ELANG JAWA

(Spizaetus bartelsi)

Population and Habitat Viability Assessment for the Javan Hawk-Eagle

Cisarua - Bogor, Indonesia

May, 1996

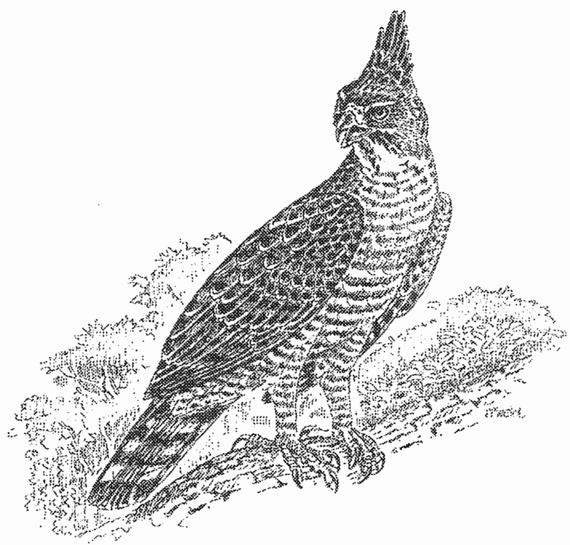
JAVAN HAWK-EAGLE (*SPIZAETUS BARTELSI*)

Population and Habitat Viability Assessment

6 - 8 May 1996

Safari Garden Hotel, Taman Safari Indonesia
Bogor, Java Barat, Indonesia

Jansen Manansang, Philip Miller, James W. Grier and Ulysses Seal, Editors



Sponsored By:
CalEnergy Company, Inc.
Peter Kiewit Sons', Inc.

A Collaborative Workshop:
Indonesian Department of Forest Protection and Nature Conservation (PHPA)
Taman Safari Indonesia
Conservation Breeding Specialist Group (IUCN/SSC/CBSG)

A contribution of the IUCN/SSC Conservation Breeding Specialist Group in collaboration with the Indonesian Directorate of Forest Protection and Nature Conservation (PHPA) and Taman Safari Indonesia (TSI/PKBSI).

The sponsors of the PHVA workshop were CalEnergy Company, Inc. and Peter Kiewit Sons', Inc.

Cover Illustration: Photo of Javan Hawk-eagle (*Spizaetus bartelsi*) at Taman Safari Indonesia courtesy of Philip Miller. Javan Hawk-eagle artwork by F. Weick.

Manansang, J., P. Miller, J.W. Grier, and U.S. Seal. 1997. *Population and Habitat Viability Assessment for the Javan Hawk-Eagle (*Spizaetus bartelsi*).* Conservation Breeding Specialist Group (SSC/IUCN): Apple Valley, MN.

Additional copies of this publication can be ordered through the SSC/IUCN Conservation Breeding Specialist Group, 12101 Johnny Cake Ridge Road, Apple Valley, MN 55124-8151, USA. Send checks for US$35.00 (to cover printing and shipping costs) payable to CBSG; checks must be drawn on a US Bank. Funds may be wired to First Bank NA ABA No. 091000022 for credit to CBSG Account Number 1100 1210 1736. Payment by Visa or MasterCard is also acceptable.

The CBSG Institutional Conservation Council : these generous contributors make possible the work of the Conservation Breeding Specialist Group

Conservators ($10,000 and above)
Australasian Species Management Prog.
California Energy Co., Inc.
Chicago Zoological Society
Columbus Zoological Gardens
Denver Zoological Gardens
Exxon Corporation
Fossil Rim Wildlife Center
International Union of Directors of Zoological Gardens
Metropolitan Toronto Zoo
Minnesota Zoological Garden
Omaha's Henry Doorly Zoo
Saint Louis Zoo
Sea World, Inc.
Walt Disney World Company
White Oak Conservation Center
Wildlife Conservation Society - NY
Zoological Society of Cincinnati
Zoological Society of San Diego

Guardians ($5,000-$9,999)
Cleveland Zoological Society
Friends of Zoo Atlanta
John G. Shedd Aquarium
Loro Parque
Lubee Foundation
Toledo Zoological Society
Zoological Parks Board of New South Wales

Protectors ($1,000-$4,999)
Allwetter Zoo Munster
Africam Safari
Audubon Institute
Bristol Zoo
Burgers' Zoo
Caldwell Zoo
Calgary Zoo
Cologne Zoo
Copenhagen Zoo
Detroit Zoological Park
El Paso Zoo
Federation of Zoological Gardens of Great Britain and Ireland
Fort Wayne Zoological Society
Fort Worth Zoo
Gladys Porter Zoo
Greater Los Angeles Zoo Association
Houston Zoological Garden
Indianapolis Zoological Society
International Aviculturists Society
Jacksonville Zoological Park
Japanese Association of Zoological Parks & Aquariums
Jersey Wildlife Preservation Trust
Living Desert
Marwell Zoological Park
Milwaukee County Zoo
NOAHS Center
North Carolina Zoological Park
North of England Zoological Society, Zoological Society of London
Chester Zoo
Oklahoma City Zoo
Paignton Zoological & Botanical Gardens
Parco Natura Viva Garda Zoological Park
Penscynor Wildlife Park
Philadelphia Zoological Garden
Phoenix Zoo
Pittsburgh Zoo
Royal Zoological Society of Antwerp
Royal Zoological Society of Scotland
San Antonio Zoo
San Francisco Zoo
Schoenbrunner Tiergarten
Sedgwick County Zoo
Sunset Zoo (10 year commitment)
Taipei Zoo
The WILDS
The Zoo, Gulf Breeze, FL
Urban Services Dept. of Hong Kong
Union of German Zoo Directors
Washington Park Zoo
Wassenaar Wildlife Breeding Centre
Wilhelma Zoological Garden
Woodland Park Zoo
Yong-In Farmland
Zoological Parks Board of Victoria
Zoological Park Organization
Zurich Zoological Garden

Stewards ($500-$999)
Aalborg Zoo
Arizona-Sonora Desert Museum
Banham Zoo
Camperdown Wildlife Center
Cotswold Wildlife Park
Dickerson Park Zoo
Dutch Federation of Zoological Gardens
Erie Zoological Park
Fota Wildlife Park
Givskud Zoo
Granby Zoological Society
Great Plains Zoo
Knoxville Zoo
Lincoln Park Zoo
Nat. Zool. Gardens of South Africa
Odense Zoo
Orana Park Wildlife Trust
Paradise Park
Prudence P. Perry
Perth Zoological Gardens
Riverbanks Zoological Park
Rolling Hills Ranch (5 year commitment)
Rostock Zoo
Royal Zoological Society of Southern Australia
Rotterdam Zoo
Thrigby Hall Wildlife Gardens
Tierpark Rheine
Twycross Zoo
Wellington Zoo
World Parrot Trust
Zoo de la Casa de Campo-Madrid
Welsh Mt. Zoo/Zool. Society of Wales
Zoologischer Garten Frankfurt

Curators ($250-$499)
Emporia Zoo
Marie and Edward D. Plotka
Racine Zoological Society
Roger Williams Zoo
The Rainforest Habitat
Topeka Zoological Park
Tropical Bird Garden

Sponsors ($50-$249)
African Safari
Alameda Park Zoo
Shigeharu Asakura
Apenheul Zoo
Belize Zoo
Brandywine Zoo
Claws 'n Paws
Darmstadt Zoo
Elaine M. Douglass
Dreher Park Zoo
Endangered Wildlife Trust
Exotarium
Hancock House Publisher
Marvin Jones
Kew Royal Botanic Gardens
Lisbon Zoo
Miller Park Zoo
National Aviary in Pittsburgh
National Birds of Prey Centre
Jean H. Nudell
Ocean World Taipei Incorporation
Steven J. Olson
PAAZAB
Parco Faunistico "La Torbiera"
Potter Park Zoo
Teruku Shimizu
Tokyo Zoological Park Society
Touro Parc-France

Supporters ($25-$49)
Bighorn Institute
DGHT Arbeitsgruppe Anuren
Folsom Children's Zoo & Botanical Garden
Jardin aux Oiseaux
Lee Richardson Zoo
Memphis Zoo
Natur- u. Artenschutz in den Tropen
Oglebay's Good Children's Zoo
Speedwell Bird Sanctuary
Tautphaus Park Zoo
Terrasimia Preservation Trust
Zoocheck Canada Inc.
Zoological Society of Trinidad & Tobago

15 April 1997

Javan Hawk-Eagle

(Spizaetus bartelsi)

Population and Habitat Viability Assessment

TABLE OF CONTENTS

POPULATION AND HABITAT VIABILITY ASSESSMENT FOR THE JAVAN HAWK-EAGLE (*Spizaetus bartelsi*)

Taman Safari Indonesia
6 - 8 May 1996

Section 1
Executive Summary And Recommendations

RINGKASAN EKSEKUTIF

Elang Jawa (*Spizaetus bartelsi*) adalah satwa yang telah kritis terancam bahaya kepunahan dan merupakan satwa endemik di Jawa. Baru-baru ini jenis satwa ini ditetapkan oleh Presiden sebagai satwa nasional sehingga jenis satwa ini telah menarik perhatian dan kesadaran masyarakat. Apalagi jenis Elang Jawa ini adalah yang paling mirip dengan simbol negara Indonesia yaitu Garuda Pancasila. Pada awalnya populasi Elang Jawa tersebar di seluruh hutan tropika basah di Jawa tetapi saat ini populasinya telah jatuh ke tingkat yang mengkhawatirkan antara 80 - 108 pasang. Hal ini diduga kuat merupakan akibat dari luasnya konversi hutan di Jawa, perburuan liar, dan bencana alam. Populasinya saat ini terpecah-pecah ke dalam beberapa sub-populasi di Jawa Barat, Jawa Tengah dan Jawa Timur dan kemungkinan untuk saling berhubungan atau berpindah dari satu populasi ke populasi lainnya sangat kecil. Usaha untuk melakukan konservasi Elang jawa mengalami kendala-kendala diantaranya sedikitnya informasi tentang penyebarannya saat ini, tidak adanya prioritas kebijaksanaan dan kurangnya biaya. Untuk itu Direktur Jenderal PHPA Ir. Soemarsono dan Ir. Dwiatmo Siswomartono M.Sc pada saat diselenggarakannya workshop Conservation Assessment and Management Program (CAMP) bulan April 1995 di Spanyol menyarankan perlunya ada suatu PHVA Elang jawa. Peserta workshop CAMP yang terdiri dari para peneliti, pengelola dan wakil dari 12 organisasi konservasi burung pemangsa telah setuju untuk pertama kalinya bekerja sama dalam proyek penilaian status ancaman terhadap burung-burung pemangsa secara global.

CBSG secara resmi diundang oleh Ir. Soemarsono, Direktur Jenderal Perlindungan Hutan dan Pelestarian Alam, departemen kehutanan dan Ir. Dwiatmo siswomartono , Direktur Bina Kawasan Suaka Alam dan Konservasi Flora Fauna untuk membantu pelaksanaan PHVA Elang Jawa di Indonesia pada bulan Mei 1996. Drs. Jansen Manansang dan Tonny Sumampau menawarkan untuk menjadi tuan rumah dalam workshop tersebut di Taman Safari Indonesia (TSI) yang merupakan pusat reproduksi satwa langka Indonesia.

Tujuan dari workshop ini adalah untuk membantu pelaksana di daerah dan pembuat kebijaksanaan untuk: 1) memformulasikan prioritas untuk program manajemen praktis untuk pelestarian dan pemulihan Elang Jawa di habitat alamnya, 2) mengembingkan analisis resiko dan simulasi model populasi species Elang Jawa yang dapat dipakai sebagai pedoman untuk mengevaluasi pengelolaan dan penelitian, 3) mengidentifikasi daerah habitat tertentu untuk mendapatkan perlindungan, 4) mengidentifikasi dan memulai alih teknologi dan training, 5) mengembangkan program penangkaran dengan memakai individu hasil sitaan dalam hubungannya dengan konservasi populasi di alam, dan 6) mengidentifikasi dan merekrut kolaborator di dalam negeri dan masyarakat internasional.

Elang Jawa dianggap kritis terancam punah karena penyebarannya yang terbatas, populasinya yang menurun, dan kemungkinan untuk dapat punah yang diakibatkan oleh beberapa faktor yang mengancam seperti hilangnya mangsa, hilangnya habitat, perburuan, dan bencana alam. Tujuan dari konservasi dan pengelolaan adalah untuk menjaga populasi Elang Jawa yang viabel secara genetik, lestari dan hidup bebas. Evaluasi terhadap resiko merupakan kepedulian utama dalam pengelolaan species terancam dan sasarannya adalah untuk mengurangi resiko dari bahaya kepunahan sampai pada tingkat yang dapat ditolerir. Sebuah software komputer untuk membantu simulasi dan evaluasi secara kuantitatif telah tersedia dan VORTEX sebagai salah satu bagian dari Lokakarya Population and Habitat Viability Assessment (PHVA). Teknik ini dapat memperbaiki indentifikasi dan rangking dari resiko dan dapat membantu penilaian dalam pemilihan cara pengelolaan.

Empat puluh empat ahli biologi, pengelola kawasan dan pembuat keputusan hadir dalam Workshop Population and Habitat Viability Assessment (PHVA) di Safari Garden Hotel, Cisarua, Indonesia pada tanggal 6-8 mei 1996 untuk menerapkan prosedur penilaian resiko yang baru dikembangkan dan memformulasi serta menguji skenario pengelolaan Elang Jawa. Lokakarya ini merupakan kerjasama antara PHPA, TSI/PKBSI, dan Conservation Breeding Specialist Group (CBSG) yang merupakan bagian dari Species Survival Commission/World Conservation Union (SSC/IUCN). Tujuannya adalah untuk menilai data populasi di alam dan di dalam pemeliharaan sebagai dasar untuk menilai resiko terhadap kepunahan, menilai perbedaan skenario dalam pengelolaan, mengevaluasi dampak dari pengambilan dari populasi di alam, menilai strategi yang mungkin dapat diterapkan untuk reintroduksi dan mengembangkan simulasi model stokastik populasi. Model-model tersebut menduga resiko kepunahan dan laju kehilangan genetik yang merupakan interaksi antara faktor-faktor demografik, genetik dan lingkungan yang dapat dipakai sebagai alat untuk pengelolaan subspecies. Sasaran lain diantaranya adalah penentuan daya dukung dan kebutuhan habitat, peranan penangkaran dan kebutuhan riset prioritas.

Pada hari pertama dipresentasikan data dari populasi alam dan dalam pemeliharaan. Setelah presentasi pengarahan proses PHVA, peserta dikelompokkan dalam empat working groups (wild population, captive population, people management dan population biology and modelling) untuk melihat secara rinci informasi yang tersedia, mendengarkan ide-ide, dan untuk mengembangkan rekomendasi dan skenario pengeloaan. Model simulasi populasi stokastik dibuat dan dimulai dalam suatu rentang nilai untuk variabel-variabel kunci untuk menduga viabilitas populasi di alam menggunakan software modelling VORTEX. Dengan menggunakan data dari literatur dan konsultasi dengan para peserta, satu seri nilai populasi dasar yang telah disepakati sebagai parameter yang diperlukan oleh VORTEX . Angka-angka ini kemudian dipakai untuk membuat model pada tiga populasi terpisah di Jawa. Populasi terpisah yang berada di Jawa Tengah mempunyai permasalahan yang berbeda dengan yang di daerah lain sebab populasi yang berada di Jawa Tengah tidak berada di dalam kawasan konservasi sehingga ancaman yang ada berbeda dan oleh sebab itu populasi ini dibuat model tersendiri.

Laporan lokakarya ini mencakup tujuan untuk pemulihan populasi, rekomendasi untuk penelitian dan pengelolaan populasi di alam dan dalam penangkaran, penyuluhan dan informasi kepada masyarakat serta sejarah keberadaan populasi, pengelolaannya, dan biologi populasi serta simulasi modelling populasi.

REKOMENDASI

Populasi dan Sasaran Pengelolaan

Sasaran pengelolaan ini adalah meningkatnya jumlah pasangan pada populasi Elang Jawa dewasa sebanyak 30-40% di alam dalam waktu 10 tahun dapat tercapai melalui pengelolaan dan perlindungan.

Populasi di Alam dan Modelling

Populasi Elang Jawa di alam diperkirakan 80-120 pasang. Dengan memasukkan habitat-habitat yang belum diketahui serta perbaikan metodologi survai mungkin jumlahnya dapat mencapai 105-200 pasang. Namun populasinya terpisah menjadi kira-kira tiga subpopulasi utama dimana tiap subpopulasi tersebut masih terpisah-pisah lagi. Tingkat perpindahan dan pertukaran antar populasi yang terpisah tersebut masih belum diketahui. Model yang dibuat menunjukkan bahwa kemampuan hidup (survival) populasi Elang jawa sangat sensitif terhadap perubahan tingkat kematian pada setiap kelas umur. Proyeksi populasi dan resiko yang paling optimistik, dengan data yang ada saat ini dan data yang ada pada species elang lain yang mirip, menunjukkan laju pertambahan tahunan sebesar 3%. Hal ini merupakan hasil dari potensi reproduksi yang relatif rendah dimana hanya satu telur dalam setiap kali bertelur dalam satu sarang, laju penetasan yang tinggi, dan bertelur paling cepat setiap dua tahun. Tingginya kematian akibat gangguan kegiatan manusia merupakan ancaman yang utama terhadap survival jenis ini di seluruh penyebarannya di Jawa. Laju pertambahan populasi yang lambat ini sangat sulit dideteksi dalam suatu pengelolaan yang optimum, dengan sistem survei yang baik sekalipun. Sehingga data sensus populasi yang konsisten dan sistematik sangat dibutuhkan untuk mengetahui perubahan tersebut. Metodologi untuk sensus yang akurat dan sensitif perlu diperbaiki, melalui pemanfaatan ahli terbaik yang ada dalam bidang teknik-teknik kuantitatif sensus lapangan.

1. Penggunaan metodologi yang tersedia saat ini untuk pemetaan habitat yang mungkin ada serta untuk sampling distribusi dan jumlah populasi. Penelitian dalam bidang: a) penilaian populasi Elang Jawa, b) penilaian habitat dan pemetaan, c) kehilangan sarang karna ulah manusia.

2. Menyelidiki umur spesifik dalam hal kemampuan hidup pada populasi di alam, terutama dewasa, anakan dan sarang. Menyelidiki proporsi betina yang berbiak setiap tahun pada populasi di alam.

3. Menyediakan hardware, software dan training yang diperlukan agar secara rutin model-model VORTEX dari populasi dan pengelolaan Elang Jawa dapat diperhalus.

4. Menggunakan populasi penangkaran untuk menentukan sex ratio pada anakan, umur pertama kali berbiak, jumlah anakan (telur), kesuburan telur, dan kemampuan menetas pada telur.

5. Studi lapangan sangat diperlukan untuk mengetahui besarnya, penyebaran dan intensitas fragmentasi pada populasi Elang Jawa di Alam. Penentuan jarak penyebaran burung-burung muda perlu dilakukan. Pengetahuan sejauh mana ada ancaman tambahan pada populasi dan habitat sangat diperlukan.

6. Apabila reintroduksi dari dalam penangkaran perlu dilakukan maka perlu dilakukan monitoring untuk setiap individu dengan radio-telemetry terutama 10 burung pertama selama 2-3 musim berbiak sehingga dapat diketahui pemanfaatan habitat untuk membantu penentuan habitat potensial dan keberhasilan reintroduksi.

7. Meneliti kembali tata guna lahan saat ini untuk menghindarkan konversi habitat Elang Jawa potensial ke dalam penggunaan lahan yang tidak kompatibel dengan konservasi Elang Jawa.

Program Pendidikan dan Kesadaran Umum

8. Pembentukan "Yayasan Elang Garuda" untuk mendukung kegiatan-kegiatan konservasi Elang Jawa.

9. Pengembangan kurikulum untuk dimasukkan dalam pendidikan sekolah formal.

10. Peningkatan partisipasi masyarakat yang berada di dalam dan di sekitar habitat Elang Jawa.

11. Mengadakan pelatihan untuk staf lapangan dalam bidang kemampuan manajemen, ekologi dan komunikasi turisme.

12. Memperbaiki fasilitas-fasilitas dan sumber daya pendidikan turisme

13. Menunjuk koordinator untuk memimpin suatu komite kecil pengelolaan untuk mengevaluasi dan memberi saran dalam hal pengembangan ide-ide dasar dan rekomendasi untuk keperluan pengelolaan Elang Jawa.

14. Mengkoordinasikan kegiatan PHPA dengan kegiatan Pemerintah di Pusat maupun Daerah untuk memasukkan rekomendasi yang sangat berguna ke dalam suatu Master Plan (yang sedang dikembangkan) untuk jenis tersebut.

15. Demografi dan populasi manusia di dalam dan sekitar kawasan konservasi perlu dievaluasi untuk membuat perhitungan proyeksi dampak jangka panjang pada habitat Elang Jawa dan resiko dari penangkapan.

Populasi dalam Penangkaran

16. Burung-burung yang berada dalam penangkaran perlu diintegrasikan dalam suatu pengelolaan dan program penangkaran yang terkoordinasi. Pengembangan perkandangan yang cocok, pengelolaan, dan sistem kesehatan merupakan hal yang sangat diperlukan. Penentuan jenis kelamin terhadap Gunung de penanglearan merupakan hal penting sebagai datar untuk program pengembang biakan.

17. Suatu management Plan dan manual pengembang-biakan harus dibuat, dipublikasikan di Indonesia dan disebarkan kepada semua pihak yang bekerja sama untuk pelestarian Elang Jawa.

18. Menggunakan populasi yang ada di dalam pemeliharaan saat ini untuk program penangkaran, penelitian biologi dari spesies, dan pendidikan kepada umum.Burung-burung yang saat ini ada di pemeliharaan kemungkinan besar diambil sewaktu masih anakan dari sarang dan dibesarkan di dalam pemeliharaan dalam kondisi yang sangat berbeda. Burung-burung tersebut tidak cocok untuk reintroduksi ke habitat alamnya walaupun melalui karantina, perlakuan dan pengkondisian.

19. Program penangkaran di Indonesia memerlukan Spesies Koordinator, Studbook Keeper, dan Komite Manajemen Penangkaran untuk membuat draft dan mengimplementasikan masterplan populasi penangkaran.

EXECUTIVE SUMMARY

The critically endangered Javan Hawk-eagle (*Spizaetus bartelsi*) is endemic to Java in Indonesia. It was recently designated the national bird of Indonesia which increased public awareness and interest. Historically, the population was widely distributed in the wet tropical forests of Java but has since declined to an estimated 80-108 pairs of birds as the result of habitat loss from extensive deforestation on Java, sporadic hunting, and disturbance. They may be fragmented into several subpopulations in West, Central and East Java with limited capability for natural exchange. Efforts to establish a practical conservation management and research program for this species have been hampered by a lack of information on their current distribution, difficulties in protecting them in remote areas, uncertain priorities, and lack of funding. A Population and Habitat Viability Assessment (PHVA) for the Javan Hawk-eagle was suggested by Ir. Soemarsono and Ir Dwiatmo of the Department of Forest Protection and Nature Conservation (PHPA) in December 1995. A PHVA was also recommended at the landmark collaborative Conservation Assessment and Management Program (CAMP) Workshop in Spain in April of 1995. Participants in the CAMP included scientists, managers and representatives of 12 raptor conservation organizations who had agreed, for the first time, to work together on this global raptor threat and status assessment project of mutual interest.

CBSG was officially invited by Ir. Soemarsono, Director-General Perlindungan Hutan dan Pelestarian Alam, Depart. Kehutanaan, (PHPA, Ministry of Forestry) and Ir Dwiatmo Siswomartono Director of BKFF (Department of Conservation of Flora and Fauna, PHPA) to conduct the PHVA for the Javan Hawk-eagle in Indonesia in May 1996. Drs Jansen Manansang and Tony Somampau offered to host the course and workshop at Taman Safari Indonesia (TSI). Taman Safari Indonesia is the official Indonesian Center for Reproduction of Endangered Species in Captivity.

The objectives of the course and workshop were to assist local managers and policy makers to: 1) formulate priorities for a practical management program for survival and recovery of the Javan Hawk-eagle in wild habitat, 2) develop a risk analysis and simulation population model for the species which can be used to guide and evaluate management and research activities, 3) identify specific habitat areas that may need protection and management, 4) identify and initiate useful technology transfer and training, 5) develop a captive program using the confiscated birds and define its relationship to the conservation of the wild population, and 6) identify and recruit potential collaborators within Indonesia and in the international community.

The Javan Hawk-eagle is considered critically endangered due to its restricted range, declining numbers and the possibility of extinction from a number of threats such as decline or loss of prey, habitat loss, poaching, and natural catastrophes. The management and conservation objective is to maintain a genetically viable, self-sustaining, free-living Javan Hawk-eagle population. In order to achieve this goal, it is necessary to understand the risk factors that affect survival of the Hawk-eagle. Risk evaluation is a major concern in endangered species management and a goal is to reduce the risk of extinction to an acceptable level. A set of software tools to assist simulation and quantitative evaluation of risk of extinction is available and was used as part of Population and Habitat Viability Assessment Workshop. This technique can improve identification and ranking of risks and can assist assessment of management options.

Forty-five biologists, managers, and decision makers attended a Population and Habitat Viability Assessment (PHVA) Workshop in Cisarua, Bogor, Indonesia at the Safari Garden Hotel on May 6-8, 1996 to apply the recently developed procedures for risk assessment and formulation and testing of management scenarios to the Javan Hawk-eagle. The workshop was a collaborative effort of PHPA, TSI/PKBSI, and the Conservation Breeding Specialist Group (CBSG) of the Species Survival Commission/World Conservation Union (SSC/IUCN). The purpose was to review data from the wild and captive populations as a basis for assessing extinction risks, assessing different management scenarios, evaluating the effects of removals from the populations, examining possible strategies for reintroductions and developing stochastic population simulation models. These models estimate risk of extinction and rates of genetic loss from the interactions of demographic, genetic, and environmental factors as a tool for ongoing management of the subspecies. Other goals included determination of habitat and carrying capacity requirements, role of captive propagation, and prioritized research needs.

The first day consisted of a series of presentations summarizing data from the wild and captive populations. After a presentation on the PHVA process the participants formed four working groups (wild population, captive population, people management, and population biology and modelling) to review in detail current information, to hear all ideas, and to develop management scenarios and recommendations. Stochastic population simulation models were developed and initialized with ranges of values for the key variables to estimate the viability of the wild population using the VORTEX software modelling package. Using data compiled from the literature and by consultation with workshop participants, a series of agreed baseline population values for the parameters required by the VORTEX program were developed. These were then used to model the three potentially separated populations on Java. The Central Javan population fragments have their own unique set of threatening processes, mainly because the population there is not protected in a park or wildlife area and they are modeled separately.

This workshop report includes objectives for recovery of the population, a set of recommendations for research and management of the wild and captive populations, on public education and information as well as sections on the history of the population, its management, and the population biology and simulation modelling of the population.

RECOMMENDATIONS

Population and Management Goals

A management goal of a 30-40% increase of the numbers of breeding pairs in the wild Javan Hawk-eagle population in 10 years can be achieved with management and protection.

Wild Populations and Modeling

The total population of the Javan Hawk-eagle is estimated at 80 - 120 pairs. Unexplored habitat and improved census methodology may increase this number to 105 - 200 pairs. However, the population is fragmented into perhaps three major subpopulations with further habitat fragmentation within each subpopulation. The degree of movement and exchange between these subpopulations and fragments is unknown. The models indicate that the survival of Javan Hawk-eagle populations is very sensitive to changes in mortality of each of the age classes. The most optimistic population and risk projections, with current data on the species and with data from other eagle species, indicates an annual rate of increase of about 3%. This is a result of its relatively low reproductive potential with a single egg in a clutch, high hatching rates, and nesting in alternate years. Increased mortality from human activities is a major threat to the survival of the species throughout its range in Java. Slow rates of increase in these populations, with optimal management will be difficult to detect. Consistent and systematic population census data will be needed for detection of such changes. Methodologies for accurate and sensitive censuses need to be refined, using the best available expertise in quantitative field census techniques.

1. Apply current methodology for mapping possible habitat availability for the species and for statistical sampling of distribution and numbers. Implement research on: a) population assessment of the Javan Hawk-eagle, b) habitat assessment and mapping, c) nest losses due to human interference.

2. Investigate age-specific survivorship in wild populations, in particular of adults, of yearlings and of nests. Investigate breeding participation rates of the females in wild populations.

3. Provide the hardware, software and training necessary to allow the routine use and refinement of VORTEX models of the Javan Hawk-eagle populations and management activities.

4. Use captive populations to determine sex ratio at hatching, age of first reproduction, distribution of clutch sizes, egg fertility, and hatching rates.

5. Determine the size, distribution and degree of fragmentation of Javan Hawk-eagle populations. Determination of dispersal ranges of juvenile birds needs to be done. The

extent of any additional threats to these populations and their habitat also requires investigation.

6. Should reintroductions of captive birds be considered, use radio telemetry to monitor re-introductions of captive birds. It is essential that the results of every bird of the first 10 released be monitored for at least 2-3 breeding seasons to allow investigation on habitat selection and use to assist the determination of potential available habitat and establishment of breeding.

7. Review current land-use practices and regulations to prevent the conversion of potential Javan Hawk-eagle habitat into uses incompatible with Javan Hawk-eagle conservation.

Public Education and Awareness Program

8. Establish a "Javan Hawk-eagle Foundation" to facilitate activities on the conservation of the Javan Hawk-eagle.

9. Develop an environmental awareness curriculum to be included in formal education throughout the country.

10. Increase the participation of local communities inside and outside the protected areas within the Javan Hawk-eagle range.

11. Provide training for park staff in management skills, ecology, and tourist communications.

12. Improve tourist education resources and facilities.

13. Appoint a coordinator to head a small management committee, to evaluate and advise on the ideas and recommendations received for management of the Javan Hawk-eagle.

14. Coordinate PHPA activities with local and national governments to incorporate useful recommendations from the Javan Hawk-eagle into a Master Plan (already being developed) for the species.

15. Evaluate the demography of the human population within and near the protected areas to assist projections of long term impacts on the Javan Hawk-eagle habitat and risk of removals.

Captive Populations

16. Integrate captive birds into a coordinated management and captive breeding program. Development of suitable housing, management, and health care is a high priority.

Determination of the sex of the captive birds is a high priority as a basis for a breeding program.

17. Compile a management plan and husbandry manual, published in Indonesian and distributed to all collaborators working with captive Javan Hawk-eagles. Additionally, key personnel working with captive birds should receive in-depth training in raptor breeding, captive management, and veterinary aspects at recognized, established programs in other countries.

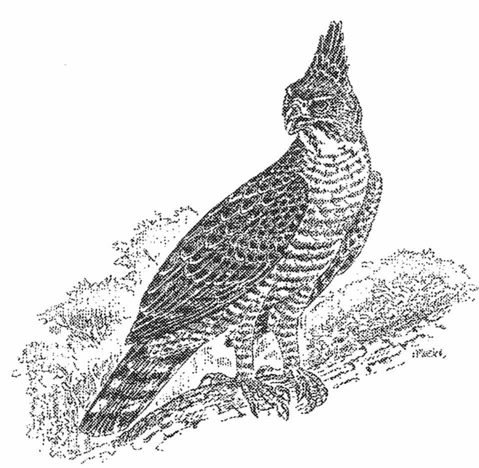
18. Utilize founder representation of the existing captive population for a breeding program, for studies of the biology of the species, and for public education. The birds currently in captivity probably were all taken as chicks from the nest and reared in captivity under widely different conditions. They are not likely to be suitable for reintroduction into the wild even with quarantine, treatment, and conditioning.

19. A captive management program in Indonesia for the Javan Hawk-eagle will require a Species Coordinator, a Studbook Keeper and a Captive Management Committee to draft and implement a captive population master plan.

POPULATION AND HABITAT VIABILITY ASSESSMENT FOR THE JAVAN HAWK-EAGLE (*Spizaetus bartelsi*)

Taman Safari Indonesia
6 - 8 May 1996

Section 2
Spizaetus bartelsi: An Introduction



OFFICIAL INVITATION

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

Gedung Pusat Kehutanan Manggala Wanabhakti Blok IV Lt. 8, Jl. Jend. Gatot Subroto Jakarta Pusat (10270)
Telp. (021) 5730312, 5730313, Fax. (62-21) 5734818 Telex : 45996 DEPHUT IA

Jakarta, 15 February 1996

No : 108/DJ-VI/BKff/96

To : ULLYSES SEAL,
IUCN/SSC Conservation Breeding Specialist Group (CBSG)
Johnny Cake Road , Apple Valley , MN 55124, U S A

Fax : 1-612-432-2757

From : Ir Soemarsono
Director General of PHPA
Ministry of Forestry Indonesia

Subject : Javan Eagle PHVA Workshop

We would like to request the assistance of CBSG to coordinate a PHVA Workshop for Javan Eagle in Indonesia. The best time would be sometimes in April 1996. Please contact Mr Jansen Manangsang at Taman Safari Indonesia about the details of the workshop as he might be able to organize the venue of the workshop.

As for the last workshops, we would appreciate the support of about 20 PHPA staff to attend the Javan Eagle Workshop so that we can learn from the experience and be part of the process in developing a conservation action plan for Javan Eagle.

Your assistance in this very important issue in Indonesia is very much appreciated, and we look forward to hearing your reply.

Yours sincerely,

Soemarsono
Director General of PHPA

CC:
Mr Jansen Manangsang,
Director of Taman Safari Indonesia

DEPARTEMEN KEHUTANAN
DIREKTORAT JENDERAL PERLINDUNGAN HUTAN DAN PELESTARIAN ALAM
Alamat : Gedung Pusat Kehutanan Jl. Jend. Gatot Subroto Telp. 5730315, 5734818 JAKARTA

SAMBUTAN DIREKTUR JENDERA PHPA PADA LOKAKARYA KONSERVASI ELANG JAWA

Assalamualaikum Wr. Wb.

Salam sejahtera dan selamat pagi,

Saudara-saudara para pesertra lokakarya, para undangan dan hadirin sekalian yand saya hormanti.

Puji dan syukur kita panjatkan kepada Tuhan Yang Maha Esa, atas rachmat dan karunianya yang dilimpahkan kepada kita semua sehingga pada hari ini kita dapat berkumpul bersama di tempat ini dalam keadaan sehat wal'afiat dalam rangka menghadiri lokakarya konservasi Elang Jawa yang dise lenggarakan atas kerjasama Direktorat Jenderal Perlindungan Hutan dan Pelestarian Alam Departemen Kehuatanan, IUCN/CBSG dan Taman Safari Indonesia.

Pada kesempatan ini saya ingin mengungkapkan rasa kegembiraan saya, karena Saudara-saudara dapat menghadiri lokakarya ini untuk memberikan sumbang saran dalam konservasi Elang Jawa, tentunya sumbang saran Saudara ini akan sangat berarti bagi upaya meningkatkan pembanguan berwawasan lingkungan yang berkelanjutan pada umumnya, konservasi sumberdaya alam hayati pada khususnya.

Elang Jawa sebagai burung nasional yang dideklarasikan oleh Presiden Soeharto pada tanggal 10 Januari 1993 melalui Keppres No. 4 Tahun 1993 dimana Elang Jawa sebagai Satwa Langka, karena kemiripannya dengan "Burung Garuda" yaitu symbol lambang Negara Indonesia, merupakan satwa yang termasuk dalam katagori Endangered Species, karena diperkirakan total populasi pada saat ini kurang lebih 200 ekor dan merupakan tanggung jawab pemerintah serta masyarakat untuk melestarikannya.

Para hadirin yang saya hormati,

Elang Jawa sebagai burung endemik Jawa yang hidup di hutan mulai dataran rendah maupun sampai ketinggian 3000m, tersebar di Jawa Barat, Jawa Tengah, yaitu di Gunung Halimun, Gunung Salak dan Gunung Slamet, juga di Jawa Timur dapat ditemukan di Meru Betiri dan Ijen sampai di Baluran.

Elang Jawa sebagai Endangered Species, talah mengalami penurunan populasi yang cukup drastis akibat dari pemburuan liar, polusi obat-obatan hama dan penyakit, perubahan habitat sejalan dengan laju pertumbuhan penduduk Jawa dan lain-lain.

Para hadirin yang saya hormati,

Arah dan strategi konservasi sumberdaya alam hayati dan ekosistemnya telah dibuat dan diundangkan yang tertuang dalam Undang-undang Nomor 5 Tahun 1990.

Strategi konservasi dan upaya pelestarian dan pemanfataan yang lestari mempunyai tiga embanan yaitu:

a. Perlindungan sistem penyangga kehidupan
b. Pengawetan keanekaragaman plasma nutfah
c. Pemanfataan secara lestari.

Ketiga embanan tersebut merupakan satu kesatuan filosofis yang menyatu dan sebagai upaya dalam pelaksanaannya ditempuh antara lain dengan cara konservasi in-situ dan konservasi ex-situ.

Para hadirin yang saya hormati,

Peran serta masyarakat dalam konservasi sumberdaya alam hayati dan ekosistemnya dirahkan dan digerakkan oleh pemerintah melalui berbagai bentuk kegiatan yang berdaya guna dan berhasil guna sehingga informasi-informasi terbaru yang ilmiah populer dapat dikembangkan dan dimasyarakatkan baik oleh Lembaga Swadaya Masyarakat maupun perguruan-perguruan tinggi.

Para hadirin yang saya hormati,

Besar harapan saya agar dalam lokakarya ini Saudara-saudara dapat merumuskan hal-hal yang sangkat mendasar untuk dapat mengimplementasikan kegiatan konservasi Elang Jawa agar dapat lestari.
Saya berharap bahwa rumusan hasil-hasil lokakarya ini merupakan petunjuk-petunjuk para pakar Elang Jawa tentang status, perkembangannya serta arah pengelolaan lebih lanjut yang akan menjadi bahan pertimbangan serta acuan kebijaksanaan tentang pengelolaan Elang Jawa.

Pari hadirin yang saya hormati,

Sekali lagi saya sampaikan terima kasih kepada IUCN/CBSG, Taman Safari Indonesia dan panitia penyelenggara serta Saudara-saudara peserta yang telah membentu suksesnya lokakarya ini, semoga sumbangan pemikiran Saudara-saudara dapat bermanfaat bagi pengembangan konservasi Elang Jawa dan satwa liar lain di Indonesia.

Akhirnya dangan mengucapkan Bismillahirochmanirohim, dengan ini lokakarya Elang Jawa secara resmi dinyatakan dibuka.

Kami atas nama Departemen Kehutanan mengucapkan selamat berlokakarya, semoga Tuhan memberkahi kita sekalian.

Wassalamualaikum Wr. Wb.

Direktur Jenderal,

SOEMARSONO

Opening Address from The Director General of The Department of Forest Protection and Nature Conservation

Good morning Ladies and Gentlemen,

This morning we are here for a Workshop on Population and Habitat Viability Assessment for the Javan Hawk-eagle. This workshop is a collaborative effort of the Directorate General of Forest Protection and Nature Conservation - Ministry of Forestry, IUCN/CBSG, and Taman Safari Indonesia. I would like to express my appreciation to everybody in this room for being here to share your ideas and knowledge. The knowledge and ideas would be very helpful to conserve our Javan Hawk-eagle.

On January 10, 1993, through Presidential Decree no. 4/1993, the Javan Hawk-eagle was declared as our national bird and a symbol of rare species by President Soeharto on account of its resemblance with *Burung Garuda*, our mythological birds, and because its rarity and uniqueness.

Ladies and Gentlemen,

As its name implies, the Javan Hawk-eagle is restricted to the island of Java. It is confined to lowland and montane forest up to 3000 m and mainly occurs in the best-preserved forest areas. The bird still can be found in Gunung Halimun, Gunung Salak, Gunung Slamet, Meru Betiri National Park, Ijen, and Baluran National Park.

The Javan Hawk-eagle is an endangered species. Its population has been decreasing due to illegal hunting, pollution caused by insecticides, and habitat fragmentation caused by the increasing number of human population in Java.

Ladies and Gentlemen,

Policy on conservation of natural resources and ecosystem in Indonesia was formulated in the Act no. 5/1990. Based on the Act, we have 3 major conservation strategies, namely protection of life support system, preservation of biodiversity, and sustainable utilization. The conservation effort basically can be done either in the natural habitat (*in-situ*) or outside the natural habitat (*ex-situ*).

People participation is needed in order to conserve and protect the Javan Hawk-eagle. In addition, we also need research agencies, universities, NGOs, nature lovers, local governments, and other agencies to execute the conservation actions. It is my hope that we will be able to formulate the necessary actions to conserve Javan Hawk-eagle through assessment of status, distribution, bio-ecology, and other important aspects.

In this occasion, I would like to express my sincere thanks to IUCN/CBSG, Taman Safari Indonesia, the organizing committee, and all participants of the workshop. Finally, I declare this workshop open. Thank you.

Director General, Soemarsono

OBYEK WISATA NASIONAL & LEMBAGA KEGIATAN KONSERVASI EX - SITU

Taman Safari Indonesia

CISARUA - BOGOR

(0251) 4422 4433 - 4443 . Fax (0251) 328225

Jakarta Office : (021) 7695482 . Fax (021) 7690587

Welcome Address

JAVAN HAWK EAGLE PHVA WORKSHOP

By Drs. Jansen Manansang

Taman Safari Indonesia, 6 - 8 Mei 1996

Good morning ladies and gentlemen,

I would like to welcome everyone to the Javan Hawk Eagle PHVA Workshop, a special welcome to the Director General of PHPA Mr. Ir. Soemarsono, The Chairman of PKBSI Ir. Lukito Daryadi, MSc, The Chairman of CBSG - Dr. Ulie Seal, and all our colleagues from America, Europe, China and other institutions participating in this workshop.

This is the ninth PHVA workshop to be hosted by PHPA in cooperation with CBSG and Taman Safari Indonesia/PKBSI. The aims of this workshop are :

1. To assess the population of Java Hawk Eagle in the wild, and also the probability for their survival without intervention.

2. To assess the possibilities on an increase or decline in numbers due to inter environmental changes, and conflicting habitat management plans.

3. To define field methods, to assess population status and quality of habitat.

4. To assess what role captive breeding can play as an option in repopulating or translocation.

Java Hawk Eagle (*Spizateus bartelsi*) is one of the most protected birds in Indonesia, becoming one of the most rare eagles in the world. The Javan Hawk Eagle is a rare species or endemic to the Island of Java. Their population has been decreasing through the loss habitat, illegal hunting and human activities.

In 1993, on the National Fauna and Flora Day "5 November" , the Javan Hawk Eagle was declared by the President of The Republic of Indonesia as the Indonesian Rare Animal, the Javan Hawk Eagle has been the symbol of the Republic of Indonesia since Indonesia proclaimed Independence in 1945.

As one of the first steps to preserve this rare species, TSI as the designated Ex - Situ Conservation Center of Indonesia, is busy building up a Javan Eagle Captive Breeding Program.

This workshop is possible thanks to the collaboration of PHPA, PKBSI and CBSG. Hopely this ninth workshop will be successful, thus ensuring the continuance of further workshops for other species.

Thank you

Jansen Manansang.

CalEnergy Joins Effort to Protect Endangered Species

CalEnergy and Kiewit Construction Company *(a subsidiary of Peter Kiewit Sons', Inc.),* in collaboration with the Conservation Breeding Specialist Group (CBSG), have joined forces to sponsor Population and Habitat Viability Assessments (PHVA) for two endangered species --- one in the Philippines and one in Indonesia.

CBSG is an international conservation organization dedicated to protecting the world's plant and animal species. Its mission is to conserve and establish populations of threatened species through captive breeding programs and through intensive protection and management of various plant and animal populations in the wild.

"Because of our involvement in the Philippines and Indonesia, we felt this was a perfect opportunity to assist these countries with their conservation efforts," said David L. Sokol, Chairman and Chief Executive Officer.

The Philippine and Indonesian wildlife and government officials have invited the CBSG to conduct these two assessments. CBSG uses numerous processes and tools it has developed to carry out its globally recognized program. More important, decisions are then made by the Philippine and Indonesian wildlife officials allowing practical and expedient implementation of a resulting management program.

As the word of CBSG's successful work has spread, so has the demand for its services. To meet this growing demand, CBSG has begun to train scientists worldwide. The PHVA workshops they have developed bring together biologists and other professionals to assess the extinction risk and develop better management strategies for particular endangered species. Their goal is to share knowledge and permit ongoing evaluation of the conservation of plants and animals.

Two such endangered species identified by the CBSG are the **Javan Hawk-Eagle** from Indonesia and the **Tamaraw** from the Philippines.

The **Javan Hawk-Eagle**, a member of the eagle species, is found in the western part of Java. It is considered an endangered species due to the large decrease in the forests and the increase in human population in Java.

The **Tamaraw**, a member of the wild Asian buffalo species is located on the Mindoro Island in the Philippines. Because of the increased cattle ranching, poor nutrition, and a decrease in their habitat the Tamaraw is now in danger of becoming extinct.

The PHVA workshops will assist local Philippine and Indonesian managers and policy makers in:

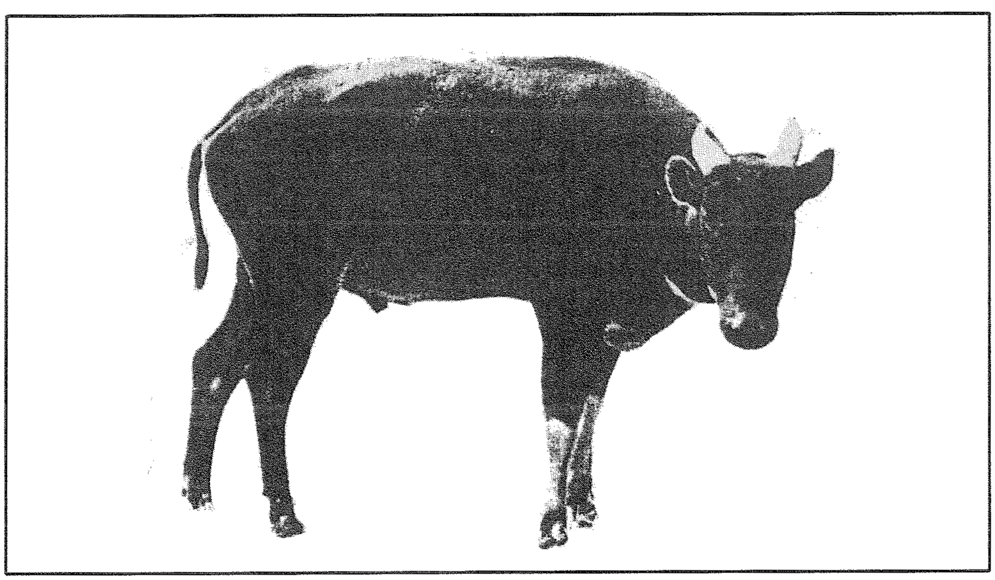
- *formulating priorities for practical management programs for survival and recovery*
- *developing risk analysis and simulated population models which can be used to guide and evaluate management and research activities*
- *identifying and initiating useful technology transfer and training*

An in-depth analysis of each species will assess their:

life history, population dynamics, ecology, demographics, genetics, environmental factors, risk of extinction, and perceived threats

Both the **Tamaraw** and **Javan Hawk-Eagle** PHVA workshops are scheduled to be held in May.

Javan Hawk-Eagle, an endangered species of the eagle, can be found in Indonesia.



The Tamaraw, an endangered species of the wild Asian buffalo, can be found in the Philippines.

SUARA PEMBARUAN

Selasa, 7 Mei 1996

Elang Jawa Mengalami Penurunan Populasi Yang Drastis

CISARUA — Elang Jawa (*Spizaetus bartelsi*) sebagai endangered species, kini telah mengalami penurunan populasi yang cukup drastis.

Hal ini disebabkan pemburuan-pemburuan liar, polusi obat-obatan hama dan penyakit, perubahan habitat sejalan dengan laju pertumbuhan penduduk Jawa dll.

Menurut Dirjen Perlindungan Hutan dan Pelestarian Alam (PHPA) Soemarsono, dalam sambutan tertulisnya yang dibacakan oleh Direktur PHPA, Ir Dwiatmo Siswomartono, pada Lokakarya Konservasi Elang Jawa di Hotel Safari, Cisarua, Senin (6/5) siang, elang Jawa sebagai burung nasional yang dideklarasikan oleh Presiden Soeharto pada 10 Januari 1993, melalui Keppres No 4 tahun 1993.

Mirip

Disebutkan, elang Jawa sebagai satwa langka karena kemiripannya dengan burung garuda, simbol lambang Negara Indonesia.

Burung ini merupakan satwa yang termasuk dalam kategori endangered species.

Karena, diperkirakan total populasi pada saat ini sekitar 200 ekor, dan merupakan tanggung jawab pemerintah serta masyarakat untuk melestarikannya.

Elang Jawa sebagai burung endemik Jawa yang hidup di hutan mulai dataran rendah maupun sampai ketinggian 3.000m, tersebar di Jawa Barat, Jawa Tengah, yakni di Gunung Halimun, Gunung Salak dan Gunung Slamet.

Juga di Jawa Timur dapat ditemukan di Meru Betiri dan Ijen sampai Baluran.

Dikatakan, arah dan strategi konservasi sumberdaya akan hayati dan ekosistemnya telah dibuat dan diundangkan, yang tertuang dalam Undang-Undang (UU) No. 5 tahun 1990.

Strategi Konservasi

Strategi konservasi dan upaya pelestarian, serta pemanfataan yang lestari menurut Soemarsono, mempunyai tiga embanan, yakni perlindungan sistem penyangga kehidupan, pengawetan keanekaragaman plasma mutfah, dan pemanfataan secara lestari.

Ketiga embanan tersebut merupakan satu kesatuan filosofis yang menyatu, dan sebagai upaya yang dalam pelaksanaannya ditempuh antara lain dengan cara konservasi insitu dan exsitu.

Sementara itu, dalam lokakarya yang diikuti sekitar 58 peserta antara para pakar burung dari Amerika Serikat, Eropa, Filipina serta tuan rumah Indonesia terungkap, hasil penelitian yang dilakukan terhadap pasar-pasar burung ditemukan sedikitnya sembilan ekor burung elang jawa, yang dijual secara bebas.

Direktur PHPA, Ir Dwiatmo Siswomartono, yang ditanya Pembaruan membenarkan, burung elang Jawa sudah semakin kritis kehidupannya di habitatnya di Pulau Jawa.

Untuk itu, pihaknya mengimbau kepada masyarakat agar tidak memelihara elang Jawa, supaya populasi yang sudah turun drastis ini tidak punah.

Sulit Diperkirakan

Karena, betapa sayangnya bila satwa yang satu ini sampai hilang dan punah akibat kecerobohan kita sendiri.

"Mereka yang memelihara elang jawa, sama saja membunuh satwa ini secara pelan-pelan", ujarnya kepada Pembaruan, seusai lokakarya.

Populasi elang Jawa semakin manurun akibat populasi penduduk dan masyarakat perambah hutan semakin meningkat, sehingga posisi Elang Jawa tersisih.

Sehingga jumlah perkiraan elang Jawa ini sulit diperkirakan.

Di Taman Safari Indonesia, kini ada sekitar enam ekor Elang Jawa yang merupakan titipan dari hasil sitaan PHPA, dan ada juga yang merupakan sumbangan dari masyarakat pecinta satwa yang lebih menyukai hewannya dipelihara oleh TSI.

Mandra

Seekor elang Jawa yang ada di TSI dan diberi nama mandra, merupakan burung Elang Jawa yang paling jinak.

Mandra yang perkasa ini dengan gagahnya bertengger di antara jenis elang-elang lainnya di TSI.

Mandra dengan gagahnya mengangkat jambulnya setelah pelatihnya membelai-belai lehernya, kemudian dengan galak mandra melihat ke ara orang-orang di sekelilingnya.

"Ayo Mandra, yang gagah dong kalau dipotret," pinta sang pelatih sambil terus mengelusnya. (B-3)

Population and Habitat Viability Assessment (PHVA):
CBSG Training and Technology Transfer Courses

The PHVA course teaches range country managers, biologists and decision makers about practical applications of conservation biology techniques which are effective in improving management of species and habitats at risk. The training procedure assists in development by the participants of population viability assessments for each population of a species or subspecies. The assessment for each species will undertake an in-depth analysis of information on the life history, population dynamics, ecology, and population history of the individual populations. Information on the demography, genetics, and environmental factors pertinent to assessing the status of each population and its risk of extinction under current management scenarios and perceived threats will be assembled in preparation for the PHVA and for the individual populations before the course begins and during the training sessions. Simultaneously with addressing the species and habitat problems, the training emphasis, using a real problem case in the range country, is to provide information and technology transfer that will directly improve the functional capability of managers and assist in decision and policy making on the basis of the best available scientific information. Ten to twenty local managers as well as intermediate supervisors and higher level officials participate.

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

12101 Johnny Cake Ridge Road, Apple Valley, MN 55124-8151, USA
Tel: 1-612-431-9325 Fax: 1-612-432-2757 E-mail: cbsg@epx.cis.umn.edu

Relevant information includes data on: 1) age of first reproduction for males and females, 2) inter-birth interval in the wild population, 3) first-year mortality, 4) sex ratio at birth, 5) juvenile mortality, 6) adult sex ratio, 7) breeding strategy—monogamous or polygynous in a season, 8) adult mortality (by sex if available), 9) population size, 10) habitat carrying capacity and possible changes through time, 11) environmental variables influencing either reproduction or mortality, 12) potential catastrophic events and their effects upon reproduction or mortality in the year of occurrence, 13) dispersal and movement of animals between breeding groups, 14) mapping of geographic distribution, and 15) patterns of current and projected land use.

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

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

(1) factors likely to have operated in the decline of the species or its failure to recover with management and whether they are still important,
(2) techniques for monitoring the status of the population during the management manipulations to allow their evaluation and modification as new information is developed,
(3) the role of disease in the dynamics of the wild population, in potential reintroductions or translocations, and in the location and management of captive populations,
(4) formulation of quantitative genetic and demographic population goals for recovery of the species and what level of management will be needed to achieve and maintain those goals,
(5) the potential uses of reproductive technology for the conservation of the species whether through assisted reproduction or genome banking,
(6) the need for molecular taxonomic, genetic heterozygosity, and parentage studies,
(7) the possible need for metapopulation management for long term survival of the species,
(8) the possible role of inbreeding in the dynamics and management of captive and wild population(s),
(9) cost estimates for each of the activities suggested for furthering conservation management of the species.
10) the need for specific policy decisions,
11) local training needs and means of accomplishment,
12) further CBSG-assisted training.

PHVA Course: Preparation and Documentation Needs

Information to be included in briefing book:

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

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

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

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

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

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

7. Life history information - particularly that useful for the modelling. Includes (sex specific where possible): adult body weight, age of first reproduction, mean litter or clutch size, interbirth interval, first year mortality, adult mortality, breeding structure (monogamous or polygamous in a given season), and seasonality of breeding.

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

9. Regional and international studbooks - hard copy and entered in Single Population Animal Record Keeping System (SPARKS). If needed we (CBSG) will do the entry into SPARKS. Results of genetic and demographic analyses using software provided with SPARKS.

10. Species Survival Plan (SSP) and similar master plans for any captive populations.

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

SSC MISSION

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

PHVA WORKSHOPS

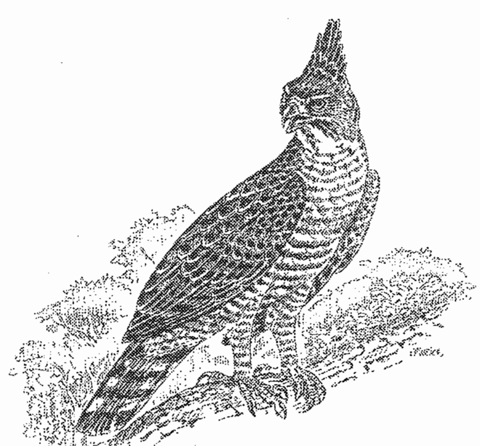
Guidelines

- Every idea or plan or belief about the Javan Hawk-eagle can be examined and discussed
- Everyone participates and no one dominates
- Set aside (temporarily) all special agendas except saving the Javan Hawk-eagle
- Assume good intent
- Yes and...
- Stick to our schedule...begin and end promptly
- Primary work will be conducted in sub-groups
- Facilitator can call "time-out"
- Agreements on recommendations by consensus
- Plan to complete and review draft report by end of meeting
- Adjust our process and schedule as needed to achieve our goals

POPULATION AND HABITAT VIABILITY ASSESSMENT FOR THE JAVAN HAWK-EAGLE (*Spizaetus bartelsi*)

Taman Safari Indonesia
6 - 8 May 1996

Section 3
Javan Hawk-Eagle Wild Population Status and Management



WILD POPULATION STATUS AND MANAGEMENT WORKING GROUP REPORT

Working Group Leader: Achmad Abdullah
Working Group Facilitator: Jito Sugardjito

Data on the distribution of Javan Hawk-eagles have shown that this species is distributed throughout Java. We analyzed some of the 53 localities from which the species has been reported. Based on these sites, we grouped them into 24 separate subpopulations. Ten were populations located in West Java, 5 populations in Central Java, and 9 populations in East Java. We also calculated the number of individuals seen in each major population to be 69, 38, and 22 individuals in West Java, Central Java, and East Java respectively. The biggest population is in population V with 20 individuals (Gn. Pancar, Telaga Warna, Gede Pangrango, Cisarua, Tapos, Perbawati). The second largest is population XII with 18 individuals in Dieng Plateau. The third is population XI (Gn. Selamet and Gn. Pembarisan) with 13 individuals. The next population with 12 individuals is population IV (Gn. Papandayan, Kawah Kamojang, Darajat, Leuweung Sancang). Each of the remaining populations has less than 10 individuals.

The area of population V, which holds the highest number of Javan Hawk-eagles, is 16,092 ha. The Dieng Plateau population area is 27,500 ha. The area of population XI is 20,000 ha and the area for population IV is 17,189 ha. Based on these data the largest area does not necessarily hold the highest number of individuals. Two big areas which contain small populations are in population XVII (Idjen, Raung, Kalibaru, Iyang Plateau) with 83,900 ha, but only 5 individuals. The complete list of distribution sites and population sizes is in Table 3-1. Accompanying this Table is a series of Figures that plot the distribution of the species based on data from Sözer and Nijman (1995). It is important to recognize that the identities of populations listed in Table 3-1 are different from those shown in Figures 3-1 through 3-3, pages 41-45.

The threats that could be important for the safety of the species were categorized into the following:

a. Encroachment (including habitat modification and conversion)
b. Illegal hunting
c. Fire
d. Competition
e. Habitat conversion
f. Gas pollution
g. Fertilizer
h. Pesticides
I. Volcanic eruption
j. Landslide
k. Storm.

Based on the threats mentioned above we believe the most threatened area is population VI (Gn. Halu, Ciwide, Gambung Gn. Tilu, Pengalengan, Gn. Patuha) and the next is population XV (Gn. Merapi and Kedungombo). The population with high numbers, but also receiving high threats is population V (Gn. Pancar, Telaga warna, Cisarua, Tapos, Gn. Gede Pangrango, Perbawati).

Based on the management issues we categorized some activities that should be taken into consideration, namely:

1. Strengthen the law enforcement and protection of conservation areas where Javan Hawk-eagles are found.
2. Monitor the wild populations through field surveys.
3. Review current land use and extend protected habitat for the Javan Hawk-eagle.
4. Inventory.
5. Community awareness.
6. Interactions with central and local governments.

Referring to the populations that we have reviewed, we propose some management measures for securing the Javan Hawk-eagle in the wild. These consist of:

1. Intensive safe-guarding of the areas described above.
2. Assessment of the carrying capacity in the areas listed.
3. Intensive population monitoring in the four priority areas, i.e., Populations IV, V, XI, and XII.
4. Establishment of Dieng Plateau as a new protected area.
5. Population assessment in the area where the Javan Hawk-eagle is possibly present, but not known at the moment, such as South of Bandungg, Gn. Merbabu, and Gn. Lawu.

Table 3-1. Distribution and status of the Javan Hawk-eagle (*Spizaetus bartelsi*) throughout Java.

Pop #	Distribution	Area (ha)	Pairs	Year	Remarks	Threats
WEST JAVA						
I	Gn. Honje	20,000	2	1995	*	a,b,c,d
II	Rawa Danau SNR	2,500	2	1995	*	a,b,c,d,e,f,g,h
	Sangiang island NRP	528	4	1994	*	
	Gn. Karang		1	1995	**	
	Curug Gendang		1	1991	**	
III	Gn. Salak		2	1996	*	a,b,c,d,e,g,h
	Gn. Halimum NP	40,000	4	1994	*	
	Cidahu		1	1981	*	
IV	Gn. Papandayan SNR/NRP	7,032	2	1995	**	a,b,c,d,e,g,h
	Kamojang SNR/NRP	8,000	1	1995	**	
	Darajat, Kamojang		2	1987	*	
	Leuweung Sancang SNR	2,157	7	1995	*	
V	Gn. Pancar NRP	447	4	1992	**	a,b,c,d,e,f,g,h
	Telaga Warna SNR/NRP	350	2	1995	**	
	Cisarua		1	1994	*	
	Tapos		2	1995	*	
	Gn. Gede-Pangrango NP	15,295	8	1995	*	
	Perbawati		3	1989	*	
VI	Gn. Halu		1	1982	*	a,b,c,d,e,f,g,h,i
	Ciwidey		1	1908	***	
	Gambung, Gn. Tilu		1	1931	***	
	Pangalengan		1	1933	***	
	Gn. Patuha		2	1931	*	
VII	Sukawayana SNR/NRP	32	2	1991	**	b,c,d,e,g,h

Pop #	Distribution	Area (ha)	Pairs	Year	Remarks	Threats
	Cibutun		1	1927	*	
	Gn. Masigit		2	1928	**	
	Sukamaju, Sukabumi		1	1928	***	
VIII	Gn. Sawal WR	5,400	5	1995	*	a,e,j
IX	Gn. Tampomas NRP	1,250	?	1995	**	b,c
X	Gn. Tangkuban Perahu	1,660	6	1995	**	b,f,j
	Gn. Melati		1	1909	***	
		Central Java				
XI	Gn. Slamet	20,000	10	1994	*	b,c,j
	Gn. Pembarisan		3	1994	*	
XII	Dieng Plateau	27,500	18	1994	*	a,b,c,f,h,j
XIII	Gn. Ungaran	7,500	4	1994	*	a,b,c,h,j
XIV	Gn. Muria	12,000	2	1995	*	a,b,c,h,j
XV	Gn. Merapi	15,000	4	1996	*	a,b,c,d,f,h,i,j,k
	Kedungombo		1	1996	*	
		East Java				
XVI	Merubetiri NP	58,000	1	1996	*	a,b,h
XVII	Ijen	9,200	2	1990	*	b,e,f
	Gn. Raung	60,000	1	1990	*	
	Kalibaru		1	1991	*	
	Yang Plateau	14,700	1	1989	*	
XVIII	Baluran NP	25,000	?	1995	**	
XIX	Alas Purwo NP	42,625	1	1995	**	b
	Pasir Putih		2	1995	*	

Pop #	Distribution	Area (ha)	Pairs	Year	Remarks	Threats
XX	Suryo GFP		3	1996	*	b
	Trawas		1	1992	*	
XXI	Gn. Kawi	50,000	3	1993	*	b,e
XXII	Gn. Wilis-Liman	45,000	1	?	**	b,c
XXIII	Lebak Harjo	16,000	4	1996	*	b,e
	Gn. Dorowati		1	1993	*	
XXIV	Bromo-Tengger-Semeru NP	58,000	?	?	**	

Remark: * = Direct Observation; ** = Indirect Information; *** = Collected

Threats:
- a. Encroachment
- b. Illegal hunting
- c. Fire
- d. Competition
- e. Habitat conversion
- f. Gas pollution
- g. Fertilizer
- h. Pesticide
- i. Volcanic eruption
- j. Landslide
- k. Storm

Wild Population Management

Inside Protected Area	Outside Protected Area
West Java	
Safe guarding	Extension
Monitoring	Wildlife Traffic
Inventory	Inventory
Habitat Rehabilitation	Monitoring
Central Java	
	Inventory
	Monitoring
East Java	
Safe guarding	Inventory
Monitoring	Monitoring
Inventory	

Proposed Actions

1. Need more detailed surveys in terms of inventory, distribution and populations of Javan Hawk-eagle.

2. Enhance extension to the people through NGO and conservation cadre

3. Need to allocate more conservation areas specifically in the relation to the specific habitat of Javan-Hawk Eagle.

4. Need protection of some habitats which are not now protected.

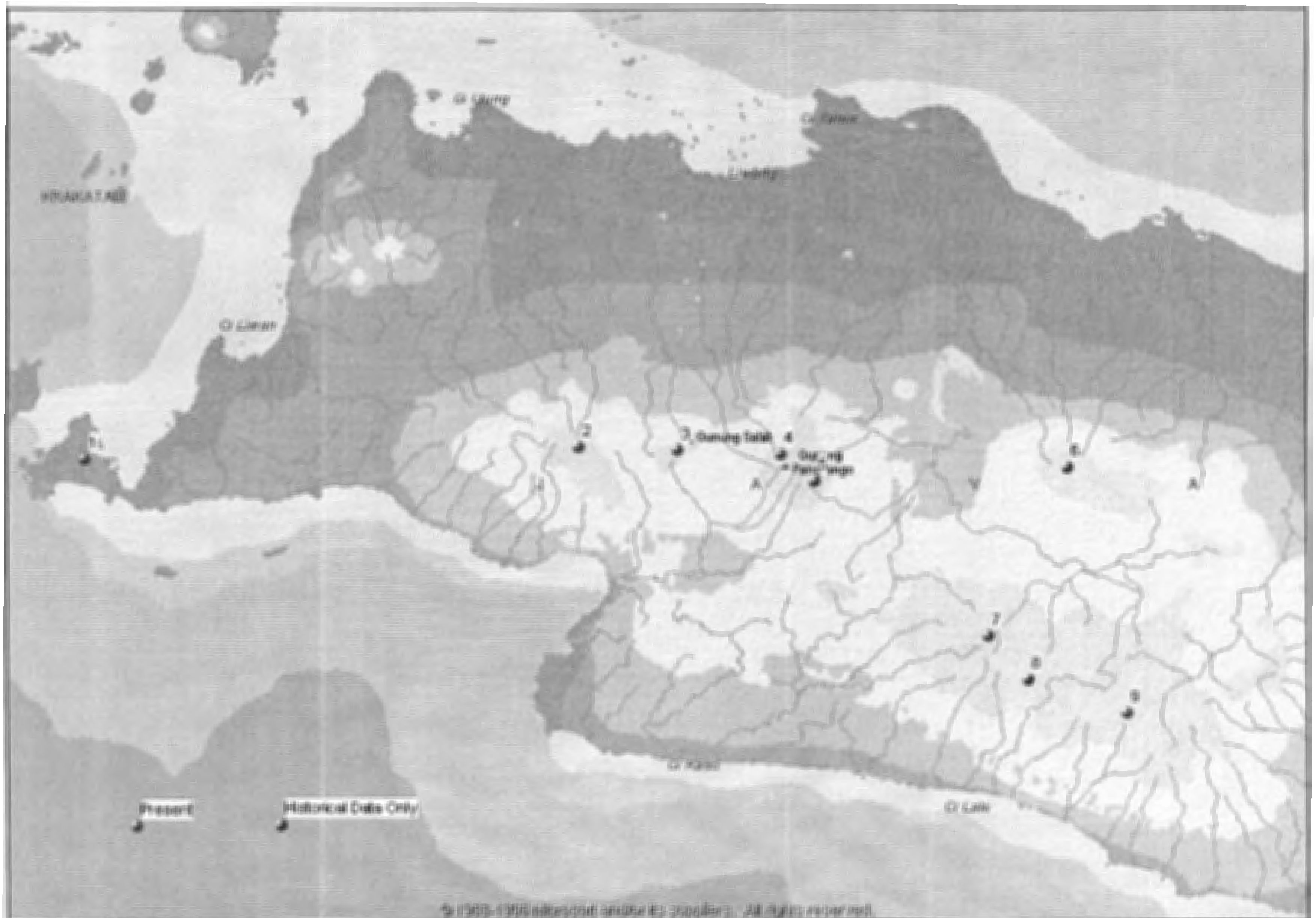


Figure 3-1. Distribution of the Javan Hawk-eagle (*Spizaetus bartelsi*) in West Java, after Sözer and Nijman (1995). 1. Ujung Kulon, 2. Mt. Halimun, 3. Mt. Salak, 4. Mt. Pangrango, 5. Mt. Gede, 6. Mt. Tangkuban Perahu, 7. Mt. Halu, 8. Mt. Patuha, 9. Mt. Papandayan.

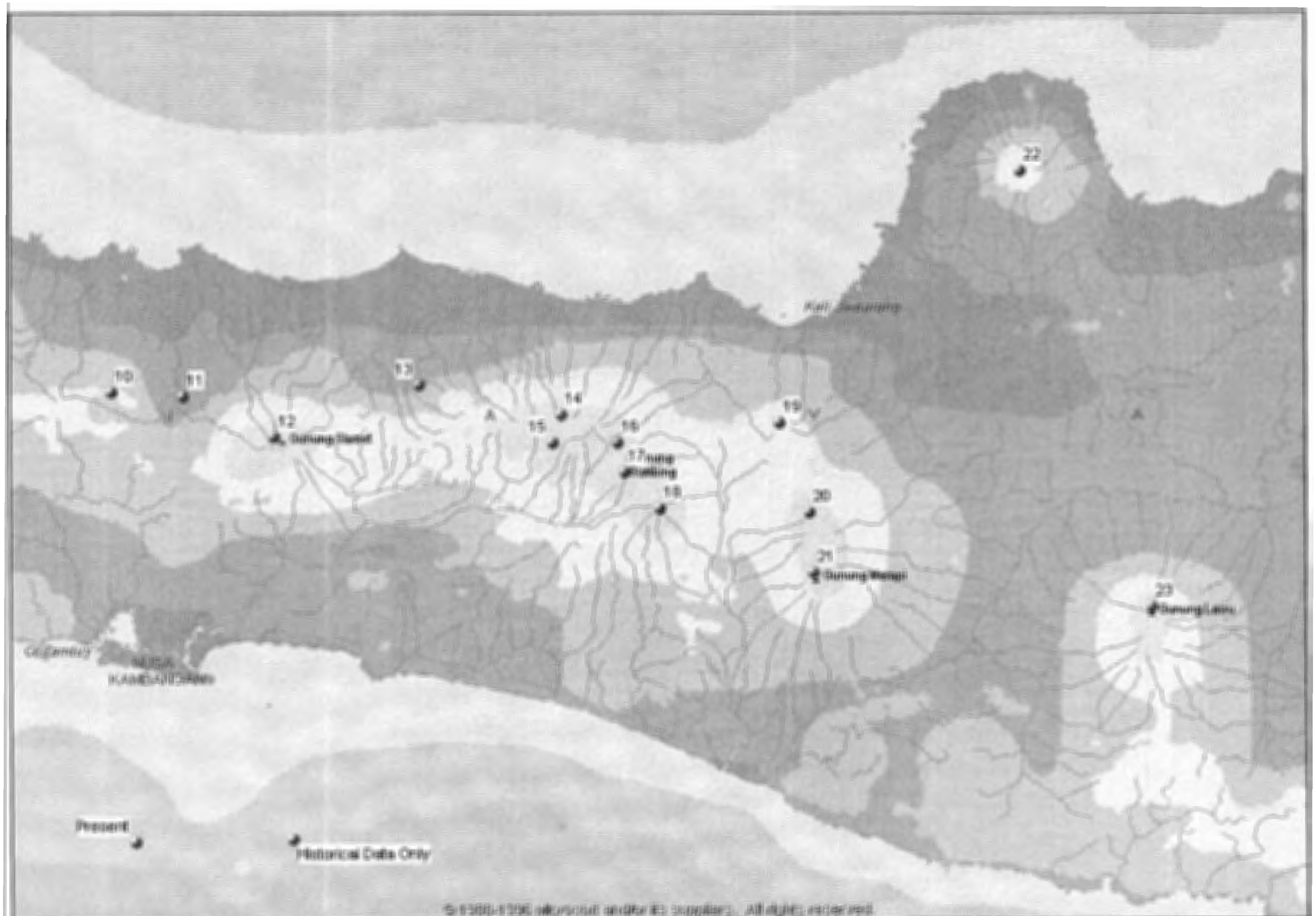


Figure 3-2. Distribution of the Javan Hawk-eagle (*Spizaetus bartelsi*) in Central Java, after Sözer and Nijman (1995). 10. Mt. Segara, 11. Karanunyar, 12. Mt. Slamet, 13. Mt. Besar, 14. Mt. Prahu, 15. Mt. Bismo, 16. Mt. Butak, 17. Mt. Sindoro, 18. Mt. Sumbing, 19. Mt. Ungaran, 20. Mt. Merbabu, 21. Mt. Merapi, 22. Mt. Muria, 23. Mt. Lawu.

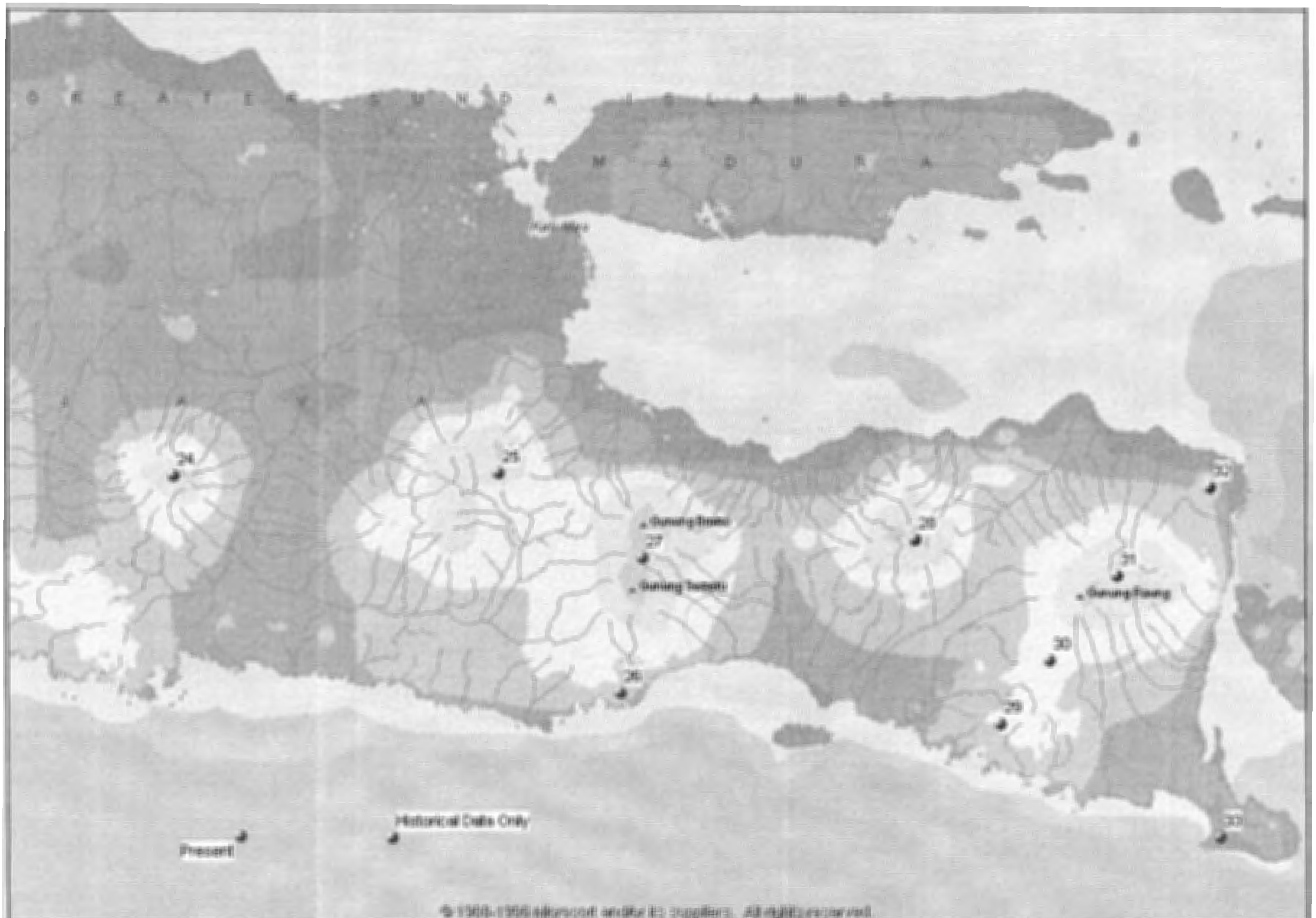


Figure 3-3. Distribution of the Javan Hawk-eagle (*Spizaetus bartelsi*) in East Java, after Sözer and Nijman (1995). 24. Mt. Liman-Wilis, 25. Mt. Kawi-Arjuno, 26. Lebakharjo, 27. Mt. Tengger-Bromo, 28. Yang Highlands, 29. Meru Betiri, 30. Kalibaru, 31. Ijen Highlands, 32. Baluran, 33. Alas Purwo.

Comments by James W. Grier

Management of the Wild Population

The number one priority for management of the Javan Hawk-eagle is to protect known nest sites and their surrounding habitat, to prevent further loss of habitat and removal of young from the nests.

Inventory of the Numbers and Locations of Wild Javan Hawk-Eagles

The immediate priority for Javan Hawk-eagle research is a better understanding of the existing numbers and locations of birds. For birds in the wild, additional and continuing surveys are imperative, using the best and most realistic techniques available or that can be developed. Ideally, a complete census would be conducted. That ideal is probably impossible. The next ideal goal would be to employ statistically valid sampling methodology, with attention to both spatial and temporal sampling considerations. Stratified sampling might be useful. In addition (or instead - if even sampling methodology proves infeasible), additional sources of information might include reward systems—as being currently employed for locating Philippine eagle nests.

Specific actions that are recommended are:

1. Continue recording and accumulating anecdotal, *ad libitum,* and systematic information on bird numbers and locations.

2. Develop a reward system for <u>information</u> (but not for birds!) on nesting Javan Hawk-eagles (including ability to confirm reports).

3. Conduct a population statistics workshop (intensive, 1 week) to build capacity in sampling design and data interpretation, to permit better inferences and assessment of available data.

4. As an outgrowth or outcome of #3, design an improved methodology for surveying Javan Hawk-eagles in the wild.

Note that mark-recapture techniques are not recommended for estimating population size of the Javan Hawk-eagle (but see banding for dispersal information). Mark-recapture (including via banding) has not proved useful for population estimation of other species of raptors except under certain circumstances such as using ptagial tags. Ptagial tags (or other prominent means of marking) entail risks that are not acceptable at present for the Javan Hawk-eagle. These risks include: possible injury to the birds, (particularly involving personnel without thorough training), interference with pair bonding and other social interactions, and the possibility of attracting unnecessary human attention to the marked birds.

For improved information on the numbers and locations of captive birds, connections need to be discussed and explored for both persons and groups currently holding birds and the sources of those birds. In other words, better information is needed on the taking of birds from the wild: to what extent it is actually occurring, who is involved, and how (via education, law enforcement, or providing better incentives) to redirect these activities. Perhaps, ideally, the present captors can be recruited as knowledgeable allies for finding and protecting wild nests.

Dispersal and Movement Data

The second highest priority, after the population inventory, for research on Javan Hawk-eagle involves their various daily, seasonal, home-range, and life-time movements. These data are important to understand:

1. the dispersal and fates of young as they become independent,

2. requirements for and extent of home ranges for resources (particularly prey),

3. the size and locations of defended territories (and, hence the availability of room for or exclusion of other Javan Hawk-eagles, including reintroduced individuals), and

4. the degree or possibility of movements between habitat patches, genetic mixing without human intervention, and the existence of isolated subpopulations.

Two techniques are recommended for obtaining this information: banding and radio-telemetry. Both bands and transmitters can be applied on nestlings by climbing to nests. It might also be possible to trap other birds for banding and telemetry. It is critical, however, that all persons involved in hands-on work with live birds (climbing to nests, handling nestlings, trapping, etc.) be properly and adequately trained through supervised apprenticeship experience to avoid injury to both the birds and the persons. Standard, ground-based telemetry, may benefit from collaborative work with others who have experience with telemetry in Indonesia or under similar conditions (e.g., with hornbills). Satellite-based telemetry might also be considered, perhaps with international collaboration and support (e.g., from Japan, France, or USA).

Reforestation

Tree planting and cultivation, of native species and natural diversity, for the purposes of replacing lost forest and Javan Hawk-eagle habitat, is a major, long-term goal. This goal is consistent and compatible with both natural conservation and socio-economic concerns. The people need what the eagles need: clean and ample water supplies and climatic amelioration as provided by the presence of an adequate extent of rainforest.

Population Goals

The Javan Hawk-eagle metapopulation consists of wild and captive components, with each of these being potentially divided further into subgroups. At present there is an estimated 80-120 pairs of birds in the wild, 20 known in captivity (including 6 at Taman Safari Indonesia, 2 at Taman Mini, and 8 at the Jakarta bird markets), plus others in private hands.

Population modelling has shown a reasonable upper limit to growth under wild conditions managed for maximum growth to be about 3% per annum. The captive population, under artificial levels of survival, additional input, and reproduction, could grow at about 6% per year. In addition, an increase in known numbers in the wild is likely to result from increased survey efforts and efficiency. The current target for the total population of adult pairs in ten years is tabulated in Table 3-2.

Table 3-2. Ten year target population growth of Javan Hawk-eagles based upon a 3% annual growth rate in the wild. The number of adult pairs is listed - not the actual population size and not including immature birds.

Year	0	1	2	3	4	5	6	7	8	9	10
Wild[a]	120	124	127	131	135	139	143	148	152	157	161
Survey[b]	2	4	6	8	8	10	20	22	22	24	24
Captive[c]	10	11	12	12	13	14	14	15	16	17	18
Total	132	139	145	151	156	163	177	185	190	198	203

a. Based on a 3% increase per year.
b. Number of additional known wild adult pairs due to increased survey effort and efficiency (hypothetical numbers).
c. Number of adult pairs in captivity (hypothetical numbers based on 20 birds or 10 pairs initially plus an annual increment of 2 birds or 1 pair from confiscation or rehabilitation, minus some for mortality, plus those resulting from annual reproduction in captivity starting with year 6 and maturing in year 9).

Reintroduction of Birds to the Wild

Overview

Reintroduction of Javan Hawk-eagle to the wild, of either captivity-produced young or of rehabilitated birds should not be seriously considered for the near future. It may, however, play an extremely important role in the long term plans for the species.

Releasing birds to the wild at present, without better understanding the chances of survival for such birds (involving, e.g., habitat availability and prey resources to support the birds, extent of territory occupancy by the current wild population, and local human attitudes and actions toward the birds), could well amount to giving the birds a death warrant and literally throwing them away.

Rehabilitated birds should only be considered for return to the wild on a case by case basis. Older birds (say, beyond one year of age) with relatively minor injuries or other problems and from known, suitable locations should be returned to the wild at their original location. Birds suffering major dehabilitating problems (e.g., impaired flight, senses, or capacity to capture prey), and all birds from unknown or non-suitable locations should be retained in captivity as potential breeders or for educational purposes.

All confiscated birds taken as young and young initially produced by captive breeding should be kept in captivity and managed as future breeding stock until the target level for genetic diversity and production has been achieved.

One way to view the role of individual birds in captivity is to consider their value to the future of the species. One bird released to the wild is worth "one bird" facing uncertain chances of survival and eventual reproduction. One bird in captivity, on the other hand, assuming proper care and management, can be worth "many birds" in the future -- including for reintroduction to the wild -- because survival in captivity is nearly guaranteed and the probability of reproduction is high. That bird can produce many young and initiate several new generations, thus causing a multiplying effect as for example has happened with Peregrine Falcons in North America.

Captive Breeding and Interactive Management

Depending on (1) the extent to which the wild population is divided into isolated subpopulations and (2) the degree that the available habitat is occupied, captive-produced young might or might not be needed for release to the wild. The conditional aspects (1 and 2) above cannot be evaluated at this time and need to be the objects of additional research (addressed elsewhere). In the meantime, however, it would be more prudent to establish a captive breeding capability and not ultimately need it than to not have it and discover later that it was necessary or even critical to the survival of the species.

Developing the capacity for captive breeding from scratch will involve several components and stages:

* development of suitable facilities and support aspects (including a proper foodstock program)
* training of personnel
* assembling suitable breeding stock.

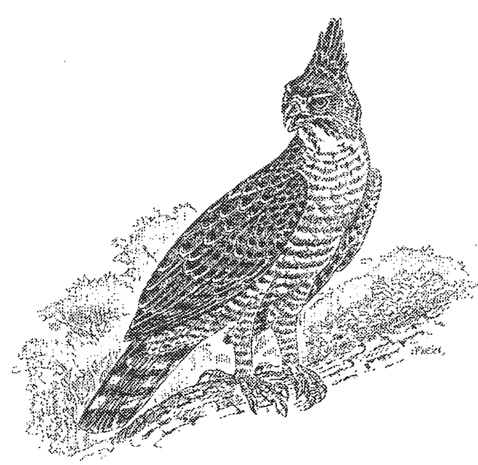
To avoid "putting all the eggs in one basket," at least two breeding sites should be considered. It is important that funding, placement of birds, etc. be coordinated and cooperative to prevent counterproductive competition for resources.

Because (1) training of personnel and the development of facilities will take time (estimated two to six years), (2) a number of potentially suitable birds are already in captivity, and (3) some persons and groups are concerned about or object to deliberately taking additional young from the wild, taking of new wild young does not need to be contemplated for the present. The need and desirability of taking new stock from the wild can be reassessed at a later date.

POPULATION AND HABITAT VIABILITY ASSESSMENT FOR THE JAVAN HAWK-EAGLE (*Spizaetus bartelsi*)

Taman Safari Indonesia
6 - 8 May 1996

Section 4
Life History and Population Modelling



Life History and Population Modelling of the Javan Hawk-Eagle

<u>Working Group Members</u>:
Th. Chandra Wasis, KpB Biosphere
Indra Arinal, Sub belai KSDA Jawa Timur III
Sri Paryanti
Ani Mardiastuti, Bogor Agricultural University
Philip Miller, Conservation Breeding Specialist Group
M. Indrawan, Conservation International—Indonesia Program
Tubagus Ischak, Universitas Indonesia
Sri Handini

Introduction

The Javan Hawk-eagle, *Spizaetus bartelsi*, is among the world's rarest species of raptors. Current estimates of the world's population of this rainforest raptor, endemic to the island of Java in Indonesia, range from about 80-110 adult pairs with an unknown number of accompanying subadults and juveniles. These population estimates are constantly under review as new survey projects are implemented.

As with virtually all tropical rainforest raptors, the Javan Hawk-eagle is directly threatened by the fragmentation and destruction of suitable forest habitat. Consequently, the remaining birds are distributed among relatively small, isolated patches of forest. As these forest patches continue to degrade under continued human pressures, the risks of local extinction of these small remnant populations increase. Additionally, the removal of young Hawk-eagles for the local bird-market trade may be a considerable burden to wild population persistence.

The need for and consequences of intensive management strategies can be modeled to suggest which practices may be the most effective in conserving the Javan Hawk-eagle. VORTEX, a simulation software package written for population viability analysis, was used as a tool to study the interaction of a number of life history and population parameters treated stochastically, to explore which demographic parameters may be the most sensitive to alternative management practices, and the test the effects of a suite of possible management scenarios.

The VORTEX package is a Monte Carlo simulation of the effects of deterministic forces as well as demographic, environmental, and genetic stochastic events on wild populations. VORTEX models population dynamics as discrete sequential events (e.g., births, deaths, sex ratios among offspring, catastrophes, etc.) that occur according to defined probabilities. The probabilities of events are modeled as constants or a random variables that follow specified distributions. The package simulates a population by stepping through the series of events that describe the typical life cycles of sexually reproducing, diploid organisms. (Note: The original programs that formed the basis for early versions of VORTEX were initially written for raptors, particularly Peregrine Falcons and Bald Eagles.)

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 our knowledge of the biology of the Javan Hawk-eagle, the conditions affecting the population as well as possible changes in the future. What little data exists on the population biology of Javan Hawk-eagles was utilized for this analysis. The primary sources of this information used at the PHVA workshop were van Balen (1996), Meyburg et al. (1989), and unpublished reports from a number of Indonesian researchers participating in the exercise. When sufficient data were unavailable to estimate a given parameter, general demographic data from other raptor species were used to provide a basis for the estimate. In particular, data from the Ornate Hawk-eagle *Spizaetus ornatus* (e.g., Madrid 1990, 1991), Peregrine Falcon (e.g., Grier and Barclay 1988) and Bald Eagle (e.g., Grier 1980, 1991) proved useful in this regard.

Input Parameters for Simulations

Mating System: Monogamous. While direct observations have not been made for Javan Hawk-eagles, it is presumed that their breeding behavior includes the formation of strong bonds between individual pairs. This has been observed in Ornate Hawk-eagles and other *Spizaetus* as well.

Age of First Reproduction: VORTEX precisely defines breeding as the time at which offspring are born, not simply the age of sexual maturity. In addition, the program uses the mean (or median) age rather than the earliest recorded age of chick production. All indications from field observations of *Spizaetus* indicate that individuals begin breeding at three years of age. Consequently, all models were constructed using this as the age of first reproduction.

Age of Reproductive Senescence: VORTEX assumes that animals can breed (at the normal rate) throughout their adult life. Data on bald eagles in North America suggests that individual birds can live, and probably reproduce, as long as 25-30 years. No data exist on longevity for Javan Hawk-eagles; as a result, we set the age of reproductive senescence for this species at 30 years based on this information from other species. While it is possible for birds to reach this age in the models, the life tables constructed for this species make this event highly unlikely (see below).

Fledgling Production: For the purposes of modelling Javan Hawk-eagle population dynamics, we defined "reproduction" for a given female as the successful fledging of a chick. Javan Hawk-eagle females are thought to lay a single egg every two to three years. This would translate into 33-50% of the adult females within a given population laying eggs in a particular year. Assuming a 3-year interval, and given some undefined level of nesting failure as well as some relatively small proportion of successful nesting attempts failing to produce fledglings, we set the lower limit to reproduction at 25% of the adult females raising a fledgling per year. If the interval between eggs were closer to two years, and if a high proportion of nesting and fledging attempts were successful, we might envision as many as 50% of the adult females successfully fledging young annually. We chose an intermediate level of 33% female reproduction to complement these two bracketing values.

Annual variation in female reproduction is modeled in VORTEX by entering a standard deviation (SD) for the proportion of females that do not reproduce in a given year. Since no appropriate data were available for this or related species, we set this variation to approximately 25% of the mean value. VORTEX then determines the proportion of females breeding each year of the simulation by sampling from a binomial distribution with the specified mean (e.g., 50%) and standard deviation (e.g., 12.5%). The sex ratio (proportion of males) of fledglings produced in a given year was set at 0.500 based on the assumption of equal numbers of males and females at the time of fledging.

Male Breeding Pool: Although no data are available for this parameter, we assumed that all adult males are available for breeding in a given year. Each male has an equal chance of siring offspring annually.

Mortality: Again, data are lacking on the mortality of specific age-sex classes of Javan Hawk-eagles. As a result, we were forced to rely on general life-history characteristics of raptor species in order to construct alternative mortality schedules.

Survival of both juvenile and adult Javan Hawk-eagles is intimately related to human activities. The removal of nestlings for private bird collections may be a significant factor influencing mortality in this age class. Additionally, the continued disruption and fragmentation of nesting habitat leads to increased mortality of adult birds and, perhaps particularly, subadult birds that attempt to disperse from their natal range to nearby territories that may be separated by large patches of unsuitable, open habitat. Javan Hawk-eagle population subjected to considerable human-induced mortality were designated as "high mortality" populations. Populations that may be largely free from many of these additional mortality factors may show a mortality schedule more representative of the collective set of raptor species inhabiting tropical forests. This was called the "baseline" mortality schedule. Finally, vigorous efforts directed at reducing or perhaps eliminating the human-mediated sources of mortality may result in survival rates greater than those for more natural, undisturbed populations. This was deemed the "low mortality" schedule. The specific rates for these three mortality schedules are given below:

Age (Years)	High	Baseline	Low
0-1	30%	15%	10%
1-2	60	30	20
2-3	30	15	10
Adult	10	5	3.5

This establishment of three alternative mortality schedules allows us to both evaluate the sensitivity of Javan Hawk-eagle populations to changes in mortality and to quantitatively assess the relative impact of human-based mortality factors and of directed management efforts aimed specifically at reducing mortality across all age classes.

As with the environmental variation set for female reproduction, we set the annual variation in mortality to be approximately 25% of the mean rates.

Catastrophes: Catastrophes are singular environmental events that are outside the bounds of normal environmental variation affecting reproduction and/or survival. Natural catastrophes can be tornadoes, floods, droughts, disease, or similar events. These events are modeled in VORTEX by assigning a probability of occurrence and a severity factor ranging from 0.0 (maximum or absolute effect) to 1.0 (no effect).

The Indo-Pacific is a tectonically active area with many volcanoes situated near the tectonic plate margins. In particular, a number of Java's mountains are in fact active volcanoes. These mountains run in a chain along the entire primary axis of the island. Data for Java barat (west Java) indicates the eruption of three volcanoes within the past 50 years. We used this observation to set the frequency (or probability of occurrence) of this catastrophe at 6% annually. Because of the distribution of volcanoes along the entire axis of the island, we assumed that this threat was also present in Java Tenga (Central Java) and Java Timur (East Java). Estimates of the severity of this type of event are difficult to obtain for Javan Hawk-eagles. It was assumed that, despite the bird's ability to escape immediate danger from the eruption, falling ash and toxic gases that accompany these events would take a toll on the birds. In addition, the alteration of the landscape following an eruption would also result in a lowered frequency of successful reproduction in the year an eruption occurred. Consequently, we set the severity of this catastrophe at 0.75 for both reproduction and survival. In other words, both reproduction and survival are reduced by 25% during the year a volcanic eruption occurs on the island. This type of event is expected to occur about every 16 years on average during the population simulation.

Initial Population Size: Current estimates of Javan Hawk-eagle distribution indicate that the species is scattered across the island in several small, isolated forest fragments (see the section on Wild Populations for a more complete discussion of this topic). In order to investigate the viability of populations of varying size, we developed a series of models with initial population sizes of 15, 30, 60, 90, 150, and 200 individuals. These values span the range from very small remnant patches to much larger, aggregate populations occupying much larger regions of Java. In addition, individuals in all models were distributed among the available age-sex classes according to the stable age distribution calculated using Leslie matrix algorithms from the existing mortality and reproductive schedules appropriate for the scenario in question.

Carrying Capacity: The carrying capacity, K, for a given habitat patch defines an upper limit for the population size, above which additional mortality is imposed across all age classes in order to return the population to the value set for K. VORTEX, therefore, uses K to impose density-dependence on survival rates. The program also has the capability of imposing density-dependent effects on reproduction that change as a function of K, but since no such data are available for Javan Hawk-eagle populations, we chose not to include density-dependent reproduction in our models.

Because of the dramatic reduction in available habitat over the last few decades, we assumed that all remaining suitable habitat is essentially saturated with Javan Hawk-eagles. Consequently, all models were constructed with the carrying capacity equivalent to the initial population size.

Iterations and Years of Projection: All scenarios were simulated 500 times, with population projections extending for 100 years. Output results were summarized at 10-year intervals for use in some of the figures that follow. All simulations were conducted using VORTEX version 7.1 (January 1996).

Results from Simulation Modeling

Results of the simulation models appear in Tables 4-1 through 4-10. Each table represents a specified set of conditions, for example, the presence or absence of inbreeding depression, initial population size, etc. Within each Table, the results are organized in a nested structure: each initial population size was run with or without catastrophes and inbreeding depression under specified mortality conditions.

The column headings for the Tables are as follows:

- r_d: deterministic instantaneous growth rate, calculated by Leslie matrix methods from life-table data;
- r_s (SD): mean (standard deviation) of stochastic growth rate across iterations, calculated from annual variation in population size;
- P(E): probability of extinction over the 100-year time span of the simulations, calculated as the proportion of iterated populations that become extinct within 100 years;
- T(E): mean time to extinction for those populations becoming extinct;
- N_{100} (SD): mean final size (standard deviation) of those population remaining extant after 100 years;
- H_{100}: proportion of the original heterozygosity expected to remain in extant populations after 100 years.

Note that VORTEX output file numbers are given for each scenario for future reference and retrieval, if necessary.

Figures 4-1 through 4-7 are a graphical compilation of the modelling results, attempting to show the relationships between specific factors and their impact on population persistence.

Deterministic Results

The deterministic population growth rates for each scenario, calculated from life tables using Leslie matrix algorithms, are presented in the fourth column of Tables 4-1 through 4-10. These calculations assume that birth and death rates are constant (no annual variations nor stochastic fluctuations), there is no limitation of mates, and inbreeding has no impact on fecundity or viability. Note that mortality, inclusion or exclusion of catastrophes and proportional female reproductive success are the only variables that affect these deterministic rates. Therefore, the long-term rate of growth in these populations, in the absence of stochastic variation, is independent of initial population size and habitat carrying capacity.

Positive values indicate population growth, while negative values indicate population decline. A population with $r_d < 0$ is in deterministic decline (deaths outpace births), and will go extinct. The difference between the deterministic population growth rate and the stochastic growth rate resulting from the simulations (r_s, see below) can give an indication of the impact of stochastic factors on population persistence.

In the absence of inbreeding depression, deterministic growth rates are strongly negative under conditions of high mortality (r_d = -0.125 to -0.080). By contrast, all deterministic growth rates are positive when mortality levels are low (r_d = 0.012 to 0.075). Under conditions of intermediate, baseline mortality, deterministic growth is negative only when the breeding success of females is low (i.e., File #JHE204: r_d = -0.019). Under very optimal (and perhaps unrealistic) conditions, the long-term expected growth rate can approach nearly 8% per year (i.e., File #JHE209: r_d = 0.075).

If catastrophes are eliminated from the simulations, deterministic growth increases under all conditions from about 13% to nearly 23%. However, high mortality scenarios still result in strong population decline of at least 6% per year. Even without considering the additional destabilizing factors associated with stochastic fluctuations in these populations, Javan Hawk-eagle populations appear to be unable to sustain high rates of mortality resulting from removal of juveniles from nests as well as from reduction in available habitat.

Inspection of these deterministic growth rates indicates the considerable sensitivity of Javan Hawk-eagle populations to increases in mortality when compared to similar proportional increases in adult female reproductive success. The incremental change in r_d is about 0.005 per 10% change in the proportion of adult females breeding annually, while the corresponding change for age-specific mortality is approximately 0.010. In other words, the incremental change in deterministic growth with respect to mortality is about twice as great as that with respect to female reproductive success.

Stochastic Simulation Results

Calculation of population growth rates from average birth and death rates in a life table will over-estimate long-term population growth if there are fluctuations in demographic parameters, even random sampling variation. Inclusion of these random forces in the population modelling process results in stochastic growth rates that are, in every instance, lower than the deterministic growth rates calculated from the mean life-table parameters. In fact, many scenarios result in negative stochastic growth despite the calculated deterministic growth rate being positive. For example, under intermediate levels of mortality and female reproductive success and a population size of 15 individuals (Table 4-1: File #JHE205), the deterministic growth rate is 0.003 while the stochastic growth rate resulting from the simulation is r_s = -0.018. This phenomenon is expected to be more common when population sizes are small and the action of stochastic forces is of greater significance.

As with the case of deterministic growth, stochastic growth is strongly negative (in fact, even more so) when mortality is high, even when catastrophes are excluded from the models.

The most optimistic scenarios, with high reproductive success and low mortality across all age classes, results in the potential for about 5% to 9% annual growth. However, inspection of the entire range of scenarios suggests that a more reasonable estimate for the highest growth rate obtainable from intensive population management is 3-4%.

Under the same conditions of mortality and fecundity, smaller populations experience lower rates of stochastic growth compared to larger populations. In addition, the removal of catastrophes from the models increases the stochastic growth potential of Javan Hawk-eagle populations. In some cases, removal of additional mortality imposed by these infrequent but severe events switches a population around from stochastic decline to stochastic increase (see, for example, Files #JHE207 and JHE216, Table 4-1). While the specific characteristics of volcanic eruptions on Java and their effects on Javan Hawk-eagle populations are currently unknown, these results suggest that mediation of their effects can have real and measurable benefits for population persistence. In a similar fashion, when inbreeding depression is included in those models using smaller population sizes, the rate of population decline is accelerated in nearly all scenarios. Once again, even though the nature and extent of inbreeding and its deleterious fitness consequences are not specifically known in Javan Hawk-eagle populations in the wild, these models indicate the need to consider the additional complications genetic processes can generate in small populations.

An analysis of the sensitivity of Javan Hawk-eagle stochastic population growth to changes in mortality and fecundity values leads to a very similar conclusion to that performed with respect to deterministic growth rates. These populations show a much greater sensitivity to changes in age-specific mortality than to changes in female reproductive success.

Because of the extreme rate of stochastic population decline observed under conditions of high mortality, extinction of simulated Javan Hawk-eagle populations is virtually certain, regardless of initial population size and the extent of catastrophic environmental variation (column 6, Tables 4-1 through 4-10). Moreover, population extinction is quite rapid, with a mean time to extinction of less than 60 years. For the smaller, more highly fragmented populations, this time to extinction is considerably less. Intermediate levels of mortality can yield high extinction risks as well, particularly when population sizes are small and female reproductive success is low. As long as mortality is kept at relatively low levels, larger populations (N_0 = 90 - 200) are generally safe from extinction even when female reproductive success is less than desired. If inbreeding depression is added to the models, the extinction risk is increased regardless of the other conditions modeled. Additionally, particularly when mortality and fecundity are favorable, the removal of catastrophic fluctuations can substantially reduce the risk of extinction in the smallest populations (compare, for example, Files #JHE209 and JHE218). These results clearly illustrate the additional risks faced by very small, isolated populations.

Even if the population extinction risk is low, population size may decline throughout the duration of the simulation. This is observed most frequently in larger populations that may take longer than 100 years to show appreciable extinction risk. For example, when female reproductive success is low and mortality is intermediate, a population starting with 150 individuals declines by nearly 50% despite observing only a 0.6% risk of extinction (Table 4-9:

File #JHE357). When stochastic growth rates are positive, the populations remain at or very near their appropriate carrying capacities for the duration of the simulations.

The retention of population heterozygosity, even when the risk of extinction is quite small, can be low for very small populations. As an example, nearly 50% of the original heterozygosity is lost from a population of 15 individuals despite a stochastic annual growth rate of 7% and only a 4% risk of extinction in 100 years. It is clear, therefore, that these small populations experience substantial risks from genetic as well as demographic processes.

These risks are graphically illustrated in Figures 4-1 through 4-6. Also of interest in these figures is the interaction between population size and level of mortality, assuming an intermediate level of female reproductive success. In the smallest populations, even low mortality can lead to marked extinction risk from stochastic demographic and environmental fluctuations. As population size increases, lower mortality leads to increasingly lower extinction risk and a lower reduction in population size during the time frame of the simulations.

In summary, the considerable fragmentation of Javan Hawk-eagle populations throughout its current distribution leads to isolation of small remnant populations with, based on results obtained from stochastic population simulation modelling using VORTEX, reduced population growth, greater extinction risk, and reduced levels of genetic variation. Moreover, sensitivity analysis using this modelling approach demonstrates the considerable sensitivity of these populations to variable age-specific mortality. This is perhaps best illustrated in Figure 4-7. Each bar in the graph gives the probability of extinction averaged over all scenarios with a given parameter value. For example, the mean probability of population extinction for all scenarios in which the proportion of adult females breeding annually was 25% is 0.558 (the left-most bar in the figure). The figure shows that smaller population size and lowered reproductive success among adult females do in fact lead to increased extinction risk. However, the data indicate that the primary determinant of extinction risk is age-specific mortality. It is interesting to note that, as population size increases, the mean extinction risk converges to about 33% (the right-most bars in the figure). This is a direct result of one-third of all scenarios for a given population size having high mortality with 100% extinction risk while the remaining scenarios with lower mortality are virtually risk-free.

Conclusions and Recommendations

Because of the species' general life-history characteristics—most notably the production of just a single egg at best every two years—populations of Javan Hawk-eagles can be expected to increase at about 3-4% annually under reasonable conditions. This fact, combined with model results such as those described above, point to the need for management efforts directed toward the minimization of human-induced mortality in Javan Hawk-eagle populations.

Based on the results of the VORTEX simulation models developed for the Javan Hawk-eagle, the following specific recommendations can be made:

1. Study the home range, locations, and habitat carrying capacities in order to review the degree of Hawk-eagle population fragmentation.

2. Universities and research agencies are encouraged to gather data on inbreeding depression in the Javan Hawk-eagle. This will be a very long term goal involving captive-bred birds.

3. Collect data on the frequency of volcanic eruptions on the island. This can be done by the Meteorological and Geophysical Agencies. Conduct research on the impact of volcanic activity on the region by comparing areas subjected to periodic volcanic activity with those areas far from such activity. In addition, it is important to develop plans designed to minimize the impacts of volcanic activity in susceptible areas.

4. Study the potential for bird-banding as a technique for determining age of breeding in Javan Hawk-eagles. Conduct a preliminary study on closely-related species such as *Spizaetus cirrhatus* to gain insight into this important demographic parameter. During banding efforts, radio transmitters (preferably solar-powered and less than 2% of the nestling body weight) should also be fitted.

5. Initiate studies designed to determine the normal lifespan of Javan Hawk-eagles in the wild. This can be accomplished through banding studies as well as from data on captive individuals.

6. Study general nest-site characteristics in order to gain more insight into Javan Hawk-eagle breeding biology. Develop methodologies that will help to understand the breeding biology of the species, including the sexing of wild birds. Encourage local inhabitants to assist in the nest location efforts. Incentives need to be developed in order to encourage this association.

Sample VORTEX Input File

```
JHE250.OUT      ***Output Filename***
Y      ***Graphing Files?***
N      ***Each Iteration?***
Y       ***Screen display of graphs?***
500      ***Simulations***
100      ***Years***
10      ***Reporting Interval***
1      ***Populations***
N      ***Inbreeding Depression?***
Y      ***EV correlation?***
1      ***Types Of Catastrophes***
M      ***Monogamous, Polygynous, or Hermaphroditic***
3      ***Female Breeding Age***
3      ***Male Breeding Age***
30      ***Maximum Age***
0.500000      ***Sex Ratio***
1      ***Maximum Litter Size***
N      ***Density Dependent Breeding?***
67.000000      ***Population 1: Percent Litter Size 0***
33.000000      ***Population 1: Percent Litter Size 1***
12.009612      ***EV--Reproduction***
15.000000      ***Female Mortality At Age 0***
4.000000      ***EV--FemaleMortality***
30.000000      ***Female Mortality At Age 1***
8.000000      ***EV--FemaleMortality***
15.000000      ***Female Mortality At Age 2***
4.000000      ***EV--FemaleMortality***
5.000000      ***Adult Female Mortality***
2.000000      ***EV--AdultFemaleMortality***
15.000000      ***Male Mortality At Age 0***
4.000000      ***EV--MaleMortality***
30.000000      ***Male Mortality At Age 1***
8.000000      ***EV--MaleMortality***
15.000000      ***Male Mortality At Age 2***
4.000000      ***EV--MaleMortality***
5.000000      ***Adult Male Mortality***
2.000000      ***EV--AdultMaleMortality***
6.000000      ***Probability Of Catastrophe 1***
1.000000      ***Severity--Reproduction***
1.000000      ***Severity--Survival***
Y      ***All Males Breeders?***
Y      ***Start At Stable Age Distribution?***
30      ***Initial Population Size***
30      ***K***
0.000000      ***EV--K***
N      ***Trend In K?***
N      ***Harvest?***
N      ***Supplement?***
Y      ***AnotherSimulation?***
```

Sample VORTEX Output File

```
VORTEX -- simulation of genetic and demographic stochasticity

JHE250.OUT
Wed May  8 23:13:13 1996


  1 population(s) simulated for 100 years, 500 iterations

  No inbreeding depression

  First age of reproduction for females: 3   for males: 3
  Age of senescence (death): 30
  Sex ratio at birth (proportion males): 0.50000


Population 1:
  Monogamous mating; all adult males in the breeding pool.

  Reproduction is assumed to be density independent.

    67.00 (EV = 12.14 SD) percent of adult females produce litters of size 0
    33.00 percent of adult females produce litters of size 1

   15.00 (EV = 4.00 SD) percent mortality of females between ages 0 and 1
   30.00 (EV = 8.00 SD) percent mortality of females between ages 1 and 2
   15.00 (EV = 4.00 SD) percent mortality of females between ages 2 and 3
    5.00 (EV = 2.00 SD) percent annual mortality of adult females (3<=age<=30)
   15.00 (EV = 4.00 SD) percent mortality of males between ages 0 and 1
   30.00 (EV = 8.00 SD) percent mortality of males between ages 1 and 2
   15.00 (EV = 4.00 SD) percent mortality of males between ages 2 and 3
    5.00 (EV = 2.00 SD) percent annual mortality of adult males (3<=age<=30)
    EVs may have been adjusted to closest values
        possible for binomial distribution.
    EV in reproduction and mortality will be correlated.

  Frequency of type 1 catastrophes: 6.000 percent
    with 1.000 multiplicative effect on reproduction
     and 1.000 multiplicative effect on survival

  Initial size of Population 1:
    (set to reflect stable age distribution)
 Age 1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
25 26 27 28 29 30    Total
     2  1  1  1  1  0  1  1  0  1  0  1  0  1  0  1  0  0  1  0  0  1  0  0
0  0  1  0  0  0     15  Males
     2  1  1  1  1  0  1  1  0  1  0  1  0  1  0  1  0  0  1  0  0  1  0  0
0  0  1  0  0  0     15  Females

  Carrying capacity = 30 (EV = 0.00 SD)

Deterministic population growth rate (based on females, with assumptions of
  no limitation of mates, no density dependence, and no inbreeding
depression):

     r =  0.019     lambda = 1.019     R0 =     1.272
   Generation time for:  females = 12.72    males = 12.72
```

Sample VORTEX Output File (Continued)

```
Stable age distribution:  Age class    females     males
                                  0    0.059       0.059
                                  1    0.049       0.049
                                  2    0.034       0.034
                                  3    0.028       0.028
                                  4    0.026       0.026
                                  5    0.025       0.025
                                  6    0.023       0.023
                                  7    0.021       0.021
                                  8    0.020       0.020
                                  9    0.019       0.019
                                 10    0.017       0.017
                                 11    0.016       0.016
                                 12    0.015       0.015
                                 13    0.014       0.014
                                 14    0.013       0.013
                                 15    0.012       0.012
                                 16    0.011       0.011
                                 17    0.011       0.011
                                 18    0.010       0.010
                                 19    0.009       0.009
                                 20    0.009       0.009
                                 21    0.008       0.008
                                 22    0.007       0.007
                                 23    0.007       0.007
                                 24    0.006       0.006
                                 25    0.006       0.006
                                 26    0.006       0.006
                                 27    0.005       0.005
                                 28    0.005       0.005
                                 29    0.005       0.005
                                 30    0.004       0.004

Ratio of adult (>= 3) males to adult (>= 3) females: 1.000


Population 1

Year 10
     N[Extinct] =       0, P[E] = 0.000
     N[Surviving] =   500, P[S] = 1.000
     Population size =            26.61 (   0.16 SE,     3.59 SD)
     Expected heterozygosity =    0.957 (  0.000 SE,    0.006 SD)
     Observed heterozygosity =    0.996 (  0.001 SE,    0.012 SD)
     Number of extant alleles =   30.46 (   0.15 SE,     3.44 SD)

Year 20
     N[Extinct] =       1, P[E] = 0.002
     N[Surviving] =   499, P[S] = 0.998
     Population size =            25.74 (   0.20 SE,     4.38 SD)
     Expected heterozygosity =    0.931 (  0.001 SE,    0.013 SD)
     Observed heterozygosity =    0.982 (  0.001 SE,    0.026 SD)
     Number of extant alleles =   21.00 (   0.12 SE,     2.75 SD)
```

Sample VORTEX Output File (Continued)

```
Year 30
     N[Extinct] =       2, P[E] = 0.004
     N[Surviving] =   498, P[S] = 0.996
     Population size =          24.75 (   0.24 SE,     5.45 SD)
     Expected heterozygosity =  0.902 (  0.001 SE,    0.024 SD)
     Observed heterozygosity =  0.959 (  0.002 SE,    0.042 SD)
     Number of extant alleles = 15.67 (   0.11 SE,     2.57 SD)

Year 40
     N[Extinct] =       6, P[E] = 0.012
     N[Surviving] =   494, P[S] = 0.988
     Population size =          23.87 (   0.28 SE,     6.26 SD)
     Expected heterozygosity =  0.873 (  0.002 SE,    0.039 SD)
     Observed heterozygosity =  0.924 (  0.003 SE,    0.059 SD)
     Number of extant alleles = 12.56 (   0.11 SE,     2.40 SD)

Year 50
     N[Extinct] =      11, P[E] = 0.022
     N[Surviving] =   489, P[S] = 0.978
     Population size =          23.51 (   0.31 SE,     6.91 SD)
     Expected heterozygosity =  0.840 (  0.003 SE,    0.058 SD)
     Observed heterozygosity =  0.897 (  0.003 SE,    0.075 SD)
     Number of extant alleles = 10.39 (   0.11 SE,     2.37 SD)

Year 60
     N[Extinct] =      20, P[E] = 0.040
     N[Surviving] =   480, P[S] = 0.960
     Population size =          22.76 (   0.32 SE,     6.93 SD)
     Expected heterozygosity =  0.812 (  0.004 SE,    0.079 SD)
     Observed heterozygosity =  0.874 (  0.004 SE,    0.097 SD)
     Number of extant alleles =  8.91 (   0.10 SE,     2.17 SD)

Year 70
     N[Extinct] =      26, P[E] = 0.052
     N[Surviving] =   474, P[S] = 0.948
     Population size =          22.35 (   0.34 SE,     7.37 SD)
     Expected heterozygosity =  0.783 (  0.004 SE,    0.084 SD)
     Observed heterozygosity =  0.848 (  0.005 SE,    0.108 SD)
     Number of extant alleles =  7.78 (   0.09 SE,     2.00 SD)

Year 80
     N[Extinct] =      39, P[E] = 0.078
     N[Surviving] =   461, P[S] = 0.922
     Population size =          22.88 (   0.33 SE,     7.08 SD)
     Expected heterozygosity =  0.757 (  0.004 SE,    0.095 SD)
     Observed heterozygosity =  0.810 (  0.006 SE,    0.124 SD)
     Number of extant alleles =  6.95 (   0.09 SE,     1.84 SD)

Year 90
     N[Extinct] =      45, P[E] = 0.090
     N[Surviving] =   455, P[S] = 0.910
     Population size =          22.74 (   0.33 SE,     7.12 SD)
     Expected heterozygosity =  0.731 (  0.005 SE,    0.110 SD)
     Observed heterozygosity =  0.779 (  0.007 SE,    0.140 SD)
     Number of extant alleles =  6.20 (   0.08 SE,     1.76 SD)
```

Sample VORTEX Output File (Continued)

```
Year 100
     N[Extinct] =       52, P[E] = 0.104
     N[Surviving] =    448, P[S] = 0.896
     Population size =            22.89 (   0.33 SE,     6.92 SD)
     Expected heterozygosity =    0.704 (  0.006 SE,   0.126 SD)
     Observed heterozygosity =    0.754 (  0.007 SE,   0.152 SD)
     Number of extant alleles =    5.70 (   0.08 SE,     1.64 SD)


In 500 simulations of Population 1 for 100 years:
  52 went extinct and 448 survived.

This gives a probability of extinction of 0.1040 (0.0137 SE),
  or a probability of success of          0.8960 (0.0137 SE).

52 simulations went extinct at least once.
Of those going extinct,
    mean time to first extinction was 66.92 years (2.74 SE, 19.79 SD).

No recolonizations.

Mean final population for successful cases was 22.89 (0.33 SE, 6.92 SD)

   Age 1       2   Adults    Total
    1.20    0.88    9.39     11.47  Males
    1.23    0.91    9.28     11.42  Females

Without harvest/supplementation, prior to carrying capacity truncation,
  mean growth rate (r) was 0.0106 (0.0005 SE, 0.1124 SD)

Final expected heterozygosity was      0.7036 ( 0.0059 SE,  0.1256 SD)
Final observed heterozygosity was      0.7544 ( 0.0072 SE,  0.1518 SD)
Final number of alleles was              5.70 (   0.08 SE,    1.64 SD)
*************************************************************************
```

Table 4-1. Javan Hawk-eagle population viability: Initial population size (N_0) = 15; no inbreeding depression. See text for definitions of column headings.

File #	% Breeding	Mortality	r_d	r_s (SD)	P(E)	T(E)	N_{100} (SD)	H_{100}
Catastrophes								
JHE201	25	High	-.125	-.150 (.266)	1.000	14	—	—
JHE202	33	"	-.108	-.134 (.269)	1.000	16	—	—
JHE203	50	"	-.080	-.112 (.266)	1.000	18	—	—
JHE204	25	Baseline	-.019	-.037 (.194)	0.956	43	7 (4)	0.427
JHE205	33	"	.003	-.018 (.189)	0.834	50	8 (4)	0.424
JHE206	50	"	.039	.015 (.172)	0.494	54	11 (4)	0.430
JHE207	25	Low	.012	-.005 (.166)	0.642	55	9 (4)	0.475
JHE208	33	"	.035	.018 (.158)	0.412	56	12 (3)	0.515
JHE209	50	"	.075	.052 (.150)	0.186	56	13 (3)	0.474
No Catastrophes								
JHE210	25	High	-.109	-.139 (.259)	1.000	16	—	—
JHE211	33	"	-.092	-.116 (.254)	1.000	18	—	—
JHE212	50	"	-.064	-.095 (.247)	1.000	21	—	—
JHE213	25	Baseline	-.003	-.019 (.162)	0.832	52	8 (4)	0.463
JHE214	33	"	.019	.004 (.146)	0.502	56	10 (4)	0.487
JHE215	50	"	.056	.036 (.132)	0.180	56	13 (3)	0.496
JHE216	25	Low	.028	.016 (.125)	0.290	61	12 (3)	0.534
JHE217	33	"	.052	.038 (.119)	0.114	61	13 (3)	0.546
JHE218	50	"	.092	.073 (.113)	0.040	60	14 (2)	0.511

Table 4-2. Javan Hawk-eagle population viability: Initial population size (N_0) = 15; inbreeding depression (Heterosis model: 3.14 lethal equivalents). See text for definitions of column headings.

File #	% Breeding	Mortality	r_d	r_s (SD)	P(E)	T(E)	N_{100} (SD)	H_{100}
Catastrophes								
JHE219	25	High	-.125	-.158 (.273)	1.000	14	—	—
JHE220	33	"	-.108	-.142 (.272)	1.000	16	—	—
JHE221	50	"	-.080	-.118 (.270)	1.000	17	—	—
JHE222	25	Baseline	-.019	-.048 (.198)	0.994	38	5 (2)	0.524
JHE223	33	"	.003	-.033 (.191)	0.986	46	5 (2)	0.420
JHE224	50	"	.039	-.009 (.182)	0.838	58	7 (4)	0.475
JHE225	25	Low	.012	-.020 (.173)	0.908	54	5 (3)	0.542
JHE226	33	"	.035	-.003 (.166)	0.738	59	8 (4)	0.522
JHE227	50	"	.075	.024 (.152)	0.384	66	10 (4)	0.512
No Catastrophes								
JHE228	25	High	-.109	-.135 (.257)	1.000	16	—	—
JHE229	33	"	-.092	-.121 (.249)	1.000	18	—	—
JHE230	50	"	-.064	-.096 (.246)	1.000	22	—	—
JHE231	25	Baseline	-.003	-.031 (.165)	0.962	52	5 (3)	0.437
JHE232	33	"	.019	-.015 (.155)	0.844	60	6 (3)	0.520
JHE233	50	"	.056	.010 (.139)	0.470	69	9 (4)	0.535
JHE234	25	Low	.028	-.004 (.133)	0.584	67	8 (4)	0.551
JHE235	33	"	.052	.016 (.120)	0.332	71	10 (4)	0.572
JHE236	50	"	.092	.043 (.115)	0.122	67	12 (3)	0.561

Table 4-3. Javan Hawk-eagle population viability: Initial population size (N_0) = 30; no inbreeding depression. See text for definitions of column headings.

File #	% Breeding	Mortality	r_d	r_s (SD)	P(E)	T(E)	N_{100} (SD)	H_{100}
Catastrophes								
JHE237	25	High	-.125	-.146 (.240)	1.000	19	—	—
JHE238	33	"	-.108	-.131 (.250)	1.000	22	—	—
JHE239	50	"	-.080	-.104 (.238)	1.000	26	—	—
JHE240	25	Baseline	-.019	-.033 (.172)	0.804	56	10 (6)	0.587
JHE241	33	"	.003	-.010 (.156)	0.464	62	15 (8)	0.627
JHE242	50	"	.039	.026 (.138)	0.082	67	24 (7)	0.673
JHE243	25	Low	.012	.001 (.138)	0.244	65	19 (8)	0.667
JHE244	33	"	.035	.026 (.130)	0.068	65	24 (7)	0.704
JHE245	50	"	.075	.063 (.125)	0.010	86	28 (4)	0.704
No Catastrophes								
JHE246	25	High	-.109	-.123 (.224)	1.000	23	—	—
JHE247	33	"	-.092	-.114 (.227)	1.000	25	—	—
JHE248	50	"	-.064	-.085 (.219)	0.998	31	6 (—)	—
JHE249	25	Baseline	-.003	-.011 (.127)	0.390	68	15 (8)	0.653
JHE250	33	"	.019	.011 (.112)	0.104	67	23 (7)	0.704
JHE251	50	"	.056	.047 (.102)	0.006	83	28 (3)	0.714
JHE252	25	Low	.028	.022 (.098)	0.042	76	26 (5)	0.743
JHE253	33	"	.052	.045 (.094)	0.000	—	28 (3)	0.741
JHE254	50	"	.092	.084 (.091)	0.000	—	29 (2)	0.708

Table 4-4. Javan Hawk-eagle population viability: Initial population size (N_0) = 30; inbreeding depression (Heterosis: 3.14 lethal equivalents). See text for definitions of column headings.

File #	% Breeding	Mortality	r_d	r_s (SD)	P(E)	T(E)	N_{100} (SD)	H_{100}
Catastrophes								
JHE255	25	High	-.125	-.147 (.244)	1.000	20	—	—
JHE256	33	"	-.108	-.132 (.240)	1.000	21	—	—
JHE257	50	"	-.080	-.111 (.238)	1.000	25	—	—
JHE258	25	Baseline	-.019	-.042 (.172)	0.954	55	6 (5)	0.551
JHE259	33	"	.003	-.025 (.163)	0.748	64	9 (6)	0.637
JHE260	50	"	.039	.006 (.145)	0.260	73	17 (8)	0.665
JHE261	25	Low	.012	-.012 (.143)	0.504	71	12 (8)	0.673
JHE262	33	"	.035	.008 (.134)	0.216	73	18 (8)	0.706
JHE263	50	"	.075	.045 (.122)	0.018	74	26 (6)	0.719
No Catastrophes								
JHE264	25	High	-.109	-.127 (.222)	1.000	22	—	—
JHE265	33	"	-.092	-.114 (.220)	1.000	25	—	—
JHE266	50	"	-.064	-.090 (.215)	1.000	30	—	—
JHE267	25	Baseline	-.003	-.023 (.135)	0.674	72	9 (6)	0.633
JHE268	33	"	.019	-.004 (.119)	0.294	77	16 (8)	0.706
JHE269	50	"	.056	.030 (.101)	0.018	70	25 (6)	0.737
JHE270	25	Low	.028	.010 (.097)	0.098	76	21 (8)	0.754
JHE271	33	"	.052	.031 (.092)	0.010	81	26 (5)	0.758
JHE272	50	"	.092	.064 (.089)	0.000	—	29 (2)	0.744

Table 4-5. Javan Hawk-eagle population viability: Initial population size (N_0) = 60; no inbreeding depression. See text for definitions of column headings.

File #	% Breeding	Mortality	r_d	r_s (SD)	P(E)	T(E)	N_{100} (SD)	H_{100}
Catastrophes								
JHE273	25	High	-.125	-.145 (.227)	1.000	25	—	—
JHE274	33	"	-.108	-.126 (.221)	1.000	28	—	—
JHE275	50	"	-.080	-.102 (.223)	1.000	34	—	—
JHE276	25	Baseline	-.019	-.030 (.150)	0.586	68	13 (9)	0.708
JHE277	33	"	.003	-.004 (.131)	0.144	76	32 (18)	0.775
JHE278	50	"	.039	.032 (.120)	0.002	49	51 (11)	0.828
JHE279	25	Low	.012	.004 (.121)	0.068	75	38 (17)	0.812
JHE280	33	"	.035	.030 (.113)	.004	71	51 (12)	0.844
JHE281	50	"	.075	.070 (.111)	0.000	—	57 (6)	0.836
No Catastrophes								
JHE282	25	High	-.109	-.123 (.202)	1.000	29	—	—
JHE283	33	"	-.092	-.107 (.203)	1.000	33	—	—
JHE284	50	"	-.064	-.081 (.199)	1.000	42	—	—
JHE285	25	Baseline	-.003	-.009 (.104)	0.150	81	30 (16)	0.794
JHE286	33	"	.019	.016 (.090)	0.002	77	51 (11)	0.852
JHE287	50	"	.056	.052 (.086)	0.000	—	58 (4)	0.847
JHE288	25	Low	.028	.026 (.081)	0.002	80	55 (7)	0.875
JHE289	33	"	.052	.049 (.080)	0.000	—	58 (3)	0.866
JHE290	50	"	.092	.088 (.079)	0.000	—	59 (3)	0.843

Table 4-6. Javan Hawk-eagle population viability: Initial population size (N_0) = 60; inbreeding depression (Heterosis model: 3.14 lethal equivalents). See text for definitions of column headings.

File #	% Breeding	Mortality	r_d	r_s (SD)	P(E)	T(E)	N_{100} (SD)	H_{100}
Catastrophes								
JHE291	25	High	-.125	-.142 (.220)	1.000	25	—	—
JHE292	33	"	-.108	-.127 (.222)	1.000	28	—	—
JHE293	50	"	-.080	-.104 (.217)	1.000	33	—	—
JHE294	25	Baseline	-.019	-.037 (.154)	0.748	69	10 (9)	0.703
JHE295	33	"	.003	-.015 (.135)	0.294	78	21 (15)	0.760
JHE296	50	"	.039	.022 (.120)	0.018	73	47 (14)	0.836
JHE297	25	Low	.012	-.004 (.122)	0.140	76	30 (17)	0.814
JHE298	33	"	.035	.021 (.113)	0.010	85	47 (14)	0.847
JHE299	50	"	.075	.057 (.111)	0.000	—	55 (8)	0.846
No Catastrophes								
JHE300	25	High	-.109	-.125 (.197)	1.000	28	—	—
JHE301	33		-.092	-.113 (.202)	1.000	31	—	—
JHE302	50		-.064	-.085 (.197)	1.000	40	—	—
JHE303	25	Baseline	-.003	-.016 (.107)	0.238	80	20 (14)	0.777
JHE304	33	"	.019	.008 (.089)	0.008	90	43 (14)	0.855
JHE305	50	"	.056	.043 (.084)	0.000	—	57 (5)	0.858
JHE306	25	Low	.028	.019 (.079)	0.000	—	51 (10)	0.873
JHE307	33	"	.052	.041 (.078)	0.000	—	57 (5)	0.876
JHE308	50	"	.092	.078 (.076)	0.000	—	59 (3)	0.852

Table 4-7. Javan Hawk-eagle population viability: Initial population size (N_0) = 90; no inbreeding depression. See text for definitions of column headings.

File #	% Breeding	Mortality	r_d	r_s (SD)	P(E)	T(E)	N_{100} (SD)	H_{100}
Catastrophes								
JHE309	25	High	-.125	-.141 (.213)	1.000	28	—	—
JHE310	33	"	-.108	-.125 (.215)	1.000	31	—	—
JHE311	50	"	-.080	-.096 (.210)	1.000	39	—	—
JHE312	25	Baseline	-.019	-.028 (.141)	0.440	75	19 (16)	0.742
JHE313	33	"	.003	-.003 (.121)	0.066	74	48 (26)	0.838
JHE314	50	"	.039	.033 (.115)	0.004	82	79 (15)	0.885
JHE315	25	Low	.012	.007 (.111)	0.030	84	61 (24)	0.882
JHE316	33	"	.035	.030 (.108)	0.000	—	79 (16)	0.898
JHE317	50	"	.075	.071 (.107)	0.000	—	87 (8)	0.890
No Catastrophes								
JHE318	25	High	-.109	-.122 (.195)	1.000	32	—	—
JHE319	33	"	-.092	-.106 (.194)	1.000	37	—	—
JHE320	50	"	-.064	-.082 (.193)	1.000	43	—	—
JHE321	25	Baseline	-.003	-.006 (.090)	0.046	82	45 (24)	0.858
JHE322	33	"	.019	.016 (.082)	0.000	—	78 (13)	0.904
JHE323	50	"	.056	.053 (.081)	0.000	—	88 (5)	0.900
JHE324	25	Low	.028	.026 (.076)	0.000	—	85 (5)	0.916
JHE325	33	"	.052	.050 (.075)	0.000	—	88 (4)	0.908
JHE326	50	"	.092	.090 (.074)	0.000	—	89 (3)	0.893

Table 4-8. Javan Hawk-eagle population viability: Initial population size (N_0) = 90; inbreeding depression (Heterosis model: 3.14 lethal equivalents). See text for definitions of column headings.

File #	% Breeding	Mortality	r_d	r_s (SD)	P(E)	T(E)	N_{100} (SD)	H_{100}
Catastrophes								
JHE327	25	High	-.125	-.141 (.211)	1.000	28	—	—
JHE328	33	"	-.108	-.126 (.209)	1.000	31	—	—
JHE329	50	"	-.080	-.101 (.212)	1.000	38	—	—
JHE330	25	Baseline	-.019	-.035 (.144)	0.580	76	13 (13)	0.750
JHE331	33	"	.003	-.012 (.126)	0.172	80	35 (24)	0.834
JHE332	50	"	.039	.027 (.113)	0.002	89	76 (18)	0.888
JHE333	25	Low	.012	.002 (.111)	0.054	85	54 (25)	0.878
JHE334	33	"	.035	.024 (.107)	0.000	—	73 (19)	0.897
JHE335	50	"	.075	.063 (.106)	0.000	—	85 (9)	0.897
No Catastrophes								
JHE336	25	High	-.109	-.125 (.194)	1.000	32	—	—
JHE337	33	"	-.092	-.108 (.191)	1.000	36	—	—
JHE338	50	"	-.064	-.084 (.185)	1.000	45	—	—
JHE339	25	Baseline	-.003	-.011 (.093)	0.084	88	34 (22)	0.849
JHE340	33	"	.019	.011 (.081)	0.000	—	71 (17)	0.903
JHE341	50	"	.056	.047 (.079)	0.000	—	87 (5)	0.903
JHE342	25	Low	.028	.022 (.074)	0.000	—	82 (9)	0.918
JHE343	33	"	.052	.044 (.073)	0.000	—	87 (5)	0.913
JHE344	50	"	.092	.082 (.072)	0.000	—	89 (3)	0.898

Table 4-9. Javan Hawk-eagle population viability: Initial population size (N_0) = 150; no inbreeding depression. See text for definitions of column headings.

File #	% Breeding	Mortality	r_d	r_s (SD)	P(E)	T(E)	N_{100} (SD)	H_{100}
Catastrophes								
JHE345	25	High	-.125	-.140 (.208)	1.000	32	—	—
JHE346	33	"	-.108	-.123 (.207)	1.000	36	—	—
JHE347	50	"	-.080	-.097 (.202)	1.000	45	—	—
JHE348	25	Baseline	-.019	-.026 (.129)	0.252	80	26 (24)	0.807
JHE349	33	"	.003	-.003 (.114)	0.020	84	77 (44)	0.889
JHE350	50	"	.039	.035 (.109)	0.000	—	136 (22)	0.932
JHE351	25	Low	.012	.007 (.108)	0.012	78	106 (38)	0.927
JHE352	33	"	.035	.031 (.105)	0.000	—	133 (22)	0.937
JHE353	50	"	.075	.071 (.105)	0.000	—	145 (13)	0.932
No Catastrophes								
JHE354	25	High	-.109	-.121 (.186)	1.000	37	—	—
JHE355	33	"	-.092	-.104 (.184)	1.000	42	—	—
JHE356	50	"	-.064	-.079 (.180)	1.000	54	—	—
JHE357	25	Baseline	-.003	-.005 (.081)	0.006	78	76 (38)	0.916
JHE358	33	"	.019	.017 (.077)	0.000	—	136 (16)	0.943
JHE359	50	"	.056	.054 (.076)	0.000	—	147 (6)	0.938
JHE360	25	Low	.028	.027 (.072)	0.000	—	143 (10)	0.949
JHE361	33	"	.052	.050 (.071)	0.000	—	147 (5)	0.945
JHE362	50	"	.092	.090 (.069)	0.000	—	149 (4)	0.935

Table 4-10. Javan Hawk-eagle population viability: Initial population size (N_0) = 200; no inbreeding depression. See text for definitions of column headings.

File #	% Breeding	Mortality	r_d	r_s (SD)	P(E)	T(E)	N_{100} (SD)	H_{100}
Catastrophes								
JHE363	25	High	-.125	-.138 (.201)	1.000	35	—	—
JHE364	33	"	-.108	-.121 (.200)	1.000	39	—	—
JHE365	50	"	-.080	-.097 (.199)	0.998	48	7 (—)	0.704
JHE366	25	Baseline	-.019	-.025 (.124)	0.174	83	33 (32)	0.836
JHE367	33	"	.003	-.002 (.111)	0.008	87	108 (56)	0.921
JHE368	50	"	.039	.036 (.107)	0.000	—	183 (26)	0.948
JHE369	25	Low	.012	.008 (.104)	0.002	94	138 (54)	0.944
JHE370	33	"	.035	.032 (.103)	0.000	—	183 (26)	0.954
JHE371	50	"	.075	.072 (.103)	0.000	—	193 (16)	0.949
No Catastrophes								
JHE372	25	High	-.109	-.121 (.182)	1.000	39	—	—
JHE373	33	"	-.092	-.105 (.181)	1.000	45	—	—
JHE374	50	"	-.064	-.077 (.176)	0.994	59	3 (2)	0.513
JHE375	25	Baseline	-.003	-.004 (.078)	0.002	75	108 (50)	0.939
JHE376	33	"	.019	.018 (.075)	0.000	—	185 (19)	0.958
JHE377	50	"	.056	.054 (.074)	0.000	—	197 (7)	0.953
JHE378	25	Low	.028	.027 (.070)	0.000	—	191 (12)	0.962
JHE379	33	"	.052	.051 (.069)	0.000	—	197 (7)	0.958
JHE380	50	"	.092	.091 (.068)	0.000	—	199 (6)	0.951

Figure Legends

Figure 4-1. Probability of extinction (a) and population size (b) for simulated Javan Hawk-eagle populations with the initial population size and carrying capacity set to 15 individuals and the proportion of successfully breeding adult females set at 33%. The three curves in each figure correspond to the three different levels of age-specific mortality used in the models (see accompanying figure legend). Inbreeding depression is absent from the models shown.

Figure 4-2. Probability of extinction (a) and population size (b) for simulated Javan Hawk-eagle populations with the initial population size and carrying capacity set to 30 individuals and the proportion of successfully breeding adult females set at 33%. The three curves in each figure correspond to the three different levels of age-specific mortality used in the models (see accompanying figure legend). Inbreeding depression is absent from the models shown.

Figure 4-3. Probability of extinction (a) and population size (b) for simulated Javan Hawk-eagle populations with the initial population size and carrying capacity set to 60 individuals and the proportion of successfully breeding adult females set at 33%. The three curves in each figure correspond to the three different levels of age-specific mortality used in the models (see accompanying figure legend). Inbreeding depression is absent from the models shown.

Figure 4-4. Probability of extinction (a) and population size (b) for simulated Javan Hawk-eagle populations with the initial population size and carrying capacity set to 90 individuals and the proportion of successfully breeding adult females set at 33%. The three curves in each figure correspond to the three different levels of age-specific mortality used in the models (see accompanying figure legend). Inbreeding depression is absent from the models shown.

Figure 4-5. Probability of extinction (a) and population size (b) for simulated Javan Hawk-eagle populations with the initial population size and carrying capacity set to 150 individuals and the proportion of successfully breeding adult females set at 33%. The three curves in each figure correspond to the three different levels of age-specific mortality used in the models (see accompanying figure legend). Inbreeding depression is absent from the models shown.

Figure 4-6. Probability of extinction (a) and population size (b) for simulated Javan Hawk-eagle populations with the initial population size and carrying capacity set to 150 individuals and the proportion of successfully breeding adult females set at 33%. The three curves in each figure correspond to the three different levels of age-specific mortality used in the models (see accompanying figure legend). Inbreeding depression is absent from the models shown.

Figure 4-7. Effect of varying different population parameters on the probability of extinction in simulated Javan Hawk-eagle populations. Each bar in the graph gives the probability of extinction averaged over all scenarios with the given parameter value.

Figure 4-1. Initial Population Size = 15

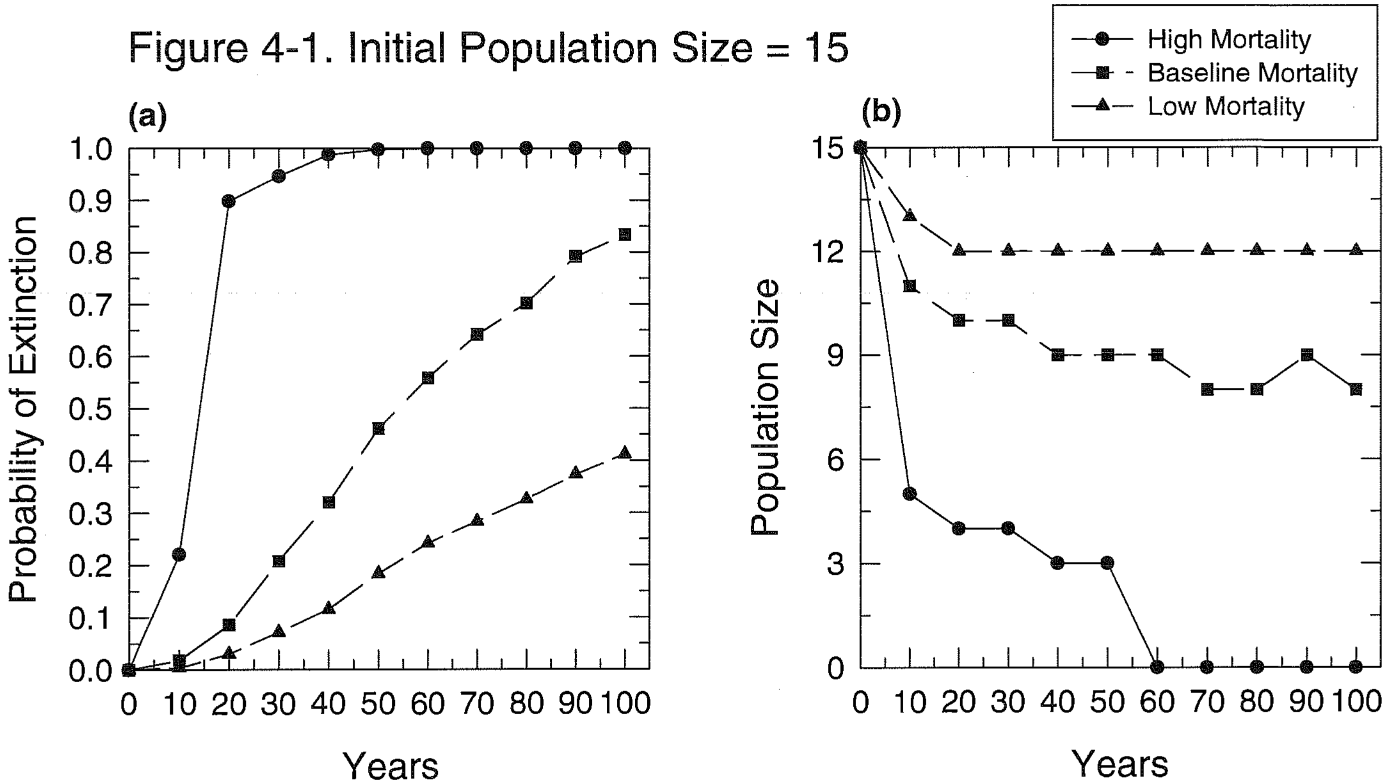


Figure 4-2. Initial Population Size = 30

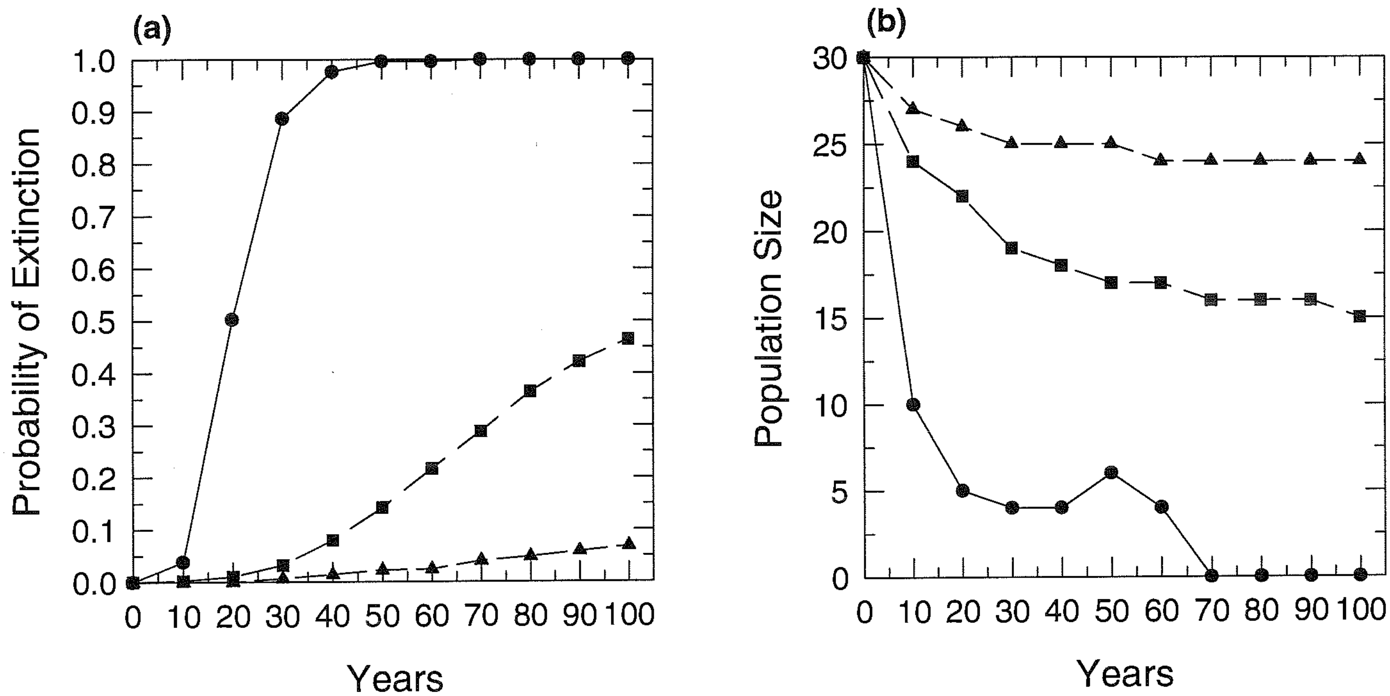


Figure 4-3. Initial Population Size = 60

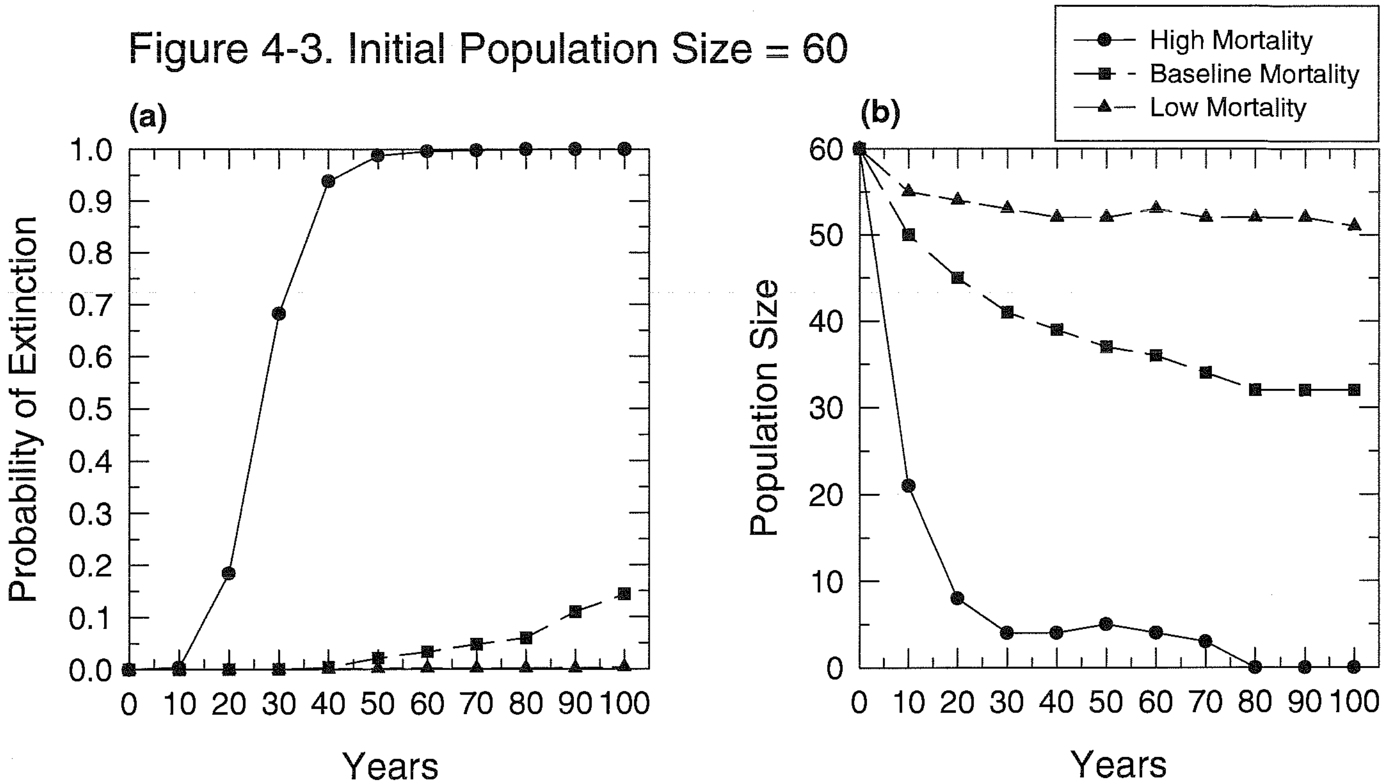


Figure 4-4. Initial Population Size = 90

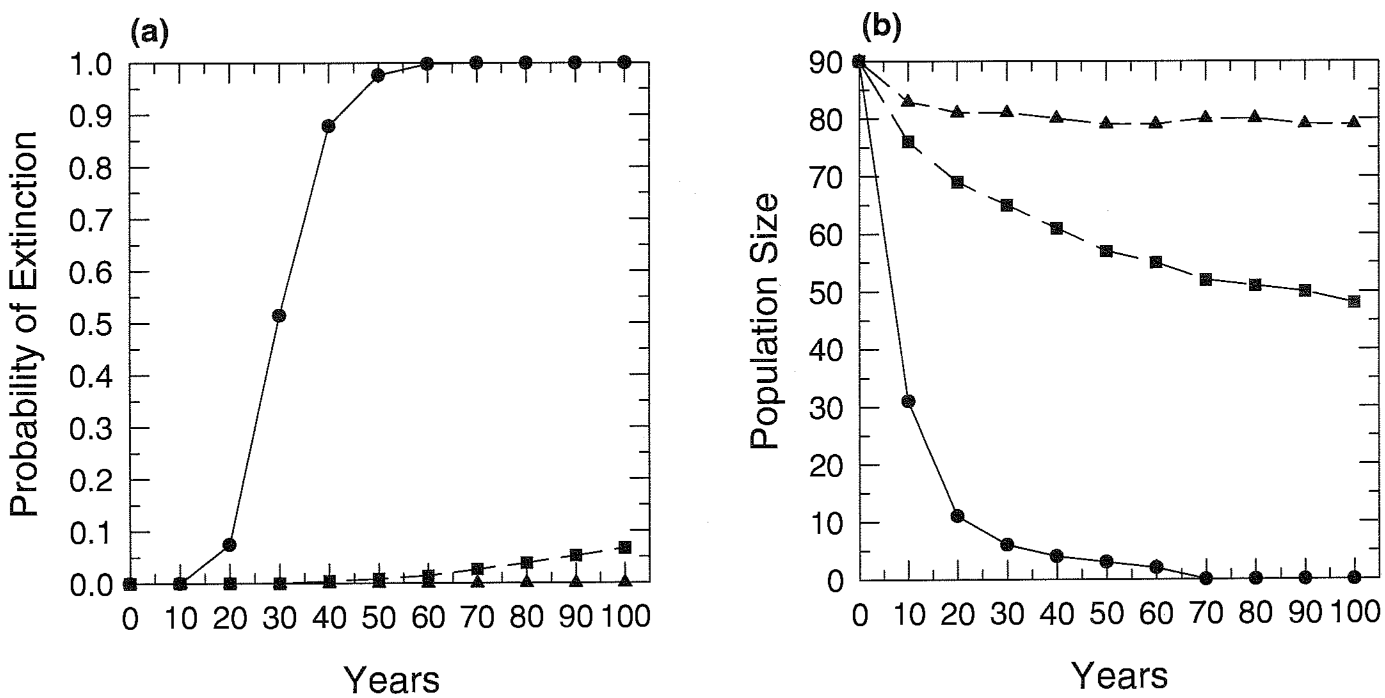


Figure 4-5. Initial Population Size = 150

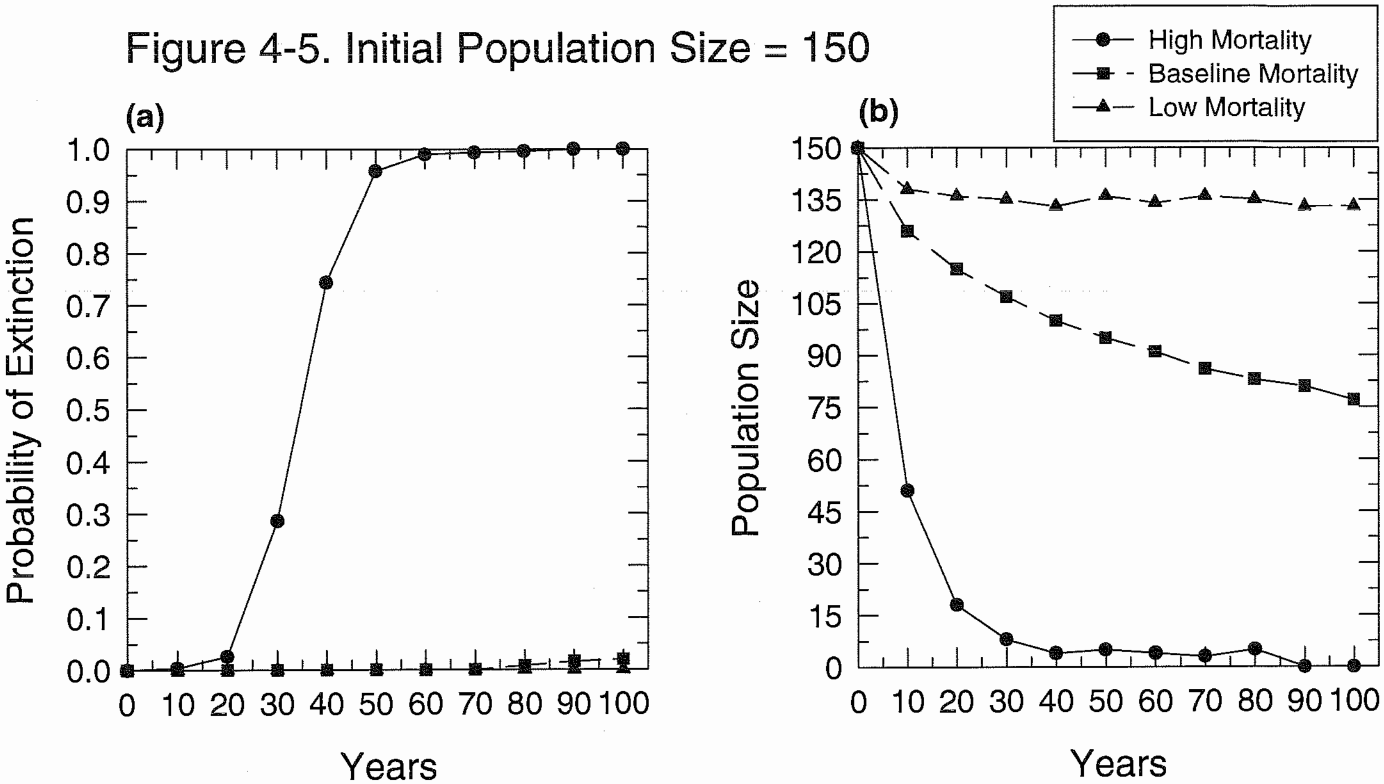


Figure 4-6. Initial Population Size = 200

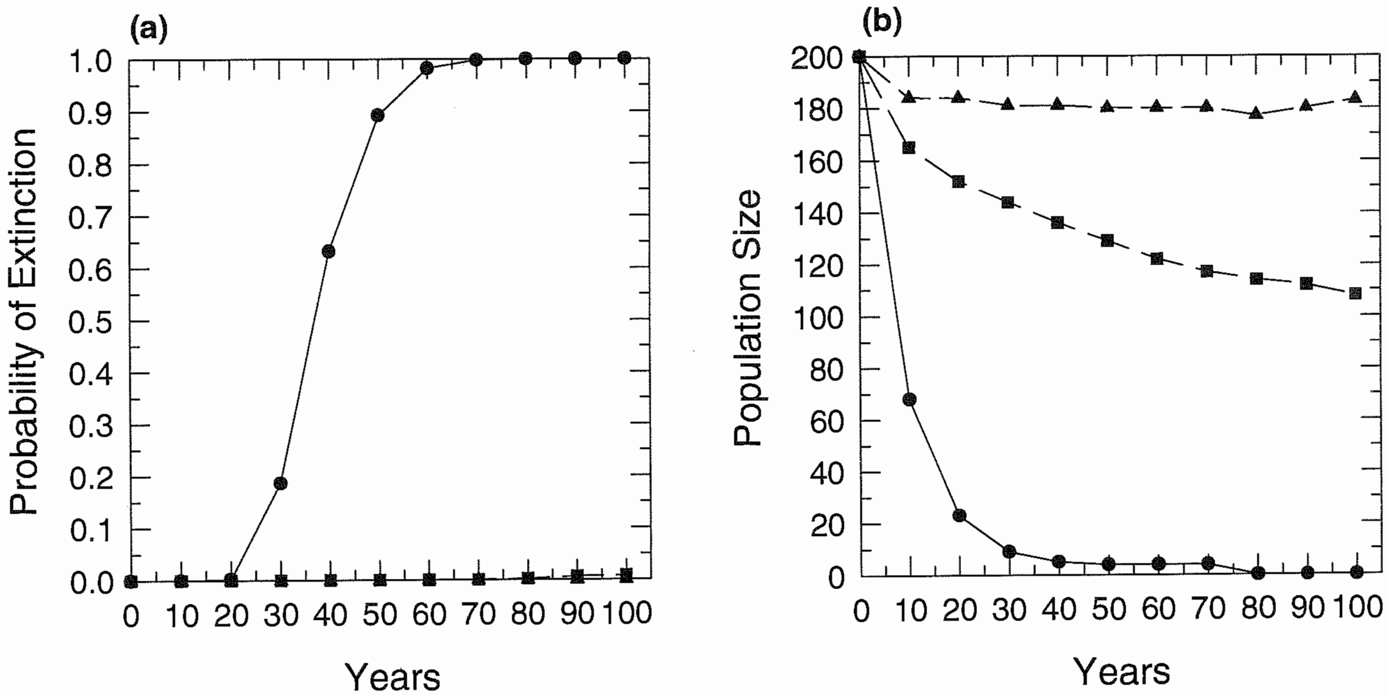
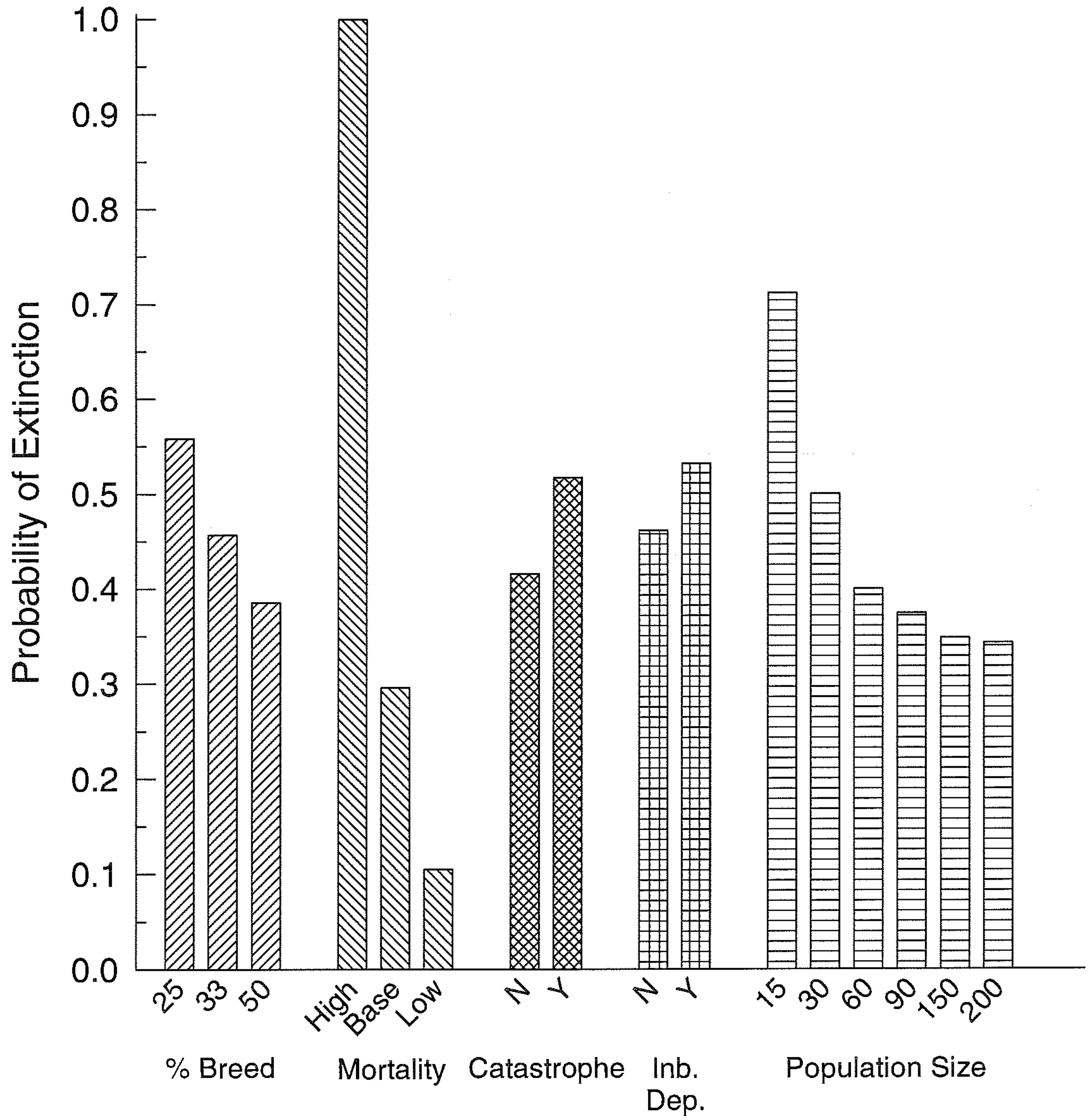


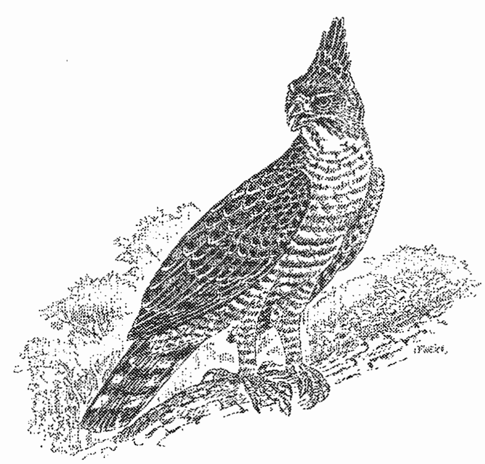
Figure 4-7.
Javan Hawk Eagle Sensitivity Analysis:
Probability of Extinction



POPULATION AND HABITAT VIABILITY ASSESSMENT FOR THE JAVAN HAWK-EAGLE (*Spizaetus bartelsi*)

Taman Safari Indonesia
6 - 8 May 1996

Section 5
Human Issues



HUMAN ISSUES

Working Group Members:
Ir. Dwiatmo Siswomartono, Msc., PHPA
Dr. Ir. Samedi, PHPA
Ir. Wandoyo Siswanto, Msc., Sub Balai KSDA DKI Jakarta
M. Taufan Suranto, FK3I
Hidayat Santosa, Gede Pangrango National Park
Tulus Sibuea, Wetlanda International - Indonesia Program
Sunarto
Lusiana N. Ladjar

I. Two main groups of people

1. Supporting Conservation:
   Management authorities
   Researchers
   NGOs
   Press
   Schools
   Local people
   Zoos
   Local governments
   Breeders

2. Opposed to Conservation
   - Illegal hunters
   - Illegal traders
   - Keepers
   - Poachers
   - Polluters

II. Activities identification (see Table)

RECOMMENDATION

1. Establishment of "Javan Hawk-eagle Foundation".

2. Training for enhancing the knowledge, capability and awareness of public in general on Javan Hawk-eagle conservation.

3. Fund raising for Javan Hawk-eagle conservation activities.

4. Increasing welfare of local communities surrounding Javan Hawk-eagle habitats.

5. Strengthening law enforcement.

6. Consolidation/coordination and integration of related agencies on Javan Hawk-eagle conservation, including land use planning.

7. Dissemination of information.

8. National and international technical coperation for Javan Hawk-eagle conservation.

9. Breeding shall be prioritized.

10. Establishment of information center.

11. Provision of Javan Hawk-eagle research and conservation facilities.

ACTION

1. Training

A. Technical training in wild Javan Hawk-eagle management for:
    1. Field personnel of PHPA
    2. NGO and other PHPA counterparts
    Responsible agencies: PHPA*, Training Center for Forestry Officials

B. Technical training in captive breeding of Javan Hawk-eagle for:
    1. Zoo-keepers
    2. Private breeders
    Responsible agencies: PKBSI*, PHPA

C. Training on conservation aspects of Javan Hawk-eagle for :
    1. Extension workers
    2. Education specialists
    3. School teachers
    Responsible agencies: PHPA*, NGO

2. Implementation of programs on extension and education

A. Campaign on protection of Javan Hawk-eagle through:
    1. Mass Media
    2. Posters, booklets, leaflets, brochures, souvenirs, etc.
    3. Guide book for Javan Hawk-eagle
    Responsible agencies: PHPA*, NGO

B. Production of extension and education materials
    Responsible agencies: PHPA*, NGO, Training Center for Forestry Officials

C. Extension programs directed to:

1. Government officials (including police) in the forms of workshops, seminars, etc.
2. Local communities
3. Park and zoo visitors

D. Encouraging zoos, individual keepers, etc. to prioritized breeding rather than display.

3. Law enforcement

A. Conservation areas/habitat and markets through regular patrols
Responsible agencies: PHPA*

B. Undercover operations
Responsible agencies: PHPA*, Police dept.

C. Integrated operations
Responsible agencies: PHPA*, Police dept.

D. Inventory of bird owners
Responsible agencies: PHPA*, NGO

4. Cooperation

A. Inter-agencies coordination through Coordination meetings (periodical)
Responsible agencies: PHPA*, PKBSI, NGO, Local Government

B. Technical cooperation among agencies on captive and wild population development & management (including cooperation with international institutions)
Responsible agencies: PHPA*, PKBSI, NGO

5. Promotion of local community welfare

A. Assisting local communities to increase income through development of activities such as: honey bee culture, silk-worm culture, social forestry and handicrafting.

B. Involving local people in conservation activities such as ecotourism, tourist interpretation, etc.

6. Provision of facilities

A. Provision of research and survey equipment

B. Construction of research stations and huts.
Responsible agencies: PHPA*

7. Establishment of Javan Hawk-eagle Foundation

A. Developing a board of directors.

B. Funding

C. Establishment of information and communication center

D. Promoting research and development

E. Promoting education, training and extension.
Responsible agencies: Workshop participants

* Leading agency

II. Activities identification

People Group	Activities	Problem	Approach
I. Positive			
1. Local wildlife management	Protection and safe-guarding of conservation areas and species. Education, extension.	-Human Resources -Funding -Expertise	-Training, facilities provision , welfare (incentive-disincentive) -Fund-raising, Gov. budget -Expertise -Press, establishing foundation for Javan Hawk-eagle and consortium -Technical assistance -Comparative study
2. Researchers	Research, survey,	-Funding	-Fund-raising, government budget, Technical cooperation -Dissemination of publication
3. NGOs	Community awareness Survey/assessment	-Funding -Human Resources -Legitimation of activity	-Self fund raising, technical cooperation -NGO Networking and coperation -Communication between govt-NGO
4. Press	Community awareness	-Limitation of information	-Dissemination of information and communication -Public based fund raising through mass media
5. Schools	Environmental education	-Not included in school curriculum	-Cooperation between PHPA-Ministry of education on environmental education -Strenghtening the capability of nature lovers and conservation cadres -Provision on reseach facilities by govt. -Provision of education materials, training for school teachers
6. Local community	-Tradition -Sustainable farming -Awareness	-Lack of education and knowledge -Subsistence life	-Strenghtening the capability of nature lovers in local community -Creating job opportunities
7. Zoos	-Ex-situ conservation -Education/extension -Research	-Funding -Human Resources	-National/international network between zoos -Breeding as first priority rather than exhibition -Pro-active management

People Group	Activities	Problem	Approach
8. Local gov.	-Community guidance -Law enforcement -Education and extension	-Information -Human resources -Knowledge	-Intersectoral coordination in law enforcement -Provision of information materials
9. Breeders	-Breeding	-Human resources -Knowledge	-Increasing breeding capability of Javan Hawk-eagle -Cooperation between national/international breeders/zoos
II. Negative			
1. Illegal hunters	-Hunting for sale -Hunting for consumption -Hunting for hobby	-Demand -Economic problems -Lack of control -Limitation of knowledge -License for hunting and legal weapon	-Education and law enforcement -Creating job opportunities
2. Illegal traders	-Trading	-Valuable -High demand -Lack of control -Lack of law enforcement	-Education and law enforcement
3. Bird Keepers	-Owner keeping as hobby -Trading	-Prestige -Hobby -Value -Economic pressure	-Education and law enforcement
4. Poachers	-Wood collecting, wild caught -Farming	-Economic pressure -Lack of law enforcement	-Education and law enforcement
5. Polluters	-Pests and disseases control -Industry	-Intensive farming	-Education and law enforcement
6. Developers	-Habitat conversion	-Lack of law enforcement -Policy inconsistency	-Education and law enforcement -Coordination -Land use planning

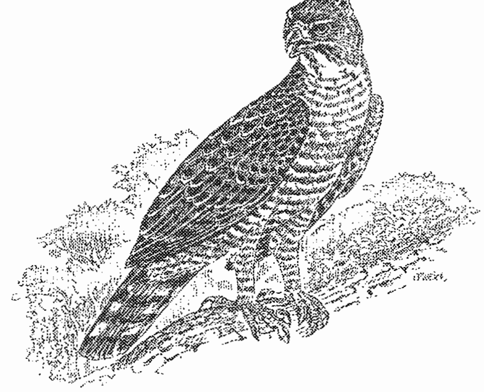
Time Table for Recommended Action

No.	Action Program			Year			Remarks
		1	2	3	4	5	
1.	Establishment of Javan Hawk-eagle Foundation (JaHe Foundation)	*********					Immediately after the workshop
2.	Training	*********	********				High priority for both in-situ and ex-situ conservation
3.	Extension and education	*********	********	*********	********	*********	-
4.	Law enforcement	*********	********	*********	********	*********	-
5.	Technical cooperation	*********	********	*********	********	*********	Foreign assistance prioritized
6.	Promotion of local community welfare			*********	********	*********	Integrated activities among govt. agencies
7.	Provision of facilities for research and conservation activities		********	*********			First phase should be provided by the govt.

POPULATION AND HABITAT VIABILITY ASSESSMENT FOR THE JAVAN HAWK-EAGLE (*Spizaetus bartelsi*)

Taman Safari Indonesia
6 - 8 May 1996

Section 6
Javan Hawk-Eagle
Captive Population Management



JAVAN HAWK-EAGLE CAPTIVE POPULATION MANAGEMENT

Working Group Members:
Jansen Manansang (chair), Taman Safari Indonesia
Haris W. Arafin, KpB Prenjak
Dan Cassidy, Omaha's Henry Doorly Zoo
Oscar Effendi
Firman
Jiri Holba, Taman Safari Indonesia
Budi Irawanto, Kebun Binatang Ragunan
Sharmy Prastiti, Taman Safari Indonesia
Dedi Ruswandi,Kebun Binatang Ragunan
Sudharto, Kebun Binatang Surabaya
Sulistami
Toni Sumampouw
Ismu Sutanto Suwelo
Endang Budi Utami, Taman Burung TMII

Introduction

The Javan Hawk-eagle, endemic to Java, Indonesia and protected by law, is tentatively listed by the IUCN as critically endangered. Wild populations are estimated to be 80-108 pairs. There are currently 7 birds in only two zoos in Indonesia, one in a private collection and an estimated 10 in local bird markets for a total of 19 birds thought to be in captivity. All of these birds are of unknown sex. None of the current population appears to have been bred in captivity and none has produced offspring. It may be possible to collaborate with private holders of birds and it is imperative to bring all of the birds from the bird market into the captive management program.

There are seven zoos on the island of Java, one birdpark in Java and Bali, Indonesia that are member of the Perhimpunan Kebun Binatang Se-Indonesia (PKBSI-Indonesian Zoological Parks Association) and all may be willing to participate in a propagation and management program for the Java Hawk-eagle. The PKBSI has already established a similar program for the Sumatran tiger (*Panthera tigris sumatrae*), which can serve as a model for the Javan Hawk-eagle.

Javan Hawk-Eagle Captive Management Program in the PKBSI

A minimum of 20 reproducing pairs in not less than two locations will be required to achieve the goal of initiating a long term captive management program. Today, zoos in many regions of the world are organizing well-planned and tightly coordinated programs for captive management to meet the above goals. In North America these programs are called Species Survival Plans (SSP), in Europe they are the European Endangered Species Programs (EEP) and in Australasia they are the Australasian Species Management Programs (ASMP). China, Japan, India, Thailand, Malaysia, Phillippines and Indonesia have equivalent programs and more are being developed worldwide.

An official captive management program is designed to reinforce, not replace, wild populations. All too often the general public expects individuals of endangered species at their local zoo to be released back into the wild. This is not the case. Rather, the captive population needs to be perceived as a reservoir of genetic material (that represents the species, not just individuals) that can periodically be used to re-establish populations that have been lost within their natural range or to revitalize wild populations that have become depressed by genetic and demographic problems.

A master plan is the core of the captive management program. This document provides institution by institution and animal by animal recommendations on mate selection, animal relocations (from zoo to zoo for better breeding combinations), breeding and surplusing (a euphemism denoting the animal is no longer needed for breeding, either for genetic or demographic reasons), and finally, technical and financial support for programs that advance the conservation of the Javan Hawk-eagle in its natural range.

Summary Recommendations

I. Sexing, Identification, and Record-Keeping

The highest priority should be given to sex identification and permanent individual identification and record keeping for all Javan Hawk-eagles in captivity. First, a vet proficient in laparascopic sexing of birds of prey should be brought to Java to sex all birds currently in captivity and train zoo personnel in sexing techniques. At the same time medical training pertinent to birds of prey could be exchanged. All birds should be given permanent IDs using implant transponder (Trovan system) and leg bands should be placed right in the male and left in the female. All details regarding origin of wild caught Javan Hawk-eagle and supporting documents should be included as part of the animals permanent records.

II. Training

As already mentioned, sexing of birds is the highest priority and hands-on-training in this area is crucial to the long term captive management of this species. Other areas of training of equal importance, but less urgent, are artificial insemination techniques, artificial incubation and hand rearing techniques and record keeping.

Experts in these fields should be invited to Indonesia to conduct training courses. Eventually staff from Indonesian zoos, universities and PHPA staff will take part in training courses at facilities, outside of Indonesia, that specialize in captive management of birds of prey.

III. Facilities

Breeding centers should be established in at least two facilities to avoid losing a large proportion of the known captive population to a catastrophic event such as volcanic eruption or disease outbreak. Currently Taman Safari Indonesia houses 6 Javan Hawk-eagles.

Breeding facilities should have three solid sides (wood, concrete, or other), one side barred or slatted, top should be wire fabric or net, with 4X4 cm openings (small enough to keep birds from getting their heads stuck).

Approximately half of the top should provide shade.

Recommended dimensions for breeding enclosures are 6 m long, 4 m wide and 2.5 m height. The floor should be sloped for drainage and of gravel or dirt and vegetation, not concrete. Perches should be natural branches of various diameter and placed at different heights. A small pool also should be provided for bathing. Each breeding enclosure should have a 1 m^2 nest platform approximately 2 m above ground level and in a shaded corner of the enclosure.

Where possible feeding should take place from outside the enclosure. A double entry system for each enclosure will reduce the likelihood of accidental escape. Breeding pairs should not have visual contact with other Javan Hawk-eagles.

Display facilities can be more spacious to appeal to the public but display birds should be those least likely to reproduce in captivity, such as juveniles or birds with behaviour problems. Displays should be accompanied by educational graphics, indicating the birds endangered status, and collaboration between zoos and government agencies.

A separate quarantine facility should be provided for all newly acquired birds.

A husbandry manual will need to be developed by the Javan Hawk-eagle Management Program and distributed to all facilities holding The Javan Hawk-eagle.

IV. Pairing and Exchange of Birds

The PKBSI will establish a master plan, the Javan Hawk-eagle Captive Management Program, and will appoint a Javan Hawk-eagle studbook keeper to maintain the captive database. This person would report annually to the PKBSI on the total numbers, births, deaths and transfers in the captive population.

Pairing and exchange of birds will follow the recommendations of the Javan Hawk-eagle Captive Management Program.

All birds should be evaluated for breeding potential; based on the type of rearing, certain individuals may be more likely to become breeders than others and resources should be devoted to birds with the highest potential for breeding.

V. Feeding, Husbandry and Medical Aspects

Current feeding strategies are whole, eviscerated chicken once per day. This seems to be adequate. An occasional mouse or lizard may provide some variety but the need for a varied diet does not seem to be indicated at this time.

Routine beak and talon maintenance may become necessary and the training courses mentioned earlier will address these concerns. Birds should be weighed on an opportunistic basis to avoid stress, e.g. if there is a need or medical problems.

Behavioural observations should be made and kept as part of the birds permanent records. In light of the paucity of knowledge of the bird's natural history, all biological and behavioral information will most likely be useful.

VI. Assisted Reproduction

Assisted reproduction will no doubt be crucial to the long term propagation of this species. Limited fecundity and assumed low breeding potential for the current captive population suggest artificial insemination, double clutching, and artificial incubation and hand-rearing as a potential means to increase reproductive rates to increase the size of the captive population. Hand-reared birds will not be produced for re-introduction. As mentioned previously in this document, hands-on-training and exchange of technical information will be a crucial part of this program.

VII. Reintroduction

If reintroduction of captive Java Hawk-eagles becomes a viable possibility, detailed prerelease quarantine, prerelease conditioning, and post release monitoring protocols need to be developed prior to release.

VIII. International Collaboration

This captive breeding program is intended to be international in scope. Although all known Javan Hawk-eagles in captivity are currently in Indonesia, it is the hope of this program to involve experts in birds of prey from all over the world.

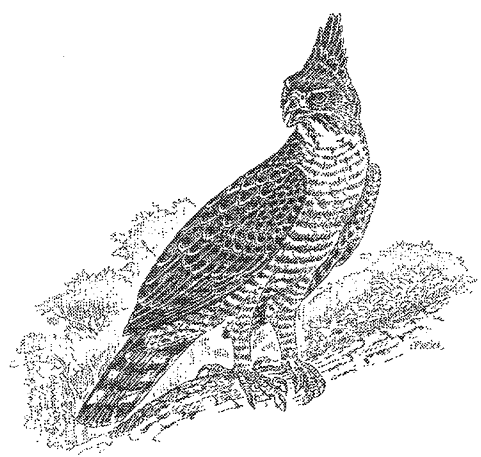
IX. Annual Captive Program Review

The captive breeding program should be reviewed on an annual basis. This review process should include input from other zoos, bird of prey facilities, field scientists and PHPA participants.

POPULATION AND HABITAT VIABILITY ASSESSMENT FOR THE JAVAN HAWK-EAGLE (*Spizaetus bartelsi*)

Taman Safari Indonesia
6 - 8 May 1996

Section 7
Appendix I.
Workshop Participants List



JAVAN HAWK-EAGLE PHVA WORKSHOP PARTICIPANTS

Achmad Abdullah
Sub Balai KSDA Jabar II
Jl. Baru Kertasari 11. Ciamis
Tel: 0265-773549

Haris W. Arifin
kpB Prenjak - Himakova
Kampus 1PB Darmaga
PO Box 168, Bogor
Tel/Fax: 621677, 634424

Indra Arinal
Sub balai KSDA Jawa Timur II
Jl. Jawa No. 36
Jember
Tee: 0331-85079

Nadjmatun Baroroh
Balai KSDA Jawa Barat
Jl. Sukarno Hatta 751 km. 11,2
Bandung 40292
Tel: 022-309367

Daniel Cassidy
Omaha's Henry Doorly Zoo
3701 South 10th Street
Omaha NE 68107-2200 USA
Tel: 1-402-733-8401
Fax: 1-402-733-4415

Oscar Effendy
KpB Biosphere
Fakultas Biologi Universitas gajah Mada
Jl. Teknika Selatan
Sekip Utara
Yogyakarta 55281

Rustam Effendi
Jl. Delima IV/9 Tanjung Duren
Jakarta 11470
Tel: 021-5685382

Firman
Jl Tebet Barat Dalam X E/13
Jakarta Selatan 12810

James W. Grier
Zoology Dept., Stevens Hall
Bolley Drive
North Dakota State University
Fargo ND 58105-5517 USA
Tel: 1-701-231-8444
Fax: 1-701-231-7149

Suwarno Hadisusanto
Laboratory of Ecology
Faculty of Biology UGM
Yogyakarta 55281
Tele: (027?) 902-260

Hapsoro
Telapak Indonesia
Jl. Sempur Kaler No. 16
Bogor
Tel: 0251-320792
Fax: 0251-622202

Jiri Holba
Taman Safari Indonesia
Jn. Raya Puncak 601
Bogor 16750, Indonesia

Faustina Ida
PHPA Manggala Wanabakti
Blok 7, LT 7
Jl. Gatot Subroto
Jakarta, Indonesia
Tel/Fax: 62-021-5720227

M. Indrawan
Conservation Int'l - Indonesia Program
Jalan H. Samali Raya #51
Jakarta 12051
Tel: 799-3955; 794-7731

Budi Irawanto
Kebun Binatang Ragunan (Ragunan Zoo)
Jl. Harsono Rm. No. 1 Ragunan
Jakarta 12550
Tel: (021) 780-6975
Fax: (021) 780-5280

Tubagus M. Ischak
Jurusan Biologi
Fakultas Matematik Dan Pengetahuan Alam
Universitas Indonesia, Kampus Depok
Depok 16424
Fax: 786-3431
Tel: 727-0163

Istanto D.
Sub Balai KSDA Jawa Tengah
Jl. Menteri Supeno I/2
Semarang
Tel: 024-414750

Paul Jepson
BirdLife Internatinal-Indonesia Program
P.O. Box 310/Boo
Bogor 16001 Indonesia

Lusiana Nogo Ladjar
Jl. Lobi-Lobi I/19
Jakarta 12520
Tel: 780-5608
Jl. Arteri RT005/06 No. 15
Jakarta 12150
Tele: 722-7951

Jansen Manansang
Taman Safari Indonesia
Cisarua, Bogor 16750
Indonesia
Tel: 62-0251-253222
Fax: 62-0251-253555

Ani Mardiastuti
Dept of Forest Resources Conservation
Faculty of Forestry
Bogor Agricultural University
PO Box 168 Bogor 16001
Tel: 62-251-621947
Fax: 62-251-621256
E-mail aniipb@indo.net.id

Philip Miller
Conservation Breeding Specialist Group
12101 Johnny Cake Ridge Road
Apple Valley MN 55124-8151 USA
Tel: 1-612-431-9325
Fax: 1-612-432-2757
E-mail: cbsg@epx.cis.umn.edu

Sharmy Prastiti
Taman Safari Indonesia
Jn. Raya Puncak 601
Bogor 16750, Indonesia

Dedi Ruswandi
Kebun Binatang Ragunan (Ragunan Zoo)
Jl. Harsono Rm. No. 1 Ragunan
Jakarta 12550
Tel: (021) 780-6975
Fax: (021) 780-5280

Samedi
Directorate General PHPA
Manggala Wanabakti Blg.
Block 7, 7th floor
Jl. Gatot Subroto
Jakarta
Tel/Fax : 62-21-5720227

Hidayat Santosa
Gede Pangrango National Park
Jl. Raya Cibodas
P.O. Box 3 Sindanglaya
Cipanas - Cianjur 42353

Ulysses Seal
Conservation Breeding Specialist Group
12101 Johnny Cake Ridge Road
Apple Valley MN 55124-8151 USA
Tel: 1-612-431-9325
Fax: 1-612-432-2757
E-mail: cbsg@epx.cis.umn.edu

Iwan Setiawan
Birdlife International - Indonesia Programme
Jl. A. Yani No. 11
Bogor
Tel/Fax: 0251 - 333254

Tulus T.H. Sibuea
Wetlands International - Indonesia Programme
Jl. Arzimar III/17
P.O. Box 254
Bogor 16002
Tel: 0251-312189
Fax: 0251-325755

Wandojo Siswanto
Sub Balai KSDA DKI Jakarta
Jl. Salemba Raya no. 16
Jakarta Pusat
Tel/Fax: 021-3904402

Dwiatmo Siswomartono, Direktur
Bina Kawasan Suaka Alam dan
Konservasi Flora Fauna -- PHPA
Manggala Wanabakti Bldg. 8th Fl
Jl. Gatot Subroto
Jakarta Indonesia

Sudharto PH
Kebun Binatang Surabaya
Jl. Setail 1. Surabaya
Jawa Timur
Tel: (031) 578703

Mr. Tony Sumampau
Taman Safari Indonesia
Jl. Raya Puncak No. 601
Cibeurem Cisarua 16750
Bogor, Java Barat Indonesia
Tel: 62-251-4422
Fax: 62-251-328225

Sunarto
Jl. Satrio Wibowo Selatan 44
Purwotomo
Solo
Fax: 0271-715500

M. Taufan Suranto
FK3I, Jl. Menado No. 32 Bandung
Tel/Fax: 022-431930
E-mail : men32@melsa.net.id
Jl. Pekalongan 3
Bandung 40291

Sutandi
Sub BKSDA Jawa Barat
Jl. Gede Bage Selatan No. 117
Bandung
Tel/Fax: 767715

Endang Budi Utami
Taman Burung TMII (TMII Bird Park)
Jakarta 13560
Tel: 840-1722, 840-9282
Fax: 840-1722

Asrama Vidasa
Jl. Tawangsari CT II/F-10
Yogyakarta 55281

Th. Candra Wasis
KpB Biosphere
Fakultas Biologi Universitas Gajah Mada
Jl. Sekip Utara
Yogyakarta 55281

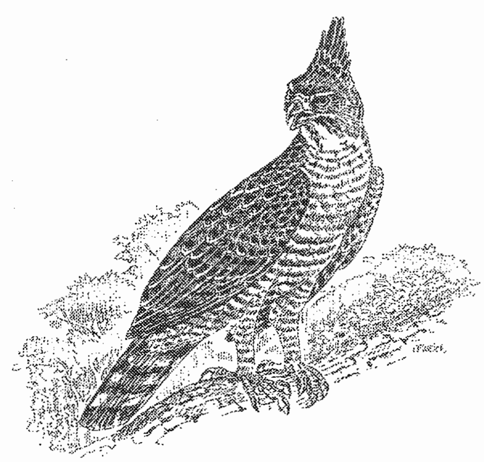
IGN. Pramana Yuda
Fak. Biologi, Universitas Atma Jaya
Yogyakarta
Jl. Babarsari 44, Yogyakarta 55281
Tel: 0274-565411
Fax: 565258
Kutilang Birdwatching Club
Jl. Kaliurang Km 6
Gy. Pandega Maharsi 9
Yogyakarta 55281

Ratna Yuniawati
Jl. Kober Rt 002/03 No. 1
Ponjok Cina Depok 16424
Tele: 786-3630
Majalah Unggas Indonesia
Jl. Mesjid Bendungan 1 No. 6
Cawang 111 Jak - tim
Tele: 809-0980

POPULATION AND HABITAT VIABILITY ASSESSMENT FOR THE JAVAN HAWK-EAGLE (*Spizaetus bartelsi*)

Taman Safari Indonesia
6 - 8 May 1996

Section 8
Appendix II.
References and Workshop Presentations



General Literature

Amadon, D. 1953. Remarks on the Asiatic Hawk-eagles of the genus *Spizaetus*. Ibis 95:492-500.

Andrew, P. 1985. An annotated checklist of the birds of the Cibodas-Gunung Gede Nature Reserve. Kukila 2:10-28.

van Balen, S. 1991. The Java Hawk-Eagle *Spizaetus bartelsi*. WWGBP project report No. 1, March 1990. Birds of Prey Bulletin 4:33-40.

van Balen, S. 1996. Javan Hawk-eagle (*Spizaetus bartelsi*): threatened species assessment series No. 1. PHPA/BirdLife International - Indonesia Programme. Bogor.

van Balen, S. And B.-U. Meyburg. 1994. The Java Hawk-Eagle *Spizaetus bartelsi*: results of recent research on distribution, status and ecology. Pages 89-92 in: Meyburg, B.-U. And R.D. Chancellor, eds. Raptor Conservation Today. WWGBP and The Pica Press.

van Balen, S., D. Dewi, and P.R.; Jepson. 1994. Observations at a Java Hawk-eagle nest. Tropical Biodiversity 2:329-331.

Bartels, E. 1931. Vogels van Kole beres. Nat. Wet. Tijdschr. Ned. Ind. 91:308-348.

Bartels, M. 1924. Waarnemingen omtrent *Spizaetus cirrhatus limnaetus* Horsf. en *Spizaetus nipalensis kelaarti* Legge op Java. Jaarb. Cl. Ned. Vogelk. 14:11-21.

Bartels, M.E.G. 1923. Neues aus Java. Orn. Monatsber. 31:54-57.

Bishop, K.D. 1989. In: Roberts, C. Recent reports. O.B.C. Bulletin 7:34-40.

Collar, N.J., M.J. Crosby and A.J. Stattersfield. 1994. Birds to Watch 2. The World List of Threatened Birds. BirdLife Conservation Series No. 4. Cambridge.

Delsman, H.C. 1926. Vogelleven in het oerbosch. I. Trop. Natuur 15: 193-197.

Finsch, O. 1908. Ein neuer Irrgast für Java (*Spizaetus kelaarti* Legge). Orn. Monatsber. 16:44-45.

Grier, J.W. 1980. Modeling approaches to Bald Eagle population dynamics. Wildlife Society Bulletin 8(4): 316-322.

Grier, J.W. 1991. Importance of survival rates for populations of long-lived, slowly reproducing organisms. Poster presented at Wildlife 2001: Populations, Oakland, CA (reprints available on request).

Grier, J.W., and J.H. Barclay. 1988. Dynamics of founder populations established by reintroduction. In T.J. Cade, J.H. Enderson, C.G. Thelander and C.M. White. Peregrine Falcon Populations. Peregrine Fund, Boise, ID.

Hellebrekers, W.Ph.J. and A. Hoogerwerf. 1967. A further contribution to our ecological knowledge of the island of Java (Indonesia). Zool. Verh. 88:1-164.

Hoogerwerf, A. 1948. Contribution to the knowledge of the dostribution of the birds on the island of Java. Treubia 19:84-137.

Hoogerwerf, A. 1949. De avifauna van jibodas en omgeving, inclusief het natuur-monument Tjibodas-G. Gede. Bogor, West Java.

Kooiman, J.G. 1940. Mededeelingen over het voorkomen in Oost-Java van enkele voor dit gewest nog niet in de literatur genoemde vogels. Ardea 29:98-108.

Kooiman, J.G. 1941. Vogels van het Ijang-Hoogland. Irena 1:9-18.

Kuroda, N. 1936. The birds of the island of Java. Vol. 2: Non-Passerines. Kuroda, Tokyo.

Madrid, J.A. 1991. Reproductive biology and behaviour of the Ornate Hawk-eagle (*Spizaetus ornatus*) in Tikal National Ppark. Pages 93-113 in: Whitacre, D.F., W.A. Burnham, and P.J. Jenny, eds. Progress Report IV, Maya Project, Boise, Idaho: The Peregrine Fund.

Meyburg, B.-U., S. van Balen, J.M. Thiollay, and R.D. Chancellor. 1989. Observations on the endangered Java Hawk Eagle *Spizaetus bartelsi.* Pages 279-299 in: Meyburg, B.-U. and R.D. Chancellor, eds. Raptors in the Modern World. WWGBP, Berlin, London, and Paris.

Nijman, V. And R. Sözer. 1995. Conservation action plan for the Javan Hawk-eagle. First Draft. PHPA/BirdLife International - Indonesia Programme. Bogor.

Nijman, V. and R. Sözer. 1996. Conservation of the Javan Hawk-eagle and other endemic bird species on Java: Priority areas for conservation in Central Java. Bogor: PHPA/BirdLife International - Indonesia Programme (Technical Memorandum No. 11).

Richards, G. and L. Richards. 1988. Java and Bali, 26th June to 23rd July 1988. Birdwatchers' report.

Rozendaal, F.G. 1981. De bijdragen van M.E.G. bartels (1871-1936) en zijn zoons Max Jr. (1902-1943), Ernst (1904-1976) en Hans (geboren 1906) tot de kennis van de avifauna van de Indische archipel. Biohistorisch Inst. Der Rijksuniversitet, Utrecht.

Schlegel, H. 1866. De vogels van Nederlansch Indië. Valkvogels.

Sody, H.J.V. 1956. De Javaanse bosvogels. Maj. Ilmu Alam Ind. 112:153-170.

Sody, H.J.V. 1989. Diets of Javanese birds. Pages 164-221 in: Becking, H.J. Henri Jacob Victor Sody (1892-1959). His life and work. Brill, Leiden.

Sözer, R. and V. Nijman. 1995a. Behavioural ecology, distribution and conservation of the Javan Hawk-eagle *Spizaetus bartelsi* Stresemann, 1924. Verslagen en Technische Gegevens No. 62. Inst. Syst. and Pop. Biol., Un. of Amsterdam.

Sözer, R. and V. Nijman. 1995b. The Javan Hawk-eagle: New information on its distribution in Central Jawa and notes on its threats. Trop. Biodiversity 3:49-55.

Stresemann, E. 1924. Raubvogelstudien. J. f. Orn. 72:429-446.

Stresemann, E. 1938. *Spizaetus alboniger* (Gmelin.) und *Spizaetus nanus* Wallace, zwei fälschlich vereinigte Arten. J. f. Orn. 86:425-431.

Stresemann, E. and D. Amadon. 1979. Order Falconiformes. Pages 271-425 in: Mayr, E. and G.W. Cottrell, eds. Check-list of the Birds of the World. Vol. 1. Harvard University Press, Cambridge.

Sujatnika, and P.R. Jepson. 1995. Priority proposed protected areas for the conservation of global biodiversity in Indonesia. Bogor: PHPA/BirdLife International - Indonesia Programme (Memorandum Teknis No. 3).

Thiollay, J.-M. and B.-U. Meyburg. 1988. Forest fragmentation and the conservation of raptors: survey on the island of Java. Biol. Conservation 44:229-250.

Tobias, J. and L. Phelps. 1994. Sumatra, Java and Bali. A report of birds and mammals recorded in the Greater Sundas. Birdwatchers' report.

UNDP/FAO. 1982. National conservation plan for Indonesia, Vol. III: Java and Bali. Bogor, Indonesia: Food and Agriculture Organization of the United Nations (Field Report 36).

Beberapa Masukan Untuk Rencana Pemulihan Populasi Elang Jawa (*Spizaetus bartelsi*)[1]

Haris W. Arifin[2] dan Ani Mardiastuti[3]

Abstrak

Berdasarkan survey terbaru yang dilakukan oleh Sözer dan Nijman (1995), dugaan populasi Elang Jawa yang tersisa adalah 81-108 pasang. Apabila dibandingkan dengan luasan hutan primer yang tersisa di Pulau Jawa dan untuk mempertahankan kelangsungan hidup burung ini di masa datang, maka dipandang perlu untuk meningkatkan populasi Elang Jawa hingga mencapai jumluh optimum. Makalah ini mengetengahkan beberapa masukan dalam upaya pemulihan populasi Elang Jawa di habitatnya. Pembahasan bertitik tolak dari faktor-faktor yang menjadi pembatas (*limiting factors*) bagi Elang Jawa. Kemampuan reproduksi yang rendah, fragmentasi habitat, kompetisi dengan burung pemangsa lain, dan tekanan dari luar (gangguan manusia) adalah contoh-contoh dari faktor pembatas di atas. Upaya penetapan kawasan konservasi yang terpadu, penciptaan kondisi lingkungan yang mendukung perkembangbiakan burung ini, pemantauan populasi Elang Jawa dan pemantauan kompetitor serta satwa mangsa (*prey*) merupakan upaya-upaya yang dapat dilakukan untuk memulihkan populasi Elang Jawa. Disamping itu, perlu dibarengi dengan kebijaksanaan konservasi eks-situ, penelitian dan pendidikan serta penyuluhan pada masyarakat (*public awareness*). Semua usaha di atas harus memperoleh dukungan dari berbagai pihak, baik berupa dukungan moril, kebijakan, sarana dan prasarana maupun dukungan finansial yang memadai.

Pendahuluan

Bertepatan dengan hari Lingkungan Hidup Dunia ke-18 pada tanggal 5 Juni 1990, Presiden Republik Indonesia menetapkan Melati (*Jasminum sambac*) sebagai puspa bangsa, Anggrek Bulan (*Phalaenopsis amabilis*) sebagi puspa pesona dan Padma Raksasa (*Rafflesia arnoldi*) sebagai puspa langka. Untuk melengkapi identitas bangsa, maka pada tanggal 10 Januari 1993 ditetapkan pula tiga satwa nasional yaitu Komodo (*Varanus komodoensis*) sabagai satwa nasional, ikan Siluk Merah (*Scherophagus formosus*) sebagai satwa pesona, dan Elang Jawa sebagai satwa langka (Widyastuti, 1993).

Penetapan Elang Jawa sebagai satwa langka merupakan hal yang tepat karena burung ini mengingatkan bangsa Indonesia akan Lambang Negaranya (Burung Garuda) dan karena kelangkaan serta keunikannya. Elang Jawa sebagai salah satu ragam hayati yang hanya dimiliki

---

[1]Makalah pada Lokakarya Population and Habitat Viability Analysis tentang Burung Elang Jawa *Spizaetus bartelsi*, Hotel Safari Garden, Cisarua-Bogor, 6-8 Mei 1996.

[2]Mahasiswa Konservasi Sumberdaya Hutan, Fakultas Kehutanan IPB dan Anggota Kelompok Pemerhati Burung (kpB *PRENJAK*) HIMAKOVA IPB.

[3]Staf Pengajar pada Jurusan Konservasi Sumberdaya Hutan, Fakultas Kehutanan IPB, P.O. Box. 168 - Bogor 16001.

oleh Indonesia perlu dijaga kelestariannya. Tulisan berikut mengetengahkan beberapa saran untuk program pemulihan populasi Elang Jawa.

Bio-Ekologi Elang Jawa

Secara taksonomi, Elang Jawa termasuk marga Spizaetus, suku Acciptridae. Secara lengkap, klasifikasi burung ini adalah:

Filum	:Chordata
Anak Filum	:Vertebrata
Kelas	:Aves
Bangsa	:Falconiformes
Suku	:Accipitridae
Anak Suku	:Aquilinae
Marga	:Spizaetus
Jenis	:*Spizaetus bartelsi* (Widyastuti, 1993)

Elang ini berukuran besar (60 cm) dengan jambul menonjol. Burung dewasa memiliki ciri-ciri sebagai berikut: berjambul, mahkota dan garis kumis (sungut) hitam; bagian sisi kepala dan tengkuk merah coklat; punggung dan sayap coklat gelap; ekor coklat bergaris-garis hitam; kerongkongan putih dengan bagian tengah bergaris-garis hitam, bagian bawah lainnya keputih-putihan bergaris merah sawo matang. Burung yang belum dewasa keputih-putihan atau kemerah-merahan pada begian bawahnya dan tanpa garis atau coretan (MacKinnon, 1990).

Pengetahuan tentang status dan distribusi Elang Jawa amat minim. Perkiraan populasi Elang Jawa saat ini adalah 81-108 pasang (Sözer dan Nijman, 1995). Penyebaran burung ini terbatas de Pulau Jawa, yaitu: Ujung Kulon, Gn. Halimun, Gn. Salak, Gn. Gede Pangrango, Gn. Papandayan, Gn. Patuha, Gn. Segara, Karanganyar, Gn. Slamet, Gn. Besar, Gn. Prahu, Gn. Merapi, Gn. Wilis, Gn. Arjuno, Gn. Iyang, TN. Meru Betiri, Kalibaru, Ijen dan TN. Alas Purwo (Sözer dan Nijman, 1994).

Daerah jelajah burung ini bervariasi antara 1200 dan 3000 ha. Dalam kondisi habitat yang tidak optimal, ukuran home range mungkin lebih besar (Sözer dan Nijman, 1994). Seperti halnya karnivor lain, burung ini memangsa burung-burung besar dan mamalia seperti ayam hutan, kelelawar buah dan musang (MacKinnon, 1990).

Musim perkembangbiakan tercatat pada bulan Mei hingga Agustus (MacKinnon, 1990). Sedangkan menurut Sözer dan Nijman (1994), musim breeding antara akhir November sampai Agustus. Sebagian besar, sarang ditemukan pada pohon rasamala (*Altingia excelsa*) dengan jumlah telur sebanyak satu buah. Telur ini akan menetas setelah 47 hari dierami oleh induk betina. Pembesaran anak membutuhkan waktu antara 11-13 minggu namun burung muda tetap tergantung pada orangtuanya hingga berumur 1,5 tahun. Dewasa kelamin diperkirakan setelah berumur tiga tahun.

Rencana Pemulihan Populasi Elang Jawa

Rencana pemulihan Elang Jawa (*Spizaetus bartelsi*) yang akan diuraikan bertitik tolak dari faktor-faktor yang menjadi pembatas bagi kehidupan Elang Jawa. Faktor-faktor pembatas tersebut selengkapnya dapat dilihat pada gambar 1. Tahapan-tahapan yang diusulkan adalah:

1. Kegiatan Penelitian Dan Pendidikan;
2. Konservasi In-Situ;
3. Konservasi Ex-Situ.

Tehapan kegiatan penelitian dan pendidikan berupa penelitian dasar tentang masalah-masalah yang berkaitan dengan bio-ekologi Elang Jawa dan pendidikan serta latihan. Hal ini perlu dilakukan mengingat pengetahuan tentang spesies ini masih minim, sehingga pengamatan dan penelitian harus lebih diintensifkan. Beberapa hal yang perlu memperoleh perhatian utama adalah kepastian populasi Elang Jawa, penyebaran, tipe-tipe habitat yang disukai dan kondisi biologu secara umum. Program pendidikan dan pelatihan bertujuan untuk menghasilkan tenaga-tenaga ahli Elang Jawa yang kompeten. Tenaga ahli ini sedapat mungkin merupakan tenaga lapangan setempat yang memperoleh pelatihan khusus. Tenaga ahli dapat didatangkan dari berbagai lembaga penelitian atau universitas atau dengan cara tukar menukar informasi dengan tenaga ahli luar negeri yang telah berhasil dalam pengelolaan spesies elang yang memiliki kekerabatan dekat dengan Elang Jawa.

Kegiatan konservasi in-situ merupakan upaya-upaya untuk mengatasi faktor-faktor pembatas bagi Elang Jawa. Tindakan yang dapat dilakukan dibagi lagi berdasarkan jenis faktor pembatas. Usulan tindakan tersebut adalah:

1. Usulan Untuk Mengatasi Kendala Habitat:
   a. Perlunya penetapan kawasan konservasi di Pulau Jawa yang dapat menjamin kelangsungan hidup Elang Jawa.
   b. Kawasan konservasi harus terpadu sehingga tidak tercipta fragmentasi habitat yang mengakibatkan terdapatnya populasi-populasi kecil yang terpisah.
   c. Perlu dipertimbangkan untuk membuat menara pengamatan, memelihara jalan setapak dalam areal konservasi sehingga memudahkan pemantauan populasi Elang Jawa.
   d. Melindungi pohon rasamala (*Altingia excelsa*) atau pohon lain yang digunakan sebagai tempat bersarang bagi Elang Jawa.
   e. Menciptakan habitat yang disukai oleh Elang Jawa pada daerah dimana tidak ditemukan populasi burung tersebut, sehingga menarik perhatian populasi Elang Jawa dari tempat lain.
   f. Mencegah terjadinya degradasi dutan akibat pembukaan lahan secara liar dengan cara penetapan tapal batas kawasan konservasi yang jelas dan penerapan sanski yang tegas bagi penyerobotan lahan.

2. Usulan Untuk Mengatasi Kendala Biologi
   a. Memantau populasi Elang Jawa secara terus menerus.
   b. Menciptakan kondisi yang mendorong berlangsungnya proses biologis dan fisiologis Elang Jawa sebagaimana mestinya.

3. Usulan Untuk Mengatasi Kendala Ekologi
   a. Pemantauan secara ketat beredarnya pestisida-pestisida yang tidak dapat diuraikan secara biologis karena sebagai karnivor puncak, Elang Jawa mempunyai berpotensi tercemar pestisida akibat akumulasi dari satwa mangsanya.
   b. Pemantauan populasi spesies yang diduga menjadi kompetitor Elang Jawa dan spesies-spesies uang menjadi mangsanya yang secara langsung atau tidak langsung berpengaruh terhadap fluktuasi populasi Elang Jawa.

4. Usulan Untuk Mengatasi Tekanan Dari Luar (Gangguan Manusia)
   a. Memperketat penjagaan kawasan dari pencurian terutama pada musim perkembangbiakan Elang Jawa.
   b. Menerapkan sanski hukum yang pasti dan tegas terhadap pelanggar atau pencuri dalam kawasan konservasi.
   c. Menumbuhkan dan menanamkan rasa memiliki kawasan konservasi bagi masyarakat di sekitarnya melalui penyuluhan dan pengikutsertaan masyarakat dalam upaya pengelolaannya.
   d. Menanamkan pengertian kepentingan keberadaan Elang Jawa sebagai satwa endemik yang hanya ada di daerah tertentu saja sehingga masyarakat setempat mempunyai kebangaan atas keberadaan burung ini dan timbul rasa memiliki yang tinggi.
   e. Mencegah penduduk agar tidak menebang pohon rasamala dan pohon lain yang berpotensi sebagai pohon sarang dengan cara mengalihkan pada pohon komersial lain.
   f. Menjadikan penduduk sebagai pemandu (*guide*) bagi turis/peneliti yang ingin mengamati kehidupan Elang Jawa di suatu kawasan.
   g. Penduduk sekitar kawasan konservasi Elang Jawa mempunyai royalti terhadap produk-produk yang berkaitan dengan Elang Jawa sebagai kompensasi atas penjagaan kawasan oleh penduduk setempat.

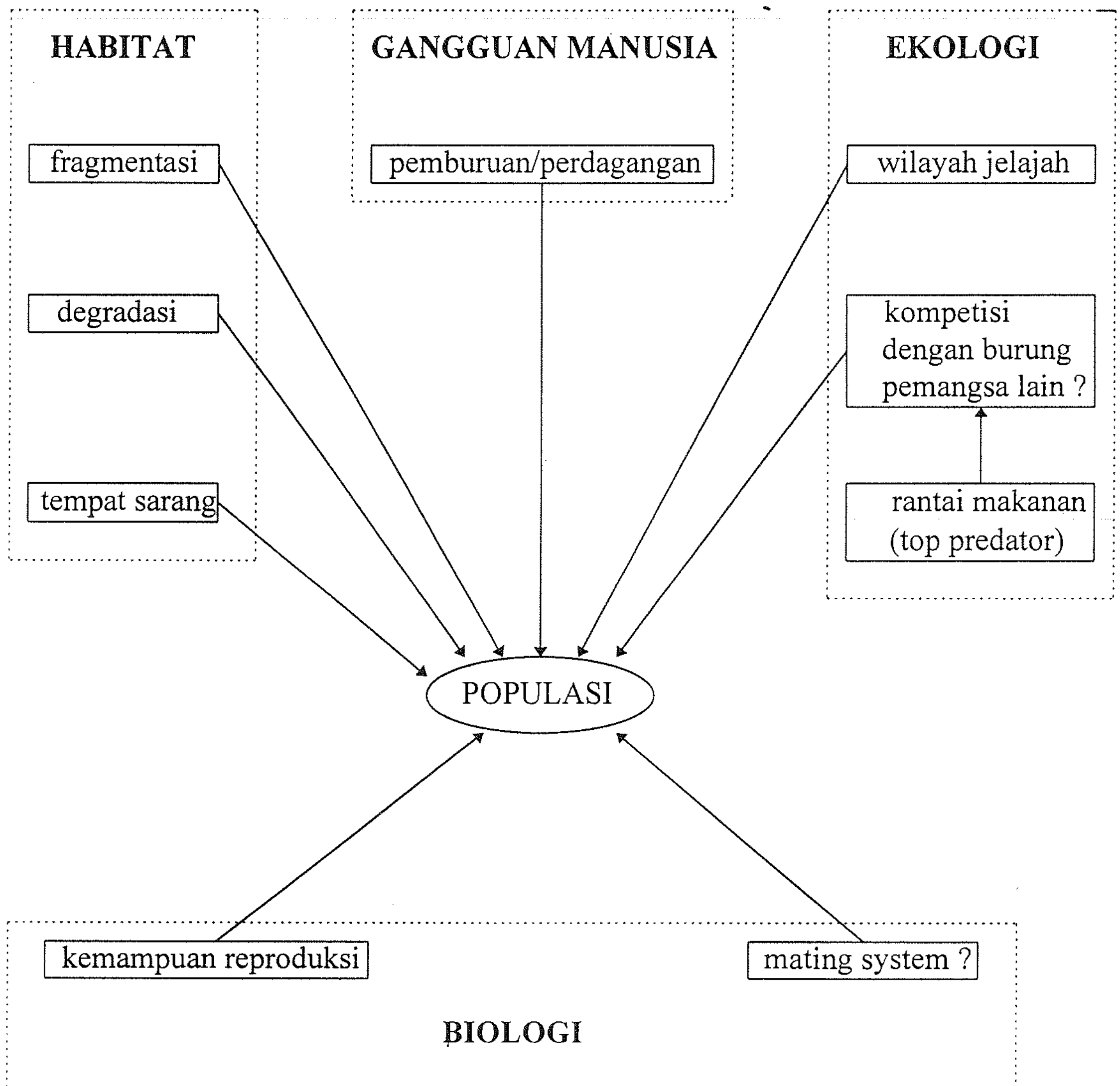
Kebijakan konservasi eks-situ uang dapat dilakukan antara lain adalah menampung Elang Jawa hasil sitaan pada tempat khusus yang telah ditunjuk (misalnya: kebun binatang, taman safari), mengembangkan teknik-teknik pengembangbiakan Elang Jawa yang diawasi secara ketat dan program aksi lain yang ditujukan lanhsung pada masyarakat luas. Program aksi tersebut, antara lain adalah:

a. Kampanye besar-besaran demi pelestarian Elang Jawa untuk anak-anak hingga orang dewasa ke seluruh penjuru tanah air.
b. Bekerjasama dengan pihak indistriawan agar mencantumkan gambar Elang Jawa pada setiap produknya sehingga dikenal masyarakat.
c. Pribadi-pribadi yang memiliki Elang Jawa diarahkan dan ditanamkan pengertian bahwa pemeliharaan hanya boleh dilakukan melalui upaya penangkaran sehingga populasi Elang Jawa meningkat dan kepuasan pribadi penangkar terpenhui. Hal ini diawasi secara ketat oleh instansi terkait (PHPA).
d. Pengawasan yang lebih ketat terhadap perdagangan burung ini dan disertai penerapan sanski hukum yang tegas.
e. Pencegahan pengambilan Elang Jawa oleh pihak luar negiri apabila tidak disertai dengan alasan yang kuat dan jelas, sehingga Elang Jawa hanya dimiliki oleh Bangsa Indonesia.

Penutup

Seluruh usulan di atas tidak akan terlaksana dengan baik tanpa dorongan dan bantuan dari segala pihak. Pihak pemerintah (PHPA), kalangan peneliti, kalangan swasta (taman safari, eksportir burung) dan masyarakat luas harus sepakat dalam menjalankan segala program yang berkaitan dengan upaya pemulihan populasi Elang Jawa. Segala upaya harus didukung dengan sarana dan prasarana yang memadai dan dukungan finansial yang kuat. Dukungan finansial ini dapat diperoleh melalui sumber-sumber dana sebagai berikut:

a. Dana reboisasi yang dibayar oleh HPH.
b. Sebagian dari asset kekayaan perusahaan besar di Indonesia (konglomerat).
c. Denda yang dikenakan pada perusahaan yang mencemari lingkungan.
d. Pajak dari perusahaan yang bahan bakunya berasal dari sumber-sumber alam yang tanpa pengolahan lebih lanjut dapat langsung dipasarkan (misal perusahaan air mineral, penambangan pasir).



Gambar 1. Faktor Pembatas Populasi Elang Jawa (dimodifikasi dari Mardiastuti, 1996).

Kendala Biologi dan Ekologi Dalam Pelestarian Elang Jawa[1]

Ani Mardiastuti[2]

Abstrak

Dalam melakukan pelestarian diperlukan informasi yang berkaitan dengan faktor pembatas (*limiting factors*). Faktor pembatas ini dapat berhubungan dengan kondisi habitat, biologi, maupun gangguan yang disebabkan oleh manusia. Dalam makalah ini akan diuraikan beberapa kendala penting dalam upaya pelestarian Elang Jawa (*Spizaetus bartelsi*), khususnya yang berkaitan dengan aspek biologi, ekologi dan kondisi habitat. Secara alamiah, Elang Jawa memiliki beberapa karakteristik yang berpotensi sebagai kendala. Laju *survival*nya rendah sehingga pertumbuhan populasi sangat lambat. Posisinya pada rantai makanan tertinggi (*top predator*), dikaitkan dengan kemungkinan adanya pencemaran pestisida, diduga berperan pula dalam menurunkan populasi. Populasi yang kecil dan terpecah-pecah akibat habitat yang terfregmentasi selanjutnya akan menyebabkan *inbreeding* dan mengakibatkan peningkatan keseragaman genetik. Kebutuhan makrohabitatnya sangat spesifik, yaitu hutan hujan dataran rendah atau dataran tinggi yang masih utuh. Tipe hutan semacam ini sudah semakin sedikit. Kebutuhan tempat untuk bersarang diduga juga spesifik, sehingga hanya tempat-tempat tertentu saja yang dapat dipakai untuk berbiak. Jenis ini juga memerlukan wilayah jelajah yang relatif luas. Selain itu, Elang Jawa juga merupakan spesies pulau (*island species*) yang hanya ditemukan di Pulau Jawa. Sifat endemik ini menyebabkan Elang Jawa sangat tergantung pada habitat hutan yang tersisa di Pulau Jawa.

Pendahuluan

Identifikasi kendala sebagai faktor pembatas suatu jenis satwa merupakan tahapan awal untuk melakukan pelestarian jenis tersebut. Elang Jawa (*Spizaetus bertelsi* Stresemann 1924) termasuk satwa endemik dan langka yang perlu dilestarikan. Populasi jenis elang ini sudah semakin sedikit dan diduga terus menurun dari waktu ke waktu.

Banyak faktor yang terkait dengan penyebab kelangkaan jenis ini. Beberapa jenis satwaliar, termasuk Elang Jawa secara alami memiliki karakteristik yang mudah langka atau mudah punah. Dalam makalah ini akan dibahas beberapa sifat ekologi dan biologis yang potensial untuk menjadi hambatan atau kendala dalam melakukan pelestarian Elang Jawa. Mengingat bahwa pengetahuan tentang Elang Jawa hingga kini masih sangat terbatas, beberapa aspek bio-ekologi ini mungkin masih bersifat spekulasi.

---

[1]Makalah pada Lokakarya Population and Habitat Viability Analysis tentang Burung Elang Jawa *Spizaetus bartelsi*, Hotel Safari Garden, Cisarua-Bogor, 6-8 Mei 1996.

[2]Staf Pengajar pada Jurusan Konservasi Sumberdaya Hutan, Fakultas Kehutanan IPB, P.O. Box. 168 - Bogor 16001.

Penjabaran kendala ini tidak dimaksudkan menyurutkan langkah kita untuk melestarikan Elang Jawa. Dari uraian makalah ini, diharapkan dapat ditentukan tindakan yang tepat untuk melakukan konservasi. Kendala-kendala non-alami lain yang berkaitan dengan gangguan manusia dan kesadaran masyarakat untuk melestarikan Elang Jawa tidak dibahas dalam makalah ini.

Kendala-Kendala Alamiah

Fragmentasi dan Degradasi Habitat

Populasi Elang Jawa telah dicoba untuk diestimasi. Kompilasi data terakhir (van Balen 1996, Nijman and Sözer 1995, Sözer dan Nijman 1995a) memberikan angka 81 hingga 108 pasang dengan kemungkinan tambahan 23 hingga 31 pasang lagi pada tempat-tempat yang belum sempat diteliti. Setengah (40-53 pasang) dari populasi ini terdapat di Jawa Timur khususnya di Taman Nasional Meru Betiri dan Cagar Alam G. Kawi/Arjuno. Sepertiganya (28-37 pasang) dijumpai di Jawa Barat, khususnya di kompleks hutan Taman Nasional G. Halimun/Hutan Lindung G. Salak, sedangkan sisanya (13-18 pasang) terdapat di Jawa Tengah, terutama di Hutan Lindung G. Besar/G. Perahu dan Cagar Alam G. Slamet.

Populasi Elang Jawa ini menyebar pada 15 lokasi dengan ukuran wilayah hunian bervariasi antara 50 hingga 500 km^2 (Sözer dan Nijman 1995a). Wilayah yang kecil juga berarti bahwa daerah dedalaman (*interior*) relatif kecil dibandingkan dengan luasan wilayah tepian (*edge*). Jadi sesungguhnya luasan habitat yang efektif akan lebih sempit dari luasan wilayah hunian Elang Jawa.

Pada saat mangsa sulit diperolah dari wilayah jelajahnya, kemungkinan Elang Jawa akan mengembara ke luar wilayah jelajahnya. Jika kebetulan daerah tersebut rawan terhadap perburuan, maka elang lebih mudah terlihat manusia, sehingga lebih rentan terhadap perburuan.

Selatnya bila hutan hunian Elang Jawa terganggu (ukurannya berkurang atau kualitasnya menurun), maka dapat dipastikan bahwa populasi elang di tempat itu tidak dapat bertahan dan kemungkinkan besar akan punah secara lokal. Migrasi ke tempat lain hampir tidak memungkinkan meningat jarak antar lokasi cukup jauh.

Kebutuhan Habitat dan Tempat Bersarang

Elang Jawa menempati habitat hutan hujan dataran rendah dan dataran tinggi yang masih utuh, hingga pada ketinggian 3.500m (van Balen 1996; Nijman dan Sözer 1995; Sözer dan Nijman 1995a). Van Balen (1996) memperkirakan hutan di Jawa masih cocok untuk habitat Elang Jawa tinggal seluas 5.230 km^2 (terdiri dare 2.590 km^2 hutan dataran rendah dan 2.640 km^2 hutan pegunungan).

Dari pengemetan Sözer dan Nijman (1995a) diketahui pula bahwa Elang Jawa ini ditemuka pada hutan hujan dataran rendah Taman Nasional Ujung Kulon dan di lokasi-lokasi lain di Jawa Timur. Agaknya Elang Jawa ini dapat pula hidup di dataran rendah. Namun hutan hujan dataran rendah Jawa kebanyakan tidak ter*cover* dalam jaringan kawasan konservasi, sehingga Elang Jawa terdesak ke tempat-tempat lebih tinggi yang kebetulan merupakan kawasan konservasi.

Tempat bersarang diketahui (n = 4) adalah pohon Rasamala (*Altingia excelsa*) (van Balen 1994; Sözer dan Nijman 1995a). Pemilihan Rasamala ini diduga karena jenis pohon ini tinggi, mempunyai batang bebas cabang yang tinggi pula dan memiliki penutupan tajuk yang cukup lebat (Sözer dan Nijman 1995a). Belum diketahui apakah Elang Jawa menggunakan jenis pohon lain untuk bersarang. Mengingat bahwa penyebaran Rasamala terutama hanya di Jawa Barat, kemungkinan besar pohon jenis lain dengan karakteristik yang serupa dipakai sebegai tempat bersarang (khususnya di Jawa Tengah dan Timur).

Dari pengamatan terdahulu (Sözer dan Nijman 1995a; van Balen et al. 1994) terungkap pula bahwa pohon yang dipakai lebih tinggi (*emergent*) dari pohon lain di sekitarnya. Bersarang pada tempat tinggi akan menguntungkan bagi Elang Jawa yang mempunyai kebiasaan terbang melayang (*soaring*). *Emergent trees* ini seringkali tidak ditemukan pada suatu wilayah, khususnya bila ketinggian kanopi hampir seragam.

Inbreeding

Seperti telah disebutkan terdahulu, populasi jenis ini terpecah-pecah menjadi 15 sub-populasi. Masing-masing lokasi dihuni oleh 1 hingga 16 pasang, dangan modus sekitar 4-6 pasang (Sözer dan Nijman 1995a; van Balen 1996). Setiap lokasi ini terpisah satu sama lain (terfragmentasi), sehingga tidak memungkinkan sub-populasi tersebut saling berinteraksi.

Rendahnya sub-populasi pada setiap lokasi memberikan implikasi genetika yang kurang menguntungkan. Kemungkinan besar akan terjadi perkawinan antar burung yang memiliki kekerabatan yang sangat dekat (*inbreeding*). Pada beberapa penelitian terhadap satwaliar dalam penangkaran, *inbreeding* ini menimbulkan keseragaman genetik (homozygositas) dan dapat menyebabkan penurunan jumlah keturunan, penurunan daya hidup dan mengacaukan keseimbangan sex ratio (Gall 1987).

Dari informasi yang masih terbatas ini belum dapat disimpulkan adanya *inbreeding* pada Elang Jawa. Satu hal yang dapat dipastikan adalah bahwa peluang terjadinya inbreeding ini menjadi lebih tinggi pada populasi yang kecil.

Wilayah Jelajah

Sözer dan Nijman (1995a) memperkirakan wilayah jelajah Elang Jawa bervariasi antara 12 km^2 (Gede-Pangrango) hingga 33 km^2 (Gunung Slamet). Sedangkan untuk Elang Jawa di Alas Purwo, estimasi wilayah jelajah oleh Meyburg et al. (1989) adalah seluas 124 - 155 km^2.

Informasi mengenai *overlapping* wilayah jelajah antar pasangan Elang Jawa masih belum diketahui, demikian pula tentang perilaku teritorial. Dengan asumsi wilayah jelajah rata-rata 40 km^2 dan satu sama lain tidak overlap, maka luasan hutan Jawa (yang diasumsikan cocok untuk Elang Jawa, 5.230 km^2) hanya mampu mendukung 130 pasang.

Burung pemangsa cenderung mempunyai wilayah jelajah (*home range*) yang luas. Secara umum dapat dikatakan bahwa jenis burung pemangsa yang mempunyai ukuran tubuh besar cenderung memiliki wilayah jelajah yang lebih luas. Craighead dan Craighead (1969) lebih lanjut menyatakan bahwa topografi, distribusi dan tipe vegetasi, serta distribusi dan kepadatan mangsa sangat mempengaruhi ukuran, bentuk dan pola wilayah jelajah.

Bila suatu habitat mempu menyediakan komponen-komponen habitat, terutama makanan dan tempat bersarang, maka wilayah jelajah tiap pasang dapat dipersempit sehingga lokasi tersebut dapat dihuni lebih banyak elang. Dari luasan wilayah jelajah pada setiap lokasi dapat ditentukan prioritas pengelolaan habitat. Habitat Elang Jawa di Alas Purwo, misalnya, agaknya kurang baik jika dibandingkan dengan Gede Pangrango.

Laju Survival

Elang Jawa secara alamiah memiliki laju *survival* sangat rendah. Jenis burung ini diketahui mencapai dewasa setelah berumur tiga sampai empat tahun dan dipercayai pula berbiak hanya sekali dalam dua atau tiga tahun. Jumlah telur hanya satu butir, dierami selama 46 - 48 hari. Setalah anakan lahir, anakan tersebut tinggal dangan kedua orang tuanya sampai satu hingga satu setengah tahun. Elama itu sang anak masih sangat tergantung pada induknya (van Balen 1996; Nijman dan Sözer 1995; Sözer dan Nijman 1995a).

Dengan laju pertumbuhan populasi yang sangat rendah ini, diperkirakan bahwa dalam satu tahun populasi Elang Jawa hanya dapat bertambah 30 anakan (Sözer dan Nijman 1995b) hingga 50 anakan (van Balen 1996). *Survivorship* (kemampuan hidup) untuk setiap kelas umur dan jenis kelamin belum diketahui. Jenis burung pada umumnya tergolong ke dalam kurva *survivorship* tipe II, yaitu memiliki peluang mati yang tetap (*constant*) untuk setiap kelas umur.

Kemampuan maksimum untuk berbiak dan bertahan hidup sesungguhnya dapat dipelajari dari penelitian di penangkaran. Pada saat ini diketahui hanya terdapat 6 ekor Elang Jawa di penangkaran (Taman Safari Indonesia dan Kebun Binatang Surabaya) (Sözer dan Nijman 1995a) dan belum ada yang mempu berbiak. Dengan demikian belum dapat dipastikan penyebab kemampuan berbiak yang rendah ini: karena rendahnya kemampuan biologis atau kualitas habitat yang tidak memadai.

Top Predator dan Pestisida

Pada rantai mekanan dalam suatu ekosistem, Elang Jawa merupakan *top predator*. Posisi sebagai predator ini membutuhkan kemampuan fisik yang selalu prima untuk memburu mangsa. Jika kemampuan berburu menurun, misalnya karena cedara, elang ini tidak dapat bertahan hidup.

Posisi pada titik akhir dari rantai mekanan ternyata juga merugikan jika pada habitat tersebut telah tercemar pestisida. Pestisida terbukti ampuh membunuh hama, khususnya serangga. Sayangnya pestisida ini juga membunuh jenis-jenis *non-target* lainnya dan terkait dalam sistem rantai makanan yang kompleks. Pada rantai makanan sederhana, pestisida dapat saja masuk ke dalam tubuh burung pemangsa melalui rute: ulat-burung kecil-burung pemangsa.

Pestisida yang mengandung organochlorin (misalnya Aldrin Chlordane, DDT, Endrin, Lindane) telah terbukti merugikan satwaliar. Disamping berfungsi sebagai racun, bahan kimia ini sangat stabil, sehingga dapat bertahan lama tanpa terurai di lingkungannya. Selain itu, bahan kimia ini juga larut dalam lemak sehingga dapat terakumulasi dalam tubuh satwa. Pada dosis rendah juga dapat mengganggu pembiakan jenis-jenis burung tertentu (Newton 1988).

DDT - organochlorin yang pertama dan yang umum dijumpai - sesungguhnya tidak beracun untuk burung. Namun turunan kimianya, yaitu DDE, terbukti menyebabkan penipisan cangkang telur (Newton 1988) karena manghambat enzym carbonat anhidrase didalam kelenjar kulit telur burung (Ekha 1988).

Pengaruh pestisida terdahap Elang Jawa masih belum diketahui. Di negara-negara lain di benua Eropa dan Amerika Salatan, pestisida terbukti mengurangi populasi burung-burung pemangsa seperti Peregrine Falcon, Sparrowhawk, Sharp-shinned Hawk, Cooper's Hawk, Osprey, dan Bald Eagle karena menurunkan daya tetas (Newton 1988).

Pestisida telah lama digunakan oleh petani Indinesia untuk membasmi hama. DDT, misalnya, telah dipakai petani Indonesia pada tahun 1950 - an. Pada saat ini dapat dikatakan bahwa pestisida masih sangat dibutuhkan untuk mambasmi hama secara teratur agar diperoleh hasil pertanian (khususnya padi) yang memuaskan. Melihat kecenderungan konsumi pestisida yang kian meningkat, bukan tidak mungkin bahwa Elang Jawa (dan spesies burung lainnya) telah terkena pencemaran pestisida.

Spesies Pulau

Populasi suatu pulau akan lebih mudah terancam dibandingkan dengan populasi yang sama pada benua disebabkan oleh lebih kecilnya ukuran dan keterbatasan lainnya. Atas dasar tersebut, populasi suatu pulau lebih mudah terancam karena aktifitas manusia seperti pertanian, perburuan, perusakan habitat, serta introduksi predator, penyakit dan pesaing (Pakpahan dan Mardiastuti 1991).

Ekosistem pulau terbukti sangat berbeda dengan ekosistem benua. Spesies yang berada di pulau memiliki dejarat isolasi yang tinggi sehingga cenderung untuk menjadi endemik karena memiliki garis evolusi yang terpisah dengan nenek moyangnya (Pakpahan dan Mardiastuti 1991). Keendemikan Elang jawa ini menyulitkan para taksonomis dalam menentukan nama spesies yang tepat. Bahkan pada awal penemuan spesimen Elang Jawa pada tahun 1820, jenis ini diidentifikasi sebagai *Spizaetus cirrhatus* (Sözer dan Nijman 1995a).

Sejarah telah memberikan pelajaran bahwa spesies pulau sangat rentan terhadap kepunahan. King (1985) mengungkapkan bahwa dari spesies burung yang telah punah sejak tahun 1600, sebanyak 93% merupakan spesies pulau yang endemik. Elang Jawa - dan juga jenis-

jenis burung lain yang endemik - dengan demikian tergolong ke dalam jenis yang secara alamiah memang sangat rentan terhadap kepunahan.

Penutup

dari urain di ata, dapat disimpulkan bahwa sesungguhnya secara alamiah Elang Jawa ini mempunyai kendala habitat, ekologi, dan biologi. Beberapa kendala masih mungkin untuk diatasi, beberapa lainnya (khususnya kendala biologi) sulit atau bahkan tidak dapat di atasi.

Kendala-kendala tersebut seringkali terkait satu sama lain. Fragmentasi, misalnya berkaitan dengan jumlah populasi, *inbreeding*, penyediaan tempat bersarang, dan wilayah jelajah. Kendala lain yang berkaitan dengan gangguan manusia harus pula diidentifikasi.

Selain itu, meningat bahwa pengetahuan tentang Elang Jawa ini masih sangat sedikit, diperlukan penelitian lebih lanjut yang berkaitan dengan sifat-sifat biologi, kondisi ekologis maupun keadaan habitatnya. Upaya-upaya konservasi untuk Elang Jawa ini perlu diformulasikan bersama-sama dan diimplementasikan secepatnya, sebelum jenis kebanggaan ini punah.

Pustaka

van Balen, S., D. Dewi, and P.R.; Jepson. 1994. Observations at a Java Hawk-eagle nest. Tropical Biodiversity 2:329-331.

van Balen, S. 1996. Javan Hawk-eagle (*Spizaetus bartelsi*): threatened species assessment series No. 1. PHPA/BirdLife International - Indonesia Programme. Bogor.

Craighead, J.J. dan F.C. Craighead, Jr. 1969. Hawks, Owls, and Wildlife. New Yorl: Dover Publications, Inc.

Ekha, I. 1988. Dilema pestisida: tragedi revolusi hijau. Penerbit Kanisius. Yogyakarta.

Gall, G.A.E. 1987. Inbreeding. Pages 47-87 in: Ryman, N., and F. Utter (eds.). Population Genetics and Fishery Management. Seattle, WA: University of Washington Press.

King, W.B. 1985. Island birds: will he future repeat the past? Pages 3-15 in: Moors, P.J. (Ed.). Conservation of Island Birds. ICBP Technical Publication No. 3.

Meyburg, B.-U., S. van Balen, J.M. Thiollay, dan R.D. Chancellor. 1989. Observations on the endangered Java Hawk Eagle *Spizaetus bartelsi*. Pages 279-299 in: Meyburg, B.-U. and R.D. Chancellor (Eds.). Raptors in the Modern World. WWGBP, Berlin, London, and Paris.

Newton, I. 1985. Birds of prey - the raptors. Pages 94-117 in Flightless Birds and Birds of Prey: All the World's Animals Series. Toronto, Canada: Torstar Books.

Nijman, V. dan R. Sözer. 1995. Conservation action plan for the Javan Hawk-eagle. First Draft. PHPA/BirdLife International - Indonesia Programme. Bogor.

Pakpahan, A. dan A. Mardiastuti. 1991. Implikasi struktur kepulauan terhadap strategi pembangunan pertanian yang berkelanjutan. Makalah pada Kongress II PERHIMPI. Malang, 20-22 Agustus 1991.

Sözer, R. dan V. Nijman. 1995a. Behavioural ecology, distribution and conservation of the Javan Hawk-eagle *Spizaetus bartelsi* Stresemann, 1924. Verslagen en Technische Gegevens No. 62. Inst. Syst. and Pop. Biol., Un. of Amsterdam.

Sözer, R. dan V. Nijman. 1995b. The Javan Hawk-eagle: new information on its distribution in Central Jawa and notes on its threats. Trop. Biodiversity 3:49-55.

Catatan Untuk Elang Jawa (*Spizaetus bartelsi*) di Gunung Salak Jawa Barat[1]

Jarwadi B. Hernowo[2]

Abstrak

Elang Jawa (*Spizaetus bartelsi*) adalah jenis burung pemangsa yang sangat langka, endemik Jawa dan sebarannya lebih terkonsentrasi serta terfragmentasi di hutan pegunungan di Jawa Barat. Oleh karena burung ini memiliki kendala-kendala baik dari unsur populasi yang tesebar tidak merata, jumlah individu kecil 51-62 pasang di seluruh Jawa, dewasanya agak lambat (3-4 tahun), jumlah telur per sarang (satu butir) dan tiap 2-3 tahun sekali berbiak serta habitatnya yang berupa hutan pegunungan yang cenderung menyusut, maka upaya pelestarian Elang Jawa harus mendapat perhatian yang serius. Upaya pelestarian terhadap habitat yang menjamin kelangsungan hidup Elang Jawa merupakan prioritas penting. Terutama untuk luasan hutan pegunungan yang cukup besar dan bersambungan. Tersedianya dengan cukup pohon-pohon emergent merupakan komponen habitat yang penting dalam mendukung pelestarian Elang Jawa.

Pendahuluan

Elang Jawa (*Spizaetus bartelsi*) merupakan jenis burung kelompok pemangsa yang tergolong sangat langka dan memiliki penyebaran yang terbatas di Pulau Jawa (MacKinnon, 1990). Kondisi populasi Elang Jawa sudah terancam oleh karena kendala populasi (intrinsic factors) dan habitatnya yang semakin menyempit dan terfragmentasi. Sebaran lokal burung tersebut lebih terkonsentrasi di wilayah Jawa Barat daripada dua propinsi lainnya (van Balen dan Meyburg, 1994). Secara mumu Elang Jawa pada saat ini lebih tersebar di hutan-hutan alam pegunungan daripada di hutan alam detaran rendah.

Total populasi Elang Jawa diperkirakan sekitar 51-62 pasang (van Balen dan Meyburg, 1994). Seperti umumnya burung pemangsa, Elang Jawa memiliki home range yang cukup luas (30-40 km^2 menurut van Balen dan Meyburg, 1994) dan terbatasnya luas hutan di Pulau Jawa yang cocok untuk burung tersebut, oleh karena itu kendala dari segi habitat cukup penting untuk diperhatikan dalam upaya konservasinya.

Dari segi populasi, burung ini diduga akan dewasa setelah umur 3-4 tahun dan akan berbiak setiap 2-3 tahun sekali dengan telur hanya 1 butir (Brown dan Amadon, 1968; Klein et al., 1988; Hellebrekers dan Hoogerwerf, 1967 yang dikutip oleh S`zer dan Nijman, 1995). Hal ini juga merupakan faktor kendala bagi perkembangan Elang Jawa. Informasi bagi bio-ekologi dari

---

[1]Makalah pada Lokakarya Population and Habitat Viability Analysis tentang Burung Elang Jawa (*Spizaetus bartelsi*), Hotel Safari Garden, Cisarua-Bogor, 6-8 Mei 1996.

[2]Staf Pengajar pada Jurusan Konservasi Sumberdaya Hutan, Falkutas Kehutanan IPB, P.O. Box 168 - Bogor 16001.

Elang Jawa masih sangat terbatas, sehingga penelitian yang berkaitan dengan populasi dan habitat sangat diperlukan untuk upaya konservasi burung tersebut.

Tulisan ini didasarkan pada pengamatan lapangan tanggal 20 Maret 1996 yang kontak langsung dengan obyek ± 35 menit dan kegiatan pemantauan lingkungan flora dan fauna di lokasi Uap Panas Bumi Unocal, Gunung Salak Sukabumi 9-24 Maret 1996. Lokasi ditemukan Elang Jawa di kompleks Gunung Gagak Gunung Salak lereng bagian barat daya.

Habitat

Elang Jawa (*Spizaetus bartelsi*) menyukai habitat yang sangat terkait dengan tipe hutan. Umumnya habitat burung tersebut adalah hutan alam dataran rendah sampai pegunungan (evergreen forest). Ditemukan seekor Elang Jawa 20 Maret 1996 di tipe habitat hutan pegunungan ± 1000m dpl kawasan hutan Gunung Salak, Sukabumi di lokasi Lapangan Uap Panas Bumi Unocal Awibengkok (AW8). Secara umum, habitatnya adalah hutan pegunungan dengan dominasi pohon jenis pasang (*Quercus* sp.) dan pusaa (*Schima wallichii*). Berdasarkan pengamatan kualitatif terdapat empat strata tajuk vegetasi, yaitu tajuk pohon dominan, lapisan tajuk kedua adalah tingkat tiang, lapisan tajuk ketiga adalah tingkat pancang, anakan dan tumbuhan bawa serta lapisan tajuk pohon mencuat (emergent). Tingkat pohon emergent antara lain bayur (*Pterospermum javanicum*) sedangkan lapisan tajuk bawah didominasi oleh paku rane (*Selaginella*).

Pohon Untuk Tidur (Roosting Tree)

Sekitar pukul 06.30 WIB teramati burung Elang Jawa yang baru bangun dari pohon tidur (*Pterospermum javanicum*). Pohon tersebut tergolong emergent tree. Elang tersebut hinggap di tajuk tengah dengan ketinggian " 20m. Pohon yang disukai untuk tidur tampaknya pohon yang tinggi (emergent) dangan percabangan sudut lebar (>90E). Di kawasan hutan Gunung Salak masih banyak jenis-jenis pohon yang termasuk emergent tree seperti pasang (*Quercus* sp.), saninten (Castanopsis sp.) dan puspa (*Schima wallichii*). Untuk istirahat dan berjemur, Elang Jawa memilih pohon yang tergolong tinggi (>15m) dengan kerapatan daun rawang, bahkan pada pohon mati.

Ciri Morfologi Yang Teramati

Secara umum ukuran tubuh besar, berjambul dengan 2 helai bulu tengah cukup panjang. Warna bulu tubuh atas, sayap, leher, tengkuk adalah coklat keabuan. Warna paruh kehitaman, mata berwarna kuning serta tenggorokan berwarna putih kotor bergaris-garis coklat kemerahan. Bulu pada khaki dan tungkai bergaris-garis kecoklatan dan ujung tungkai bulunya berwarna putih kotor. Jari-jarinya berwarna kuning dan kuku berwarna hitam. Ekor berwarna coklat kotor bergaris putih 4 buah. Burung ini tampaknya belum dewasa dengan warna umumya coklat keabuan. Apabila telah dewasa, warna bulu akan coklat terang agak kemerahan.

Perilaku Yang Teramati

Pada saat burung Elang Jawa ini teramati, sedang bertengger di pohon bayur dengan sesekali mangembangkan bulu tubuh dan menyelisik. Lima menit kemudian terbang ke pohon yang telah mati (tajuk dengan daun telah rontok). Sekitar 30 menit dapat diamati perilaku berjemur dan menyelisik elang tersebut. Pada saat berjemur, elang ini sering mengembangkan sayapnya dan sesekali mengangkat jambulnya. Ketika berjemur, burung elang tersebut sering disamber-sambar oleh 3 ekor srigunting kelabu (*Dicrurus leucopaheus*). Tampaknya burung srigunting ingin mengusir elang tersebut. Burung elang kelihatannya kurang memberikan perlawanan hanya sesekali mencoba mematuk srigunting tetapi tidak kena sasaran. Setelah 30 menit teramati kemudian elang tersebut terban sekitar 200 m dari tempat berjemur dan masih dikejar-kejar oleh burung srigunting. Lalu burung ini hinggap di tajuk pertengahan pohon.

Respon elang tersebut terhadap pengamant tampaknya tidak penakut, karena beberapa kali elang ini juga melihat terhadap pengamat. Meskipun pengament sering pindah tempat dari pohon tempat berjemur elang tetap tidak menunjukkan reaksi terganggu. Baik pandangan elang terhadap pengamat maupun pengamat terhadap elang bebas (tidak terhalang) karena di tempat terbuka cukup luas sekitar 2000 m^2.

Pelestarian Habitat

Masih besar kemungkinan ditemukan individu-individu lainnya di kompleks Gunung Salak maupun di Gunung Halimun. Apabila dilihat dari komposisi floristik kedua gunung tersebut tidak jauh berbeda seperti umumnya hutan pegunungan di Jawa Barat. Oleh karena itu tampaknya sangat penting kompleks Gunung Salak dan Gunung Halimun dijadikan sebagai salah satu areal konservasi untuk pelestarian Elang Jawa. Selain itu kajian tehadap komponen habitat seperti tempat sarang (pohon sarang), pohon sebagai tempat tidur dan istirahat serta potensi pakan perlu diteliti. Inventarisasi dan sensus populasi Elang Jawa di kedua kompleks gunung tersebut harus dilakukan.

Ucapan Terima Kasih

Penulis mengucapkan terima kasih atas terselesainya tulisan kepada Dr. Ani Mardiastuti atas saran dan pustakanya untuk menyampaikan temuan ini pada Lokakarya Population, Habitat and Viability Analysis tentang Burung Elang Jawa (Spizaetus bartelsi), Hotel Safari Garden, Cisarua-Bogor, 6-8 Mei 1996. Dan untuk saudara Haris W. Arifin yang telah membantu dalam pengetikan.

<u>Daftar Pustaka</u>

van Balen, S. and B.U. Meyburg. 1994. The Java Hawk Eagle *Spizaetus bartelsi*: results of recent research on distribution, status and ecology. In *Raptor Conservation Today* (B.U. Meyburg and R.D. Chancelor, eds) pp. 89-92. Berlin: WWBGP and Pica Press.

Mackinnon, J. 1990. Field Guide to the Birds of Java and Bali. Yogyakarta: Gadjah Mada University Press.

Sözer, R. and V. Nijman. 1995. The Javan Hawk Eagle: New Information on its distribution in Central Java and notes on its threats. Tropical Biodiversity 3 (1): 49.

Koleksi Elang di Kebun Binatang[1]

Drs. Ismu Sutanto Suwelo
Widyaiswara Utama Madya pada Pusat Diklat Departemen Kehutanan
Anggota Pengurus Perhimpunan Kebun Binatang Se Indonesia

Dalam rangka penelitian tentang pelestrian Elang Bondol atau Wulung (Brahminy Kite), *Haliastur indus* di kawasan DKI Jakarta tahun 1991 yang disponsori Yayasan Nasional Bina Samudera dengan kerjasama PKBSI telah dilakukan inventarisasi koleksi elang di kebun-kebun binatang di Jawa.

Data dan informasi yang dikumpulkan adalah mengenai jumlah dan jenis-jenis burung elang, keadaan sangkar, penempatannya dan ransum yang diberkan terutama terhadap elang bondol.

Di delapan kebun binatang di Jawa dipelihara tujuh jenis elang (Accipitridae) eengan jumlah koleksi 215 ekor; yang terbanyak bido (Changeable Hawk-eagle), *Spilornis cheela*: 84 ekor; kemudian elang bondol (Brahminy Kite), Haliastur indus: 50 ekor. Yang terbanyak memiliki jumlah individu eland adalah Surabaya, sedang terbanyak jenisnya adalah Taman Burung TMII.

Kebanyakan elang dipelihara dalam sangkar-sangkar kecil meskipun ada yang agak besar dan burung-burungnya dicampur.

[1]Disampaikan pada Lokakarya Elang Jawa yang diadakan Ditjen PHPA tanggal 6-8 Mei 1996 di Hotel Safari Garden, Cisarua, Bogor.

Conservation Status of the Javan Hawk-Eagle:
A Preliminary Evaluation by the PHPA / BirdLife International - Indonesia Programme

Paul Jepson
BirdLife International - IP
P.O. Box 310/Boo
Bogor 16001, Indonesia

Abstract

Since 1994 the PHPA/BirdLife International - IP has conducted and facilitated a series of studies and reviews on the conservation status of the Javan Hawk-eagle. These are summarized in van Balen (1996) which provides the basis for this presentation.

We estimate the breeding population to be between 81 and 108 pairs distributed in 15 forest areas on Java. A further 23-31 pairs may exist in smaller forest fragments not yet surveyed. No estimate is available for the number of immature birds present in the population.

The two primary threats to the species are illeal collection of young birds from the nest and continued degradation of forest habitats, particularly at the margins of upland forest areas. The central Java population may be the most vulnerable from the latter pressure, because the protceted area network in this region is not yet developed.

Key biological information required to develop effective long-term management strategies for the species is lacking. This includes precise data on home range, dispersive behaviour of immature birds, and population demography.

Based on this current evaluation, we propose a conservation strategy focusing on five elements:

- Strengthening the Java protected area network through the establishment of new reserves at Gunung Slamet and Gunung Prahu in Central Java.
- Reducing the incidence of removel of nestlings through a combination of: regular monitoring of bird markets, supported by confiscations and prosecutions; limiting the number of bird parks or zoos that are allowed to exhibit or keep Javan Hawk-eagles; locate and guard nest trees in protected areas.
- A public awareness programme, targeting schools and the mass media to raise support for Javan Hawk-eagle conservation.
- The initiation of a research programme focusing on developing a more precise understanding of: home range and optimum habitat; dispersive behaviour of the species; breeding ecology and juvenile mortality.
- Establishment of a Javan Hawk-eagle focus group to promote inter-agency action.

Usulan Kegiatan:
Survey Elang Jawa (*Spizaetus bartelsi*) di Taman Nasional Gunung Halimun, Jawa Barat: Juli 1996 - Juli 1997

Biological Science Club (BScC)
Jl. Lobi-lobi / No. 19 Pasar Minggu
Jakarta 12520
Tel / Fax: (021) 7805608
E-mail: bscc@indo.net.id

Pendahuluan

Elang Jawa (*Spizaetus bartelsi*) merupakan spesies yang memiliki status terancam punah dan endemik Jawa. Sehubungan dengan status Elang Jawa tersebut kemudian pemeritah Indonesia menjadikan satwa ini menjadi simbol satwa nasional. Sampai sekarang belum diketahui jumlah keberadaan Elang Jawa pada beberapa kawasan konservasi dan jumlah populasinya secara pasti. Saat ini diperkirakan hanya sekitar 50 individu saja yang masih hidup dibeberapa kanutng-kantung hutan yang masih tersisa di pulau Jawa. Di Jawa Barat keberadaan Elang Jawa dijumpai di Taman Nasional Gunung Halimun dan Taman Nasional Gede-Pangrango.

Taman Nasional Gunung Halimun dengan luas 40.000 ha masuk ke dalam tiga kabupaten seperti; kabupaten Bogor di bagian sebelah utara, kabupaten Lebak di bagian sebelah barat, kabupaten Sukabumi di sebelah selatan. Terdapat 17 desa yang berada di sekitarnya dengan 7 desa merupakan daerah yang berada dalam kawasan (*enclave*). Taman Nasional ini mempunyai hutan dataran tinggi terluas di Pulau Jawa.

Latar Belakang

Keanekaragaman hayati oleh kalangan akademis dipandang mempunyai pengertian "umbrella term" terhadap keberadaan derajat sumber daya hayati. Timbulnya konsep ini dikarenakan semakin tidak terdeskripsikannya bentuk kekayaan hayati di dunia, terutama sekali kekayaan alam hutan tropika yang hampir punah akibat beberapa kendala, antara lain yaitu eksploitasi sumberdaya alam yang berlebihan.

Beberapa jenis ragam hayati yang eksklusif karena langka dan unik akan mengalami ancaman pelestarian karena diburu. Karena memiliki nilai ekonomi uang sangat kuat dan tinggi, maka secara khusus banyak usaha yang dilakukan untuk mengupayakan penggalian dan pengambangan sumberdaya hayati, baik yang telah ada maupun yang belum terinventarisasi sebagai usaha pemenuhan kebutuhan.

Kawasan hutan Taman nasional Gunung Halimun merupakan satu-satunya kawasan knoservasi yang memiliki keanekaragaman hayati yang cukup tinggi dan tipe-tipe ekosistem yang khas bila dibandingkan dengan beberapa kawasan konservasi lainnya di Pulau Jawa. Pada

kawasan ini terdapat kurang lebih 300 jenis burung dengan beberapa jenis diantaranya jenis endemik Jawa. Termasuk didalamnya Elang Jawa (*Spizaetus bartelsi*).
Hasil penelitan Biological Scneice Club (1988-1994) bekerjasama dengan University of East Anglia dan LIPI (1992) di Taman Nasional Gunung Halimun dijumpai Elang Jawa (*Spizaetus bartelsi*) yang merupakan salah satu jenis burung endemik yang berstatus langka dan dilindungi, namun belum diketahui secara pasti jumlah individu, distribusi dan keberadaan satwa ini di Pulau Jawa khususnya pada Taman Nasional Gunung Halimun.

Mengingat keberadaan jenis Elang Jawa (*Spizaetus bartelsi*) yang cukup memprihatinkan, maka perlu dilakukan suatu penelitian yang memerlukan penanganan secara serius dan terarah. Sebelum penelitian mengarah kepada penelitian yang lebih serius perlu dilakukan survey yang dapat mengetahui keberadaan satwa ini pada beberapa lokasi dalan kawasan konservasi Taman Nasional Gunung Halimun.

Tujuan

Mengetahui status keberadaan Elang Jawa di Taman Nasional Gaunugn Halimun.

Objektivitas

1. Evaluasi keberadaan Elang Jawa (*Spizaetus bartelsi*) pada Taman Nasional Gunung Halimun.

2. Mendapatkan data keberadaan Elang Jawa (*Spizaetus bertelsi*) di dalam hutan, tempat terbuka seperti perkebunan dan perladangan yang berada di sekitar dan di dalam kawasan Taman Nasional Gunung Halimun.

Metodologi

Pengamatan dilakukan dengan menggunakan 4 metode yaitu:

1. *Metode jalur* (Wilson dan Wilson, 1974.
   Metode ini dilakukan pada kawasan hutan di setiap lokasi pengamatan yang telah ditentukan. Jalur yang dibuat sebanyak 3 jalur dengan panjang jalur 3 km. Titik awal jalur ditarik dari batas hutan hingga ke dalam kawasan hutan. Jarak antara satu jalur dengan jalur lainnya sepanjang 2 km. Waktu pengamatan dimulai dari pukul 05.30 WIB sampai dengan pukul 17.30 WIB. Data yang dicatat yaitu: jumlah individu, waktu perjumpaan, lokasi saat ditemukan, jarak antara pengamat dengan burung, dan aktivitasnya.

2. *Distribution count*
   Daerah penyebaran dari Burung Elang Jawa ditentukan berdeasrkan lokasi ditemukannya individu burung tersebut, yang selanjutnya di petakan kedalam peta berskala 1:500.000.

3. *Sensus Sarang*
   Pada survey ini, data pohon sarang yang diambil meliputi data ketinggian sarang (dari tanah), lokasi pohon sarang, ketinggian lokasi pohon sarang (altitude) dan jenis pohon sarang.

4. *Wawancara*
Dalam survey ini juga dilakukan melalui wawancara secara informal pada masyarakat sekitar kawasan baik tokoh pemerintah, petugas PHPA, tokoh masyarakat, pemburu atau petani tentang keberadaan Burung Elang Jawa.

Lokasi

1. Halimun Utara
Gunung Halimun 1
Gunung Bintang Gading
Baligir Putih
Perkebunan Pasir Madang

2. Halimun Barat
Gunung Jaya Sempurna
Ciawitali
Cantela Wangi

3. Halimun selatan
Gunung Halimun 2
Gunung Barengbeng

4. Halimun Timur
Gunung Botol
Gunung Kendeng
Cikaniki
Perkebunan Nirmala
Padan arum
Garung, Cilanggar

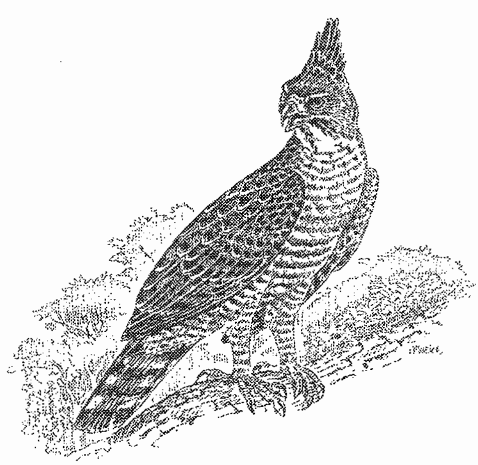
Pelaksana:	Biological Science Club
Supervisor:	Drs. Ismu S. Suwelo
Koordinator:	Rustam Effendi S. Si
anggota:	Lusiana Nogo Ladjar S.Si
	Roni

Hasil Yang Diharapkan

Dari kegiatan survey yang akan dilakukan dapat diketahui secara pasti keberadaan Burung Elang Jawa di Taman Nasional Gunung Halimun, Jawa Barat serta masukan-masukan mengenai aktivitas dalam hutan yang potensial menjadi gangguan bagi satwa tersebut, sehingga rencana pelestarian Burung Elang Jawa dapat terlaksana dengan adanya penelitian yang lebih mendalam.

POPULATION AND HABITAT VIABILITY ASSESSMENT FOR THE JAVAN HAWK-EAGLE (*Spizaetus bartelsi*)

Taman Safari Indonesia
6 - 8 May 1996



Section 9
Appendix III.
IUCN Policy Statements

THE IUCN POLICY STATEMENT ON CAPTIVE BREEDING

Prepared by the
SSC Captive Breeding Specialist Group

As approved by the 22nd Meeting of the IUCN Council Gland, Switzerland

4 September 1987

SUMMARY: Habitat protection alone is not sufficient if the expressed goal of the World Conservation Strategy the maintenance of biotic diversity, is to be achieved. Establishment of self-sustaining captive populations and other supportive intervention will be needed to avoid the loss of many species, especially those at high risk in greatly reduced, highly fragmented, and disturbed habitats captive breeding programmes need to be established before specks are reduced to critically low numbers, and thereafter need to be coordinated Internationally according to sound biological principles, with a view to the maintaining or re establishment of viable populations in the wild.

PROBLEM STATEMENT

IUCN data indicate that about 3 per cent of terrestrial earth is gazetted for protection. Some of this and much of the other 97 per cent is becoming untenable for many species, and remaining populations are being greatly reduced and fragmented. From modern population biology one can predict that many species will be lost under these conditions. On average more than one mammal, bird, or reptile species has been bst in each year this century. Since extinctions of most taxa outside these groups are not recorded, the loss rate for all species is much higher.

Certain groups of species are at particularly high risk, especially forms with restricted distribution, those of large body size, those of high economic value, those at the top of food chains, and those which occur only in climax habitats. Species in these categories are likely to be bst first, but a wide range of other 10rms are also at risk. Conservation over the bng term will require management to reduce risk, including *ex situ* populations which could support and interact demographically and genetically with wild populations.

FEASIBILITY

Over 3,000 vertebrate species are being bred in zoos and other captive animal facilities. When a serious attempt is made, most species breed in captivity, and viable populations can be maintained over the long term. A wealth of experience is available in these institutions, including husbandry, veterinary medicine, reproductive biology, behaviour, and genetics. They offer space for supporting populations of many threatened taxa, using resources not competitive with those for *in situ* conservation. Such captive stocks have in the past provided critical support for some wild populations (e.g. American bison, *Bison bison*), and have been the sole escape from extinction for others which have since been re-introduced to the wild (e.g. Arabian oryx, *Otyx leucoryx*).

RECOMMENDATION

IUCN urges that those national and international organizations and those individual institutions concerned with maintaining wild animals in captivity commit themselves to a general policy of developing demographically self-sustaining captive populations of endangered species wherever necessary.

SUGGESTED PROTOCOL

WHAT: The specific problems of the species concemed need to be considered, and appropriate aims for a captive breeding programme made explicit.

WHEN: The vulnerability of small populations has been consistently under estimated. This has erroneously shifted the timing of establishment of captive populations to the last moment, when the crisis is enormous and when extinction is probable. Therefore, timely recognition of such situations is critical, and is dependent on information on wild population status, particularly that provided by the IUCN Conservation Monitoring Centre. Management to best reduce the risk of extinction requires the establishment of supporting captive populations much earlier, preferably when the wild population is still in the thousands. Vertebrate taxa with a current census below one thousand individuals in the wild require close and swift cooperation between field conservationists and captive breeding specialists, to make their effort complementary and minimize the likelihood of the extinction of these taxa.

HOW: Captive populations need to be founded and managed according to sound scientific principles for the primary purpose of securing the survival of species through stable, self-sustaining captive populations. Stable captive populations preserve the options of reintroduction and/or supplementation of wild populations.

A framework of international cooperation and coordination between captive ~ breeding institutions holding species at risk must be based upon agreement to cooperatively manage such species for demographic security and genetic diversity. The IUCN/SSC Captive Breeding Specialist Group is an appropriate advisory body concerning captive breeding science and resources.

Captive programmes involving species at risk should be conducted primarily for the benefit of the species and without commercial transactions. Acquisition of animals for such programmes should not encourage commercial ventures or trade. Whenever possible, captive programmes should be carried out in parallel with field studies and conservation efforts aimed at the species in its natural environment.

IUCN GUIDELINES FOR THE PLACEMENT OF CONFISCATED LIVE ANIMALS[2]

Statement of Principle:

When live animals are confiscated by government authorities, these authorities have a responsibility to dispose of them appropriately. Within the confines of national and international law, the ultimate on disposition of confiscated animals must achieve three goals: 1) to maximise conservation value of the specimens without in any way endangering the health, behavioral repertoire, genetic characteristics, or conservation status of wild or captive populations of the species[1]; 2) to discourage further illegal or irregular[2] trade in the species; and 3) to provide a humane solution, whether this involves maintaining the animals in captivity, returning them to the wild, or employing euthanasia to destroy them.

Statement of Need:

Increased regulation of trade in wild plants and animals and enforcement of these regulations has resulted in an increase in the number of wildlife shipments intercepted by government authorities as a result of non-compliance with these regulations. In some instances, the interception is a result of patently illegal trade; in others, it is in response to other irregularities. While in some cases the number of animals in a confiscated shipment is small, in many others the number is in the hundreds. Although in many countries confiscated animals have usually been donated to zoos and aquaria, this option is proving less viable with large numbers of animals and, increasingly, for common species. The international zoo community has recognized that placing animals of low conservation priority in limited cage space may benefit those individuals but may also detract from conservation efforts as a whole. They are, therefore, setting conservation priorities for cage space (IUDZG/CBSG 1993).

With improved interdiction of the illegal trade in animals there is an increasing demand for information to guide confiscating agencies in the disposal of specimens. This need has been reflected in the formulation of specific guidelines for several groups of organisms such as parrots (Birdlife International in prep) and primates (Harcourt in litt.). However, no general guidelines exists.

In light of these trends, there is an increasing demand - and urgent need - for information and advice to guide confiscating authorities in the disposition of live animals. Although specific guidelines have been formulated for certain groups of organisms, such as parrots (Birdlife International in prep.) and primates (Harcourt 1987), no general guidelines exist.

---

[2] Although this document refers to species, in the case of species with well-defined subspecies and races, the issues addressed will apply to lower taxonomic units.

When disposing of confiscated animals, authorities must adhere to both national and international law. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) requires that confiscated individuals of species listed on the treaty's Appendices be returned to the "state of export . . . or to a rescue centre or such other place as the Management Authority deems appropriate and consistent with the purpose of the Convention." (Article VIII). However the treaty does not elaborate on this requirement, and CITES Management Authorities must act according to their own interpretation, not only with respect to repatriation but also as regards what constitutes disposition that is "appropriate and consistent" with the treaty. Although the present guidelines are intended to assist CITES Management Authorities in making this assessment, they are designed to be of general applicability to all confiscated live animals.

The lack of specific guidelines has resulted in confiscated animals being disposed of in a variety of ways. In some cases, release of confiscated animals into existing wild populations has been made after careful evaluation and with due regard for existing guidelines (IUCN 1987, IUCN 1995). In other cases, such releases have not been well planned and have been inconsistent with general conservation objectives and humane considerations, such as releasing animals in inappropriate habitat, dooming these individuals to starvation or certain death from other causes against which the animals are not equipped or adapted. Such releases may also have strong negative conservation value by threatening existing wild populations as a result of: 1) diseases and parasites acquired by the released animals while in captivity spreading into existing wild populations; 2) individuals released into existing populations, ro in areas near to existing populations, not being of the same race or sub-species as those in the wild population, resulting in mixing of distinct genetic lineages; 3) animals held in captivity, particularly juveniles and immatures, acquiring an inappropriate behavioral repertoire from individuals of other species, and/or either losing certain behaviors, or not developing the full behavioral repertoire, necessary for survival in the wild. Also, it is possible that release of these animals could result in inter-specific hybridisation.

Disposition of confiscated animals is not a simple process. Only on rare occasions will the optimum course to take be clear-cut or result in an action of conservation value. Options for the disposition of confiscated animals have thus far been influenced by the public's perception that returning animals to the wild is the optimal solution in terms of both animals welfare and conservation. A growing body of scientific study of re-introduction of captive animals suggests that such actions may be among the least appropriate options for many reasons. This recognition requires that the options available to confiscating authorities for disposition be carefully reviewed.

Management Options:

In deciding on the disposition of confiscated animals, priority must be given to the well-being and conservation of existing wild populations of the species involved, with all efforts made to ensure the humane treatment of the confiscated individuals. Options for disposition fall into three

principal categories: 1) maintenance of the individual(s) in captivity; 2) returning the individual(s) in question to the wild; and 3) euthanasia.
Within a conservation perspective, by far the most important consideration in reviewing the options for disposition is the conservation status of the species concerned. Where the confiscated animals represent an endangered or threatened species, particular effort should be directed towards evaluating whether and how these animals might contribute to a conservation programme for the species. The decision as to which option to employ in the disposition of confiscated animals will depend on various legal, social, economic and biological factors. The "Decision Tree"[1] provided in the present guidelines is intended to facilitate consideration of these options. The tree has been written so that it may be used for both threatened and common species. However, it recognizes that the conservation status of the species will be the primary consideration affecting the options available for placement, particularly as the expense and difficulty of returning animals to the wild (see below) will often only be justified for threatened species. International networks of experts, such as the IUCN-Species Survival Commission Specialist Groups, should be able to assist confiscating authorities, and CITES Scientific and Management Authorities, in their deliberations as to the appropriate disposition of confiscated specimens.

Sending animals back automatically to the country from which they were shipped, the country in which they originated (if different), or another country m which the species exists, does not solve any problems. Repatriation to avoid addressing the question of disposition of confiscated animals is irresponsible as the authorities in these countries will face the same issues concerning placement as the authorities in the original confiscating country.

OPTION 1-- **CAPTIVITY**

Confiscated animals are already in captivity; there are numerous options for maintaining them in captivity. Depending on the circumstances, animals can be donated, loaned, or sold. Placement may be in zoos or other facilities, or with private individuals. Finally, placement may be either in the country of origin, the country of export (if different), the country of confiscation. or in a country with adequate and/or specialised facilities for the species in question. If animals are maintained in captivity, in preference to either being returned to the wild or euthanized, they must be afforded humane conditions and ensured proper care for their natural lives.

Zoos and aquaria are the captive facilities most commonly considered for disposition of animals, but a variety of captive situations exist where the primary aim of the institution or individuals involved is not the propagation and resale of wildlife. These include:

Rescue centres, established specifically to treat injured or confiscated animals, are sponsored by a number of humane organisations in many countries.

Life-time care facilities devoted to the care of confiscated animals have been built in a few countries.

Specialist societies or clubs devoted to the study and care of single taxa or species(e.g., reptiles, amphibians, birds) have, in some instances, provided an avenue for the disposition of confiscated animals without involving sale through intermediaries. Placement may be made directly to these organisations or to individuals who are members.

Humane Societies may be willing to ensure placement of confiscated specimens with private individuals who can provide humane life-time care.

Research laboratories (either commercial or non-commercial, e.g. universities) maintain collections of exotic animals for many kinds of research (e.g. behavioural, ecological, physiological, psychological, medical). Attitudes towards vivisection, or even towards the non-invasive use of animals in research laboratories as captive study populations, vary widely from country to country. Whether transfer of confiscated animals to research institutions is appropriate will therefore engender some debate. However, it should be noted that transfer to facilities involved in research conducted under humane conditions may offer an alternative -- and one which may eventually contribute information relevant to the species' conservation. In many cases, the lack of known provenance and the risk that the animal in question has been exposed to unknown pathogens will make transfer to a research institution an option that will be rarely exercised or desired.

CAPTIVITY - Sale, Loan or Donation

Animals can be placed with an institution or individual in a number of ways. It is critical, however. that two issues be separated: the ownership of the animals and/or their progeny, and the payment of a fee by the institution/individual receiving the animals. Paying the confiscating authority, or the country of origin, does not necessarily give the person or institution making the payment any rights (these may rest with the confiscating authority). Similarly, ownership of an animal can be transferred without payment. Confiscating authorities and individuals or organizations participating in the placement of confiscated specimens must clarify ownership. both of the specimens being transferred and their progeny. Laws dictating right of ownership of wildlife differ between nations, in some countries ownership remains with the government, in others the owner of the land inhabited by the wildlife has automatic rights over the animals.

When drawing up the terms of transfer many items must be considered, including:

-- ownership of both the animals involved and their offspring (dictated by national law) must be specified as one of the terms and conditions of the transfer (it may be necessary to insist there is no breeding for particular species, e.g. primates). Either the country of origin or the country of confiscation may wish to retain ownership of the animals and/or their progeny. Unless specific legal provisions apply, it is impossible to assure the welfare of the animals following a sale which includes a transfer of ownership.

-- sale or payment of a fee to obtain certain rights (e.g. ownership of offspring) can provide a means of placement that helps offset the costs of confiscation.

--sale and transfer of ownership should only be considered in certain circumstances, such as where the animals in question are not threatened and not subject to a legal proscription on trade (e.g., CITES Appendix I) and there is no risk of stimulating further illegal or irregular trade.

--sale to commercial captive breeders may contribute to reducing the demand for wild-caught individuals.

--sale may risk creating a public perception of the confiscating State perpetuating or benefitting from illegal or irregular trade.

--if ownership is transferred to an organization to achieve a welfare or conservation goal, the confiscating authority should stipulate what will happen to the specimens should the organization wish to sell/transfer the specimens to another organization or individual.

--confiscating authorities should be prepared to make public the conditions under which confiscated animals have been transferred and, where applicable, the basis for any payments involved.

CAPTIVITY-- **Benefits**

The benefits of placing confiscated animals in a facility that will provide life-time care under humane conditions include;

a) educational value;
b) potential for captive breeding for eventual re-introduction;
c) possibility for the confiscating authority to recoup from sale costs of confiscation;
d) potential for captive bred individuals to replace wild-caught animals as a source for trade.

CAPTIVITY- **Concerns**

The concerns raised by placing animals in captivity include:

A) **Disease.** Confiscated animals may serve as vectors for disease. The potential consequences of the introduction of alien disease to a captive facility are more serious than those of introducing disease to wild populations (see discussion page 9); captive conditions might encourage disease spread to not only conspecifics. As many diseases can not be screened for, even the strictest quarantine and most extensive screening for disease can not ensure that an animal is disease free. Where quarantine cannot adequately ensure that an individual is disease free, isolation for an indefinite period, or euthanasia, must be carried out.

B) **Escape.** Captive animals maintained outside their range can escape from captivity and become pests. Accidental introduction of exotic species can cause tremendous damage and in certain cases, such as the escape of mink from fur farms in the United

Kingdom, the introduction of exotics can result from importation of animals for captive rearing.

C) **Cost of Placement**. While any payment wi11 place a value on an animal, there is little evidence that trade would be encouraged if the institution receiving a donation of confiscated animals were to reimburse the confiscating authority for costs of care and transportation. However, payments should be explicitly for reimbursement of costs of confiscation and care, and, where possible, the facility receiving the animals should bear all such costs directly.

D) **Potential to Encourage Undesired Trade**. Some (e.g., Harcourt 1987) have maintained that any transfer - whether commercial or non-commercial - of confiscated animals risks promoting a market for these species aud creating a perception of the confiscating state being involved in illegal or irregular trade.

Birdlife International (in prep.) suggests that in certain circumstances sale of confiscated animals does not necessarily promote undesired trade. They offer the following requirements that must be met for permissible sale by the confiscating authority: I) the species to be sold is already available for sale legally in the confiscating country in commercial quantities; and 2) wildlife traders under indictment for; or convicted of, crimes related to import of wildlife are prevented from purchasing the animals in question. However, experience in selling confiscated animals in the USA suggests that it is virtually impossible to ensure that commercial dealers suspected or implicated in illegal or irregular trade are excluded, directly or indirectly, in purchasing confiscated animals.

In certain circumstances sale or loan to commercial captive breeders may have a clearer potential for the conservation of the species, or welfare of the individuals, than non-commercial disposition or euthanasia. However, such breeding programmes must be carefully assessed as it may be difficult to determine the effects of these programmes on wild populations.

OPTION 2-- RETURN TO THE WILD

These guidelines suggest that return to the wild would be a desirable option in only a very small number of instances and under very specific circumstances. The rationale behind many of the decision options iii this section are discussed in greater detail in the IUCN Re-introduction Guidelines (IUCN/SSC RSG 1995) which, it is important to note, make a clear distinction between the different options for returning animals to the wild. These are elaborated below.

I) **Re-introduction**: an attempt to establish a population in an area that was once part of the range of the species but from which it has become extirpated.
Some of the best known re-introductions have been of species that had become extinct in the wild. Examples include: Pere David's deer (*Elaphurus davidanus*) and the Arabian

oryx (*Oryx leucoryx.*). Other re-introduction programmes have involved species that exist in some parts of their historical range but have been eliminated from other areas; the aim of these programmes is to re-establish a population in all area, or region, from which the species has disappeared. An example of this type of r~introduction is the recent re-introduction of the swift fox (*Vulpes velox*) in Canada.

2) **Reinforcement of an Existing Population**: the addition of individuals to all existing population of the same taxon.

Reinforcement can be a powerful conservation tool when natural populations are diminished by a process which, at least in theory, can be reversed. An example of a successful reinforcement project is the golden lion tamarin *(Leontopithecus rosalia)* project in Brazil. Habitat loss, coupled with capture of live animals for pets, resulted in a rapid decline of the golden lion tamarin. when reserves were expanded, and capture for the pet trade curbed, captive-bred golden lion tamarins were then used to supplement depleted wild populations.

Reinforcement has been most commonly pursued when individual animals injured by human activity have been provided with veterinary care and released. Such activities are common in many western countries, and specific programmes exist for species as diverse as hedgehogs and birds of prey. However common an activity, reinforcement carries with it the very grave risk that individuals held in captivity, even temporarily, are potential vectors for the introduction of disease into wild populations.

Because of inherent disease risks and potential behavioural abnormalities, reinforcement should only be employed in instances where there is a direct and measurable conservation benefit (demographically and/or genetically, and/or to enhance conservation in the public's eye), for example when reinforcement will significantly add to the viability of the wild population into which an individual is being placed.

3) **Conservation Introductions:** (also referred to as Beneficial or Benign Introductions - IUCN 1995): an attempt to establish a species, for the purpose of conservation, outside its recorded distribution but within a suitable habitat in which a population can be established without predicted detriment to native species.

Extensive use of conservation introductions has been made in New Zealand, where endangered birds have been transferred to off-shore islands that were adjacent to, but not part of the animals' original range. Conservation introductions can also be a component of a larger programme of re-introduction, an example being the breeding of red wolves on islands outside their natural range and subsequent transfer to mainland range areas (Smith 1990).

RETURN To THE WILD - CONCERNS

Before return to the wild of confiscated animals is considered, several issues of concern must be considered in general terms; welfare, conservation value, cost, and disease.

a) **Welfare**. While some consider return to the wild to be humane, ill-conceived projects may return animals to the wild which then die from starvation or suffer an inability to adapt to an unfamiliar or inappropriate environment. This is not humane. Humane considerations require that each effort to return confiscated animals to the wild be thoroughly researched and carefully planned. Such returns also require long-term commitment in terms of monitoring the fate of released individuals. Some (e.g., International Academy of Animal Welfare Sciences 1992) have advocated that the survival prospects for released animals must at least approximate those of wild animals of the same sex and age class in order for return to the wild to be seriously considered. While such demographic data on wild populations are, unfortunately, rarely available, the spirit of this suggestion should be respected -- there must be humane treatment of confiscated animals when attempting to return them to the wild.

b) **Conservation Value And Cost**. In cases where returning confiscated animals to the wild appears to be the most humane option, such action can only be undertaken if it does not threaten existing populations of conspecifics or populations of other interacting species, or the ecological integrity of the area in which they live. The conservation of the species as a whole, and of other animals already living free, must take precedent over the welfare of individual animals that are already in captivity.

Before animals are used in programmes in which existing populations are reinforced, or new populations are established, it must be determined that returning these individuals to the wild will make a significant contribution to the conservation of the species, or populations of other interacting species. Based solely on demographic considerations, large populations are less likely to go extinct, and therefore reinforcing existing very small wild populations may reduce the probability of extinction. In very small populations a lack of males or females may result in reduced population growth or population decline and, therefore, reinforcing a very small population lacking animals of a particular sex may also improve prospects for survival of that population. However, genetic and behavioural considerations, as well as the possibility of disease introduction, also play a fundamental role in determining the long term survival of a population.

The cost of returning animals to the wild in an appropriate manner can be prohibitive for all but the most endangered species (Stanley Price 1989; Seal et al. 1989). The species for which the conservation benefits clearly outweigh these costs represent a tiny proportion of the species which might, potentially, be confiscated In the majority of cases, the costs of appropriate, responsible (re)introduction will preclude return to the wild. Poorly planned or executed (re)introduction programmes are no better than dumping animals in the wild and should be vigorously opposed on both conservation and humane grounds.

c) **Founders And Numbers Required**. Most re-introductions require large numbers of founders, usually released in smaller groups over a period of time. Hence, small groups of confiscated animals may be inappropriate for re-introduction programmes, and even larger groups will require careful management if they are to have any conservation value for re-introduction programmes. In reality, confiscated specimens will most often only be of potential value for reinforcing an existing population, despite the many potential problems this will entail.

c) **Source of Individuals**. If the precise provenance of the animals is not known (they may be from several different provenances), or if there is any question of the source of animals, supplementation may lead to inadvertent pollution of distinct genetic races or sub~species. If particular local races or sub-species show specific adaptation to their local environments mixing in individuals from other races or sub-species may be damaging to the local population. Introducing an individual or individuals into the wrong habitat type may also doom that individual to death.

a) **Disease**. Animals held in captivity and/or transported, even for a very short time, may be exposed to a variety of pathogens. Release of these animals to the wild may result in introduction of disease to con-specifics or unrelated species with potentially catastrophic effects. Even if there is a very small risk that confiscated animals have been infected by exotic pathogens, the potential effects of introduced diseases on wild populations are so great that this will often prevent returning confiscated animals to the wild (Woodford and Rossiter 1993, papers in *J Zoo and Wildlife Medicine* 24(3), 1993).

Release of any animal into the wild which has been held in captivity is risky. Animals held in captivity are more likely to acquire diseases and parasites. While some of these diseases can be tested for, tests do not exist for many animal diseases. Furthermore, animals held in captivity are frequently exposed to diseases not usually encountered in their natural habitat. Veterinarians and quarantine officers, taking that the species in question is only susceptible to certain diseases, may not test for the diseases picked up in captivity. It should be assumed that all diseases are potentially contagious.

Given that any release incurs some risk, the following "precautionary principle" must be adopted: *if there is no conservation value in releasing confiscated specimens, the possibility of accidentally introducing a disease, or behavioural and genetic aberrations into the environment which are not already present, however unlikely, may rule out returning confiscated specimens to the wild as a placement option.*

RETURN TO THE WILD: BENEFITS

There are several benefits of returning animals to the wild, either through re-introduction for the establishment of a new population or reinforcement of an existing population.

a) **Threatened Populations**: In situations where the existing population is severely threatened, such an action might improve the long-term conservation potential of the species as a whole, or of a local population of the species (e.g., golden lion tamarins).

b) **Public Statement**: Returning animals to the wild makes a strong political/educational statement concerning the fate of animals (e.g., orangutans (*Pongo pygmaeus*) and chimpanzees (*Pan troglodytes*) - Aveling & Mitchell 1982, but see Rijksen & Rijksen-Graatsma 1979) and may serve to promote local conservation values. However, as part of any education or public awareness programmes, the costs and difficulties associated with the return to the wild must be emphasized.

OPTION 3- EUTHANASIA

Euthanasia: the killing of animals carried out according to humane guidelines -- is unlikely to be a popular option amongst confiscating authorities for disposition of confiscated animals. However, it cannot be over-stressed that euthanasia may frequently be the most feasible option available for economic, conservation and humane reasons. hi many cases, authorities confiscating live animals will encounter the following situations:

a) Return to the wild in some manner is either unnecessary (e.g., in the case of a very common species), impossible, or prohibitively expensive as a result of the need to conform to biological (IUCN/SSC RSG ~995) and animal welfare guidelines (International Academy of Welfare Sciences 1992).

b) Placement in a captive facility is impossible, or there are serious concerns that sale will be problematic or controversial.

c) During transport, or while held in captivity, the animals have contracted a chronic disease that is incurable and, therefore, are a risk to any captive or wild population. hi such situations, there may be no practical alternative to euthanasia.

EUTHANASIA -ADVANTAGES:

a) From the point of view of conservation of the species involved, and of protection of existing captive and wild populations of animals, euthanasia carries far fewer risks (e.g. loss of any unique behavioural/genetic/ecological variations within an individual representing variation within the species) when compared to returning animals to the wild.

b) Euthanasia will also act to discourage the activities that gave rise to confiscation, be it smuggling or other patently illegal trade, incomplete or irregular paperwork, poor packing, or other problems, as the animals in question are removed entirely from trade.

c) Euthanasia may be in the best interest of the welfare of the confiscated animals. Release to the wild will carry enormous risks for existing wild populations and may pose severe challenges to the survival prospects of the individual animals, who may, as a result, die of starvation, disease or predation.

d) Cost: euthanasia is cheap compared to other options. There is potential for diverting resources which might have been used for re-introduction or lifetime care to conservation of the species in the wild.

When animals are euthanized, or when they die a natural death while in captivity, the dead specimen should be placed in the collection of a natural history museum, or another reference collection in a university or research institute. Such reference collections are of great importance to studies of biodiversity. if such placement is impossible, carcasses should be incinerated to avoid illegal trade in animal parts or derivatives.

EUTHANASIA- RISKS

a) There is a risk of losing unique behavioural, genetic and ecological material within an individual or group of individuals that represents variation within a species.

DECISION TREE ANALYSIS

For decision trees dealing with "Return to the Wild" and "Captive Options" the confiscating party must first ask the question:

Question 1: Will "Return to the Wild" make a significant contribution to the conservation of the species?

The most important consideration in deciding on placement of confiscated specimens is the conservation of the species in question. Conservation interests are best served by ensuring the survival of as many individuals as possible. The release of confiscated animals therefore must improve the prospects for survival of the existing wild population. Returning an individual to the wild that has benn held in captivity will always involve some level of risk to existing populations of the same or other species in the ecosystem to which the animal is returned because there can never be absolute certainty that a confiscated animal is disease- and parasite-free. In most instances, the benefits of return to the wild will be outweighed by the costs and risks of such an action. If returning animals to the wild is not of conservation value, captive options pose fewer risks and may offer more humane alternatives.

Q1 Answer: No: Investigate "Captive Options"
Yes: Investigate "Return to the Wild Options"

DECISION TREE ANALYSIS: CAPTIVITY

The decision to maintain confiscated animals in captivity involves a simpler set of considerations than that involving attempts to return confiscated animals to the wild.

Question 2: Have animals been subjected to a comprehensive veterinary screening and quarantine?

Animals that may be transferred to captive facilities must have a clean bill of health because of the risk of introducing disease to captive populations.

Theses animals must be placed in quarantine to determine if they are disease-free before being transferred to a captive-breeding facility.

Q2 Answer: Yes: Proceed to Question 3.
No: Quarantine and screen and move to Question 3.

Question 3: Have animals been found to be disease-free by comprehensive veterinary screening and quarantine or can they be treated for any infection discovered?

If; during quarantine animals are found to harbour diseases that cannot reasonably be cured, they must be euthanized to prevent infection of other animals. If the animals are suspected to have come into contact with diseases for which screening is impossible, extended quarantine, donation to a research facility, or euthanasia must be considered.

Q3 Answer: Yes: Proceed to Question 4
No: If chronic and incurable infection, first offer animals to research institutions. impossible to place in such institutions, euthanize.

Question 4: Are there grounds for concern that sale will stimulate further illegal or irregular trade?

Commercial sale of Appendix I species is not permitted under the Convention as it is undesirable to stimulate trade in these species. Species not listed in any CITES appendix, but which are nonetheless seriously threatened with extinction, should be afforded the same caution.

Sale of confiscated animals, where legally permitted, is a difficult option to consider. while the benefits of sale -- income and quick disposition -- are clear, there are many problems that may arise as a result of further commercial transactions of the specimens involved. Equally, it should be noted that there may be circumstances where such problems arise as a result of a non-commercial transaction or that, conversely, sale to commercial captive breeders may contribute to production of young offsetting the capture from the wild.

More often than not, sale of threatened species should not take place. Such sales or trade in threatened species may be legally proscribed in some countries, or by CITES. There may be rare cases where a commercial captive breeding operation may purchase or receive individuals for breeding, which may reduce pressure on wild populations subject to trade. In all circumstances, the confiscating authority should be satisfied that:

1) those involved in the illegal or irregular transaction that gave rise to confiscation cannot obtain the animals;
2) the sale does not compromise the objective of confiscation; and, finally,
3) the sale will not increase illegal, irregular or otherwise undesired trade in the species.

Previous experience with sale in some countries (e.g., the USA) has indicated that selling confiscated animals is beset by both logistic and political problems and that, in addition to being controversial, it may also be counter-productive to conservation objectives.

Q4 Answer: Yes: Proceed to Question 5a.
No: Proceed to Question 5b.

Question 5a: Is space available in a non-commercial captive facility (e.g., life-time care facility, zoo, rescue centre, specialist society, their members or private individuals)?

Question 5b: Is space available in a non-commercial captive facility (e.g., life-time care facility, zoo, rescue centre, specialist society, their members or private individuals) or is there a commercial facility breeding this species, and is the facility interested in the animals?

Transfer of animals to non-commercial captive-breeding facilities, if sale may stimulate further illegal or irregular trade, or commercial captive breeding facilities, an option only if sale will not stimulate further illegal or irregular trade, should generally provide a safe and acceptable means of disposition of confiscated animals. when a choice must be made between several such institutions, the paramount consideration should be which facility can:

1) offer the opportunity for the animals to participate in a captive breeding programme;
2) provide the most consistent care; and
3) ensure the welfare of the animals.

The terms and conditions of the transfer should be agreed between the confiscating authority and the recipient institution. Terms and conditions for such agreements should include:

I) a clear commitment to ensure life-time care or, in the event that this becomes impossible, transfer to another facility that can ensure life-time care, or euthanasia;
2) clear specification of ownership of the specimens concerned (as determined by national law) and, where breeding may occur, the offspring. Depending on the circumstances, ownership may be vested with the confiscating authority, the country of origin or export, or with the recipient facility.
3) clear specification of conditions under which the animal(s) or their progeny may be sold.

In the majority of instances, there will be no facilities or zoo or aquarium space available in the country in which animals are confiscated. Where this is the case other captive options should be investigated. This could include transfer to a captive facility outside the country of confiscation particularly in the country of origin, or, if transfer will not stimulate further illegal trade, placement in a commercial captive breeding facility. However, these breeding programmes must be carefully assessed and approached with caution. It may be difficult to monitor these programmes and such programmes may unintentionally, or intentionally, stimulate trade in wild animals. The conservation potential of this transfer, or breeding loan, must be carefully weighed against even the smallest risk of stimulating trade which would further endanger the wild population of the species.

In many countries, there are active specialist societies or clubs of individuals with considerable expertise in the husbandry and breeding of individual Species or groups of Species. Such societies can assist in finding homes for confiscated animals without involving sale through intermediaries. In this case, individuals receiving confiscated animals must have demonstrated expertise in the husbandry of the species concerned and must be provided with adequate information and advice by the club or society concerned. Transfer to specialist societies or individual members must be made according to terms and conditions agreed with the confiscating authority. Such agreements may be the same or similar to those executed with Lifetime Care facilities or zoos. Placement with these societies or members is an option if sale of the confiscated animals may or may not stimulate trade.

Q5 Answer: Yes: Execute agreement and Sell
No: Proceed to Question 6.

Question 6: Are institutions interested in animals for research under humane conditions?

Many research laboratories maintain collections of exotic animals for research conducted under humane conditions. If these animals are kept in conditions that ensure their welfare, transfer to such institutions may provide an acceptable alterative to other options, such as sale or euthanasia. As in the preceding instances, such transfer should be subject to terms and conditions agreed with the confiscating authority; in addition to those already suggested, it may be advisable to include terms that stipulate the types of research the confiscating authority considers permissible. If no placement is possible, the animals should be euthanized.

Q6 Answer: Yes: Execute Agreement and Transfer.
No: Euthanize.

DECISION TREE ANALYSIS -- RETURN TO THE WILD

Question 2: Have animals been subjected to a comprehensive veterinary screening and quarantine?

Because of the risk of introducing disease to wild populations, animals that may be released must have a clean bill of health. These animals must be placed in quarantine to determine if they are disease free before being considered for released.

Q2 Answer: Yes: Proceed to Question 3.
No: Quarantine and screen and move to Question 3

Question 3: Have animals been found to be disease free by comprehensive veterinary screening and quarantine or can they be treated for any infection discovered?

1. If during quarantine, the animals are found to harbour diseases that cannot reasonably be cured, unless any institutions are interested in the animals for research under humane conditions, they must be euthanized to prevent infection of other animals. If the animals are suspected to have come into contact with diseases for which screening is impossible, extended quarantine, donation to a research facility, or euthanasia must be considered.

Q3 Answer: Yes: Proceed to Question 4
No: if chronic and incurable infection, first offer animals to research institutions. if impossible to place in such institutions, euthanize.

Question 4: Can country of origin and site of capture be confirmed?

The geographical location from which confiscated individuals have been removed from the wild must be determined if these individuals are to be re-introduced or used to supplement existing populations. In most cases, animals should only be returned to the population from which they were taken, or from populations which are known to have natural exchange of individuals with this population.

If provenance of the animals is not known, release for reinforcement may lead to inadvertent hybridisation of distinct genetic races or sub-species. Related species of animals that may live in sympatry in the wild and never hybridise have been known to hybridise when held in captivity or shipped in multi-Species groups. This type of generalisation of species recognition under abnormal conditions can result in behavioural problems compromising the success of any future release and can also pose a threat to wild populations by artificially destroying reproductive isolation that is behaviourally mediated.

Q4 Answer: Yes: Proceed to Question 5.
No: Pursue 'Captive Options'.

Question 5: Do the animals exhibit behavioural abnormalities which might make them unsuitable for return to the wild?

Behavioural abnormalities as a result of captivity can result in animals which are not suitable for release into the wild. A wide variety of behavioural traits and specific behavioural skills are necessary for survival, in the short-term for the individual, and in the long-term for the population. Skills for hunting, avoiding predators, food selectivity etc. are necessary to ensure survival.

Q5 Answer: Yes: Pursue 'Captive Options'.
No; Proceed to Question 6.

Question 6:Can individuals be returned expeditiously to origin (specific location), and will benefits to conservation of the species outweigh any risks of such action?

Repatriation of the individual and reinforcement of the population will only be options under certain conditions and following the IUCN/RSG 1995 guidelines:

1) Appropriate habitat for such an operation still exists in the specific location that the individual was removed from; and
2) sufficient funds are available, or can be made available.

Q6 Answer: Yes: Repatriate and reinforce at origin (specific location) following IUCN guidelines.
No: Proceed to Question 7.

Question 7: For the species in question, does a generally recognized programme exist whose aim is conservation of the species and eventual return to the wild of confiscated individuals and or their progeny? Contact IUCN/SSC, IUDZG, Studbook Keeper, or Breeding Programme Coordinator.

In the case of Species for which active captive breeding and or re-introduction programmes exist, and for which further breeding stock/founders are required, confiscated animals should be transferred to such programmes after consultation with the appropriate scientific authorities. If the Species in question is part of a captive breeding programme, but the taxon (sub-species or race) is not part of this programme (e.g. Maguire & Lacy 1990), other methods of disposition must be considered. Particular attention should be paid to genetic screening to avoid jeopardizing captive breeding programmes through inadvertent hybridisation.

Q7 Answer: Yes: Executer agreement and transfer to existing programme.
No: Proceed to Question 8.

Question 8: Is there a need and is it feasible to establish a new r~introduction programme following IUCN Guidelines?

In cases where individuals cannot be transferred to existing r~introduction programmes, return to the wild, following appropriate guidelines, will only be possible under the following circumstances: 1) appropriate habitat exists for such an operation; 2) sufficient funds are available, or can be made available, to support a programme over the many years that (re)introduction will require; and 3) either sufficient numbers of animals are available so that re-introduction efforts are potentially viable, or only reinforcement of existing populations is considered. In the majority of cases, at least one, if not all, of these requirements will fail to be met. In this instance, either conservation introductions outside the historical range of the Species or other options for disposition of the animals must be considered.

It should be emphasized that if a particular species or taxon is confiscated with some frequency, consideration should be made as to whether to establish a re-introduction, reinforcement, or introduction programme. Animals should not be held by the confiscating authority indefinitely while such programmes are planned, but should be transferred to a holding facility after consultation with the organization which is establishing the new programme.

Q8 Answer: Yes: Execute agreement and transfer to holding facility or new programme.
No: Pursue 'Captive Options'.

References

Aveling, R. & Mitchell A.H. (1982). Is rehabilitating orang utans worthwhile? Oryx 16: 263-271.

BirdLife International (in prep). Parrots: An Action Plan for their Conservation. (BirdLife International, Cambridge: England).

Harcourt, A. H. (1987). *Options for unwanted or confiscated primates*. Primate Conservation 8:111-113.

International Academy of Animal Welfare Sciences (1992). *Welfare guidelines for the re-introduction of captive-bred mammals to the wild.* (Universities Federation for Animal Welfare, Potters Bar: United Kingdom).

IUCN (1987). *The IUCN position statement on translocation of living organisms: introductions, re-introductions and restocking*. (IUCN, Gland: Switzerland).

IUCN/SSC RSG (1995). *Draft guidelines for re-introductions*. Species Survival Commission Re-introduction Specialist Group, IUCN - The World Conservation Union.

IUDZG/CBSG (IUCN/SSC) 1993. *The World Zoo Conservation Strategy. The Role of Zoos and Aquaria of the World in Global Conservation*. IUDZG - the World Zoo Organization.

Maguire, L.A. and Lacy, W. C. (1990). Allocating scarce resources for conservation of endangered sub-Species: partitioning zoo space for tigers. Conservation Biology 4, 156-157.

Rijksen, H. D. & Rijksen-Graatsma, A. (1979). Rehabilitation, a new approach is needed. Tigerpaper 6:16-18.

Seal, U.S. & Foose, T. (1992). Captive Animal Management Program (CAMP) Summary Report. (IUCN-CBSG, Apple Valley, Minnesota: USA).

Smith, R. (1990). Island Update. Red Wolf Newsletter 2(1): 2-3.

Stanley Price, M. W. (1989) *Animal re-introduction: the Arabian oryx in Oman*. Cambridge studies in applied ecology and resource management. (Cambridge University Press, Cambridge).

DRAFT GUIDELINES FOR RE-INTRODUCTIONS

Introduction

These policy guidelines have been drafted by the Re-introduction Specialist Group of the IUCN's Species Survival Commission (Guidelines for determining procedures for disposal of species confiscated in trade are being developed separately by IUCN for CITES.) in response to the increasing occurrence of reintroduction projects world-wide, and consequently, to the growing need for specific policy guidelines to help ensure that the re-introductions achieve their intended conservation benefit, and do not cause adverse side-effects of greater impact. Although the IUCN developed a Position Statement on the Translocation of Living Organisms in 1987, more detailed guidelines were felt to be essential in providing more comprehensive coverage of the various factors involved in re-introduction exercises.

These guidelines are intended to act as a guide for procedures useful to re-introduction programmes and do not represent an inflexible code of conduct. Many of the points are more relevant to re-introductions using captive-bred individuals than to translocation of wild species. Others are especially relevant to globally endangered species with limited numbers of founders. Each re-introduction proposal should be rigorously reviewed on its individual merits. On the whole, it should be noted that re-introduction is a very lengthy and complex process.

This document is very general, and worded so that it covers the full range of plant and animal taxa. It will be regularly revised. Handbooks for re-introducing individual groups of animals and plants will be developed in future.

1. Definition of Terms

a. "Re-introduction":

An attempt to establish a species (The taxonomic unit referred to throughout the document is species: it may be a lower taxonomic unit [e.g. sub-species or race] as long as it can be unambiguously defined.) in an area which was once part of its historical range, but from which it has become extinct (CITES criterion of "extinct": species not definitely located in the wild during the past 50 years of conspecifics.). ("Re-establishment" is a synonym, but implies that the re-introduction has been successful) .

b. Translocation":

Deliberate and mediated movement of wild individuals or populations from one part of their range to another.

c. "Reinforcement/Supplementation:

Addition of individuals to an existing population.

d. Conservation/Benign Introductions:

An attempt to establish a species, for the purpose of conservation, outside its recorded distribution but within an appropriate habitat and eco-geographical area.

2. Aims and Objectives of the Re-Introduction

a. Aims:

A re-introduction should aim to establish a viable, free-ranging population in the wild, of a species or subspecies which was formerly globally or locally extinct (extirpated). In some circumstances, a re-introduction may have to be made into an area which is fenced or otherwise delimited, but it should be within the species' former natural habitat and range, and require minimal long-term management.

b. Objectives:

The objectives of a re-introduction will include: to enhance the long-term survival of a species; to re-establish a keystone species (in the ecological or cultural sense) in an ecosystem; to maintain natural biodiversity; to provide long-term economic benefits to the local and/or national economy; to promote conservation awareness; or a combination of these.

Re-introductions or translocation of species for short-term, sporting or commercial purposes - where there is no intention to establish a viable population - are a different issue, beyond the scope of these guidelines. These include fishing an(I hunting activities.

3. Multi disciplinary Approach

A re-introduction requires a Multi disciplinary approach involving a team of persons drawn from a variety of backgrounds. They may include persons from: governmental natural resource management agencies; non-governmental organizations; funding bodies; universities; veterinary institutions; zoos (and private animal breeders) and/or botanic gardens, with a full range of suitable expertise. Team leaders should be responsible for coordination between the various bodies and provision should be made for publicity and public education about the project.

4. Pre-Project Activities

a. Biological:

(I) Feasibility study and background research

● An assessment should be made of the taxonomic status of individuals to be re-introduced. They must be of the same subspecies as those which were extirpated, unless adequate numbers are not available. An investigation of historical information about the loss and fate of individuals from the re-introduction area, as well as molecular genetic studies, should be undertaken in case of doubt. A study of genetic variation within and between populations of this and related taxa can also be helpful. Special care is needed when the population has long been extinct.

● Detailed studies should be made of the status and biology of wild populations (if they exist) to determine the species' critical needs; for animals, this would include descriptions of habitat preferences, intra specific variation and adaptations to local ecological conditions, social behavior, group composition, home range size, shelter and food requirements, foraging and feeding behavior, predators and diseases. For plants it would include biotic and abiotic habitat requirements, dispersal mechanisms, reproductive biology, symbiotic relationships (e.g. with mycorrhizae, pollinators), insect pests and diseases. Overall, a firm knowledge of the natural history of the species in question is crucial to the entire re-introduction scheme.

● The build-up of the released population should be modeled under various sets of conditions, in order to specify the optimal number and composition of individuals to be released per year and the numbers of years necessary to promote establishment of a viable population.

● A Population and Habitat Viability Analysis will aid in identifying significant environmental and population variables and assessing their potential interactions, which would guide long-term population management.

(ii) Previous Re-introductions

● Thorough research into previous re-introductions of the same or similar species and wide-ranging contacts with persons having relevant expertise should be conducted prior to and while developing re-introduction protocol.

(iii) Choice of release site

● Site should be within the historic range of species and for an initial reinforcement or re-introduction have very few, or no, remnant wild individuals (to prevent disease spread, social disruption and introduction of alien genes). A conservation/ benign introduction should be undertaken only as a last resort when no opportunities for re-introduction into the original site or range exist.

- The re-introduction area should have assured, long-term protection (whether formal or otherwise).

(iv) Evaluation of re-introduction site

- Availability of suitable habitat: re-introductions should only take place where the habitat and landscape requirements of the species are satisfied, and likely to be sustained for the for-seeable future. The possibility of natural habitat change since extirpation must be considered. The area should have sufficient carrying capacity to sustain growth of the re-introduced population and support a viable (self-sustaining) population in the long run.

- Identification and elimination of previous causes of decline: could include disease; over-hunting; over-collection; pollution; poisoning; competition with or predation by introduced species; habitat loss; adverse effects of earlier research or management programmes; competition with domestic livestock, which may be seasonal.

- Where the release site has undergone substantial degradation caused by human activity, a habitat restoration programme should be initiated before the reintroduction is carried out.

(v) Availability of suitable release stock

- Release stock should be ideally closely-related genetically to the original native stock.

- If captive or artificially propagated stock is to be used, it must be from a population which has been soundly managed both demographically and genetically, according to the principles of contemporary conservation biology.

- Re-introductions should not be carried out merely because captive stocks exist, nor should they be a means of disposing of surplus stock.

- Removal of individuals for re-introduction must not endanger the captive stock population or the wild source population. Stock must be guaranteed available on a regular and predictable basis, meeting specifications of the project protocol.

- Prospective release stock must be subjected to a thorough veterinary screening process before shipment from original source. Any animals found to be infected or which test positive for selected pathogens must be removed from the consignment, and the uninfected, negative remainder must be placed in strict quarantine for a suitable period before retest. If clear after retesting, the animals may be placed for shipment.

- Since infection with serious disease can be acquired during shipment, especially if this is intercontinental, great care must be taken to minimize this risk.

- Stock must meet all health regulations prescribed by the veterinary authorities of the recipient country and adequate provisions must be made for quarantine if necessary.

• Individuals should only be removed from a wild population after the effects of translocation on the donor population have been assessed, and after it is guaranteed that these effects will not be negative.

b. Socio-Economic and Legal Activities

• Re-introductions are generally long-term projects that require the commitment of long-term financial and political support.

• Socio-economic studies should be made to assess costs and benefits of the e-introduction programme to local human populations.

• A thorough assessment of attitudes of local people to the proposed project is necessary to ensure long term protection of the re-introduced population, especially if the cause of species' decline was due to human factors (e.g. over-hunting, over-collection, loss of habitat). The programme should be fully understood, accepted and supported by local communities.

• Where the security of the re-introduced population is at risk from human activities, measures should be taken to minimize these in the re-introduction area. If these measures are inadequate, the re-introduction should be abandoned or alternative release areas sought.

• The policy of the country to re-introductions and to the species concerned should be assessed. This might include checking existing national and international legislation and regulations, and provision of new measures as necessary. Re-introduction must take place with the full permission and involvement of all relevant government agencies of the recipient or host country. This is particularly important in re-introductions in border areas, or involving more than one state.

• If the species poses potential risk to life or property, these risks should be minimized and adequate provision made for compensation where necessary; where all other solutions fail, removal or destruction of the released individual should be considered.

In the case of migratory/mobile species, provisions should be made for crossing of international/state boundaries.

5. Planning. Preparation and Release Stages

• Construction of a Multi disciplinary team with access to expert technical advice for all phases of the programme.

• Approval of all relevant government agencies and land owners, and coordination with national and international conservation organizations.

- Development of transport plans for delivery of stock to the country and site of re-introduction, with special emphasis on ways to minimize stress on the individuals during transport.

- Identification of short-and long-term success indicators and prediction of programme duration, in context of agreed aims and objectives.

- Securing adequate funding for all programme phases.

- Design of pre- and post- release monitoring programme so that each re-introduction is a carefully designed experiment, with the capability to test methodology with scientifically collected data.

- Appropriate health and genetic screening of release stock. Health screening of closely related species in re-introduction area.

- If release stock is wild-caught, care must be taken to ensure that: a) the stock is free from infectious or contagious pathogens and parasites before shipment and b) the stock will not be exposed to vectors of disease agents which may be present at the release site (and absent at the source site) and to which it may have no acquired immunity.

- If vaccination prior to release, against local endemic or epidemic diseases of wild stock or domestic livestock at the release site, is deemed appropriate, this must be carried out during the "Preparation Stage" so as to allow sufficient time for the development of the required immunity.

- Appropriate veterinary or horticultural measures to ensure health of released stock throughout programme. This is to include adequate quarantine arrangements, especially where founder stock travels far or crosses international boundaries to release site.

- Determination of release strategy (acclimatization of release stock to release area; behavioral training - including hunting and feeding; group composition, number, release patterns and techniques; timing).

- Establishment of policies on interventions (see below).

- Development of conservation education for long-term support; professional training of individuals involved in long-term programme; public relations through the mass media and in local community; involvement where possible of local people in the programme.

- The welfare of animals for release is of paramount concern through all these stages.

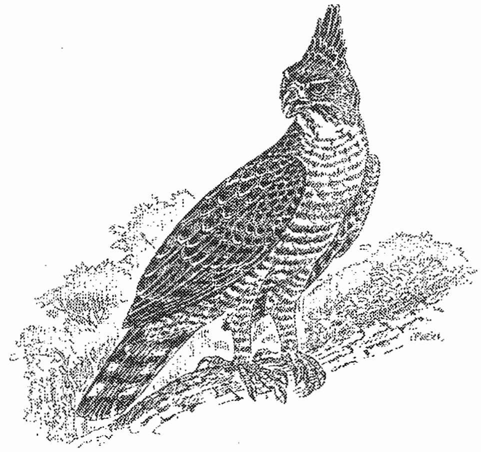
6. Post-Release Activities

- Post release monitoring of all (or sample of) individuals. This most vital aspect may be by direct (e.g. tagging, telemetry) or indirect (e.g. spoor, informants) methods as suitable.

- Demographic, ecological and behavioral studies of released stock.
- Study of processes of long-term adaptation by individuals and the population.
- Collection and investigation of mortalities.
- Interventions (e.g. supplemental feeding; veterinary aid; horticultural aid) when necessary.
- Decisions for revision rescheduling, or discontinuation of programme where necessary.
- Habitat protection or restoration to continue where necessary.
- Continuing public relations activities, including education and mass media coverage.
- Evaluation of cost-effectiveness and success of re- introduction techniques.
- Regular publications in scientific and popular literature.

POPULATION AND HABITAT VIABILITY ASSESSMENT FOR THE JAVAN HAWK-EAGLE (*Spizaetus bartelsi*)

Taman Safari Indonesia
6 - 8 May 1996



Section 9
Appendix IV.
VORTEX Technical Reference

Wildl. Res., 1993, **20**, 45–65

VORTEX: A Computer Simulation Model for Population Viability Analysis

Robert C. Lacy

Department of Conservation Biology, Chicago Zoological Society,
Brookfield, Illinois 60513, U.S.A.

Abstract

Population Viability Analysis (PVA) is the estimation of extinction probabilities by analyses that incorporate identifiable threats to population survival into models of the extinction process. Extrinsic forces, such as habitat loss, over-harvesting, and competition or predation by introduced species, often lead to population decline. Although the traditional methods of wildlife ecology can reveal such deterministic trends, random fluctuations that increase as populations become smaller can lead to extinction even of populations that have, on average, positive population growth when below carrying capacity. Computer simulation modelling provides a tool for exploring the viability of populations subjected to many complex, interacting deterministic and random processes. One such simulation model, VORTEX, has been used extensively by the Captive Breeding Specialist Group (Species Survival Commission, IUCN), by wildlife agencies, and by university classes. The algorithms, structure, assumptions and applications of VORTEX are described in this paper.

VORTEX models population processes as discrete, sequential events, with probabilistic outcomes. VORTEX simulates birth and death processes and the transmission of genes through the generations by generating random numbers to determine whether each animal lives or dies, to determine the number of progeny produced by each female each year, and to determine which of the two alleles at a genetic locus are transmitted from each parent to each offspring. Fecundity is assumed to be independent of age after an animal reaches reproductive age. Mortality rates are specified for each pre-reproductive age–sex class and for reproductive-age animals. Inbreeding depression is modelled as a decrease in viability in inbred animals.

The user has the option of modelling density dependence in reproductive rates. As a simple model of density dependence in survival, a carrying capacity is imposed by a probabilistic truncation of each age class if the population size exceeds the specified carrying capacity. VORTEX can model linear trends in the carrying capacity. VORTEX models environmental variation by sampling birth rates, death rates, and the carrying capacity from binomial or normal distributions. Catastrophes are modelled as sporadic random events that reduce survival and reproduction for one year. VORTEX also allows the user to supplement or harvest the population, and multiple subpopulations can be tracked, with user-specified migration among the units.

VORTEX outputs summary statistics on population growth rates, the probability of population extinction, the time to extinction, and the mean size and genetic variation in extant populations.

VORTEX necessarily makes many assumptions. The model it incorporates is most applicable to species with low fecundity and long lifespans, such as mammals, birds and reptiles. It integrates the interacting effects of many of the deterministic and stochastic processes that have an impact on the viability of small populations, providing opportunity for more complete analysis than is possible by other techniques. PVA by simulation modelling is an important tool for identifying populations at risk of extinction, determining the urgency of action, and evaluating options for management.

Introduction

Many wildlife populations that were once widespread, numerous, and occupying contiguous habitat, have been reduced to one or more small, isolated populations. The causes of the original decline are often obvious, deterministic forces, such as over-harvesting,

1035-3712/93/010045$10.00

habitat destruction, and competition or predation from invasive introduced species. Even if the original causes of decline are removed, a small isolated population is vulnerable to additional forces, intrinsic to the dynamics of small populations, which may drive the population to extinction (Shaffer 1981; Soulé 1987; Clark and Seebeck 1990). Of particular impact on small populations are stochastic processes. With the exception of aging, virtually all events in the life of an organism are stochastic. Mating, reproduction, gene transmission between generations, migration, disease and predation can be described by probability distributions, with individual occurrences being sampled from these distributions. Small samples display high variance around the mean, so the fates of small wildlife populations are often determined more by random chance than by the mean birth and death rates that reflect adaptations to their environment.

Although many processes affecting small populations are intrinsically indeterminate, the average long-term fate of a population and the variance around the expectation can be studied with computer simulation models. The use of simulation modelling, often in conjunction with other techniques, to explore the dynamics of small populations has been termed Population Viability Analysis (PVA). PVA has been increasingly used to help guide management of threatened species. The Resource Assessment Commission of Australia (1991) recently recommended that 'estimates of the size of viable populations and the risks of extinction under multiple-use forestry practices be an essential part of conservation planning'. Lindenmayer *et al.* (1993) describe the use of computer modelling for PVA, and discuss the strengths and weaknesses of the approach as a tool for wildlife management.

In this paper, I present the PVA program VORTEX and describe its structure, assumptions and capabilities. VORTEX is perhaps the most widely used PVA simulation program, and there are numerous examples of its application in Australia, the United States of America and elsewhere.

The Dynamics of Small Populations

The stochastic processes that have an impact on populations have been usefully categorised into demographic stochasticity, environmental variation, catastrophic events and genetic drift (Shaffer 1981). Demographic stochasticity is the random fluctuation in the observed birth rate, death rate and sex ratio of a population even if the probabilities of birth and death remain constant. On the assumption that births and deaths and sex determination are stochastic sampling processes, the annual variations in numbers that are born, die, and are of each sex can be specified from statistical theory and would follow binomial distributions. Such demographic stochasticity will be important to population viability only in populations that are smaller than a few tens of animals (Goodman 1987), in which cases the annual frequencies of birth and death events and the sex ratios can deviate far from the means. The distribution of annual adult survival rates observed in the remnant population of whooping cranes (*Grus americana*) (Mirande *et al.* 1993) is shown in Fig. 1. The innermost curve approximates the binomial distribution that describes the demographic stochasticity expected when the probability of survival is 92·7% (mean of 45 non-outlier years).

Environmental variation is the fluctuation in the probabilities of birth and death that results from fluctuations in the environment. Weather, the prevalence of enzootic disease, the abundances of prey and predators, and the availability of nest sites or other required microhabitats can all vary, randomly or cyclically, over time. The second narrowest curve on Fig. 1 shows a normal distribution that statistically fits the observed frequency histogram of crane survival in non-outlier years. The difference between this curve and the narrower distribution describing demographic variation must be accounted for by environmental variation in the probability of adult survival.

Catastrophic variation is the extreme of environmental variation, but for both methodological and conceptual reasons rare catastrophic events are analysed separately from the more typical annual or seasonal fluctuations. Catastrophes such as epidemic disease,

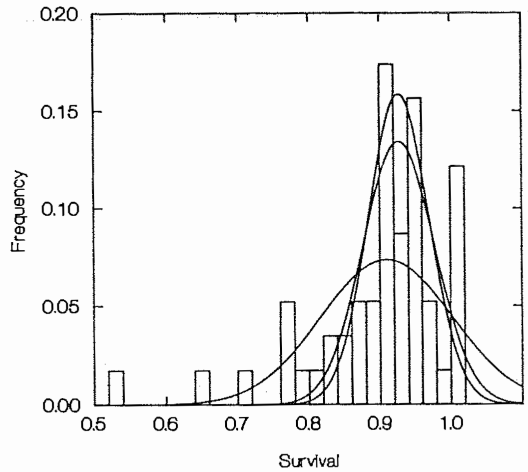


Fig. 1. Frequency histogram of the proportion of whooping cranes surviving each year, 1938–90. The broadest curve is the normal distribution that most closely fits the overall histogram. Statistically, this curve fits the data poorly. The second highest and second broadest curve is the normal distribution that most closely fits the histogram, excluding the five leftmost bars (7 outlier 'catastrophe' years). The narrowest and tallest curve is the normal approximation to the binomial distribution expected from demographic stochasticity. The difference between the tallest and second tallest curves is the variation in annual survival due to environmental variation.

hurricanes, large-scale fires, and floods are outliers in the distribution of environmental variation (e.g. five leftmost bars on Fig. 1). As a result, they have quantitatively and sometimes qualitatively different impacts on wildlife populations. (A forest fire is not just a very hot day.) Such events often precipitate the final decline to extinction (Simberloff 1986, 1988). For example, one of two populations of whooping crane was decimated by a hurricane in 1940 and soon after went extinct (Doughty 1989). The only remaining population of the black-footed ferret (*Mustela nigripes*) was being eliminated by an outbreak of distemper when the last 18 ferrets were captured (Clark 1989).

Genetic drift is the cumulative and non-adaptive fluctuation in allele frequencies resulting from the random sampling of genes in each generation. This can impede the recovery or accelerate the decline of wildlife populations for several reasons (Lacy 1993). Inbreeding, not strictly a component of genetic drift but correlated with it in small populations, has been documented to cause loss of fitness in a wide variety of species, including virtually all sexually reproducing animals in which the effects of inbreeding have been carefully studied (Wright 1977; Falconer 1981; O'Brien and Evermann 1988; Ralls *et al.* 1988; Lacy *et al.* 1993). Even if the immediate loss of fitness of inbred individuals is not large, the loss of genetic variation that results from genetic drift may reduce the ability of a population to adapt to future changes in the environment (Fisher 1958; Robertson 1960; Selander 1983).

Thus, the effects of genetic drift and consequent loss of genetic variation in individuals and populations have a negative impact on demographic rates and increase susceptibility to environmental perturbations and catastrophes. Reduced population growth and greater fluctuations in numbers in turn accelerate genetic drift (Crow and Kimura 1970). These synergistic destabilising effects of stochastic process on small populations of wildlife have been described as an 'extinction vortex' (Gilpin and Soulé 1986). The size below which a population is likely to be drawn into an extinction vortex can be considered a 'minimum viable population' (MVP) (Seal and Lacy 1989), although Shaffer (1981) first defined a MVP more stringently as a population that has a 99% probability of persistence for 1000 years. The estimation of MVPs or, more generally, the investigation of the probability of extinction constitutes PVA (Gilpin and Soulé 1986; Gilpin 1989; Shaffer 1990).

Methods for Analysing Population Viability

An understanding of the multiple, interacting forces that contribute to extinction vortices is a prerequisite for the study of extinction–recolonisation dynamics in natural populations inhabiting patchy environments (Gilpin 1987), the management of small populations (Clark and Seebeck 1990), and the conservation of threatened wildlife (Shaffer 1981, 1990; Soulé 1987; Mace and Lande 1991). Because demographic and genetic processes in small populations are inherently unpredictable, the expected fates of wildlife populations can be described in terms of probability distributions of population size, time to extinction, and genetic variation. These distributions can be obtained in any of three ways: from analytical models, from empirical observation of the fates of populations of varying size, or from simulation models.

As the processes determining the dynamics of populations are multiple and complex, there are few analytical formulae for describing the probability distributions (e.g. Goodman 1987; Lande 1988; Burgmann and Gerard 1990). These models have incorporated only few of the threatening processes. No analytical model exists, for example, to describe the combined effect of demographic stochasticity and loss of genetic variation on the probability of population persistence.

A few studies of wildlife populations have provided empirical data on the relationship between population size and probability of extinction (e.g. Belovsky 1987; Berger 1990; Thomas 1990), but presently only order-of-magnitude estimates can be provided for MVPs of vertebrates (Shaffer 1987). Threatened species are, by their rarity, unavailable and inappropriate for the experimental manipulation of population sizes and long-term monitoring of undisturbed fates that would be necessary for precise empirical measurement of MVPs. Retrospective analyses will be possible in some cases, but the function relating extinction probability to population size will differ among species, localities and times (Lindenmayer *et al.* 1993).

Modelling the Dynamics of Small Populations

Because of the lack of adequate empirical data or theoretical and analytical models to allow prediction of the dynamics of populations of threatened species, various biologists have turned to Monte Carlo computer simulation techniques for PVA. By randomly sampling from defined probability distributions, computer programs can simulate the multiple, interacting events that occur during the lives of organisms and that cumulatively determine the fates of populations. The focus is on detailed and explicit modelling of the forces impinging on a given population, place, and time of interest, rather than on delineation of rules (which may not exist) that apply generally to most wildlife populations. Computer programs available to PVA include SPGPC (Grier 1980*a*, 1980*b*), GAPPS (Harris *et al.* 1986), RAMAS (Ferson and Akçakaya 1989; Akçakaya and Ferson 1990; Ferson 1990), FORPOP (Possingham *et al.* 1991), ALEX (Possingham *et al.* 1992), and SIMPOP (Lacy *et al.* 1989; Lacy and Clark 1990) and its descendant VORTEX.

SIMPOP was developed in 1989 by converting the algorithms of the program SPGPC (written by James W. Grier of North Dakota State University) from BASIC to the C programming language. SIMPOP was used first in a PVA workshop organised by the Species Survival Commission's Captive Breeding Specialist Group (IUCN), the United States Fish and Wildlife Service, and the Puerto Rico Department of Natural Resources to assist in planning and assessing recovery efforts for the Puerto Rican crested toad (*Peltophryne lemur*). SIMPOP was subsequently used in PVA modelling of other species threatened with extinction, undergoing modification with each application to allow incorporation of additional threatening processes. The simulation program was renamed VORTEX (in reference to the extinction vortex) when the capability of modelling genetic processes was implemented in 1989. In 1990, a version allowing modelling of multiple populations was briefly named VORTICES. The only version still supported, with all capabilities of each previous version, is VORTEX Version 5.1.

VORTEX has been used in PVA to help guide conservation and management of many species, including the Puerto Rican parrot (*Amazona vittata*) (Lacy *et al.* 1989), the Javan rhinoceros (*Rhinoceros sondaicus*) (Seal and Foose 1989), the Florida panther (*Felis concolor coryi*) (Seal and Lacy 1989), the eastern barred bandicoot (*Perameles gunnii*) (Lacy and Clark 1990; Maguire *et al.* 1990), the lion tamarins (*Leontopithecus rosalia* ssp.) (Seal *et al.* 1990), the brush-tailed rock-wallaby (*Petrogale penicillata penicillata*) (Hill 1991), the mountain pygmy-possum (*Burramys parvus*), Leadbeater's possum (*Gymnobelideus leadbeateri*), the long-footed potoroo (*Potorous longipes*), the orange-bellied parrot (*Neophema chrysogaster*) and the helmeted honeyeater (*Lichenostomus melanops cassidix*) (Clark *et al.* 1991), the whooping crane (*Grus americana*) (Mirande *et al.* 1993), the Tana River crested mangabey (*Cercocebus galeritus galeritus*) and the Tana River red colobus (*Colobus badius rufomitratus*) (Seal *et al.* 1991), and the black rhinoceros (*Diceros bicornis*) (Foose *et al.* 1992). In some of these PVAs, modelling with VORTEX has made clear the insufficiency of past management plans to secure the future of the species, and alternative strategies were proposed, assessed and implemented. For example, the multiple threats to the Florida panther in its existing habitat were recognised as probably insurmountable, and a captive breeding effort has been initiated for the purpose of securing the gene pool and providing animals for release in areas of former habitat. PVA modelling with VORTEX has often identified a single threat to which a species is particularly vulnerable. The small but growing population of Puerto Rican parrots was assessed to be secure, except for the risk of population decimation by hurricane. Recommendations were made to make available secure shelter for captive parrots and to move some of the birds to a site distant from the wild flock, in order to minimise the damage that could occur in a catastrophic storm. These recommended actions were only partly implemented when, in late 1989, a hurricane killed many of the wild parrots. The remaining population of about 350 Tana River red colobus were determined by PVA to be so fragmented that demographic and genetic processes within the 10 subpopulations destabilised population dynamics. Creation of habitat corridors may be necessary to prevent extinction of the taxon. In some cases, PVA modelling has been reassuring to managers: analysis of black rhinos in Kenya indicated that many of the populations within sanctuaries were recovering steadily. Some could soon be used to provide animals for re-establishment or supplementation of populations previously eliminated by poaching. For some species, available data were insufficient to allow definitive PVA with VORTEX. In such cases, the attempt at PVA modelling has made apparent the need for more data on population trends and processes, thereby helping to justify and guide research efforts.

Description of VORTEX

Overview

The VORTEX computer simulation model is a Monte Carlo simulation of the effects of deterministic forces, as well as demographic, environmental and genetic stochastic events, on wildlife populations. VORTEX models population dynamics as discrete, sequential events that occur according to probabilities that are random variables, following user-specified distributions. The input parameters used by VORTEX are summarised in the first part of the sample output given in the Appendix.

VORTEX simulates a population by stepping through a series of events that describe an annual cycle of a typical sexually reproducing, diploid organism: mate selection, reproduction, mortality, increment of age by one year, migration among populations, removals, supplementation, and then truncation (if necessary) to the carrying capacity. The program was designed to model long-lived species with low fecundity, such as mammals, birds and reptiles. Although it could and has been used in modelling highly fecund vertebrates and invertebrates, it is awkward to use in such cases as it requires complete specification of the percentage of females producing each possible clutch size. Moreover, computer memory limitations often hamper such analyses. Although VORTEX iterates life events on an annual cycle, a user could model 'years' that are other than 12 months' duration. The simulation of the population is itself iterated to reveal the distribution of fates that the population might experience.

Demographic Stochasticity

VORTEX models demographic stochasticity by determining the occurrence of probabilistic events such as reproduction, litter size, sex determination and death with a pseudo-random number generator. The probabilities of mortality and reproduction are sex-specific and pre-determined for each age class up to the age of breeding. It is assumed that reproduction and survival probabilities remain constant from the age of first breeding until a specified upper limit to age is reached. Sex ratio at birth is modelled with a user-specified constant probability of an offspring being male. For each life event, if the random value sampled from the uniform 0–1 distribution falls below the probability for that year, the event is deemed to have occurred, thereby simulating a binomial process.

The source code used to generate random numbers uniformly distributed between 0 and 1 was obtained from Maier (1991), according to the algorithm of Kirkpatrick and Stoll (1981). Random deviates from binomial distributions, with mean p and standard deviation s, are obtained by first determining the integral number of binomial trials, N, that would produce the value of s closest to the specified value, according to

$$N = p(1-p)/s^2 .$$

N binomial trials are then simulated by sampling from the uniform 0–1 distribution to obtain the desired result, the frequency or proportion of successes. If the value of N determined for a desired binomial distribution is larger than 25, a normal approximation is used in place of the binomial distribution. This normal approximation must be truncated at 0 and at 1 to allow use in defining probabilities, although, with such large values of N, s is small relative to p and the truncation would be invoked only rarely. To avoid introducing bias with this truncation, the normal approximation to the binomial (when used) is truncated symmetrically around the mean. The algorithm for generating random numbers from a unit normal distribution follows Latour (1986).

VORTEX can model monogamous or polygamous mating systems. In a monogamous system, a relative scarcity of breeding males may limit reproduction by females. In polygamous or monogamous models, the user can specify the proportion of the adult males in the breeding pool. Males are randomly reassigned to the breeding pool each year of the simulation, and all males in the breeding pool have an equal chance of siring offspring.

The 'carrying capacity', or the upper limit for population size within a habitat, must be specified by the user. VORTEX imposes the carrying capacity via a probabilistic truncation whenever the population exceeds the carrying capacity. Each animal in the population has an equal probability of being removed by this truncation.

Environmental Variation

VORTEX can model annual fluctuations in birth and death rates and in carrying capacity as might result from environmental variation. To model environmental variation, each demographic parameter is assigned a distribution with a mean and standard deviation that is specified by the user. Annual fluctuations in probabilities of reproduction and mortality are modelled as binomial distributions. Environmental variation in carrying capacity is modelled as a normal distribution. The variance across years in the frequencies of births and deaths resulting from the simulation model (and in real populations) will have two components: the demographic variation resulting from a binomial sampling around the mean for each year, and additional fluctuations due to environmental variation and catastrophes (see Fig. 1 and section on The Dynamics of Small Populations, above).

Data on annual variations in birth and death rates are important in determining the probability of extinction, as they influence population stability (Goodman 1987). Unfortunately, such field information is rarely available (but see Fig. 1). Sensitivity testing, the examination of a range of values when the precise value of a parameter is unknown, can help to identify whether the unknown parameter is important in the dynamics of a population.

Catastrophes

Catastrophes are modelled in VORTEX as random events that occur with specified probabilities. Any number of types of catastrophes can be modelled. A catastrophe will occur if a randomly generated number between zero and one is less than the probability of occurrence. Following a catastrophic event, the chances of survival and successful breeding for that simulated year are multiplied by severity factors. For example, forest fires might occur once in 50 years, on average, killing 25% of animals, and reducing breeding by survivors by 50% for the year. Such a catastrophe would be modelled as a random event with 0·02 probability of occurrence each year, and severity factors of 0·75 for survival and 0·50 for reproduction.

Genetic Processes

Genetic drift is modelled in VORTEX by simulation of the transmission of alleles at a hypothetical locus. At the beginning of the simulation, each animal is assigned two unique alleles. Each offspring is randomly assigned one of the alleles from each parent. Inbreeding depression is modelled as a loss of viability during the first year of inbred animals. The impacts of inbreeding are determined by using one of two models available within VORTEX: a Recessive Lethals model or a Heterosis model.

In the Recessive Lethals model, each founder starts with one unique recessive lethal allele and a unique, dominant non-lethal allele. This model approximates the effect of inbreeding if each individual in the starting population had one recessive lethal allele in its genome. The fact that the simulation program assumes that all the lethal alleles are at the same locus has a very minor impact on the probability that an individual will die because of homozygosity for one of the lethal alleles. In the model, homozygosity for different lethal alleles are mutually exclusive events, whereas in a multilocus model an individual could be homozygous for several lethal alleles simultaneously. By virtue of the death of individuals that are homozygous for lethal alleles, such alleles would be removed slowly by natural selection during the generations of a simulation. This reduces the genetic variation present in the population relative to the case with no inbreeding depression, but also diminishes the subsequent probability that inbred individuals will be homozygous for a lethal allele. This model gives an optimistic reflection of the impacts of inbreeding on many species, as the median number of lethal equivalents per diploid genome observed for mammalian populations is about three (Ralls *et al.* 1988).

The expression of fully recessive deleterious alleles in inbred organisms is not the only genetic mechanism that has been proposed as a cause of inbreeding depression. Some or most of the effects of inbreeding may be a consequence of superior fitness of heterozygotes (heterozygote advantage or 'heterosis'). In the Heterosis model, all homozygotes have reduced fitness compared with heterozygotes. Juvenile survival is modelled according to the logarithmic model developed by Morton *et al.* (1956):

$$\ln S = A - BF$$

in which S is survival, F is the inbreeding coefficient, A is the logarithm of survival in the absence of inbreeding, and B is a measure of the rate at which survival decreases with inbreeding. B is termed the number of 'lethal equivalents' per haploid genome. The number of lethal equivalents per diploid genome, $2B$, estimates the number of lethal alleles per individual in the population if all deleterious effects of inbreeding were due to recessive lethal alleles. A population in which inbreeding depression is one lethal equivalent per diploid genome may have one recessive lethal allele per individual (as in the Recessive Lethals model, above), it may have two recessive alleles per individual, each of which confer a 50% decrease in survival, or it may have some other combination of recessive deleterious alleles that equate in effect with one lethal allele per individual. Unlike the situation with fully recessive deleterious alleles, natural selection does not remove deleterious alleles at heterotic loci because all alleles are deleterious when homozygous and beneficial when present in heterozygous combination with other alleles. Thus, under the Heterosis model, the impact of inbreeding on survival does not diminish during repeated generations of inbreeding.

Unfortunately, for relatively few species are data available to allow estimation of the effects of inbreeding, and the magnitude of these effects varies considerably among species (Falconer 1981; Ralls *et al.* 1988; Lacy *et al.* 1993). Moreover, whether a Recessive Lethals model or a Heterosis model better describes the underlying mechanism of inbreeding depression and therefore the response to repeated generations of inbreeding is not well-known (Brewer *et al.* 1990), and could be determined empirically only from breeding studies that span many generations. Even without detailed pedigree data from which to estimate the number of lethal equivalents in a population and the underlying nature of the genetic load (recessive alleles or heterosis), applications of PVA must make assumptions about the effects of inbreeding on the population being studied. In some cases, it might be considered appropriate to assume that an inadequately studied species would respond to inbreeding in accord with the median (3·14 lethal equivalents per diploid) reported in the survey by Ralls *et al.* (1988). In other cases, there might be reason to make more optimistic assumptions (perhaps the lower quartile, 0·90 lethal equivalents), or more pessimistic assumptions (perhaps the upper quartile, 5·62 lethal equivalents).

Deterministic Processes

VORTEX can incorporate several deterministic processes. Reproduction can be specified to be density-dependent. The function relating the proportion of adult females breeding each year to the total population size is modelled as a fourth-order polynomial, which can provide a close fit to most plausible density-dependence curves. Thus, either positive population responses to low-density or negative responses (e.g. Allee effects), or more complex relationships, can be modelled.

Populations can be supplemented or harvested for any number of years in each simulation. Harvest may be culling or removal of animals for translocation to another (unmodelled) population. The numbers of additions and removals are specified according to the age and sex of animals. Trends in the carrying capacity can also be modelled in VORTEX, specified as an annual percentage change. These changes are modelled as linear, rather than geometric, increases or decreases.

Migration among Populations

VORTEX can model up to 20 populations, with possibly distinct population parameters. Each pairwise migration rate is specified as the probability of an individual moving from one population to another. This probability is independent of the age and sex. Because of between-population migration and managed supplementation, populations can be recolonised. VORTEX tracks the dynamics of local extinctions and recolonisations through the simulation.

Output

VORTEX outputs (1) probability of extinction at specified intervals (e.g., every 10 years during a 100-year simulation), (2) median time to extinction if the population went extinct in at least 50% of the simulations, (3) mean time to extinction of those simulated populations that became extinct, and (4) mean size of, and genetic variation within, extant populations (see Appendix and Lindenmayer *et al.* 1993).

Standard deviations across simulations and standard errors of the mean are reported for population size and the measures of genetic variation. Under the assumption that extinction of independently replicated populations is a binomial process, the standard error of the probability of extinction (SE) is reported by VORTEX as

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

in which the frequency of extinction was p over n simulated populations. Demographic and genetic statistics are calculated and reported for each subpopulation and for the metapopulation.

Availability of the VORTEX Simulation Program

VORTEX Version 5.1 is written in the C programming language and compiled with the Lattice 80286C Development System (Lattice Inc.) for use on microcomputers using the MS-DOS (Microsoft Corp.) operating system. Copies of the compiled program and a manual for its use are available for nominal distribution costs from the Captive Breeding Specialist Group (Species Survival Commission, IUCN), 12101 Johnny Cake Ridge Road, Apple Valley, Minnesota 55124, U.S.A. The program has been tested by many workers, but cannot be guaranteed to be error-free. Each user retains responsibility for ensuring that the program does what is intended for each analysis.

Sequence of Program Flow

(1) The seed for the random number generator is initialised with the number of seconds elapsed since the beginning of the 20th century.

(2) The user is prompted for input and output devices, population parameters, duration of simulation, and number of interations.

(3) The maximum allowable population size (necessary for preventing memory overflow) is calculated as

$$N_{max} = (K + 3s) \times (1 + L)$$

in which K is the maximum carrying capacity (carrying capacity can be specified to change linearly for a number of years in a simulation, so the maximum carrying capacity can be greater than the initial carrying capacity), s is the annual environmental variation in the carrying capacity expressed as a standard deviation, and L is the specified maximum litter size. It is theoretically possible, but very unlikely, that a simulated population will exceed the calculated N_{max}. If this occurs then the program will give an error message and abort.

(4) Memory is allocated for data arrays. If insufficient memory is available for data arrays then N_{max} is adjusted downward to the size that can be accommodated within the available memory and a warning message is given. In this case it is possible that the analysis may have to be terminated because the simulated population exceeds N_{max}. Because N_{max} is often several-fold greater than the likely maximum population size in a simulation, a warning it has been adjusted downward because of limiting memory often will not hamper the analyses. Except for limitations imposed by the size of the computer memory (VORTEX can use extended memory, if available), the only limit to the size of the analysis is that no more than 20 populations exchanging migrants can be simulated.

(5) The expected mean growth rate of the population is calculated from mean birth and death rates that have been entered. Algorithms follow cohort life-table analyses (Ricklefs 1979). Generation time and the expected stable age distribution are also estimated. Life-table estimations assume no limitation by carrying capacity, no limitation of mates, and no loss of fitness due to inbreeding depression, and the estimated intrinsic growth rate assumes that the population is at the stable age distribution. The effects of catastrophes are incorporated into the life-table analysis by using birth and death rates that are weighted averages of the values in years with and without catastrophes, weighted by the probability of a catastrophe occurring or not occurring.

(6) Iterative simulation of the population proceeds via steps 7–26 below. For exploratory modelling, 100 iterations are usually sufficient to reveal gross trends among sets of simulations with different input parameters. For more precise examination of population behaviour under various scenarios, 1000 or more simulations should be used to minimise standard errors around mean results.

(7) The starting population is assigned an age and sex structure. The user can specify the exact age–sex structure of the starting population, or can specify an initial population size and request that the population be distributed according to the stable age distribution calculated from the life table. Individuals in the starting population are assumed to be unrelated. Thus, inbreeding can occur only in second and later generations.

(8) Two unique alleles at a hypothetical genetic locus are assigned to each individual in the starting population and to each individual supplemented to the population during the simulation. VORTEX therefore uses an infinite alleles model of genetic variation. The subsequent fate of genetic variation is tracked by reporting the number of extant alleles each year, the expected heterozygosity or gene diversity, and the observed heterozygosity. The expected heterozygosity, derived from the Hardy–Weinberg equilibrium, is given by

$$H_e = 1 - \Sigma(p_i^2),$$

in which p_i is the frequency of allele i in the population. The observed heterozygosity is simply the proportion of the individuals in the simulated population that are heterozygous. Because of the starting assumption of two unique alleles per founder, the initial population has an observed heterozygosity of 1·0 at the hypothetical locus and only inbred animals can become homozygous. Proportional loss of heterozygosity by means of random genetic drift is independent of the initial heterozygosity and allele frequencies of a population (assuming that the initial value was not zero) (Crow and Kimura 1970), so the expected heterozygosity remaining in a simulated population is a useful metric of genetic decay for comparison across scenarios and populations. The mean observed heterozygosity reported by VORTEX is the mean inbreeding coefficient of the population.

(9) The user specifies one of three options for modelling the effect of inbreeding: (a) no effect of inbreeding on fitness, that is, all alleles are selectively neutral, (b) each founder individual has one unique lethal and one unique non-lethal allele (Recessive Lethals option), or (c) first-year survival of each individual is exponentially related to its inbreeding coefficient (Heterosis option). The first case is clearly an optimistic one, as almost all diploid

populations studied intensively have shown deleterious effects of inbreeding on a variety of fitness components (Wright 1977; Falconer 1981). Each of the two models of inbreeding depression may also be optimistic, in that inbreeding is assumed to have an impact only on first-year survival. The Heterosis option allows, however, for the user to specify the severity of inbreeding depression on juvenile survival.

(10) Years are iterated via steps 11–25 below.

(11) The probabilities of females producing each possible litter size are adjusted to account for density dependence of reproduction (if any).

(12) Birth rate, survival rates and carrying capacity for the year are adjusted to model environmental variation. Environmental variation is assumed to follow binomial distributions for birth and death rates and a normal distribution for carrying capacity, with mean rates and standard deviations specified by the user. At the outset of each year a random number is drawn from the specified binomial distribution to determine the percentage of females producing litters. The distribution of litter sizes among those females that do breed is maintained constant. Another random number is drawn from a specified binomial distribution to model the environmental variation in mortality rates. If environmental variations in reproduction and mortality are chosen to be correlated, the random number used to specify mortality rates for the year is chosen to be the same percentile of its binomial distribution as was the number used to specify reproductive rate. Otherwise, a new random number is drawn to specify the deviation of age- and sex-specific mortality rates for their means. Environmental variation across years in mortality rates is always forced to be correlated among age and sex classes.

The carrying capacity (K) of the year is determined by first increasing or decreasing the carrying capacity at year 1 by an amount specified by the user to account for linear changes over time. Environmental variation in K is then imposed by drawing a random number from a normal distribution with the specified values for mean and standard deviation.

(13) Birth rates and survival rates for the year are adjusted to model any catastrophes determined to have occurred in that year.

(14) Breeding males are selected for the year. A male of breeding age is placed into the pool of potential breeders for that year if a random number drawn for that male is less than the proportion of breeding-age males specified to be breeding.

(15) For each female of breeding age, a mate is drawn at random from the pool of breeding males for that year. The size of the litter produced by that pair is determined by comparing the probabilities of each potential litter size (including litter size of 0, no breeding) to a randomly drawn number. The offspring are produced and assigned a sex by comparison of a random number to the specified sex ratio at birth. Offspring are assigned, at random, one allele at the hypothetical genetic locus from each parent.

(16) If the Heterosis option is chosen for modelling inbreeding depression, the genetic kinship of each new offspring to each other living animal in the population is determined. The kinship between a new animal, A, and another existing animal, B is

$$f_{AB}=0{\cdot}5\times(f_{MB}+f_{PB})$$

in which f_{ij} is the kinship between animals i and j, M is the mother of A, and P is the father of A. The inbreeding coefficient of each animal is equal to the kinship between its parents, $F=f_{MP}$, and the kinship of an animal to itself is $f_{AA}=0{\cdot}5\times(1+F)$. [See Ballou (1983) for a detailed description of this method for calculating inbreeding coefficients.]

(17) The survival of each animal is determined by comparing a random number to the survival probability for that animal. In the absence of inbreeding depression, the survival probability is given by the age and sex-specific survival rate for that year. If the Heterosis model of inbreeding depression is used and an individual is inbred, the survival probability is multiplied by e^{-bF} in which b is the number of lethal equivalents per haploid genome.

If the Recessive Lethals model is used, all offspring that are homozygous for a lethal allele are killed.

(18) The age of each animal is incremented by 1, and any animal exceeding the maximum age is killed.

(19) If more than one population is being modelled, migration among populations occurs stochastically with specified probabilities.

(20) If population harvest is to occur that year, the number of harvested individuals of each age and sex class are chosen at random from those available and removed. If the number to be removed do not exist for an age–sex class, VORTEX continues but reports that harvest was incomplete.

(21) Dead animals are removed from the computer memory to make space for future generations.

(22) If population supplementation is to occur in a particular year, new individuals of the specified age class are created. Each immigrant is assigned two unique alleles, one of which will be a recessive lethal in the Recessive Lethals model of inbreeding depression. Each immigrant is assumed to be genetically unrelated to all other individuals in the population.

(23) The population growth rate is calculated as the ratio of the population size in the current year to the previous year.

(24) If the population size (N) exceeds the carrying capacity (K) for that year, additional mortality is imposed across all age and sex classes. The probability of each animal dying during this carrying capacity truncation is set to $(N-K)/N$, so that the expected population size after the additional mortality is K.

(25) Summary statistics on population size and genetic variation are tallied and reported. A simulated population is determined to be extinct if one of the sexes has no representatives.

(26) Final population size and genetic variation are determined for the simulation.

(27) Summary statistics on population size, genetic variation, probability of extinction, and mean population growth rate, are calculated across iterations and printed out.

Assumptions Underpinning VORTEX

It is impossible to simulate the complete range of complex processes that can have an impact on wild populations. As a result there are necessarily a range of mathematical and biological assumptions that underpin any PVA program. Some of the more important assumptions in VORTEX include the following.

(1) Survival probabilities are density independent when population size is less than carrying capacity. Additional mortality imposed when the population exceeds K affects all age and sex classes equally.

(2) The relationship between changes in population size and genetic variability are examined for only one locus. Thus, potentially complex interactions between genes located on the same chromosome (linkage disequilibrium) are ignored. Such interactions are typically associated with genetic drift in very small populations, but it is unknown if, or how, they would affect population viability.

(3) All animals of reproductive age have an equal probability of breeding. This ignores the likelihood that some animals within a population may have a greater probability of breeding successfully, and breeding more often, than other individuals. If breeding is not at random among those in the breeding pool, then decay of genetic variation and inbreeding will occur more rapidly than in the model.

(4) The life-history attributes of a population (birth, death, migration, harvesting, supplementation) are modelled as a sequence of discrete and therefore seasonal events. However, such events are often continuous through time and the model ignores the possibility that they may be aseasonal or only partly seasonal.

(5) The genetic effects of inbreeding on a population are determined in VORTEX by using one of two possible models: the Recessive Lethals model and the Heterosis model. Both models have attributes likely to be typical of some populations, but these may vary within and between species (Brewer *et al.* 1990). Given this, it is probable that the impacts of inbreeding will fall between the effects of these two models. Inbreeding is assumed to depress only one component of fitness: first-year survival. Effects on reproduction could be incorporated into this component, but longer-term impacts such as increased disease susceptibility or decreased ability to adapt to environmental change are not modelled.

(6) The probabilities of reproduction and mortality are constant from the age of first breeding until an animal reaches the maximum longevity. This assumes that animals continue to breed until they die.

(7) A simulated catastrophe will have an effect on a population only in the year that the event occurs.

(8) Migration rates among populations are independent of age and sex.

(9) Complex, interspecies interactions are not modelled, except in that such community dynamics might contribute to random environmental variation in demographic parameters. For example, cyclical fluctuations caused by predator–prey interactions cannot be modelled by VORTEX.

Discussion

Uses and Abuses of Simulation Modelling for PVA

Computer simulation modelling is a tool that can allow crude estimation of the probability of population extinction, and the mean population size and amount of genetic diversity, from data on diverse interacting processes. These processes are too complex to be integrated intuitively and no analytic solutions presently, or are likely to soon, exist. PVA modelling focuses on the specifics of a population, considering the particular habitat, threats, trends, and time frame of interest, and can only be as good as the data and the assumptions input to the model (Lindenmayer *et al.* 1993). Some aspects of population dynamics are not modelled by VORTEX nor by any other program now available. In particular, models of single-species dynamics, such as VORTEX, are inappropriate for use on species whose fates are strongly determined by interactions with other species that are in turn undergoing complex (and perhaps synergistic) population dynamics. Moreover, VORTEX does not model many conceivable and perhaps important interactions among variables. For example, loss of habitat might cause secondary changes in reproduction, mortality, and migration rates, but ongoing trends in these parameters cannot be simulated with VORTEX. It is important to stress that PVA does not predict in general what will happen to a population; PVA forecasts the likely effects only of those factors incorporated into the model.

Yet, the use of even simplified computer models for PVA can provide more accurate predictions about population dynamics than the even more crude techniques available previously, such as calculation of expected population growth rates from life tables. For the purpose of estimating extinction probabilities, methods that assess only deterministic factors are almost certain to be inappropriate, because populations near extinction will commonly be so small that random processes dominate deterministic ones. The suggestion by Mace and Lande (1991) that population viability be assessed by the application of simple rules (e.g., a taxon be considered Endangered if the total effective population size is below 50 or the total census size below 250) should be followed only if knowledge is insufficient to allow more accurate quantitative analysis. Moreover, such preliminary judgments, while often important in stimulating appropriate corrective measures, should signal, not obviate, the need for more extensive investigation and analysis of population processes, trends and threats.

Several good population simulation models are available for PVA. They differ in capabilities, assumptions and ease of application. The ease of application is related to the number of simplifying assumptions and inversely related to the flexibility and power of the model. It is unlikely that a single or even a few simulation models will be appropriate for all PVAs. The VORTEX program has some capabilities not found in many other population simulation programs, but is not as flexible as are some others (e.g., GAPPS; Harris *et al.* 1986). VORTEX is user-friendly and can be used by those with relatively little understanding of population biology and extinction processes, which is both an advantage and a disadvantage.

Testing Simulation Models

Because many population processes are stochastic, a PVA can never specify what will happen to a population. Rather, PVA can provide estimates of probability distributions describing possible fates of a population. The fate of a given population may happen to fall at the extreme tail of such a distribution even if the processes and probabilities are assessed precisely. Therefore, it will often be impossible to test empirically the accuracy of PVA results by monitoring of one or a few threatened populations of interest. Presumably, if a population followed a course that was well outside of the range of possibilities predicted by a model, that model could be rejected as inadequate. Often, however, the range of plausible fates generated by PVA is quite broad.

Simulation programs can be checked for internal consistency. For example, in the absence of inbreeding depression and other confounding effects, does the simulation model predict an average long-term growth rate similar to that determined from a life-table calculation? Beyond this, some confidence in the accuracy of a simulation model can be obtained by comparing observed fluctuations in population numbers to those generated by the model, thereby comparing a data set consisting of tens to hundreds of data points to the results of the model. For example, from 1938 to 1991, the wild population of whooping cranes had grown at a mean exponential rate, r, of 0·040, with annual fluctuations in the growth rate, SD (r), of 0·141 (Mirande *et al.* 1993). Life-table analysis predicted an r of 0·052. Simulations using VORTEX predicted an r of 0·046 into the future, with a SD (r) of 0·081. The lower growth rate projected by the stochastic model reflects the effects of inbreeding and perhaps imbalanced sex ratios among breeders in the simulation, factors that are not considered in deterministic life-table calculations. Moreover, life-table analyses use mean birth and death rates to calculate a single estimate of the population growth rate. When birth and death rates are fluctuating, it is more appropriate to average the population growth rates calculated separately from birth and death rates for each year. This mean growth rate would be lower than the growth rate estimated from mean life-table values.

When the simulation model was started with the 18 cranes present in 1938, it projected a population size in 1991 ($N \pm \mathrm{SD} = 151 \pm 123$) almost exactly the same as that observed ($N = 146$). The large variation in population size across simulations, however, indicates that very different fates (including extinction) were almost equally likely. The model slightly underestimated the annual fluctuations in population growth [model SD $(r) = 0{\cdot}112$ *v.* actual SD $(r) = 0{\cdot}141$]. This may reflect a lack of full incorporation of all aspects of stochasticity into the model, or it may simply reflect the sampling error inherent in stochastic phenomena. Because the data input to the model necessarily derive from analysis of past trends, such retrospective analysis should be viewed as a check of consistency, not as proof that the model correctly describes current population dynamics. Providing another confirmation of consistency, both deterministic calculations and the simulation model project an over-wintering population of whooping cranes consisting of 12% juveniles (less than 1 year of age), while the observed frequency of juveniles at the wintering grounds in Texas has averaged 13%.

Convincing evidence of the accuracy, precision and usefulness of PVA simulation models would require comparison of model predictions to the distribution of fates of many replicate populations. Such a test probably cannot be conducted on any endangered species, but could and should be examined in experimental non-endangered populations. Once simulation models are determined to be sufficiently descriptive of population processes, they can guide management of threatened and endangered species (see above and Lindenmayer *et al.* 1993). The use of PVA modelling as a tool in an adaptive management framework (Clark *et al.* 1990) can lead to increasingly effective species recovery efforts as better data and better models allow more thorough analyses.

Directions for Future Development of PVA Models

The PVA simulation programs presently available model life histories as a series of discrete (seasonal) events, yet many species breed and die throughout much of the year. Continuous-time models would be more realistic and could be developed by simulating the time between life-history events as a random variable. Whether continuous-time models would significantly improve the precision of population viability estimates is unknown. Even more realistic models might treat some life-history events (e.g., gestation, lactation) as stages of specified duration, rather than as instantaneous events.

Most PVA simulation programs were designed to model long-lived, low fecundity (K-selected) species such as mammals, birds and reptiles. Relatively little work has been devoted to developing models for short-lived, high-fecundity (r-selected) species such as many amphibians and insects. Yet, the viability of populations of r-selected species may be highly affected by stochastic phenomena, and r-selected species may have much greater minimum viable populations than do most K-selected species. Assuring viability of K-selected species in a community may also afford adequate protection for r-selected species, however, because of the often greater habitat-area requirements of large vertebrates. Populations of r-selected species are probably less affected by intrinsic demographic stochasticity because large numbers of progeny will minimise random fluctuations, but they are more affected by environmental variations across space and time. PVA models designed for r-selected species would probably model fecundity as a continuous distribution, rather than as a completely specified discrete distribution of litter or clutch sizes; they might be based on life-history stages rather than time-increment ages; and they would require more detailed and accurate description of environmental fluctuations than might be required for modelling K-selected species.

The range of PVA computer simulation models becoming available is important because the different assumptions of the models provide capabilities for modelling diverse life histories. Because PVA models always simplify the life history of a species, and because the assumptions of no model are likely to match exactly our best understanding of the dynamics of a population of interest, it will often be valuable to conduct PVA modelling with several simulation programs and to compare the results. Moreover, no computer program can be guaranteed to be free of errors. There is a need for researchers to compare results from different PVA models when applied to the same analysis, to determine how the different assumptions affect conclusions and to cross-validate algorithms and computer code.

Acknowledgments

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

References

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Selander, R. K. (1983). Evolutionary consequences of inbreeding. In 'Genetics and Conservation: A Reference for Managing Wild Animal and Plant Populations'. (Eds C. M. Schonewald-Cox, S. M. Chambers, B. MacBryde and W. L. Thomas.) pp. 201–15. (Benjamin/Cummings: Menlo Park, California.)

Shaffer, M. L. (1981). Minimum population sizes for species conservation. *BioScience* **31**, 131–4.

Shaffer, M. L. (1987). Minimum viable populations: coping with uncertainty. In 'Viable Populations for Conservation'. (Ed. M. E. Soulé.) pp. 69–86. (Cambridge University Press: Cambridge.)

Shaffer, M. L. (1990). Population viability analysis. *Conservation Biology* **4**, 39–40.

Simberloff, D. A. (1986). The proximate causes of extinction. In 'Patterns and Processes in the History of Life'. (Eds D. M. Raup and D. Jablonski.) pp. 259–76. (Springer-Verlag: Berlin.)

Simberloff, D. A. (1988). The contribution of population and community biology to conservation science. *Annual Review of Ecology and Systematics* **19**, 473–511.

Soulé, M. E. (Ed.) (1987). 'Viable Populations for Conservation.' (Cambridge University Press: Cambridge.)

Thomas, C. D. (1990). What do real population dynamics tell us about minimum population sizes? *Conservation Biology* **4**, 324–7.

Wright, S. (1977). 'Evolution and the Genetics of Populations. Vol. 3. Experimental Results and Evolutionary Deductions.' (University of Chicago Press: Chicago.)

Appendix. Sample Output from VORTEX

Explanatory comments are added in italics

VORTEX—simulation of genetic and demographic stochasticity

TEST *Simulation label and output file name*

Fri Dec 20 09:21:18 1991

2 population(s) simulated for 100 years, 100 runs

VORTEX first lists the input parameters used in the simulation:

HETEROSIS model of inbreeding depression

with 3·14 lethal equivalents per diploid genome

Migration matrix:

	1	2
1	0·9900	0·0100
2	0·0100	0·9900

i.e. 1% probability of migration from Population 1 to 2, and from Population 2 to 1

First age of reproduction for females: 2 for males: 2

Age of senescence (death): 10

Sex ratio at birth (proportion males): 0·5000

Population 1:

Polygynous mating; 50·00 per cent of adult males in the breeding pool.

Reproduction is assumed to be density independent.

50·00 (EV = 12·50 SD) per cent of adult females produce litters of size 0

25·00 per cent of adult females produce litters of size 1

25·00 per cent of adult females produce litters of size 2

EV is environmental variation

50·00 (EV = 20·41 SD) per cent mortality of females between ages 0 and 1

10·00 (EV = 3·00 SD) per cent mortality of females between ages 1 and 2

10·00 (EV = 3·00 SD) per cent annual mortality of adult females (2<=age<=10)

50·00 (EV = 20·41 SD) per cent mortality of males between ages 0 and 1

10·00 (EV = 3·00 SD) per cent mortality of males between ages 1 and 2

10·00 (EV = 3·00 SD) per cent annual mortality of adult males (2<=age<=10)

EVs have been adjusted to closest values possible for binomial distribution.
EV in reproduction and mortality will be correlated.

Frequency of type 1 catastrophes: 1·000 per cent
with 0·500 multiplicative effect on reproduction
and 0·750 multiplicative effect on survival
Frequency of type 2 catastrophes: 1·000 per cent
with 0·500 multiplicative effect on reproduction
and 0·750 multiplicative effect on survival

Initial size of Population 1: (set to reflect stable age distribution)

Age	1	2	3	4	5	6	7	8	9	10	Total	
	1	0	1	1	0	1	0	0	1	0	5	Males
	1	0	1	1	0	1	0	0	1	0	5	Females

Carrying capacity = 50 (EV = 0·00 SD)
with a 10·000 per cent decrease for 5 years.

Animals harvested from population 1, year 1 to year 10 at 2 year intervals:
1 females 1 years old
1 female adults (2<=age<=10)
1 males 1 years old
1 male adults (2<=age<=10)

Animals added to population 1, year 10 through year 50 at 4 year intervals:
1 females 1 years old
1 females 2 years old
1 males 1 years old
1 males 2 years old

Input values are summarised above, results follow.

VORTEX now reports life-table calculations of expected population growth rate.

Deterministic population growth rate (based on females, with assumptions of no limitation of mates and no inbreeding depression):

r = −0·001 lambda = 0·999 RO = 0·997

Generation time for: females = 5·28 males = 5·28

Note that the deterministic life-table calculations project approximately zero population growth for this population.

Stable age distribution:

Age class	females	males
0	0·119	0·119
1	0·059	0·059
2	0·053	0·053
3	0·048	0·048
4	0·043	0·043
5	0·038	0·038
6	0·034	0·034
7	0·031	0·031
8	0·028	0·028
9	0·025	0·025
10	0·022	0·022

Ratio of adult (>=2) males to adult (>=2) females: 1·000

Population 2:

Input parameters for Population 2 were identical to those for Population 1.
Output would repeat this information from above.

Simulation results follow.

Population1

Year 10

N[Extinct] = 0, P[E] = 0·000
N[Surviving] = 100, P[S] = 1·000
Population size = 4·36 (0·10 SE, 1·01 SD)
Expected heterozygosity = 0·880 (0·001 SE, 0·012 SD)
Observed heterozygosity = 1·000 (0·000 SE, 0·000 SD)
Number of extant alleles = 8·57 (0·15 SE, 1·50 SD)

Population summaries given, as requested by user, at 10-year intervals.

Year 100

N[Extinct] = 86, P[E] = 0·860
N[Surviving] = 14, P[S] = 0·140
Population size = 8·14 (1·27 SE, 4·74 SD)
Expected heterozygosity = 0·577 (0·035 SE, 0·130 SD)
Observed heterozygosity = 0·753 (0·071 SE, 0·266 SD)
Number of extant alleles = 3·14 (0·35 SE, 1·29 SD)

In 100 simulations of 100 years of Population1:
86 went extinct and 14 survived.
This gives a probability of extinction of 0·8600 (0·0347 SE),
or a probability of success of 0·1400 (0·0347 SE).
99 simulations went extinct at least once.
Median time to first extinction was 5 years.
Of those going extinct,
mean time to first extinction was 7·84 years (1·36 SE, 13·52 SD).
123 recolonisations occurred.
Mean time to recolonisation was 4·22 years (0·23 SE, 2·55 SD).
110 re-extinctions occurred.
Mean time to re-extinction was 54·05 years (2·81 SE, 29·52 SD).

Mean final population for successful cases was 8·14 (1·27 SE, 4·74 SD)

Age 1	Adults	Total	
0·14	3·86	4·00	Males
0·36	3·79	4·14	Females

During years of harvest and/or supplementation
mean growth rate (r) was 0·0889 (0·0121 SE, 0·4352 SD)
Without harvest/supplementation, prior to carrying capacity truncation,
mean growth rate (r) was −0·0267 (0·0026 SE, 0·2130 SD)

Population growth in the simulation (r = −0·0267) was depressed relative to the projected growth rate calculated from the life table (r = −0·001) because of inbreeding depression and occasional lack of available mates.

Note: 497 of 1000 harvests of males and 530 of 1000 harvests of females could not be completed because of insufficient animals.

Final expected heterozygosity was 0·5768 (0·0349 SE, 0·1305 SD)
Final observed heterozygosity was 0·7529 (0·0712 SE, 0·2664 SD)
Final number of alleles was 3·14 (0·35 SE, 1·29 SD)

Population2

Similar results for Population 2, omitted from this Appendix, would follow.

******** Metapopulation Summary ********

Year 10

N[Extinct] = 0, P[E] = 0·000
N[Surviving] = 100, P[S] = 1·000
Population size = 8·65 (0·16 SE, 1·59 SD)
Expected heterozygosity = 0·939 (0·000 SE, 0·004 SD)
Observed heterozygosity = 1·000 (0·000 SE, 0·000 SD)
Number of extant alleles = 16·92 (0·20 SE, 1·96 SD)

Metapopulation summaries are given at 10-year intervals.

Year 100

N[Extinct] = 79, P[E] = 0·790
N[Surviving] = 21, P[S] = 0·210
Population size = 10·38 (1·37 SE, 6·28 SD)
Expected heterozygosity = 0·600 (0·025 SE, 0·115 SD)
Observed heterozygosity = 0·701 (0·050 SE, 0·229 SD)
Number of extant alleles = 3·57 (0·30 SE, 1·36 SD)

In 100 simulations of 100 years of Metapopulation:
79 went extinct and 21 survived.
This gives a probability of extinction of 0·7900 (0·0407 SE),
or a probability of success of 0·2100 (0·0407 SE).
97 simulations went extinct at least once.
Median time to first extinction was 7 years.
Of those going extinct,
mean time to first extinction was 11·40 years (2·05 SE, 20·23 SD).
91 recolonisations occurred.
Mean time to recolonisation was 3·75 years (0·15 SE, 1·45 SD).
73 re-extinctions occurred.
Mean time to re-extinction was 76·15 years (1·06 SE, 9·05 SD).

Mean final population for successful cases was 10·38 (1·37 SE, 6·28 SD)

Age 1	Adults	Total	
0·48	4·71	5·19	Males
0·48	4·71	5·19	Females

During years of harvest and/or supplementation
mean growth rate (r) was 0·0545 (0·0128 SE, 0·4711 SD)
Without harvest/supplementation, prior to carrying capacity truncation,
mean growth rate (r) was −0·0314 (0·0021 SE, 0·1743 SD)

Final expected heterozygosity was 0·5997 (0·0251 SE, 0·1151 SD)
Final observed heterozygosity was 0·7009 (0·0499 SE, 0·2288 SD)
Final number of alleles was 3·57 (0·30 SE, 1·36 SD)

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