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Abstract: This document contains a conservation strategy and an action plan for the Sumatran tiger in Indonesia. A summary of the current population status, threats, a population viability analysis, and 4 conservation priorities are presented: 1) wild tiger and habitat protection 2) development of tiger interventive management strategies 3) development of captive breeding program 4) implementation of the conservation strategy. Coordinating structures and funding are further discussed. The action plan outlines required actions in more detail.

r: Sumatran tiger photo courtesy
man Safari Indonesia (ICREW).

DIRECTORATE GENERAL OF FOREST PROTECTION
AND NATURE CONSERVATION
MINISTRY OF FORESTRY
REPUBLIC OF INDONESIA

INDONESIAN SUMATRAN TIGER CONSERVATION STRATEGY

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TAMAN SAFARI INDONESIA, CISARUA, BOGOR

INDONESIAN ZOOLOGICAL PARKS ASSOCIATION (PKBSI)

JAKARTA

1994

DEPARTEMEN KEHUTANAN

DIREKTORAT JENDERAL PERLINDUNGAN HUTAN DAN PELESTARIAN ALAM

SURAT PENGESAHAN

Nomor : 354/DJ-VI/PA/94

Dalam rangka melaksanakan konservasi harimau di Indonesia, maka **"INDONESIA TIGER CONSERVATION STRATEGY"** yang disusun oleh Direktur Jenderal Perlindungan Hutan dan Pelestarian Alam bekerjasama dengan IUCN, PKBSI, WWF, dan Taman Safari Indonesia dapat dijadikan acuan untuk konservasi harimau di Indonesia.

Demikian surat pengesahan ini dibuat untuk dipergunakan seperlunya.

Jakarta, 17 April 1994

Direktur Jenderal
Perlindungan Hutan dan
Pelestarian Alam

Ir. Sutisna Wartaputra
NIP. 080013257

dmm04/db/tc01

DEPARTEMEN KEHUTANAN

DIREKTORAT JENDERAL PERLINDUNGAN HUTAN DAN PELESTARIAN ALAM

LETTER OF ENDORSEMENT

NUMBER : 554/DJ-VI/PA/94

In order to implement the conservation of the tiger in Indonesia, the **"INDONESIAN TIGER CONSERVATION STRATEGY"** which was developed by Directorate General of Forest Protection and Nature Conservation in Cooperation with IUCN, PKBSI, WWF and Taman Safari Indonesia, is to be used as a model for the conservation of tiger Indonesia.

This letter of endorsement can be used as needed.

Jakarta, 17 April 1994

Ir. Sutisna Wartaputra

Director General of Forest Protection and Nature Conservation

doum04/fin/loo

The **INDONESIAN SUMATRAN TIGER CONSERVATION STRATEGY** is based on the Proceedings of the Sumatran Tiger Population and Habitat Viability Analysis Workshop, 22-26 November 1992, Padang, West Sumatra, Indonesia, and the Proceedings of the Regional Sumatran Tiger Captive Management Workshops, 17-19 November 1992 and 18 February 1994 at Taman Safari Indonesia, Cisarua-Bogor, Indonesia. These workshops were organized by:

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Indonesian Biodiversity

Indonesia covers only 1.3% of the Earth's land surface, yet it harbors 10% of all flowering plants, 12% of the world's mammals, 16% of the world's reptiles and amphibians, 17% of all birds and more than a quarter of all marine and freshwater fish.

This richness can be attributed to the fact that Indonesia spans two major biogeographical realms, Indo-malaya and Australia, and can be divided into seven distinct biogeographic regions. The 17,000 islands of the archipelago support a wide range and variety of habitats from lowland rain forests and mangroves to savanna grasslands, swamp forests, limestone hills, montane forests, alpine meadows and snow-topped mountains. These varied habitats support a rich flora and fauna.

These habitats and species are now threatened by developments in logging, mining, shifting agriculture and other changing land uses as Indonesia's economy expands to meet the needs of its increasing population. Lowland habitats and wetlands are particularly threatened since these are the areas most accessible for agricultural developments.

The Indonesian Government recognized the need to conserve its rich biological resources, and has made a commitment to protect 10% of the land area and eventually 20 million hectares of coastal and marine habitats as conservation areas. Although *in situ* conservation must be the first priority, the protected area network alone will not be sufficient to secure all of Indonesia's biodiversity for future generations.

The *Biodiversity Action Plan for Indonesia* sets out a strategy for action under four main headings: *in situ* conservation in terrestrial parks and protected areas; *in situ* conservation outside the protected area network (production forests, wetlands, agricultural lands); *in situ* conservation of coastal and marine resources; and *ex situ* conservation.

Much loss of biodiversity in Indonesia, as elsewhere, is due to economic policy distortions that encourage rapid exploitation of biological resources rather than sustainable use. Slowing the rate of biodiversity loss will require policy and institutional reform as well as institutional strengthening for effective action in all four areas.

The active participation and support of local communities will also be essential for *in situ* conservation for they are the responsible managers of forest, wetland and marine resources. The plan calls for greater collaboration between government agencies and local communities and NGOs to work together as partners in biodiversity conservation.

At the Sumatran Tiger Population and Habitat Viability Analysis (PHVA) workshop in November 1992, a spatial database using Geographic Information System (GIS) was developed for the five major conservation areas of Sumatra. Indonesian Land-use and Forest Status maps (series RePPProT 1988; scale 1:250,000) were used for protected area boundaries (HSA and HL) and vegetation cover. The main forest types distinguished in the five HSA areas were lowland forest (below 1,000 meters), sub-montane forest (between 1,000-2,000 meters), montane forest (above 2,000 meters), and inland and mangrove swamp. Thus, tiger numbers for the five national parks were estimated in two ways: 1) using the vegetation cover on the RePPProT (1988) maps stored in the GIS database, and 2) using tiger presence as indicated on the maps by park officials at the PHVA workshop. Again, these numbers are imperfect, but do put more accurate constraints on the extent of habitat availability, and when this is coupled with the collective observations of all experienced PHPA staff and wildlife biologists working in Sumatra, the numbers for tigers become more accurate.

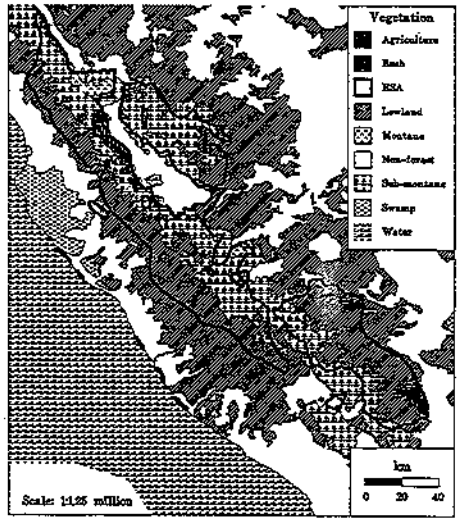

Fig. 1. GIS map of Kerinci Seblat National Park.

Results of the Sumatran Tiger PHVA Workshop indicated that there were about 400 Sumatran tigers living in five national parks and two game reserves, with another 100 tigers living in unprotected areas which will soon be lost to agriculture (see Table 1). Poaching is ongoing and uncontrolled, and forest disturbance has further fragmented these populations. The largest population of about 110 tigers is estimated to be in Gunung Leuser National Park; the remaining populations are about one-half this size or smaller. These small populations, particularly those of 50 or fewer, are extremely vulnerable to poaching or removing "problem" tigers, and because of their isolation and fragmentation, will need interventive management strategies for their long-term viability. This led to the development of an *Indonesian Sumatran Tiger Action Plan* which outlined short-term and long-term goals to address these problems.

Table 1. Summary of tiger population estimates and viability for major protected areas.

Protected Area	Total Area (ha)	Available Habitat for Tigers (ha)	Estimated Tiger Population	Est. Annual Removal Rate	Probability of Extinction in 100 yrs (P_e)	Genetic Diversity Left (H_e)
Gunung Leuser NP	900,000	360,000	110	2-4	20% (2 rem.) 87% (4 rem.)	80% 75%
Kerinci Seblat NP	1,500,000	600,000	76	6	100% (within 50 yrs.)	—
Barisan Selatan NP	357,000	282,000	68	1	1-10% (with no fragmentation)	84%
Berbak NP	163,000	114,000	50	2	97%	—
Way Kambas NP	130,000	97,500	20	0	49-94%	inbred
Kerumutan GR	120,000	78,000	30	2	100% (within 50 yrs.)	—
Rimbang GR	136,000	122,000	42	2	100% (within 25 yrs.)	—

Current Population Viability

Tiger numbers. Population viability analyses were conducted on tiger populations within the major protected areas of Sumatra. There are about 400 free-ranging tigers living within the seven major protected areas -- Gunung Leuser, Kerinci Seblat, Berbak, Way Kambas, Barisan Selatan, Kerumutan, and Rimbang. This assumes that all available habitat is occupied by tigers and that sufficient prey exist to maintain these tiger populations indefinitely. In all likelihood, this is not the case, and more thorough ground censuses need to be undertaken to establish the density of tigers across the range of habitats within these protected areas. Smaller populations of tigers were estimated to be living in a number of isolated forest patches, some of which are protected and many of which are not protected. The presence of these small, fragmented tiger populations needs to be verified by ground census and decisions made whether these populations can be linked to larger, adjacent tiger populations. Even within some large protected areas like Kerinci Seblat, the habitat is significantly fragmented and thus, tiger populations are probably also fragmented; future analyses need to be consider the degree of fragmentation in these populations. In this analysis, tigers within Kerinci Seblat were treated as a single population and the results are probably not valid.

Human pressures. Human population growth, transmigration programs and other human pressures mostly linked to agriculture will cause a decline of non-protected tiger habitat, generally referred to as production forest (HL) as well as a gradual deterioration of habitat quality at the edges of protected forest (HSA). A second significant variable is the rate of removal of tigers through poaching, poisoning and trapping. The factors that threaten tiger populations are small population size in conjunction with removals that have dramatic consequences relative to long-term survival. The smaller reserves are unlikely to support viable tiger populations in the future. Such small populations of tigers currently occurring in these areas are highly vulnerable to local catastrophes. Stochastic changes in population structure, such as marked fluctuations in the sex ratio, have proportionately more impact in smaller populations. Two ways to manage such small populations of tigers are to establish forest corridors to link smaller reserves with larger ones (if feasible), or through demographic and genetic management of metapopulations using assisted reproduction techniques.

Management strategies. Once any of these small tiger populations in Sumatra begins to decline, management strategies will need to be implemented to prevent them from going extinct. Thus, there is a need to closely monitor these populations on a continuing basis. Management strategies for the wild tiger populations that were discussed included: expanding protected populations by converting production forest (HL) to protected forest (HSA); linking isolated populations through establishing forest corridors; minimizing or stopping poaching and poisoning; increasing the prey base; and exchanging or supplementing genetic material among populations (both wild and captive).

Tiger protected areas also need to be managed according to the ecological needs of the species. That may involve the implementation of centrally located core areas where tigers and their prey live with little interference from humans. Multiple-use zones around protected areas, as employed in Indian tiger reserves, may or may not be applicable to Sumatran tigers, which have been driven from lowland habitat to less preferred sub-montane forest which are protected by virtue of their value to the maintenance of watersheds. ■

Indonesian Sumatran Tiger Conservation Strategy

Conservation and preservation of nature has been established in Government policy for many years in Indonesia. With the growing worldwide concern for conservation of nature, formulated into *The World Conservation Strategy*, Indonesia adopted it into its recent Conservation Strategy, in which conservation is based on the protection of life support systems, preservation of genetic resources and sustainable use of living natural resources.

The Indonesian Government's Act No. 4/1982 on the Management of the Living Environment and Act No. 5/1990 on Conservation of Living Resources and their Ecosystems provide a strong commitment to the conservation of nature in Indonesia.

The *Indonesian Sumatran Tiger Conservation Strategy* is based upon the above government Acts. It was formulated at the Directorate General of PHPA's Sumatran Tiger Population and Habitat Viability Analysis (PHVA) Workshop held in 1992 for wild tiger populations, and at the PKBSI Sumatran Tiger Captive Management Workshops held at the Indonesian Center for Reproduction of Endangered Wildlife (ICREW) in 1992 and 1994 for captive populations.

Objective

The objective of the *Indonesian Sumatran Tiger Conservation Strategy* is to develop and sustain a conservation program in Indonesia that will ensure the long-term viability of wild Sumatran tigers (*Panthera tigris sumatrae*) in major protected areas of Sumatra, to develop a captive management program for Sumatran tigers at ICREW and other PKBSI institutions, and to link these *in situ* and *ex situ* conservation activities for the reinforcement and recovery of wild populations as part of the IUCN/SSC CBSG *Tiger Global Animal Survival Plan (GASP)*.

Current Situation

The Sumatran tiger is critically threatened in Indonesia. There are about 400 Sumatran tigers living in five national parks and two game reserves, with another 100 tigers living in unprotected areas which will soon be lost to agriculture. Poaching is ongoing and uncontrolled, and forest disturbance has further fragmented these populations. The largest population of about 110 tigers is estimated to be in Gunung Leuser National Park; the remaining populations are about one-half this size or smaller. These small populations are extremely vulnerable to poaching or removing problem animals. Even without any further losses, the present populations are so small that they are vulnerable to severe environmental catastrophes, as well as demographic and genetic problems

typical of small populations. The continued loss or deterioration of tiger habitat further intensifies this crisis. Because of their isolation and fragmentation, these populations will need interventive management strategies to ensure their long-term viability.

Recommendations and Priorities

There are four general categories of recommendations that comprise the *Indonesian Sumatran Tiger Conservation Strategy* to ensure the long-term survival of Sumatran tigers throughout their remaining range. Each of these categories involve multiple components, many of which are overlapping. In general, they encompass absolute protection of wild tiger populations and habitat, intervention strategies for populations at risk, captive management for reinforcement and recovery of wild populations, and creation of a task force to coordinate all aspects of the *Indonesian Sumatran Tiger Conservation Strategy.*

The highest priority for the conservation of wild Sumatran tigers is to secure and protect all remaining tiger populations and their habitat.

- Enact more effective legislation and stricter enforcement of conservation laws for tigers.
- Implement immediately a review of PHPA's needs to prevent further loss of wild tigers and their habitat in the major protected areas of Sumatra.
- Improve management structure, training, resources and budget to become more effective in protecting tiger populations and their habitat.
- Develop and implement policies for better integration of conservation, development and enforcement.
- Decrease or eliminate tiger losses, either officially or illegally, from wild populations by mobilizing anti-poaching teams in major tiger protected areas (perhaps in conjunction with Sumatran rhino anti-poaching units).
- Develop an accurate (standardized) mapping system using computer linked Geographic Information Systems (GIS) to establish the extent of habitat types in protected areas, as well as distribution and habitat preference of tigers in these areas.
- Analyze land use practices in all tiger habitat, including those areas outside of protected areas, and use these data to suggest possible viable population management strategies, including extending protection to additional tiger habitat areas, linking habitats through corridors, and reconfiguring protected areas.

A second priority is to develop conservation management goals and intervention strategies for the remaining wild Sumatran tiger populations. This may include demographic and genetic support for most populations.

- Develop a set of specific recommendations for each tiger population which would consider genetic and demographic management, control of losses through poaching, poisoning and official PHPA removals, loss or deterioration of habitat and subsequent decrease in prey base, and possible expansion of habitat through incorporation of additional tiger habitat and use of corridors to link sub-populations.
- Initiate field research to establish the critical life history parameters of wild Sumatran tiger populations (particularly mean litter size and neonatal mortaility) as well as spacing patterns in lowland, peat swamp and sub-montane forests.
- Develop a program for long-term monitoring of tiger population status through time in each protected area to help support development of more effective intervention management strategies for wild tiger populations.
- Establish cooperative projects with tiger biologists in field research and analysis, beginning with a pilot project in Way Kambas NP and later extension into other protected areas dominated by sub-montane forests, such as Kerinci-Seblat NP.
- Evaluate extending boundaries of protected areas to include areas of tiger habitat and to link tiger habitats in Berbak NP and other protected areas.

A third priority is to develop a Sumatran tiger captive management program for the reinforcement and recovery of wild populations.

- Continue to support and expand the PKBSI Sumatran Tiger Captive Management Program, at both the Indonesian Center for Reproduction of Endangered Wildlife (ICREW) and within PKBSI zoos, to provide genetic and demographic resources for use in interventive management strategies of wild populations.
- Integrate *in situ* (protection of tigers and protected areas) with *ex situ* (captive tiger management) tiger programs within Indonesia so that the two programs have the same common goal, the long-term survival of wild tiger populations.
- Develop a tiger rescue team, equipment and funds to capture so-called "problem" tigers identified by PHPA outside of protected areas and incorporate these tigers into the PKBSI captive managed population. "Problem" tigers are migrants outside of protected areas that come into conflict with villagers and if not rescued, are killed by local police or military because of the threat they pose to human life.

- Medically evaluate all wild-caught "problem" tigers brought into the captive population through official PHPA removals for indicators of genetic diversity and inbreeding depression, pathogens and diseases, body weights and physical parameters.

- Continue to expand the Indonesian DNA library, blood serum bank, and genome resource bank for Sumatran tigers at the Indonesian Center for the Reproduction of Endangered Wildlife (ICREW) by collecting biomaterials from all incoming "problem" tigers.

A fourth priority is to establish a communication and infrastructure network that is responsible for the survival of Sumatran tigers in Indonesia, accountable to PHPA, national and international conservation agencies, NGOs, and the Indonesian public.

- Establish an Advisory Board of the Indonesian Sumatran Tiger Foundation, which will support the organization, management, personnel and funding of both *in situ* and *ex situ* tiger programs.

- Create a Tiger Program Officer, who will be primarily responsible for coordinating all *in situ* and *ex situ* tiger issues.

- Integrate a strong communication network among the *in situ* and *ex situ* programs, PHPA, PKBSI, ICREW, IUCN, WWF, and Indonesian and international conservation agencies to foster cooperation and the sharing of information regarding tiger conservation.

- Develop a standardized reporting system within PHPA to report in a timely manner all tiger observations, possible tiger poaching events, and tiger-human interactions from the park guards to the Sub-Balai to the Balai to the Chiefs (Kepala) of the National Parks to the Jakarta PHPA Office and to the Sumatran Tiger Advisory Board.

- Integrate an Indonesian-wide tiger conservation network into a broader conservation education program for all citizens of all ages in Indonesia.

Priority 1: Protect Wild Tigers and their Habitat

The Sumatran tiger is a species where the basis for its conservation in the wild must be in terms of aiming to keep human settlements and wildlife refuges well separated. This is becoming increasingly difficult to achieve, given the demography of the human populations in Indonesia. Prior to about 1900 when agricultural settlement in Sumatra first led to a substantial degree of deforestation, most of the island was covered in primary forest. Presumably up to that time, although its population density will always have been low, the Sumatran tiger was more or less continuously distributed throughout the whole island. Less than a century later, we find that predator has been squeezed out of huge tracts of forested areas. The conversion of primary forest into agricultural holding is a particularly serious cause of conservation problem in Sumatra, and the tiger has been among the species most seriously affected by it. The IUCN *Red Data Book* lists all the extant subspecies of tiger as endangered.

The government of Indonesia, in recognition of the importance of biodiversity in general and the long-term survival of such keystone species as the rhino, tiger and elephant in particular, has made a long-standing commitment to protect as much as possible the country's natural wealth and heritage. Already Indonesia has established more than 400 conservation areas covering 52,000 km^2 of forest land. In Sumatra many of the important conservation areas such as the Gunung Leuser NP, Kerinci-Seblat NP, Barisan-Selatan NP, Way-Kambas NP, and Berbak NP are large enough to maintain viable populations of tigers. The major national parks in Sumatra cover more than 25,000 km^2 of forest, and they protect not only the Sumatran tiger but also vital watersheds as well as thousands of other animal and plant species, many of them rare or endangered.

The tiger is very exacting in its conservation requirements for two other reasons. The need for extensive forest cover with good populations of mammalian herbivore species as its prey is clear. The other factor is the very high commercial value of the pelt (and bones), which despite strict CITES ban, is still traded illegally in the international market by smugglers. Trade in tiger skin and bones is therefore highly profitable, and even given well-organized customs enforcement, it would be inherently extremely difficult to control, let alone eliminate.

Given this background, the overwhelming emphasis in conservation policy must be on maintaining forest cover over large areas uninterrupted by human settlements and roads, where remoteness, difficulty of terrain and density of cover provide natural protection. The second axiom in any conservation policy for the Sumatran tiger, given the greatly reduced distribution, is that even quite small local populations are valuable and should be protected wherever feasible.

For the continued survival of the Sumatran tiger in the wild, protection from poaching is of vital importance. This can only be achieved by continued presence in the field of dedicated Tiger Conservation Teams performing an anti-poaching function in the major tiger protected areas: Kerinci Seblat NP, Gunung Leuser NP, Bukit Barisan Selatan NP, Way Kambas NP and Berbak NP. Kerumutan and Rimbang Game Reserves need to be evaluated for the placement of Tiger Conservation Teams in their boundaries.

PHPA needs to create Tiger Conservation Teams whose responsibilities would include patrolling of protected areas for poachers and poachers' traps, surveying or monitoring tiger populations where needed, setting up education programs for villagers living around tiger protected areas and throughout all of Indonesia, compiling information on tiger-human interactions, and all other events that are important to the tiger's continued survival.

Priority 2: Develop Tiger Interventive Management Strategies

Interactive Management Options

Tiger populations in Sumatra are fragmented and isolated into 5-12 protected areas that have varying degrees of migration between them. In the case of the five distinct National Parks, natural migration among park populations is not possible. These small isolated populations are at high risk from random and deterministic processes such as skewed sex ratio, failure to locate mates, disease, genetic drift, and inbreeding. Therefore, these populations will require intensive interactive management strategies if the tiger is to remain viable.

A high priority is to develop conservation management goals and intervention strategies for each of the remaining wild Sumatran tiger populations. This may include demographic and genetic support for populations of less than 100 animals. Special consideration needs to be given to periodic genetic supplementation to populations of 50 or fewer animals.

Most of the protected areas or their fragments are too small to retain a viable population of tigers over the long-term. Protected areas that cannot support a population of more than 50 tigers with no removal, or reserves that possess a larger population but experience removal pressure will require continuing intensive management assistance. All current tiger populations in Sumatra fall within these limits. This assistance will take the form of either augmentation (*to make greater*) of an existing population with additional tigers, genetic management, or the reestablishment of populations that have become extirpated. Passive management or no action will lead to a gradual extinction of the Sumatran tiger through attrition of the existing populations through time.

Augmentation will be required in populations that have reduced heterozygosity and begin to show inbreeding depression and/or in populations which experience severe demographic perturbations such as highly skewed sex ratios. Although augmentation or establishment are not issues requiring immediate attention in this *Indonesian Sumatran Tiger Conservation Strategy*, investigation into their feasibility should begin now, before the situation becomes so critical that these management options are no longer feasible. The following section discusses several scenarios which may be considered for management of wild Sumatran tiger populations.

No Action. As stated above, this management decision will lead to a slow decline in the number of extant tiger populations on Sumatra with the eventual extinction of the subspecies in all but the very largest parks. Even the largest population in Gunung Leuser may be at risk in the future if no action is selected.

Translocation of Wild Tigers Between Protected Areas. In this scenario, tigers are moved between or among geographic locations depending upon genetic or demographic need. This would require the capture and physical translocation of wild tigers. The decision process would include: from which site does the tiger come from, what sex and age is it, and to which site does the tiger go.

Current knowledge, based upon the assumption that reproductively effective males maintain individual territories, suggests that it would be best to move adult or subadult females rather than similarly aged males. One advantage of this strategy is that the translocated animals are already habituated to the wild, and therefore, have a higher likelihood of surviving over captive bred counterparts. Hands on access to individual tigers will increase the database exponentially on the health and genetic status of wild populations.

The number of tigers that will have to be transferred among populations to maintain genetic diversity will depend on the amount and type of genetic diversity PHPA wishes to retain and the size of the recipient population. The smaller the population and the more genetic diversity desired, the more migrants per generation required. As a general rule, one tiger per generation (every 7-10 years) may be sufficient to meet these genetic needs. This may also be an outlet for "problem" tigers such that they are not removed from the entire metapopulation.

Assisted Reproduction of Wild-Caught Adult Females. In this strategy, adult, wild female tigers are captured, held in captivity for a brief period to be artificially inseminated, and then released back into their home range. Semen is collected from wild or captive male tigers and used to inseminate wild-caught females. The primary advantage of this approach include avoiding the need to transfer tigers between populations. Again, having direct hands on access to wild tigers will help establish a database on the medical status of the wild population. The disadvantages are that females must undergo the stress of short-term capture and anesthesia. It also will be difficult, if not impossible, to determine if a female scheduled for capture is potentially pregnant. There is the remote possibility that a captured female may lose her territory. In reality, AI has been used to produce offspring one time after dozens of attempts in the tiger, so the technology is not available at this time.

Translocation (Release) of Captive Tigers into Wild Populations. Tigers used in this program should be offspring of wild-caught parents and should be released into the wild as young adults. Major decisions will include determining the sex and age class of the captive-bred young for release. The best captive-bred candidates for reintroduction are probably subadult or adult females.

The major advantage is that a captive management program exists within PKBSI and a state-of-the-art facility has been constructed at Taman Safari Indonesia. Other advantages are control over genetics, sex, and diseases of tigers to be released. The primary disadvantage is the lack of information on survivorship of captive-bred felids released into native habitats.

Field Programs of Wild Tigers

In order to develop interventive management strategies for wild tiger populations, a number of questions about the subspecies' biology and life history need to be answered by carefully planned field studies. The Sumatran tiger does not need a traditional field study that focuses only on its behavior and ecology. Critical issues that need to be resolved in order to develop management strategies are a knowledge of the tiger's life history characteristics, particularly mean litter size, neonatal mortality rates, spacing patterns in lowland, peat swamp and sub-montane forests, causes of mortality, disease profiles, genetic health, and evidence of fragmentation into sub-populations, for tigers in Sumatra. Without these pieces of information, it will be difficult to develop effective inventive management strategies, which will probably be the only way to keep wild populations viable.

Long-Term Monitoring of Wild Tigers

Wild tigers are extremely difficult to census because of their secretive nature and near complete avoidance of humans. Even where tigers are censused regularly, as in the tiger reserves of India, their numbers vary from year to year and because the estimates are based primarily upon identification of individual tiger tracks, the reliability of this technique has been suggested to be without scientific basis. In Sumatran forests of Indonesia, the census of tigers is compounded by the fact that the national parks are huge, some areas within these parks are practicably inaccessible, and because of low overall prey densities in these habitats, tiger densities are correspondingly low. Remote camera censusing has provided reasonable estimates of tigers in two areas of Gunung Leuser National Park. This promising technique needs to be expanded in scope and evaluated as a tool for the long-term monitoring of tiger populations throughout Sumatra.

The long-term monitoring of tiger populations in the major tiger protected areas should be an ongoing process. Without this information, Indonesia may lose the opportunity to augment sub-populations before they reach genetic or demographic crises.

Human-Tiger Conflict

A third aspect that is critical to the tiger's survival in Sumatra includes an evaluation of human needs and tiger needs of forest resources, conflict resolution when these needs overlap, and human attitudes towards local conservation ideas. PHPA is vague on how either poaching or official removal of tigers from forests impacts wild populations; yet, this is one of the most critical issue regarding tiger viability in the wild. Human growth trends in villages adjacent to tiger protected areas need to be modelled on how they will impact forest resources in the future. New concepts need to be designed in the study of wild tiger populations to answer these questions while there are still sufficient numbers of tigers in Sumatra to conduct the study.

Priority 3: Develop Indonesian Captive Management Program

Before populations of wild tigers fall to crisis levels, which precludes developing management strategies except in panic, captive populations of tigers need to be secured while there are still sufficient numbers of wild tigers left. These captive populations will provide a genetic and demographic reserve to reestablish or revitalize wild populations when the need and opportunity arises. The first stage in developing a regional captive management program for tigers in range countries is to establish a regional studbook, train a tiger management group in concepts of tiger management, husbandry and health, plan the breeding facility, and initiate the regional tiger masterplan. This process allows range countries to develop their own management programs for their endemic subspecies as recommended by the IUCN/SSC CBSG *Tiger GASP*.

The second-stage development of regional captive management programs provides hands-on training sessions at each zoo that focuses on proper animal health procedures for medical treatment, immobilizations, immunizations, evaluations, health maintenance and diets, and the use of ARKS record-keeping software program. This is culminated with a masterplan meeting where the masterplan with institution-by-institution breeding recommendations are drafted, translated into range country language, and distributed to participating zoos. At the same time, biological material (usually sperm, blood, and tissue) are collected and cryopreserved under the guidelines of the IUCN/SSC CBSG *Tiger Genome Resource Banking Action Plan*. These biomaterials are kept at a designated Indonesian site; currently, ICREW is taking on the responsibility of storing these materials.

The Sumatran Tiger Captive Management Program in Indonesia will serve as the heart of the global Sumatran tiger population by preserving sufficient genetic diversity to provide animals for reinforcement of world captive and wild populations as recommended in the Tiger GASP. The establishment of this Indonesian program can serve as a model for other captive management programs for endangered species in Asia.

Indonesian Tiger Studbook

All species management programs in captivity are predicated on the creation of a studbook, which establishes the identity and origin of each individual animal, and tracks each animal from birth to death. Information regarding all Sumatran tigers in Indonesian zoos has been compiled and verified for entry into the *Indonesian Sumatran Tiger Studbook* using the Single Population and Analysis Record-Keeping System (SPARKS) available through the International Species Information System (ISIS). Temporary studbook numbers were assigned to those animals which could not be linked to the *International Tiger Studbook*, kept by the Leipzig Zoo, Germany. At the completion of the first Indonesian Sumatran Tiger Captive Management Workshop, information regarding 76 Sumatran tigers (38 male, 38 female) comprised the *Indonesian Sumatran Tiger Studbook*. Of the 42 Sumatran tigers (25.17) currently living in Indonesian zoos, 11 (7.4) are wild-caught founders (only three of which have produced offspring).

Genome Resource Bank

A successful cryobiology program for tigers will have a significant impact on conserving genetic diversity. A resource of frozen tiger semen will be used interactively with living tiger populations to periodically infuse genetic material from captive or wild populations and to instill captive populations with preserved genes from previous generations. The options cryobiology brings to long-term tiger conservation strategies are limited only by our imagination, but only as long as this program proceeds in concert with protection of wild populations. The *Tiger GASP* strongly recommends that a systematic Genome Resource Bank (GRB) for tigers be initiated, which includes the collection, storage, use, exchange, and further research of genetic material from founders and selected free-ranging and captive individuals.

Rescue of "Problem" Sumatran Tigers

From time to time wild tigers wander out of their natural habitat and come into contact with local villages surrounding the national parks. Because there are no natural prey available to tigers, they usually end up killing and eating the villagers' livestock. Sometimes these tigers even turn into "man-eaters." Then the police or military are requested to help and in most instances, and because there is no safe way to capture the tiger, it is shot and killed. This is an unfortunate waste of such a valuable Indonesian resource.

When rescued tigers are transported to ICREW, each tiger must be given a medical evaluation, proper immunizations and identified with a tattoo and transponder. At the same time, biological materials (blood serum, tissue biopsies, DNA hair samples, and sperm, if male) will be collected and cryopreserved as part of the Indonesian tiger GRB program underway at ICREW.

Priority 4: Implement the Indonesian Sumatran Tiger Conservation Strategy

Advisory Board

The establishment of an Advisory Board of the Indonesian Sumatran Tiger Foundation will be critical to the tiger's survival in Indonesia. The recommended composition of the Advisory Board is as follows:

1) Directors within the Directorate General of PHPA
2) Chairman of PKBSI
3) Tiger Program Officer for wild populations
4) Tiger Coordinator for captive populations
5) University representative
6) L.I.P.I. representative
7) IUCN/SSC Cat Specialist Group representative
8) IUCN/SSC CBSG Tiger GASP Coordinator
9) Prominent Indonesian corporate leader

It is recommended that the Advisory Board should meet routinely every 2.5 years in Indonesia. Every second meeting (i.e. at 5-yearly intervals) should undertake a major review of all projects and programs, including captive management and reintroduction of Sumatran tigers. In addition to its routine meetings, the Board is authorized to appoint *ad hoc* working groups, as necessary, to address specific problems. Such groups may include appropriate members of the Board, as well as invited experts with knowledge of the specific problems under consideration.

The responsibilities of the Board shall be the giving of advice to PHPA on, and the periodic evaluation of, the following matters:

1) Organization and management of *in situ* and *ex situ* tiger conservation programs.
2) Personnel, expertise, and training relative to tiger management, both *in situ* and *ex situ*.
3) Law enforcement and protection of wild tiger populations.
4) Conservation education extension and public awareness programs.
5) Fund raising efforts and establishment of a foundation for Sumatran tigers.
6) Conservation partnership evaluation, both for wild and captive programs.
7) Crisis management for catastrophic events and emergency issues.

Funding

An overall program budget for the *Indonesian Sumatran Tiger Conservation Strategy* is needed, with a prioritization of recommended actions. Commitment to the *Indonesian Sumatran Tiger Conservation Strategy* by the Indonesian Government is essential in order for funds to be raised to support *in situ* and *ex situ* conservation programs. Components of such a budget include:

1) Increased protection and monitoring of wild tiger populations in Sumatran.
2) Strengthening of PHPA management capabilities of protected areas.
3) Initiation of field research studies on tiger status and life history.
4) Development of community relations and conservation education programs, specifically focused at villagers living near wild tiger populations and generally for Indonesian citizens nationwide.
5) Development of a tiger rescue team for "problem" tigers identified by PHPA.
6) Initiation of molecular DNA library, blood serum bank, and genome resource bank for both wild and captive Sumatran tigers.
7) Evaluation of genetic diversity of small isolated wild populations.
8) Improved facilities, nutrition and medical management of captive tigers.
9) Provision for sustainability of the Sumatran tiger conservation program through fund-raising and marketing programs.

The objectives of the *Indonesian Sumatran Tiger Conservation Strategy* will have to be "packaged" in relation to more general programs of PHPA and other government agencies, and tailored so that they are incorporated into the Government of Indonesia's budgeting procedures and Bappenas's priorities. Coordination between externally funded tiger conservation programs and protected areas where tigers occur is essential.■

Sumatran Tiger Action Plan

This *Indonesian Sumatran Tiger Conservation Strategy* has two main components: an *in situ* and an *ex situ* component. The *in situ* component is primarily responsible for the absolute protection of wild tiger populations and their habitat and for developing interventive management strategies for these populations. The *ex situ* component is responsible for the development of a captive managed population of Sumatran tigers and the genetic, disease and gamete resource banks for the reinforcement and recovery of the wild populations. These two components are based upon the recommendations and priorities of the *Indonesian Sumatran Tiger Conservation Strategy* which are guided by advice from the Tiger Advisory Board.

The recommendations and priorities set forth in the *Indonesian Sumatran Tiger Conservation Strategy* are explained in greater detail in the following *Sumatran Tiger Action Plan.* Because of the crisis facing tigers in Sumatra, these recommendations are not given priorities.

The highest priority for the conservation of wild Sumatran tigers is to secure and protect all remaining tiger populations and their habitat.

- Improved Management Structures of PHPA

  PHPA management structure should be upgraded in major protected areas of Sumatra to provide maximum protection to tiger populations and their habitat.

  PHPA policies of integrated conservation and development need to be developed and implemented in and around all National Parks. Besides its major role in development, planning, and management of protected areas, PHPA should also be involved in the regulation of buffer zone activities and land-use around protected conservation areas.

  A vitally-needed upgrade is the development of an accurate (standardized) mapping system using computer linked Geographic Information Systems (GIS) to establish the distribution and habitat preference of tigers in Sumatra.

  Through the use of GIS, analyze land-use practices in all tiger habitat, including those areas outside of protected areas, and use these data to suggest possible viable population management strategies, including extending protection to additional tiger habitat areas.

PHPA needs to create Tiger Conservation Teams whose responsibilities would include patrolling of protected areas for poachers and poachers' traps, surveying or monitoring tiger populations where needed, setting up education programs for villagers living around tiger protected areas and throughout all of Indonesia, compiling information on tiger-human interactions, and all other events that are important to the tiger's continued survival. The specific responsibilities of the Tiger Conservation Teams are listed below.

- Law Enforcement and Anti-Poaching

For the continued survival of the Sumatran tiger in the wild, protection from poaching is of vital importance. This can only be achieved by continued presence in the field of dedicated Tiger Conservation Teams performing in an anti-poaching function in the major tiger protected areas: Kerinci Seblat NP, Gunung Leuser NP, Bukit Barisan Selatan NP, Way Kambas NP and Berbak NP. Kerumutan and Rimbang Game Reserves need to be evaluated for the placement of teams in their boundaries.

Five Tiger Conservation Teams should be formed. These teams will primarily conduct tiger surveys, train additional tiger monitoring and anti-poaching units if necessary, assist in research programs, coordinate local community education programs, and document all human-tiger conflicts.

The *in situ* operation of the teams will be coordinated by the Tiger Program Officer, who will liaise with government and non-government departments, provide guidelines for field activities, and keep the Tiger Advisory Board informed of program progress.

- Prevention of Poaching

The methods employed in poaching prevention are primarily field patrols to look for traps and other signs of poachers, to destroy these traps, and to gather evidence to identify and arrest the people involved.

PHPA park guards and all Tiger Conservation Teams should have the authority to arrest poachers. They must also be adequately equipped to deal with armed poachers.

Tiger Conservation Teams will be required to develop good relations with local people, to obtain information and assistance in the prevention of poaching, and to increase awareness of the plight of the tiger and the importance of its conservation. They should also try to establish the identity of contact persons and the routes used for the trade in tiger bones and pelts, and relay such information to the appropriate authorities. Monetary rewards to individuals who identify poachers should be considered.

- Qualification of Tiger Conservation Teams

Members of the Tiger Conservation Teams should be recruited in part from people in the locality of major protected areas. All members should have considerable knowledge of the forest but in each team one member should have authority to apprehend poachers. Each team should consist of four to five members, one of which should be the team leader with appropriate rank and skills.

Salaries and other benefits for team members should be adequate to attract well-qualified people. A bonus system for good performance should be considered.

- Control of Trade in Tiger Products

Tiger Conservation Teams and the Tiger Program Officer should associate and coordinate closely with the existing Forestry Security Coordination Teams (TKPH), both at regional and national level. Procedures should be developed to ensure that appropriate action be taken upon information received from the field. Possibly special investigation techniques and procedures should be developed together with the other agencies involved.

The control of the trade in tiger products and the prosecution of offenders should be regarded as a high priority issue of national interest and PHPA should seek support from the highest levels of government.

A second priority is to develop conservation management goals and intervention strategies for each of the remaining wild Sumatran tiger populations.

- Monitoring of Tiger Populations

Initiate field research and long-term monitoring to establish the critical life history parameters of wild Sumatran tiger populations in various habitats and protected areas. Of particular significance is to determine home range size and density in lowland and submontane forest, mean litter size and neonatal mortality.

Conservation programs should be based on reliable data on the status of the populations and species, especially when dealing with critically endangered animals. To provide such data, a continuous monitoring program for Sumatran tigers should be initiated in all reserves. Reliable censusing methodology should be developed and personnel should be trained in censusing techniques and in the evaluation of the results. Teams should be trained in these exercises.

- Field Research on Sumatran Tigers

Scientific research is an essential ingredient in the conservation of endangered species, biodiversity, and protected areas. Detailed investigations on life history characteristics of the Sumatran tiger are considered essential for the long-term conservation management of the species.

Establish cooperative projects with tiger biologists in field research and analysis, beginning with a pilot project in Way Kambas NP and later extension into other protected areas dominated by sub-montane forests, such as Kerinci-Seblat NP.

Evaluate extending boundaries of protected areas to include areas of tiger habitat and to link tiger habitats in national parks and other protected areas.

A third priority is to develop an Indonesian captive management program for the reinforcement and recovery of wild populations.

- PKBSI Sumatran Tiger Captive Management Program

Continue to support and expand activities of ICREW and the PKBSI Sumatran Tiger Captive Management Program to provide genetic and demographic resources for use in inventive management strategies of wild populations. Components of this program include:

Preventive Medical Procedures. Veterinary staff need to implement their training that has focused on proper animal health procedures for medical treatment, immobilizations, immunizations, evaluations, and health maintenance. All incoming tigers and newborn tigers need to be given physical examinations, including permanent tattooing of each animal with a temporary studbook number and placement of a transponder as a backup identification system.

Tiger Facility. The tiger captive breeding facility constructed at the Indonesian Center for the Reproduction of Endangered Wildlife will serve as the site for processing all tigers rescued from the wild.

Husbandry. Animal management staff need to implement proper animal husbandry procedures for maintaining captive tigers on a day-to-day basis. The tiger husbandry manual *Management and Conservation of Captive Tigers* needs to be translated into Bahasa Indonesia and used as a guide.

Reproductive Evaluation Procedures. Training on assisted reproductive techniques needs to be updated as the technology becomes available regarding semen collection, evaluation and storage techniques necessary for the establishment of a genome resource banking program. Semen needs to be collected and cryopreserved from all incoming male tigers for permanent storage in Indonesia.

Studbook. The *Indonesian Sumatran Tiger Studbook* needs to be updated annually and the Indonesian Tiger Studbook Keeper continually kept updated in the development of new versions of SPARKS.

Masterplan. An Indonesian Captive Management Masterplan for Sumatran tigers was drafted; and a PKBSI Tiger Management Committee was formed.

- Rescue of "Problem" Tigers

Develop a Tiger Rescue Team under the direction of ICREW, equiped and funded to rescue so-called "problem" tigers identified by PHPA and incorporate these tigers into the PKBSI captive managed population. "Problem" tigers are migrants from protected areas that come into conflict with villagers and if not rescued, are killed by local police or military because of the threat they pose to human life.

Evaluate all wild-caught "problem" tigers brought into the captive population through official PHPA removals for indicators of genetic diversity and inbreeding depression, pathogens and diseases, body weights and physical parameters.

Continue to expand the DNA library, blood serum bank, and genome resource bank for Sumatran tigers at ICREW by collecting biomaterials from all incoming "problem" tigers.

A fourth priority is to establish a communication and infrastructure network that is responsible for the survival of Sumatran tigers.

- Tiger Program Officer

Establish a position of Tiger Program Officer to coordinate all activities of tiger conservation in Indonesia.

This position should be a permanent post within PHPA. The officer should report directly to the Director General PHPA and to the Tiger Advisory Board, and should coordinate his/her activities with the other directorates and other agencies involved in tiger conservation activities.

Considering the complexity of the task, the program officer should have sufficient administrative support, both from a scientific perspective and from an administrative and fiscal perspective. This includes sufficient funding for participation in field activities.

The Tiger Program Officer should develop a standardized reporting system to report tiger observations, tiger-human interactions and other relevant information from park guards (as well as Tiger Conservation Teams) to the Sub-Balai to the Balai to the Chiefs (Kepala) of the National Parks to the Jakarta PHPA Office.

The Tiger Program Officer should incorporate tiger conservation information into broader conservation education programs in Indonesia.

- Education and Awareness program

Tiger Program Officers, both *in situ* and *ex situ* should be responsible for coordinating the conservation education and awareness programs. The Tiger Conservation Teams will play an important role in the education of the people living around tiger areas.

Conservation education staff need special interpretive training skills on how to interact with people (individually and in large gatherings) and how to convey ideas regarding values, natural history, economics and Indonesian culture.■

APPENDIX I. Status of Wild Sumatran Tiger Populations

Wild tigers are extremely difficult to census because of their secretive nature and near complete avoidance of humans. Even where tigers are censused regularly, as in the tiger reserves of India, their numbers vary from year to year and because the estimates are based primarily upon identification of individual tiger tracks, the reliability of this technique has been suggested to be without scientific basis. In Sumatran forests of Indonesia, the census of tigers is compounded by the fact that the national parks are huge, some areas within these parks are practicably inaccessible, and because of low overall prey densities in these habitats, tiger densities are correspondingly low. Remote camera censusing has provided reasonable estimates of tigers in two areas of Gunung Leuser National Park. This promising technique will need to be greatly expanded in scope before we can use it for ascertaining tiger population estimates throughout Sumatra.

The historical documentation of tigers in Sumatra is meager. In 1978 a survey of Sumatra estimated the number of tigers to be about 1,000. Since then, Sumatra has undergone much agricultural development and subsequently, pristine tiger habitat has declined. Subsequent surveys of Sumatran tigers put the number "not in the thousands but in the hundreds".

A more recent survey in 1985 estimated tiger distribution based upon information obtained from local PHPA staff and people living around areas inhabited by tigers, not from direct field observations. This survey concluded that, on average, tiger densities in Sumatra were about 1 tiger per 100 km^2 in mountainous areas and 1-3 per 100 km^2 in optimal lowland habitats. Using these density estimates, it was tentatively suggested that the 26 protected areas in Sumatra could support up to 800 tigers, but that the actual number of living tigers was probably fewer.

There is evidence for the presence of tigers in 26 protected areas in Sumatra (Table 1). These areas total 4,564,121 ha or 45,600 km^2 and account for 9.6% of the total land area of Sumatra. Within these areas, tigers inhabit an altitude range from sea level to over 1,000 m. In addition, tigers are also known outside the network of protected areas, especially in rubber plantations where many of the attacks on man and livestock have been reported.

Rain forest habitat in general does not support a high biomass of large ungulates. Optimum habitat is provided by sub-climax vegetation, such as transitional zones between forest and grasslands support a higher density of tiger's principal prey species. On the other hand, lowland forests support a greater biomass of ungulate prey such as wild pig (*Sus scrofa*), sambar (*Cervus unicolor*) and barking deer (*Muntiacus muntjak*) which are among the species preferred by tiger in Sumatra. But it is precisely such lowland forest habitats rich in prey species that are fast disappearing in Sumatra as a result of a host of development programs. It is estimated that between 65% and 80% of the forests in the lowlands of Sumatra have already been lost. The mountain areas to date have been less seriously affected, but disruption of continuous cover is already substantial in some cases, and perhaps 15% of their total area may tentatively be estimated as already removed on the evidence available.

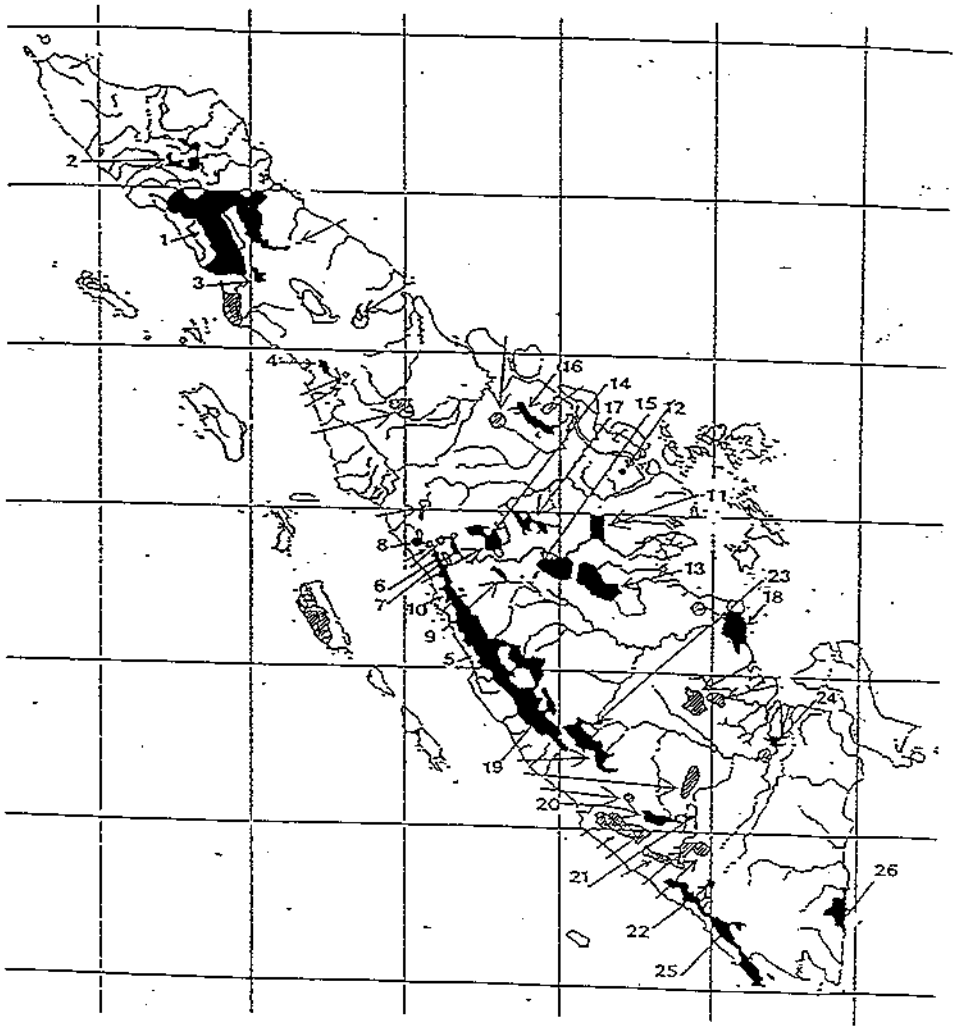

Fig. 1. Distribution of Sumatran tiger (*Panthera tigris sumatrae*). Solid shading: positive evidence of presence of tiger. Cross hatching: extent of additional suitable habitat but where positive evidence is not available. Numbers refer to the areas indicated in Table 1.

Table 1. Protected areas of Sumatra where tigers are found.

No.	Reserve/Park/Forest	Prov.	Status	Area (ha)	Alt. (m)
1	Gunung Leuser	Aceh	NP	792,675	0-3419
2	Lingga Isaq	Aceh	HR	80,000	800-2823
3	Dolok Sembelin	NSum	PFo	33,910	150-1604
4	Sibolga	NSum	NR	20,100	200-1230
5	Kerinci-Seblat	WSum	NP	1,484,650	500-3800
6	Lembah Anai	WSum	PFo	96,002	600-1811
7	Lembah Harau	WSum	PFo	23,476	600-1256
8	Maninjau	WSum	PFo	22,106	600-1724
9	Bkt.Sebelah/Pangean	WSum	PFo	22,803	600-1078
10	Bajang Air Tarusan	WSum	PFo	81,865	500-2000
11	Kerumutan Baru	Riau	GR	120,000	0-0
12	D. Pulau Besar/Bawah	Riau	GR	25,000	0-0
13	Seberida	Riau	NR	120,000	150-830
14	Bkt. Rimbang/Baling2	Riau	NR	146,000	200-1090
15	Peranap	Riau	HR	120,000	120-492
16	Siak Kecil	Riau	NR	100,000	0-20
17	Air Sawan	Riau	GR	140,000	100-176
18	Berbak	Jamb	GR	190,000	0-20
19	Merangin Barat	Jamb	PFo	64,600	1000-1931
20	Gumai Pasemah	SSum	GR	45,883	200-1776
21	Isau-Isau Pasemah	SSum	GR	12,114	500-1431
22	Gunung Raya	SSum	GR	39,500	300-2232
23	Rawas Hulu Latikan	SSum	GR	213,437	300-2384
24	Padang Sugihan	SSum	GR	75,000	0-50
25	Barisan Selatan	Ben/Lam	NP	365,000	0-1964
26	Way Kambas	Lamp	GR	130,000	0-50
	Total			4,564,121	

NB: NP=National Park; NR=Nature Reserve; HR=Hunting Reserve; GR=Game Reserve; PFo=Protection Forest. Underlined areas are lowland forests.

Recent Population Estimates of Sumatran Tigers

At the Sumatran Tiger Population and Habitat Viability Analysis (PHVA) workshop in November 1992, a spatial database using Geographic Information System (GIS) was developed for the five major conservation areas of Sumatra. Indonesian Land-use and Forest Status maps (series RePPProT 1988; scale 1:250,000) were used for protected area boundaries (HSA and HL, see Table 1 for definitions) and vegetation cover. Only vegetation cover within the five major protected areas was digitized from these maps. The main forest types distinguished in the five HSA areas were lowland forest (below 1,000 m), sub-montane forest (between 1,000-2,000 m), montane forest (above 2,000 m), and inland and mangrove swamp. In addition, other vegetation types such as bush and agriculture were included in the database.

To estimate vegetation cover outside of the five major protected areas, the World Conservation Monitoring Center (WCMC) provided a digitized coverage of vegetation on Sumatra (series RePPProT 1990; scale 1:2.5 million). WCMC's database only distinguishes between lowland forest, montane forest, inland and mangrove swamp and non-forest. Thus, all areas without forest, such as bush and agriculture, are treated as a non-forest category.

The database created therefore contains a distinction between the information available for vegetation cover inside and outside of the five major protected areas. Outside HSA boundaries all areas without forest are labeled non-forest, while inside HSA boundaries non-forest is divided into bush and agriculture. Roads, towns, and rivers were digitized from geological maps (Geological maps 1988; scale 1:250,000).

The Sumatran Tiger PHVA concentrated on the long-term viability (100 years) of tigers in HSA areas. Other areas, namely HL, were also discussed in terms of tiger numbers but an extensive analysis was not performed on these protected areas, because most of them are scheduled for conversion to agricultural purposes, are extremely small in size and isolated from larger protected areas. In an effort to gain an estimate of tiger numbers in a protected area, Griffith's estimates of tiger home range sizes in Gunung Leuser National Park were used.

Low tiger densities (1 male tiger per 380 km^2, 1 female tiger per 190 km^2) were assigned to montane forest and agricultural. Although agricultural areas may have a higher prey-base (and thus would be good tiger habitat), given poaching and poisoning pressures from humans and the tiger's propensity to avoid humans, it is unlikely that tigers would have an extensive part of their home range covering agricultural lands.

Medium tiger densities (1 male tiger per 274 km^2, 1 female tiger per 137 km^2) were assigned to submontane forest and peat-swamp forest. Submontane forest on the maps roughly corresponds to Griffiths' data (medium tiger densities were from 600 to 1700m, on our maps it is 1,000m to 2,000m). Peat-swamp habitat was assigned to this category, based upon conflicting reports of its suitability as tiger habitat (see section on Berbak National Park, below).

High tiger densities (1 male tiger per 180 km^2, 1 female tiger per 90 km^2) were assumed for lowland forest, swamp (except peat swamp forest), bush and logged forest. Logged forest was included in the high density category because secondary forest is thought to have a higher prey-base than primary forest. Bush and swamp were included in the high density category based upon the argument that tigers are especially associated with these habitats.

Tiger numbers for the five national parks were estimated in two ways: 1) using the vegetation cover on the RePPProT (1988) maps stored in the GIS database, and 2) using tiger presence as indicated on the maps by park officials at the PHVA workshop. Kerinci Seblat, Way Kambas, Barisan Selatan and Gunung Leuser all have complete data sets and both methods were used for these parks. Berbak was analyzed using only the vegetation types from the GIS database.

Gunung Leuser National Park

Tiger estimates from HSA areas (from data received at the PHVA workshop): There were 31 units labelled as lowland, swamp and logged. Two units were not labelled and were assigned lowland forest status based on the GIS database. One of the units labelled as swamp was indicated as not having tiger presence and was therefore removed from the analysis. Therefore, there were 30 units of the high density category comprising 3,000 km^2, for an estimated 16-17 male and 33-34 female tigers. There were 41 submontane units in the grid, for an estimated 14-15 male and 29-30 female tigers. There were 15 montane units in the plot, for an estimated 3-4 male and 7-8 female tigers. The total population was thus estimated to be between 102-108 tigers (33-36 male and 69-72 female).

Kerinci Seblat National Park

Tiger estimates from HSA areas (from data received at the PHVA workshop): There were 45 units of lowland and bush labelled with the presence of tigers, for an estimated 25 male and 50 female tigers. There were 30 units of submontane forest labelled for tiger presence, for an estimated 10-11 male and 21-22 female tigers. There were 17 units of agriculture and montane labelled for the presence of tigers, for an estimated population of 4-5 male and 8-9 female tigers. The total population was thus estimated between 118-122 (39-41 males and 79-81 females).

Barisan Selatan National Park

Tiger estimates from HSA areas (from data received at the PHVA workshop): From the tiger distribution received at the PHVA workshop, the tiger population of Barisan Selatan appears to be fragmented into five separate populations. The number of individuals is estimated for each population, from south to north.

The first population has 1,000 km² of lowland forest, for an estimated population of 5-6 male and 11-12 female tigers. The second population has 200 km² of lowland forest and 100 km² of agriculture, for an estimated population of 1-2 male and 2-3 female tigers. The third population has 200 km² of lowland and 100 km² of submontane forest, for an estimated population of 1-2 male and 2-3 female tigers. The fourth population 4 has 200 km² of lowland forest, for an estimated population of 1-2 male and 2-3 female tigers. The fifth population has 100 km² lowland forest with an estimated tiger pair.

The total population, using tiger presence from the grid, was estimated to be between 9-13 males and 18-22 females. If the tiger population is fragmented as depicted, there is suitable tiger habitat between these populations and because the distances between the populations are not great, tigers can probably cross these areas. Therefore, the populations are more than likely not genetically isolated.

Way Kambas National Park

Tiger estimates from HSA areas (from data received at the PHVA workshop): All 12 units labelled for tigers had lowland, bush or swamp, for an estimated 6-7 male and 13-14 female tigers. The total population was estimated at 19-21 tigers.

Berbak National Park

Tiger estimates from vegetation in GIS database (data from vegetation analysis): Using the vegetation types that occur within current park boundaries, there are 120 km² of swamp and logged forest. This results in an estimate of 1 male and 1-2 female tigers. There are 1,517 km² of peat-swamp forest, for an estimate of 5-6 male and 11-12 female tigers. The total estimated population for Berbak is between 18-21 tigers, 6-7 males and 12-14 females.

FUTURE DIRECTIONS

The results and analysis of the PHVA Workshop presented here provide a beginning, not the final result, of a commitment to ensure the long-term viability of free-ranging Sumatran tigers. As such, there are several issues that need to be further explored to gain better estimates of tiger distribution and densities. Within the context of this paper, these include: expansion of the database to include all viable tiger habitats, including both protection and production forest; identification of unsuitable habitat within these areas; better estimation of tiger home range sizes in tropical rain forest habitat; and better evaluation of the threats to wild tiger populations. ■

Table 2. Summary of tiger population estimates for five protected areas.

Protected Area	Vegetation analysis			Tiger distrib. from plots			PHVA
	M	F	Total	M	F	Total	Total
Barisan Selatan	16-18	33-35	49-53	9-13	18-22	27-35	68
Berbak	6-7	12-14	18-21	6-7	12-14	18-21	50
Gunung Leuser	36-39	74-77	110-116	33-36	69-72	102-108	110
Kerinci Seblat	44-47	89-92	133-139	40-41	80-82	120-123	76
Way Kambas	7-8	14-15	21-23	6-7	13-14	19-21	20
Kerumutan	-	-	-	-	-	-	30
Rimbang	-	-	-	-	-	-	42
Totals			339-361[a]			268-287[a,b]	396

[a] Does not include other parks with tigers (Rimbang and Kerumutan)

[b] Includes estimates from vegetation analysis of Berbak National Park.

APPENDIX II. Threats to Wild Sumatran Tigers

Poaching and illegal trade in tiger products are widespread throughout Asia. By their clandestine nature, both are difficult to detect. Poachers may bury tiger remains, including skins, if bones are the target. Unless there are sufficient forest guards, tiger carcasses are unlikely to be found and soon vanish. While skins can be easily identified, only a handful of experts can identify tiger bones, which can be readily transported and mistaken for other (legitimate) animal bones, in which there is normal trade. Tiger products are being sold in local markets in Laos, Vietnam, and Thailand, and trafficking of tiger products has been documented in India and Nepal and in Indonesia. Outside of tiger range countries, large numbers of bones and other tiger products have been found in Taiwan and South Korea, many of which were from Indonesia. It is China, however, by virtue of its large population, is the largest consumer and producer of manufactured medicines containing tiger parts.

Opinions differ on how exactly poaching and the illegal trade in tiger products impact wild populations. In recent years increased poaching levels have been documented in India, Nepal and the Russian Far East, and the consumption of tiger products in China, Taiwan and South Korea continues unabated. The question is: From where did all of these tiger parts originate? No one knows for sure from where or at what rate tigers are being removed from the wild. The general consensus, however, is that the free-ranging populations across Asia are decreasing, and unless poaching is stopped, or at least the demand for tiger products (which contributes to poaching) is stopped, these numbers will continue to decrease.

Official PHPA Reports:

- At the PHVA Workshop in November 1992, PHPA staff estimated that, on average, about 17 incidents involving problems with tigers are reported every year from the five national parks of Sumatra. Of these 17 instances, PHPA reported that about 12 resulted in tiger losses; about six through poaching or poisoning and another six through official removal by PHPA (see Vortex section of this report). These estimates are only for the five national parks of Sumatra and do not include other instances involving tigers living in much smaller and fragmented forest patches designated as game reserves or protection (and production) forests.

- The Indonesian Ministry of Forestry requires registration permits for all persons keeping endangered species. The initial registration period was to extend from February through May of 1992 (Decree No. 301/Kpts-II/1992) but was extended to October 1992 (Decree No. 479/Kpts-VI/1992). A total of 1,081 mounted tigers were reported to have been registered at the time of the PHVA workshop. The origin of these tigers was undetermined, but presumably they were from Sumatra originally, or were captive-born offspring from either wild-caught or privately-held tigers.

- Registered tiger specimens included 100 stuffed Sumatran tigers kept in houses of government officials and businessmen in South Sumatra. Another 200 stuffed tigers are held by private individuals in Lampung and about 300 in Palembang.

International Trafficking Reports:

- South Korean customs administration statistics show that, between 1975 and 1992, South Korea imported 3,720 kg of tiger bones from Indonesia. Traders in Southeast Asia report that the amount of dried tiger bones from a single tiger ranges from 6-11 kg, which implies South Korea imported the equivalent of 338-620 tigers over the 18-year period. In fact, Indonesia accounted for 61% of the total tiger bone import (6,128 kg) for South Korea.

- In the last three years alone (1991-1993), 475 kg, or about 20 tigers annually, were exported to South Korea.

- Tiger bone is an important ingredient for nine South Korea companies in the manufacture of pharmaceutical products. As of 15 October 1992 the *East Asian Medical Journal*, a South Korean bi-monthly newspaper, carried a full-page price list for Chin Hyung Dried Medicine Materials Company listing tiger bone at US$ 1,600/kg (3.3 million Rp/kg.

- In Singapore the retail price for a well-tanned adult Sumatran tiger skin is reputedly about US$ 2,000 (4.1 million Rp). The retail price for a Sumatran tiger penis is reputedly about US$ 100.

Published Reports:

- In the last decade a number of newspaper reports appeared in *The Jakarta Post* concerning tigers harassing villagers and killing their cattle. In South Aceh province, North Sumatra, a tiger killed and devoured a man and dozens of cows, goats and sheep. In West Aceh province a tigress killed a teenager and dozens of cattle before it was caught by PHPA. Local *pawangs* (traditional tiger charmers) were quoted as having successfully trapped 64 live tigers over several months.

- Since 1986 to about 1993 extensive poaching of tigers has been carried out along the forest edge in Gunung Leuser National Park, North Sumatra, especially in the west where the animals have been killed using poisoned baits. Estimates vary as to how many tigers have been killed in this period, but second-hand accounts from the leading poacher indicate as many as 50 tigers were killed between 1986 and 1990. Tiger numbers on the forest edge (much of which is still outside the park) have decreased and now pig numbers (that used to be controlled by tigers) have increased with subsequent loss of crops.

- In a report on Berbak National Park, it was stated that an average of one tiger has been killed in the vicinity of the park each year for the past eight years, according to one PHPA staff member, and three tigers are known to have been poached in 1991.

REMOVAL OF PROBLEM TIGERS BY PHPA

From time to time wild tigers causing problems for local villagers (primarily by killing and eating their livestock) are captured by PHPA and transferred to Indonesian zoos. Many of these tigers constitute the genetic founders of the Indonesian Zoological Parks Association (PKBSI) Sumatran Tiger Masterplan. The current Indonesian Sumatran Tiger Studbook (1994) lists a total of 30 (18 living) reputed wild-caught tigers from Sumatra (captured from 1965-1992). These tigers, which are outside of the boundaries of the protected areas, need to be removed by PHPA; if not, more than likely they will be poisoned or killed by villagers.

ESTIMATE OF IMPACT ON WILD POPULATIONS

It is almost impossible to estimate how many tigers are being lost to poachers, how many are being killed by poison, and how many are dying naturally. Currently, only records of tigers that have been caught by PHPA and transferred to the PKBSI for captive breeding, and a few reports of tigers being killed by police or other individuals in and around villages, are known. It is conservatively estimated that from about 1975 and 1992 a minimum of 42 tigers are lost annually from the wild population. This minimum number is derived from the following: 6 problem tigers that are removed by PHPA, and 36 tigers poached for taxidermic mounts. The validity of these numbers can be arguably challenged, but give a perspective that tigers are being lost.

This rate of removal takes into consideration that tiger bone exports may have been derived from the same tigers that were reported as taxidermic mounts or skins. This conservative rate of removal assumes that the taxidermic mounts were obtained at a constant rate and are applicable to the last several years. Also, it is difficult to reconcile historical rates with current rates of removal. Finally, not all of these tigers were necessarily wild-caught; some may have been derived from captive-born animals from the private sector.

However you interpret this information, one unescapable conclusion is that tigers are being lost from the wild, and that tiger products are leaving Indonesia and entering the pharmaceutical industry elsewhere in Asia. Vortex modelling (see Vortex section of this report) suggests that losses of wild tigers at the above rate will reduce even relatively large wild tiger populations, such as those in Gunung Leuser and Kerinci Seblat National Parks, to non-viable levels. The bottom line is that we cannot accurately quantify how many tigers are being lost, but the goal is to reduce or eliminate poaching altogether of wild tigers. ■

APPENDIX III. Sumatran Tiger Population Viability Analysis

INTRODUCTION

The tiger population on Sumatra is fragmented and isolated in 5-12 reserves and surrounding unprotected areas. Migration between some of these areas may be possible based upon the presence of forested corridors. However, no natural migration is possible among the five National Parks, so that the tiger populations in each now must function and be managed as separate genetic and demographic population units.

These small and isolated tiger populations are at risk of extinction from the interaction of random and deterministic processes (e.g., skewed sex ratio, failure to locate mates, disease, genetic drift, inbreeding depression, fighting, reduction in populations of prey animals, poaching, and poisoning). These populations and their habitat will require intensive management if the Sumatran tiger is to survive in the national parks for even 50 to 100 years.

The need for and effects of intensive management strategies can be modelled to suggest which practices may be the most effective in preserving the individual tiger populations. A stochastic population simulation modeling package, VORTEX 6.2 written by Robert Lacy and Kim Hughes was used as a tool to study the interaction of multiple variables treated stochastically to ~~gain~~ assist a better understanding of the effects of different management manipulations.

VORTEX is not intended to give absolute answers, since it is projecting stochastically the interactions of the many parameters which enter into the model and because of the random processes involved in nature. Interpretation of the output depends upon knowledge of the biology of the Sumatran tiger, the conditions affecting each of the individual populations, and possible changes in the future. The output is constrained by the input. Where needed input data are not available or uncertain, data from other tiger populations or best guesses by tiger experts were provided as input. The results from the simulations can be used to suggest the most critically needed data to provide more reliable results and thus assist the design of needed research for management of the populations.

MODEL INPUT

Tiger natural history data used for the VORTEX model were taken from published studies on the *Panthera tigris tigris* in the Royal Chitwan National Park, unpublished data contributed by the workshop participants, information from PHPA staff working in the individual Protected Areas, and information from the studbooks for captive tiger populations.

Carrying Capacity. Carrying capacity or K defines an upper limit for the population size, above which additional mortality is imposed in order to return the population to K. In other words, VORTEX uses K to impose a ceiling model of density-dependence on survival rates.

Habitat size and prey availability (density) are indicators of carrying capacity of the respective Parks and surrounding areas. Estimates of possible and probable tiger population numbers (animals 1 year and older) in the respective protected areas ranged from 25 to 150 animals. There are areas with fewer than 25 tigers but it is unlikely that any of the protected areas will sustain more than 150 animals. Therefore, 4 carrying capacities of 25, 50, 100, and 150 tigers to encompass this range were included in the sets of scenarios simulated.

Age First Reproduction. VORTEX defines breeding as the time when young are born, not the age of sexual maturity. VORTEX also assumes discrete intervals of years in the case of tigers. For tigers on average the age of first reproduction in wild populations appears to be 3 years for females and 4 years for males although younger animals in captivity can breed. These values were used in all of the simulation scenarios. The breeding structure was assumed to be polygynous.

Litter Size. Environmental variation in reproduction is modelled by entering a standard deviation (SD) for the percent of females producing litters each year. VORTEX then determines the percent breeding each year of the simulation by sampling from a binomial distribution with the specified mean (e.g., 50%) and SD (e.g., 12.5%). Thus about 66% of the time, the percent of females breeding will fall within ± 1 SD of the mean; about 95% of the time it will fall within ± 2 SD of the mean. The relative proportions of litters of each size (1, 2, 3, etc.) are kept constant; what is varied from year to year is the percent breeding (litter size > 0) and the percent not breeding (litter size = 0).

The maximum litter size observed in wild tigers is 5 cubs (also litters with more than 5 cubs comprise less than 2% of captive litters). Most information on wild tiger litter sizes is based upon observation of cubs 3-6 months of age and thus does not represent birth litter sizes. Data on *P.t. tigris* indicate mean litter sizes of 3 at this age. Limited field observations in Sumatra indicate a mean of 2 cubs at about 6 months of age. We therefore made litter size one of the variables included in all of the systematic comparisons using mean litter sizes of 2 or 3. The distributions of litter sizes for the respective means were set as follows:

The proportion of females breeding each year determines the mean interbirth interval. This interval is reported to be 2 years in wild tigers so that 50% of adult females, on average do not produce litters each year. A modest amount of annual variation was included using a standard deviation of 12.5%. The sex ratio at birth is taken as equal (0.50 proportion of males) based upon observations of more than 500 litters in captive populations.

Males Breeding. The breeding system modeled by VORTEX assumes that mates are randomly reshuffled each year and that all animals that can breed have an equal probability of breeding. A proportion of the males - 50% - were excluded from the breeding pool in a given year in the base scenarios to reflect the fact that some males are excluded from breeding by the social structure.

Age of Senescence. VORTEX assumes that animals can breed (at the species typical rates) throughout their adult lifespans. The maximum life expectancy is not used if the species does not reproduce throughout its entire life. This age was estimated as 15 years for wild tigers based upon several known age animals in Nepal and this value was used in all of the scenarios. Reproduction in captive female tigers appears to decline after 12 years of age.

Mortalities. Mortality as a percent (between 0.0 and 100.0) may be entered for each age class of immature females and males. Once reproductive age (adult) is reached, the annual probability of mortality remains constant over the life of the animal in these models and is entered only once. The mortality schedule used in all of the scenarios for the Sumatran tigers is drawn from the data on *P.t. tigris* in Nepal.

Inbreeding. A population with the level of inbreeding depression of one lethal equivalent per diploid genome may have one recessive lethal allele per individual (as in the Recessive Lethals model in VORTEX); or it may have two recessive alleles per individual, each of which confers a 50% decrease in survival; or it may have some combination of recessive deleterious alleles which equate with one fully lethal allele per individual. Natural selection does not remove deleterious alleles at heterotic (or over-dominant) loci (because all alleles in this model are partly deleterious when homozygous), thus the effects of inbreeding are unchanged during repeated generations of inbreeding. The default number of lethal equivalents for the Heterosis model is 3.14 which is a median value obtained in a study of 40 mammalian species.

Inbreeding depression has been observed in inbred lines of captive Siberian tigers (*P.t. altaica*). To include this potential threat in these models the Heterosis model in VORTEX was used in which we entered the number of "lethal equivalents" as 3.14. The inclusion of inbreeding was varied systematically in the scenarios developed for the Sumatran tiger populations so that comparisons were made under identical conditions with this factor present or absent.

Threats. Major potential threats for the wild populations of Sumatran tigers include continued loss of habitat, increasing fragmentation of remaining habitat, reduction of prey species density, removal of tigers for control purposes, and poaching for bone and skin or other products. Wild tiger populations, perhaps because of their relative isolation and thin distribution, are not known to have been affected by epidemic disease.

The impact of habitat loss has been modelled by using different carrying capacities as a guide to the changing risk of extinction with decreasing population size. Removals, on a continuing basis were modelled by using the harvest module of VORTEX with either 0, 2 or 4 adult tigers, split evenly between the sexes, removed per year. This in effect is a systematic increase in annual adult mortality. Scenarios that included losses modelled as less frequent events (catastrophes) did not include these systematic harvests or removals.

Catastrophes. Catastrophes can be thought of as the extreme of environmental variation. Catastrophes are events that impact either reproduction or survival. Catastrophes can be habitat destruction, floods, fire, disease, poaching, etc. Catastrophes do happen and are very real

considerations when attempting to model the fate of small populations. We define the impact of these catastrophes in terms of effects on reproduction and survival. A catastrophe may have occurred when a mortality rate is noted that is statistically higher than the normal variation. The reproduction and survival rates for catastrophe years are obtained by multiplying the (non-catastrophe) probability of reproduction or surviving by a severity factor. The severity factor ranges from 0.0 to 1.0. Entering 0.0 indicates a total loss of reproduction or survival for the population and 1.0 indicates that the catastrophe, if it occurs, will have no effect.

Catastrophes in wild tiger populations might include large scale fires (which they might escape but suffer the consequences of reduction in the prey base), abrupt forest removal, unusual declines in the prey population, and poaching for bone and skin or other products. Since poaching events tend to be more episodic, occurring at uncertain intervals we modelled separately the impact of events occurring on the average either at 5 (20% probability) or 10 (10% probability) year intervals. The event, in both cases, was given a severity effect of 0.90 on survival (about 10% additional loss of animals to the population, i.e. 2-3 animals in a population of 25-30 animals) and no effect on reproduction of the remaining animals. This may underestimate the negative effects on reproduction of the potential social disruption that may occur.

Age Distribution. We initialized all of the models with a stable age distribution which distributes the total population among the various age classes. The initial population sizes used were 25 for K=25 or 50 and 75 for K=100 or 150. VORTEX automatically enters values for all age classes, proportionate to the stable age distribution.

Base Models. Two basic models were constructed from the available life history data using mean litter sizes of either two or three cubs with all other variables the same. The other parameters systematically varied were carrying capacity (25, 50, 100, 150), inbreeding depression (column 4 - present or absent using a heterosis model with 3.14 lethal equivalents), and catastrophes (column 3 - absent, or present with a frequency of 10 or 20% and a survival severity factor of 0.9).

The two basic models do not include effects of annual harvests, inbreeding depression, catastrophes, or further habitat degradation. The effects of these additional factors were systematically added to the basic models to evaluate their impact on the risk of extinction and population dynamics. These factors generally increase the probability of extinction, decrease surviving population sizes, and decrease the amount of genetic variation remaining in the simulated population.

SUMMARY AND INTERPRETATION OF SIMULATION RESULTS FOR EACH PROTECTED AREA

Definitions. Estimated population sizes are for animals 1 year and older. About half this number will be breeding age adults. The estimate of removed tigers includes animals lost to poaching as well as problem animals removed. This information was provided by PHPA staff

at the workshop. The estimates of extinction risk are for 100 years. In all instances the probability of extinction is high with removals if the mean litter size is 2 cubs. The risk estimates quoted are for litter sizes of 3 with no inbreeding depression but with either 0% or a 10% probability of a catastrophe event which reduces survival by 10% in the year of occurrence. We believe that these are conservative estimates because the risks would be greater if inbreeding depression is included in these small population simulation scenarios.

Gunung Leuser National Park

Total area (ha):	≈900,000
Available habitat:	40% (360,000 ha)
Estimated population size:	110 tigers (2000 ha per tiger)
Number tigers removed per year:	2-4

Comments: Risk of extinction is 20% (100 years) given two tigers removed per year (Te mean = 59 years; 80% H_e retained); probability of extinction rises to 87% with four tigers removed per year (Te mean = 45 years; 75% H_e retained).

Kerinci-Seblat National Park

Total area (ha):	≈1,500,000
Available habitat:	40% (600,000 ha)
Estimated population size:	76 tigers (7,895 ha per tiger)
Number tigers removed per year:	6

Comments: Even if the tiger population is assumed to be one population (no fragmentation, which is unlikely), there is essentially a 100% probability of extinction within 50 years (mean=17 years to extinction). Poaching/removal has an overwhelming effect on the survival of the population.

Barisan Selatan National Park

Total area (ha):	≈356,800
Available habitat:	79% (281,872 ha)
Estimated population size:	68 tigers (4,145 ha per tiger)
Number tigers removed per year:	1

Comments: This population, with only one tiger removed per year, has less than 1% probability of extinction in 100 years, with 84% H_e retained. However, this simulation did not include catastrophes or inbreeding effects, which may increase the Pe to 10% in 100 years in this size population.

Berbak National Park

Total area (ha):	≈162,700
Available habitat:	70% (113,890 ha)
Estimated population size:	50 tigers (2,278 ha per tiger)
Number tigers removed per year:	2

Comments: Highly likely to go extinct (Pe = 97%) within 100 years (mean=31 years to extinction). Although the estimated population is smaller than that for Kerinci, the Berbak population does slightly better in the simulations because of the lower estimated level of removed/poached individuals. If the model starts with an initial population of 150 tigers (50 adults in park, 50 adults in the proposed surrounding HL area, 50 immatures), then there would be a 1% probability of extinction, with 85% H_e retained.

Way Kambas National Park

Total area (ha):	≈130,000
Available habitat:	75% (97,500 ha)
Estimated population size:	20 tigers (4,875 ha per tiger)
No. tigers removed per year:	0

Comments: Probability of extinction is 40-70% (depending upon mean litter size) within 100 years (mean=48 years to extinction). Even though no animals are being removed from the population, random events in small populations greatly increase the risk of extinction. Inclusion of inbreeding effects in the simulation model increases the risk of extinction to 94+% or the inclusion of a catastrophe at 10 % probability of occurrence increases the PE to 49%. Both factors are real risks. If the model starts with 40 tigers (additional adults plus some cubs), then there is only 2% probability of extinction, but the population becomes very inbred (only 50% H_e retained). By adding one female to the population every year, the probability of survival remains the same, but the population retains much more heterozygosity, 88% H_e .

Kerumutan Game Reserve

Total area (ha):	≈120,000
Available habitat:	65% (78,000 ha)
Estimated population size:	30 tigers (2,600 ha per tiger)
Number tigers removed per year:	2

Comments: 100% probability of extinction in 50 years with a mean time to first extinction = 15 years.

Rimbang Game Reserve

Total area (ha):	≈136,000
Available habitat:	90% (122,400 ha)
Estimated population size:	42 tigers (2,914 ha per tiger)
No. tigers removed per year:	2

Comments: There is a projected 100% probability of extinction (Te = 25 years). The populations at Kerumutan and Rumbang Game Reserves are very vulnerable to poaching effects (without poaching, results should be similar to Way Kambas with initial population size of 40); therefore, it is important to control poaching.■

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