivory trade on the African elephant Loxodonta africana population as assessed by data from the trade. *Biological Conservation*, 55: 215-229.

* Nowell, K., Chyi, W.W.L. and Pei, K.C.J. 1992. *The horns of a dilemma: the market for rhino horn in Taiwan*. TRAFFIC International, Cambridge, United Kingdom.

* Parker, I.S.C. and Martin, E.B. 1979. Trade in African rhino horn. *Oryx*, 15: 153-158.

* Pienaar, D.J., Hall-Martin, A.J. and Hitchins, P.M. 1992. Horn growth rates of free-ranging white and black rhinoceros. *Koedoe*, in press.

* Ritchie, A.T.A. 1963. The black rhinoceros (*Diceros bicornis* L.) *East African Wildlife Journal*, 1: 54-62.

* Ryder, M.L. 1962. The structure of rhinoceros horn. *Nature*, 193, 1199-1201.

* Sheeline, L. 1987. Is there a future in the wild for rhinos? *TRAFFIC USA*, 7: 1-6.

* Song, C. and Milliken, T. 1989. *The rhino horn trade in South Korea: still cause for concern*. TRAFFIC Japan, Tokyo, Japan.

* Song, C. and Milliken, T. 1990. The rhino horn trade in South Korea: still cause for concern. *Pachyderm*, 13: 5-11.

* Sutton, J.E.G. 1990. *A Thousand Years of East Africa*. British Institute in East Africa, Nairobi, Kenya.

* 't Sas-Rolfe, M.J. 1990a. Privatising the rhino industry. *Free Market Foundation Paper*, No 900501, pp. 1-42.

* 't Sas-Rolfe, M.J. 1990b. The economics of rhino extinction. *Endangered Wildlife*, 2: 4-9.

Thomson, R. 1988. To save the rhino cut out the middleman. *Magnum*, July 1988:

* Varisco, D.M. 1987. *Horns and hilts: wildlife conservation for North Yemen*. WWF US, Washington, D.C., USA.

* Varisco, D.M. 1989a. Beyond rhino horn: wildlife conservation for North Yemen. *Oryx*, 23: 215-219.

* Varisco, D.M. 1989b. From rhino horns to dagger handles: a deadly business. *Animal Kingdom*, 92: 44-49.

Vigne, L. 1984. North Yemen now takes one half of all rhino horn. *Pachyderm*, 3: 18.

Vigne, L. and Martin, E.B. 1986. Kenya tries to save its rhinos. *Quagga*, 15: 11-12.

* Vigne, L. and Martin, E.B. 1987a. The North Yemen government and the rhino horn trade. *Swara*, 10: 25-28.

* Vigne, L. and Martin, E.B. 1987b. North Yemen takes fresh steps to crack-down on rhino horn trade. *Quagga*, 18: 7-9.

* Vigne, L. and Martin, E.B. 1987c. The trade in African rhino horn in India. *Swara*, 10: 31-32.

* Vigne, L. and Martin, E.B. 1989a. Taiwan: the greatest threat to the survival of Africa's rhinos. *Pachyderm*, 11: 23-25.

Vigne, L. and Martin, E.B. 1989b. Kaziranga's calamity: a new threat to the Indian rhino. *Oryx*, 23: 124-125.

Vigne, L. and Martin, E.B. 1990. India: poachers killing rhinos by electrocution. *Wildlife Conservation*, 93: 30-31.

* Vigne, L. and Martin, E.B. 1991a. Assam's rhinos face new poaching threats. *Oryx*, 25: 215-221.

* Vigne, L. and Martin, E.B. 1991b. Major decline in Yemen's rhino horn imports. *Swara*, 14: 23-27.

* Western, D. 1982. Patterns of depletion in a Kenya rhino population and the conservation implications. *Biological Conservation*, 24: 147-156.

* Western, D. 1987. Africa's elephants and rhinos: flagships in crisis. *Trends in Ecology and Evolution*, 2: 343-346.

* Western, D. 1989. The undetected trade in rhino horn. *Pachyderm*, 11: 26-28.

Western, D. and Vigne, L. 1985. The deteriorating status of African rhinos. *Oryx*, 19: 215-220.

* WWF 1991. *Help WWF Stop the Rhino Horn Trade*. WWF International Campaign Report, Gland, Switzerland.

SUMATRAN RHINO

POPULATION AND HABITAT

VIABILITY ANALYSIS WORKSHOP

BRIEFING BOOK

SECTION 10: YAYASAN MITRA RHINO PROPOSAL FOR RHINO CONSERVATION IN INDONESIA

Captive Breeding Specialist Group

Species Survival Commission
IUCN -- The World Conservation Union
U. S. Seal, CBSG Chairman

23 September 1993

Dr. James Doherty
NYZS/International Wildlife Conservation Center
185th St. & Southern Blvd.
Bronx, NY 10460-1099

Mr. Edward Maruska
Cincinnati Zoo & Botanical Garden
3400 Vine Street
Cincinnati, OH 45220

Dear Jim and Ed:

Please find attached a proposal from the Indonesian Yayasan Mitra Rhino and PHPA regarding possible funding of the development of an *in situ* captive breeding program for Sumatran rhinos in Sumatra. I believe they are trying to respond to your request that they develop a proposal for Sumatran rhinos that you can evaluate and decide whether you want to support it or not. As you know, there will be a CBSG-sponsored Sumatran Rhino PHVA Workshop in Lampung, South Sumatra on 11-13 November 1993. Because there will be an *in situ* working group established at the workshop, I believe it would provide a good venue or forum for further discussion and closure on items presented in this proposal from the Indonesians.

I have had a number of discussions about the development of an *in situ* Sumatran rhino program with the Indonesians, Yayasan Mitra Rhino, and members of the International Rhino Foundation, as well as Bill Conway, Jim Jackson, and Ulie Seal. There is a potential to see this *in situ* project actually happen.

Mr. Sutisna, Director General of PHPA, requested that I participate in developing this *in situ* program by serving as a liaison between the Indonesian side and the North American side. Please feel free to communicate directly to Mr. Sutisna about this proposal. However, I would appreciate being copied on correspondence regarding this issue so that I can ensure that it is passed on quickly to all of the relevant Indonesians.

Sincerely yours,

Ronald L. Tilson, Ph.D.
Minnesota Zoo & CBSG Indonesian Liaison

cc: U. Seal

12101 Johnny Cake Ridge Road, Apple Valley, MN 55124, USA tel. 612-431-9325 fax 612-432-2757
(home) 9801 Pillsbury Ave. S., Bloomington, MN 55420, USA tel. 612-888-7267 fax 612-888-5550

DEPARTEMEN KEHUTANAN
DIREKTORAT JENDERAL PERLINDUNGAN HUTAN
DAN PELESTARIAN ALAM
Go Pysat Kehutanan Manggala Wanabakti, Blok 1 - Lantai 8
Telp: 5704501 - 5704502 - 5704503 - 5704504, Pesawat 301, 315, 316
Jalan Jenderal Gatot Subroto - Jakarta Pusat

Jakarta. 1 September 1993

No.: 1475/VI/PA-5/1993

To: Dr. Ronald Tilson
CBSG - SSC - IUCN - The World Conservation Union
12101 Johnny Cake Ridge Road, Apple Valley, MN 55124, USA
Fax: 1-612-432-2757

From: Widodo S. Ramono
Directorate General PHPA, Ministry of Forestry, Jakarta

Dear Dr. Ronald Tilson:

Referring to our meeting held at Hotel Indonesia, Jakarta, on 15 August 1993, we are sending you a proposal to the Sumatran Rhino Trust (SRT) for rhino conservation in Indonesia for distribution to appropriate members of the SRT as requested of you by Bapak Sutisna, DG of PHPA.

One point that we did not discuss during the meeting is Point #13 of the agreement. We know that one rhino (called "Rima"), which was captured in the area of PT Maju Raya Timber Ipuh Logging Concession Block No. 120 in Bengkulu on 12 June 1991, died in the San Diego Zoo on 25 May 1992. According to Point #13 in the agreement: "The SRT will insure that rhinos are captured in Indonesia in such a way that in the event of a death during the transport from the forest to the zoos and for a period of one year, beginning from the date of departure from the base camp, indemnity of US$ 25,000 per rhino will be paid to the Indonesian Rhino Foundation".

Therefore, as we discussed, we believe funds that SRT should pay to the Indonesian Rhino Foundation (now YMR: Yayasan Mitra Rhino) is three times US$ 20,000 (according to Point #15) plus US$ 25,000 (according to Point #13) for one rhino death, or a total or US$ 85,000. We have drafted a proposal on how best these funds can be spent to directly benefit the development of an *in situ* Sumatran rhino program.

I hope that you can explain this matter to Dr. James Doherty, that he will consider this request, and that a timely response to this proposal would be highly appreciated. We also are thankful for your very useful participation in this process.

Sincerely yours,

Widodo S. Ramono

cc: Drs. Effendi A. Sumardja, Yayasan Mitra Rhino

PROPOSAL OF SRT FUND SUPPORT
FOR
RHINO CONSERVATION IN INDONESIA

BACKGROUND

In recognizing the need to conserve Sumatran rhinos, on 8 November 1990, the Ministry of Forestry cq. Directorate General of Forest Protection and Nature Conservation (PHPA) and The Sumatran Rhino Trust (SRT) of The American Association of Zoological Parks and Aquariums (AAZPA) signed an agreement for a cooperative project for the conservation of the Sumatran rhino. The purpose of this agreement was to conserve the Sumatran rhino by sending the "doomed" rhinos captured in Sumatra to American and Indonesian zoos where the rhinos would be properly maintained and bred.

In May 1993, Dr. James Doherty, Chairman of SRT-AAZPA, declared that the Sumatran Rhino Project (SRT) was completed, which was agreed to by the Director General of PHPA on 15 August 1993 at Hotel Indonesia, Jakarta.

According to Points #13 and #15 in the Agreement between PHPA and SRT/AAZPA, SRT will contribute funds to the Indonesian Rhino Foundation/IRF (Yayasan Mitra Rhino/YMR) for US$ 25,000 as the insurance payment for the death of a Sumatran rhino in San Diego and US$ 20,000 for each of three years to support rhino conservation activities in Indonesia.

JUSTIFICATION

1. US$ 20,000/year x 3 years funding to be provided to support Sumatran rhino conservation activities managed by the Yayasan Mitra Rhino during the period of agreement, 1990-1993 (Point #15, PHPA-AAZPA Agreement, 1990).

2. US$ 25,000 to be paid by SRT to the Yayasan Mitra Rhino as the insurance payment for the death of a Sumatran rhino occurring in less than one year from the date of transport from the forest to the San Diego Zoo. (Point #13, PHPA-AAZPA Agreement, 1990). Specifically:

   A female Sumatran rhino called "Rima" was captured in the area of PT Maju Raya Timber Ipuh Logging Concession Block No. 120 in Bengkulu on 12 June 1991, and died at the San Diego Zoo in the U.S. on 25 May 1992.

3. Total funds that should be transferred from SRT to the Yayasan Mitra Rhino is US$ 60,000 + US$ 25,000 = US$ 85,000.

PROJECT ACTIVITIES

1. The funds will be used to:

   a. Prepare the organizational and personnel capabilities of Yayasan Mitra Rhino and PHPA to develop Sumatran rhino conservation efforts in Sumatra according to the *Indonesian Rhino Conservation Strategy* approved by the Indonesian government in 1993 and the *Indonesian Rhinoceros Conservation Action Plan Priorities* set in June 1993. The first document sets the priorities for rhino conservation, the second document converts the strategy into discrete project with explicit budgets to preserve and protect the Sumatran rhino in all of its habitats and national parks, and;

   b. Implement the *Indonesian Rhino Conservation Strategy* by developing an intensively managed captive breeding program inside a natural habitat area (*in-situ* captive breeding); current plans are to construct a special captive facility (10,000+ ha or more) in the Air-Hitam area, Bengkulu, which is adjacent to Kerinci-Seblat National Park.

2. The project action (step-by-step) is to:

   a. Conduct regional and local workshops in Sumatran rhino habitat areas for establishing the need for immediate conservation action for managing wild rhino populations. This would include the evaluation and analysis of the Yayasan Mitra Rhino and PHPA needs, both for infrastructure and human resources. This would also include the establishment of an *in situ* rhino preserve and the development of effective rhino protection units;

   b. Conduct field studies within all rhino habitats to suggest priorities for infrastructure development (possibly using GEF Funds if available);

   c. Develop an information and organization center (Rhino Center Officer possibly joined with YMR Secretariat Office) with full office and secretarial support (office, communication equipment, computer, etc.) and with the maintenance and operational budget for directing the rhino protection units;

   d. Perform feasibility studies of rhino habitats for identifying sites for development of an *in-situ* captive breeding facility for rhinos in Sumatra and observe other *in-situ* captive breeding facilities in other countries (possibly Malaysia and Kenya);

   e. Train Yayasan Mitra Rhino, PHPA, and other Indonesian agency personnel that will be involved in rhino conservation which can be coordinated by the Rhino Center Officer after completion of the local conditions evaluation.

ORGANIZATION

1. Name: Directorate General of Forest Protection and Nature Conservation (PHPA), Ministry of Forestry
   Address: Gedung Manggala Wanabakti, Jl, Gatot Subroto, Jakarta
   Telp/Fax: 011-62-21-5734818
   Proposers: Drs. Effendi A. Sumardja, MSc.
   Drs. Widodo S. Ramono

2. Name: Yayasan Mitra Rhino (*Foundation of Rhino Friends*)
   Address: Gedung PHPA Kehutanan, Jl. Ir. H. Juanda 15, Bogor 16122, Indonesia
   Fax: 011-62-251-313985
   Proposers: Dr. Ir. Hadi S. Alikodra
   Drs. Haerudin R. Sadjudin
   Marcellus Adi, DVM

DATE OF PROPOSAL: 1 September 1993

PROJECT DURATION: November 1993 - April 1994

BUDGET

NO.	PROJECT DESCRIPTION	COST (US$)
1	REGIONAL & LOCAL WORKSHOP (IN 4 NATIONAL PARKS)	15,000
2	FIELD STUDIES AND SURVEY	22,500
3	RHINO CENTER OFFICE / YMR SECRETARIAT	25,000
4	STUDY OF *IN-SITU* CAPTIVE BREEDING	15,000
5	TRAINING (H.R.D)	17,500
TOTAL		85,000

SUMATRAN RHINO

POPULATION AND HABITAT

VIABILITY ANALYSIS WORKSHOP

BRIEFING BOOK

SECTION 11: INTERNATIONAL STUDBOOK FOR SUMATRAN RHINO (1993)

DISTRIBUTION OF THE SUMATRAN RHINOCEROS
(*Dicerorhinus sumatrensis*)