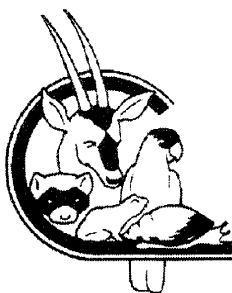
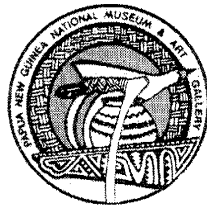


# Conservation Assessment and Management Plan for the Tree Kangaroos of Papua New Guinea

*and*

## Population and Habitat Viability Assessment for Matschie's Tree Kangaroo

*Lae, Papua New Guinea  
31 August - 4 September 1998*



**CONSERVATION ASSESSMENT AND MANAGEMENT PLAN  
FOR THE TREE KANGAROOS OF PAPUA NEW GUINEA**  
*and*  
**POPULATION AND HABITAT VIABILITY ASSESSMENT FOR  
MATSCHIE'S TREE KANGAROO**



**Lae, Papua New Guinea  
31 August – 4 September 1998**



**FINAL REPORT  
January 1999**



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Cover photo: Matschie's tree kangaroo (*Dendrolagus matschiei*) near Keweng 1 on the Huon Peninsula at 2500m, August 1996. © William Betz.

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Bonaccorso, F., P. Clark, P. Miller and O. Byers 1999. *Conservation Assessment and Management Plan for the Tree Kangaroos of Papua New Guinea and Population and Habitat Viability Assessment for Matschie's Tree Kangaroo: Final Report*. Conservation Breeding Specialist Group (SSC/IUCN), Apple Valley, MN.

Additional copies of *Conservation Assessment and Management Plan for the Tree Kangaroos of Papua New Guinea and Population and Habitat Viability Assessment for Matschie's Tree Kangaroo: Final Report* can be ordered through the IUCN/SSC Conservation Breeding Specialist Group, 12101 Johnny Cake Ridge Road, Apple Valley, MN 55124.

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**CONSERVATION ASSESSMENT AND MANAGEMENT PLAN  
FOR THE TREE KANGAROOS OF PAPUA NEW GUINEA  
*and*  
POPULATION AND HABITAT VIABILITY ASSESSMENT FOR  
MATSCHIE'S TREE KANGAROO**

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**CONSERVATION ASSESSMENT AND MANAGEMENT PLAN  
FOR THE TREE KANGAROOS OF PAPUA NEW GUINEA  
*and*  
POPULATION AND HABITAT VIABILITY ASSESSMENT FOR  
MATSCHIE'S TREE KANGAROO**

**Lae, Papua New Guinea  
31 August – 4 September 1998**

**Final Report**

**Section 1  
Executive Summary**





# **Tree Kangaroos of Papua New Guinea Population and Habitat Viability Assessment Executive Summary**

---

## **Introduction**

Reduction and fragmentation of wildlife populations and habitat are occurring at an accelerating rate worldwide. For an increasing number of taxa, these factors result in small and isolated populations that are at risk of extinction. A rapidly expanding human population, now estimated at more than 5.9 billion, will exceed 6 billion by October 1999 (United Nations Population Division, 1998). This expansion and the resulting utilization of resources has momentum that cannot be stopped, with the final result being a decreased capacity for all other species to exist simultaneously on the planet.

In Papua New Guinea (PNG), as in the rest of the world, human activities increasingly threaten the survival of natural environments and wildlife populations. As these populations are diminished, their ecological roles in ensuring a well-balanced, regulated, and sustainable ecosystem also are reduced.

Wildlife managers realize that management strategies designed to reduce the risk of species depletion must be adopted to ensure viable ecosystem functions. Successful conservation of ecosystems and wild species necessitates developing and implementing active management programs by people, governments, and non-government organizations (NGOs) that live alongside, and are responsible for, that ecosystem.

## **The Tree Kangaroos of Papua New Guinea**

All six species of tree kangaroos in PNG are endemic to the island of New Guinea. Three species occur in very small geographic ranges totally within PNG (Matschie's, Lowland and Scott's) while three other species (Doria's, Grizzled and Goodfellow's) have somewhat larger distributions including Irian Jaya Province, Indonesia. Population declines and habitat loss have accelerated in the last 3 decades. If PNG's tree kangaroos are to survive in viable populations beyond the beginning of the 21st century, a conservation plan must be created and implemented.

## **Initiation of the PHVA Process for the Tree Kangaroos of Papua New Guinea**

The Conservation Breeding Specialist Group (CBSG) was invited by the National Museum and Art Gallery, Rainforest Habitat and The Department of Conservation and Environment (DEC) to collaborate with local agencies, stakeholders and international scientists in a Population and Habitat Viability Assessment (PHVA) workshop for Matschie's tree kangaroo and Conservation Assessment and Management Plan (CAMP) workshop for all species and subspecies.

The PHVA workshop process was suggested as a useful process to assist with evaluating PNG tree kangaroo conservation priorities and to promote further conservation action. The PHVA was first proposed at a meeting of the Marsupial and Monotreme Taxon Advisory Group of the ARAZPA (to which PNG institutions are members) set up specifically to discuss tree kangaroos. In addition, the American Zoo and Aquarium Association's Tree Kangaroo Species Survival Plan (AZA TK-SSP) recognized the need for a PHVA workshop. Dr. Timothy Flannery, of the Australian Museum, researcher of tree kangaroos and author of *'Tree Kangaroos: A Curious Natural History'* was subsequently contacted and was supportive.

Both the National Museum and Art Gallery and the Department of Environment and Conservation endorsed the need for a PHVA workshop to be organized and held in PNG.

Major sponsorship was obtained from Adelaide Zoo, Currumbin Sanctuary, Melbourne Zoo and Taronga Zoo, Australia and from Columbus Zoo, San Antonio Zoological Gardens and Aquarium, Mill Mountain Zoological Park and Roger Williams Park Zoo, USA. In addition, Perth Zoo and Melbourne Zoo donated the time and expertise of an educator and an audio-visual expert, respectively.

Accordingly, a workshop was held at the University of Technology, Lae, PNG from 31 August to 4 September 1998. Forty-seven people attended the workshop which was generously hosted by the National Museum and Art Gallery, Rainforest Habitat and the Department of Conservation and Environment (DEC), and was facilitated by the IUCN/SSC Conservation Breeding Specialist Group (CBSG). The primary aim of the workshop was to develop an action plan for the long-term conservation of genetically viable populations of tree kangaroos in PNG. Specialists from PNG, Australia and the United States on population biology, captive management, reproduction, veterinary medicine, and human demographics, compiled and analyze both published and unpublished information on all six tree kangaroo species of PNG. Thirteen local landowners, representing several regions of PNG where tree kangaroos are found, had direct participation in the workshop, which had ongoing translation into pidgin. Grassroots participation and approval of methods and plans by a spectrum of landowners is essential for the success of any animal management and conservation plan in PNG where 96% of all land is in private ownership. It is important to note that wildlife in PNG is the property of the landowner, not the government. In addition, social scientists were involved to help translate human demographic and resource use trends into impacts on tree kangaroos and their habitat.

### **The PHVA Process**

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

At the beginning of each PHVA workshop, there is agreement among the participants that the general desired outcome is to prevent the extinction of the species and to maintain a viable population(s). The workshop process takes an in-depth look at the species' life history, population history, status, and dynamics, and assesses the threats putting the species at risk.

One crucial by-product of a PHVA workshop is that an enormous amount of information can be gathered and considered that, to date, has not been published. This information can be from many sources; the contributions of all people with a stake in the future of the species are considered. Information contributed by landowners, hunters, scientists, field biologists, and zoo managers all carry equal importance.

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

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

At the beginning of the workshop, the 47 participants worked in stakeholder groups to identify the major issues and needs, related to tree kangaroos and their habitat, that they wanted the PHVA/CAMP to address (see reports in Section 2). The landowner stakeholder group, working in pidgin, came up with a list of 8 issues and needs related to captive programs for reintroduction, public education, socio-economic concerns, law enforcement, and research. These, and the issues raised by the other stakeholder groups (biological/social scientists and captive managers/educators), then became the focus of four working groups: Life History and Modeling, Socio-economic Issues, Status and Distribution and Government and Legislation. The captive management stakeholder group realized that their only real need was to be guided on answering the question, "What can the captive community do to assist the conservation of tree kangaroos?". The decision was made to request all working groups to address this question and therefore no working group was needed specifically to deal with captive issues.

Each of the four working groups was asked to:

- Examine the list of problems and issues affecting the conservation of the species as they fell out under each working group topic and expand upon that list if needed.
- Identify and amplify in text the most important issues.
- Develop and elaborate action strategies to address the key issues.
- Amplify and specify the recommendations or strategies that might improve each of the priority problems or issues in detail.
- Identify the resources that would be needed to implement these recommendations.

Each group presented the results of their work in plenary sessions to guarantee that everyone had an opportunity to contribute to the work of the other groups and to assure that issues were carefully reviewed and discussed by all workshop participants. The recommendations coming from the workshop were accepted by all participants, thus representing a consensus. Working group reports can be found in Sections 3-6 of this document.

On the afternoon of day four of the workshop the landowner group reconvened to assess the progress made in addressing the issues and needs they identified on day one. They reported back to the plenary session that their concerns had been addressed and that they were satisfied.

A summary of working group recommendations is given below. There were several recommendations made that were implemented during the workshop itself, including the development, and translation into pidgin, of educational materials specifically requested by the landowners. In addition, a rapid response team was formed at the request of landowners, to respond to the urgent need for conservation action directed toward the critically endangered Scott's (*D. scottae*) tree kangaroo. This team committed to visit Lumi District, Sandaun Province within 30 days following the workshop. A Final proposal of this plan can be found in Section 8 of this report.



## Recommendations:

### ***Distribution and Status Working Group Recommendations***

Using IUCN Red List Criteria, the CAMP process assigned tree kangaroo species and subspecies to the following threat categories:

SPECIES/SUBSPECIES	CRITICALLY ENDANGERED	ENDANGERED	VULNERABLE	LOWER RISK	LOWER RISK - NEAR THREATENED
<i>D. scottae</i>	X				
<i>D. goodfellowi pulcherrimus</i>	X				
<i>D. goodfellowi buergersi</i>			X		
<i>D. goodfellowi goodfellowi</i>			X		
<i>D. spadix</i>					X
<i>D. dorianus dorianus</i>				X	
<i>D. dorianus stellarum*</i>			X		
<i>D. dorianus notatus</i>			X		
<i>D. matschie</i>			X		
<i>D. inustus finschi*</i>			X		

\* denotes PNG populations only considered for this classification from taxa extending significantly into Irian Jaya

In addition, the following recommendations were made:

1. Conduct a PNG national survey for presence/absence distribution for all tree kangaroo taxa.
2. Tree kangaroo species/subspecies classified as threatened according to IUCN categories should have intensive field research directed to learn about population trends, use of habitat and space, food requirements and other natural history factors.
3. Tissue collection for molecular systematics should receive immediate attention from many geographic points within the ranges of all tree kangaroo taxa in PNG.
4. Conduct an evaluation of the impact of hunting and cultural practices on tree kangaroo populations and habitat.
5. Conduct further research on captive populations in order to understand basic biology including reproductive physiology, social structures, and activity patterns.
6. Establish as soon as possible a Recovery Program for Critically Endangered species.
7. Publish a bilingual (Melanesian Pigin (Tok Pisin) and English) newsletter to insure that all stakeholders interested in tree kangaroos receive continuous information and input on social issues, management practices, and basic research.

### ***Life History and Modeling Working Group Recommendations***

1. Obtain more detailed information on the genetics, age structure and breeding characteristics of wild populations.
2. Obtain more accurate information on local home ranges, seasonal activity patterns, migration patterns, and individual response to habitat alteration. This will increase our ability to estimate tree kangaroo population densities and the spatial characteristics of tree kangaroo habitat.
3. Make increased use of information on tree kangaroo populations from information provided by local hunters (e.g., changes in population numbers over time, current hunting rates, additional information on species biology).
4. Explore methods of directing hunting pressure away from females
5. Develop more specific population models which allow us to determine sustainable levels of hunting in wild tree kangaroo populations

6. Careful considerations should be given by the government to ensure that the most appropriate forestry and agricultural practices are used in tree kangaroo habitat

### **Socio-economic Issues Working Group Recommendations**

1. It is recommended that research into existing environmental awareness be encouraged, but that in a climate of limited resources, we focus on programs to raise environmental awareness.
2. Develop student and community education programs to increase environmental awareness amongst the people of PNG with the aim of protecting tree kangaroos and their habitats.
3. In order to link conservation and development, local communities need to have access to alternatives for generating resources to help them meet other priority social needs (school fees, transportation fees, health, nutrition).
4. Seek sources of international funding to support conservation and development.
5. Establish a committee within PNG to record and report on PHVA recommendations.

### **Government and Legislation Working Group Recommendations**

1. Include the endorsement of the relevant Wildlife Management Area (WMA) Committee as a requirement for annual firearm license renewal and produce a handout that advises WMA Committees on options for creating firearm laws.
2. Establish dialogue between WMA Committee and district office to inform them about the WMA and associated laws and create a handout to advise WMA Committees on possible options to consider when making the laws, such as the establishment of quotas.
3. Implement the PNG Department of Environment and Conservation's (DEC) existing Wildlife Ranger Card system and resume the Wildlife Ranger training workshops.
4. Create and distribute to local communities informational materials (written in pidgin) regarding wildlife protection laws and concerns.
5. Advise local communities of the potential benefits they could pursue (e.g. eco-tourism) if they actively protect their land/wildlife and link tree kangaroo and wildlife protection with benefits to the local communities.
6. Discuss the "Australian Ambassador Species Agreement" with DEC officials.
7. Contact AZA and EAZA regarding the idea of returning the ownership of all tree kangaroos to PNG.
8. Document support, resources and projects already funded in PNG by facilities holding tree kangaroos and send back to all facilities holding tree kangaroos together with an invitation to consider further support.
9. Obtain from DEC the complete list of protected areas within PNG, together with specific contact details by the end of September.
10. Explore the potential of limited and controlled farming and exportation of selected wildlife at both the village level and other centralized facilities within PNG.
11. Produce a Newsletter that provides a link between the WMA Committees.
12. Facilities holding tree kangaroos are to be informed of captive research priorities identified at this meeting. These are:
  - Husbandry studies (including reproductive biology and manipulation, veterinary issues, dietary studies and behavioral studies) on Doria's as an analogue for Scott's.
  - Continued husbandry studies on *D.g. buergersi* as an analogue for *D.g. pulcherrimus*
  - Collection of base data for taxonomic studies (with an emphasis on Goodfellow's and Doria's)
  - Development of techniques to extract DNA from fecal samples
  - Collection of biological material for a genome resource bank to facilitate studies into storage and retrieval techniques and to allow the use of this material in relevant studies in the future.
13. PNG facilities holding or planning to hold tree kangaroos are to be informed of the captive management priorities identified at this meeting. These are:

- To continue to opportunistically acquire any species or sub-species of tree kangaroo to use in captive research, advocacy and education.
  - To investigate the feasibility of actively acquiring specimens of *D.g. pulcherrimus* and Scott's tree kangaroo in order to establish insurance populations as part of a structured conservation program.
14. Facilities holding or planning to hold tree kangaroos outside of PNG are to be informed of the captive management priorities identified at this meeting. These are:
    - To continue to manage existing captive populations of *D.g. buergersi* and Matschie's tree kangaroo to facilitate captive research, advocacy and education and in conjunction with the transfer of skills and resources to PNG.
    - To investigate the feasibility of establishing a captive population of Doria's to serve as a research analogue for Scott's tree kangaroo.
  15. Existing and potential tree kangaroo facilities to be fully utilized with regard to captive research, advocacy, education and the management of insurance populations.
  16. Encourage DEC to facilitate the work of those PNG facilities with a good track record of tree kangaroo husbandry and research (notably Phillip Leahy's facility at Zeneg and the Rainforest Habitat at Lae).
  17. DEC representatives and zoo representatives should consider specific conditions/requirements for holding protected species such as tree kangaroos and Birds-of-Paradise.

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POPULATION AND HABITAT VIABILITY ASSESSMENT FOR  
MATSCHIE'S TREE KANGAROO**

**Lae, Papua New Guinea  
31 August – 4 September 1998**

**Final Report**

**Section 2  
Stakeholder Working Group Reports**





# Landowner Stakeholder Group: Issue Generation Session

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First step, received agreement on all ground rules from the landowners and re-visited the goals: to define issues and needs of each group member. All group recording was done in pidgin.

## Issues

1. Planti bus na ples bilong tree-kangaroo I kuik long pinis nau.
2. Ol man long ples i sakim o brukim lo bilong wildlife o komti long lukautim ol abus (t-k).
3. no number 3
4. Inogat inap saveman long lainim ol man long ples/zoo long lukautim t-k.
5. T-K namba I wok long go daun:
  - a) namba bilong manmeri igo antap
  - b) ol arapela lain ikam insait nayusim gan long painim t-k.
6. Yumi no save long hamas t-k yumi gat long bus bilong yumi
7. Ola papa giraun igat save long t-k long hap bilong ol
8. Ol man long ples ilaik wokim konsevesen tasol igat sampela hevi olsem
  - a) helt sevis ino gutpela
  - b) edukesen ino gutpela
  - c) transpot sevis ino gutpela na igivim liklik taim long ol long mekim konsevesen.

## Issues

1. Many habitats of the tree kangaroo are vanishing (due to mining, logging, oil palm).
2. People go against the WMA regulations for tree kangaroos and other animals; want to hunt as much as possible; don't have power to enforce.
3. (Left out number three in order to have corresponding numbers with the needs.)
4. There is not enough experience for the people to teach locals/those responsible for looking after tree kangaroos in wild and in zoos.
5. Population of tree kangaroo is going down.
  - a) Additional hunting pressure from immigrants and increasing human populations (e.g. Wau - people coming in to mine)
  - b) New technology is being used to hunt (e.g. guns)
6. (As a landowner who hunts tree kangaroos, has hunted with dogs now and in the past,) he doesn't know how many tree kangaroos are in his bush.
7. Landowners have information about the tree kangaroo (e.g. what tree kangaroos eat, where they are, when they breed) to share and haven't been given the opportunity to share.
8. There is little time to think about conservation because of other (health, transportation, education) social needs.

## Needs

1. Need to look at keeping tree kangaroos in zoos for the possibility of reintroduction.
2. Need help to enforce the regulations (e.g. Wildlife Management Areas) decided on by the community.
3. Need to recognize tree kangaroo as protected species.
4. Need teaching for locals and zoos by experts about how to look after the tree kangaroo.
5. Need for village level laws to control (look after) tree kangaroo hunting.
6. Need for census - teaching how to count.
7. Landowners need to share information about tree kangaroos with other people.

8. Need help to address social issues in order to do conservation.

*Other Needs:*

- People in Wildlife Management areas need information to take back to their areas to help them share information to help them conserve and enforce regulations about the wildlife conservation issues. (addressing issue #2)
- Stop the purchase of guns or better regulate existing laws concerning gun licensing (addressing issue #5b)
- Need financial support to look after tree kangaroos in zoos (addressing issue #4).

***Working Group Participants:*** Banak Gamui (facilitator), Peter Uyepango, Collin Auere, Miffa Mionzing, Jimmy Iyona, John Simaga, Kaulovo Ulahaeava, Sakias Huho, Alex Moses, Jenna Borovansky (recorder)

# Captive Management Stakeholder Group: Issue Generation Session

---

## Central Issues

The captive community has resources to apply to the conservation of Tree kangaroos and/or Tree-kangaroo habitat and wants to apply those resources but does not always know how best to do it.

## Needs:

- A. **Is there is a conservation role for captive populations** (does the existing population as documented in the International Studbook serve that role or do we need to work towards a different population(s)?)
- What are local (government/landowner) attitudes towards the current zoo situation?
  - Is ownership of captive animals an issue (for government/landowners)?
  - What are the legislative requirements?

If there is a conservation role for captive populations, is it:

### 1. Generating funds?

- If so, how should the funds be directed?
- What ways of fundraising are appropriate/inappropriate for which species (e.g. 'selling' animals, including animals brought into PNG facilities, overseas/eco-tourism, etc.)?
- What role should landowners play?
- Should the effort be made within PNG?
- Should the effort be made outside?
- Are there any cultural considerations related to fundraising?

### 2. Insurance population?

- Which populations/species should be worked with? Should the captive programs be based in PNG, outside of PNG or both (e.g. perhaps work on more threatened spp. within PNG, more common spp. elsewhere)?
- How should programs be implemented?

### 3. Education/changing public awareness?

- At what level should education campaign be targeted (general public/schools/government officials)?
- What messages should be shared?
- Should an education/public awareness campaign be broad based or species specific?
- Is there a particular role for zoos in this regard?

### 4. Research?

- Programs within PNG must receive appropriate compensation for intellectual property.
- There is a role for opportunistic censusing/data collection (through people offering tree-kangaroos).
- Research priorities should be identified for all captive programs (eg. basic biology needed for in-situ work, veterinary medicine, nutrition, behavior, reproduction biology, etc.).

If there is not a conservation role for captive populations,



What to do with animals currently held?  
What to do with animals brought in to PNG facilities?

**B. Is there any other way that the captive community can contribute?**

- Communication/building alliances (e.g. MOUs)
  - What are appropriate linkage across conservation community?
  - Need to know preferred linkages/structures?
- Captive husbandry standards
- Skills/technology transfer (staff exchanges, etc.) – e.g. through WZO training grants, etc.
- Broader research objectives (i.e. support for *in situ* research)
- Storing genetic material/GRB?
- Resources: human; other

**Working Group Participants:** Gary Slater, Tony Jupp, Maria Franke, Brett Smith, Peter Clark, Gert Skipper, Mitch Bush, Ilaiah Bigilale, Christine Hopkins, Will Meikle, Sabati Eva, Jonathan Wilcken

# Biological and Social Scientist Stakeholder Group: Issue Generation Session

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## A. Need information on:

- a. life history characteristics
  - reproductive
  - mortality
- b. population characteristics
  - distribution
  - density
- c. habitat characteristics
  - availability
  - quality
  - fragmentation
- d. carrying capacity (group size?)
- e. catastrophes
  - types
  - frequency
  - vulnerabilities resulting
- f. diseases affecting tree kangaroo populations
  - then, now, future?
- g. Genetics: inbreeding
- h. How to use zoo data – how to correct

## B. Suitability for reintroduction/other management strategies (*in situ/ex situ*)

- a. potential for change in tree kangaroo habitat in future as a result of human activities
- b. how local resource use affects tree kangaroo numbers/tree kangaroo habitat
  - direct harvesting (hunting rates – before, now, future)
- c. changing natural predator numbers (snakes, dogs, birds of prey)

## C. Incomplete knowledge of taxonomy and population genetics

## D. Landowner knowledge

- a. need for information transfer (how?)
  - now/after

## E. We need to know why, how and when tree kangaroos are hunted (i.e. cultural reasons) and how this may be changing over time. This also applies to the use of other forest resources such as other fauna, timber etc.

## F. How do changes in population growth rates affect tree kangaroos and what are the links between this growth and resource use?

**Working Group Participants:** Peter Temple-Smith, Andrea Winterer, Philip Nyhus, John Williams, Phil Miller, Will Betz, Maria Franke, Frank Bonaccorso.



**CONSERVATION ASSESSMENT AND MANAGEMENT PLAN  
FOR THE TREE KANGAROOS OF PAPUA NEW GUINEA  
*and*  
POPULATION AND HABITAT VIABILITY ASSESSMENT FOR  
MATSCHIE'S TREE KANGAROO**

**Lae, Papua New Guinea  
31 August – 4 September 1998**

**Final Report**

**Section 3  
Life History and Modeling Working Group Report**





# Population Biology and Simulation Modeling of the Tree-Kangaroos of Papua New Guinea (*Dendrolagus* Sp.)

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## Introduction

The need for and consequences of alternative management strategies can be modeled to suggest which practices may be the most effective in conserving tree-kangaroos in Papua New Guinea. 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 to 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 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.

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 tree-kangaroos, the conditions affecting the populations, and possible future changes in these conditions. For a more detailed discussion of population viability analysis and the use of VORTEX in PVA, please see the Appendix at the end of this section.

Initially, emphasis in this workshop was to be given to developing a risk assessment for Matschie's tree kangaroo. As discussions within the group proceeded, however, it became clear that we could assume, in the absence of data to the contrary, that each species of tree kangaroo has very similar demography (breeding characteristics, natural mortality rates, etc.). Consequently, we have decided to broaden our scope beyond a strict discussion of Matschie's risk and are considering the extinction risks for a number of different tree kangaroo populations, basically independent of taxonomic status. We do this by assuming equivalent demography across populations, and consider model populations of different sizes to simulate different tree kangaroo taxa under specific modeled conditions. For more detailed information on the distribution, population densities, and population sizes for different taxonomic units, please refer to the CAMP data elsewhere in this report.

## Input Parameters for Simulations

Mating System: No direct data are available. A polygynous mating system has been assumed from limited field observations of other species, in particular Bennett's tree kangaroo (see Flannery et al. 1996).

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 offspring production.

Data from Matschie's Tree-kangaroos held in captivity (Wilcken et al. 1998) include records of a few females breeding in the first year (2%). However, it is not until later age classes that substantial numbers of females first breed. Fourteen percent of all 1 year old females, and 30% of all 2 year olds are recorded as having bred. From these data, we set the baseline value of age of first reproduction at 2 years.

No males in captivity have been recorded breeding in their first year, but similarly 1 and 2 year old males have been recorded breeding with relative frequency (8% and 24% of total). The baseline value was set at 2 years of age as for females.

To investigate the sensitivity of tree-kangaroo populations to measurement uncertainty in this parameter, we developed a set of models in which the age of first reproduction for both males and females was alternatively set at 3 years.

Age of Reproductive Senescence: VORTEX assumes that animals can breed (at the normal rate) throughout their adult life.

No data on longevity is available for wild populations. Data from captive populations includes records of females breeding at the age of 15 and 17 years, however reproductive output declines substantially at the age of 12 years (Wilcken et al. 1998). Assuming relatively harsher conditions in the wild, a baseline age of final reproduction was set at 10 years. To investigate population sensitivity, we also developed a set of models with an age of final reproduction at 9 years of age. Based on our assumed inter-birth interval (see below), this range would result in variation in average lifetime reproductive output of approximately one offspring per female.

Male Breeding Pool: Reports from hunters indicate that the majority of sightings of groups of Matschie's tree kangaroos comprise either adult pairs or females with young. Few reports indicate adult pairings remaining together while offspring are being raised (Wagi 1997). This may indicate relatively loose social groupings; therefore it has been assumed that social groupings do not preclude males from breeding.

Sex Ratio at Birth: Data from captive populations (N=265) indicate no evidence for birth sex ratios other than 50/50. We therefore set this parameter to equal ratio in all simulations.

Offspring Production: Little data are available from wild populations. Wagi (1997) reports the results of interviews with hunters. Eighteen of 19 hunters reported that females killed were almost always with young, perhaps indicating a relatively short inter-birth interval. Indeed, most hunters claimed females take a year to conceive and bear young, which would accord well with underlying biological factors (gestation of 32 – 42.5 days with approximately 300 days of pouch occupancy: Bach 1998). However, females with young were reported as more vulnerable, and therefore more likely to be captured.

Data from breeding females within the captive population indicate a mean interbirth interval of 1.57 yrs (95% confidence interval = 0.15) for females with a record of producing more than one offspring. This has been used to give an estimate of 64% females breeding each year for use in the initial base model.

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 (SD (Probability of a litter)) = 10%).

VORTEX then determines the proportion of females breeding each year of the simulation by sampling from a binomial distribution with a specified mean (e.g., 64%) and standard deviation (e.g., 10%).

The incidence of twinning in Matschie's Tree kangaroos is extremely rare: only one known case in captivity, with survivorship of the twins unknown (Clark pers. comm.). San Diego Zoo had twin Goodfellow's Tree kangaroo's born 4-5 years ago. Only one of those survived. We therefore set the maximum number of offspring in the model at one.

Density-Dependent Reproduction: Density dependence in reproduction (proportion of females breeding in a given year) is modelled in VORTEX according to the following equation:

$$P(N) = \left( P(0) - \left[ (P(0) - (P(K)) \left( \frac{N}{K} \right)^B \right] \right) \frac{N}{N + A}$$

in which  $P(N)$  is the percent of females that breed when the population size is  $N$ ,  $P(K)$  is the percent that breed when the population is at carrying capacity ( $K$ , to be entered later), and  $P(0)$  is the percent of females breeding when the population is close to 0 (in the absence of any Allee effect).  $B$  can be any positive number. The exponent  $B$  determines the shape of the curve relating percent breeding to population size, as population size gets large. If  $B$  is 1, the percent breeding changes linearly with population size. If  $B$  is 2,  $P(N)$  is a quadratic function of  $N$ . The term  $A$  in the density-dependence equation defines the Allee effect. One can think of  $A$  as the population size at which the percent of females breeding falls to half of its value in the absence of an Allee effect (Akçakaya 1997).

No evidence for an Allee effect is available for this analysis. In addition, we have not assumed that breeding is attenuated at high population densities.

Mortality Rates: Age- and sex-specific mortality rates were modified from data on captive populations (Wilcken et al. 1998), with the assumption that mortality rates within the wild population are somewhat higher than those observed in captivity. This would arise from stress in wild individuals for finding food, avoiding predators, etc. Significant differences in male and female survivorship were reported within the combined captive populations of *D. matschiei* and *D. goodfellowi* with males tending to die earlier than females, however the data included in the analysis are incomplete and it is not known whether this represents a generalised trend. The base model assumes the same mortality rates for both sexes.

Mortality rates for juvenile and adult age classes observed and modified are shown below, with standard deviations due to environmental variability listed in parentheses:

Age class	Mortality (%)	
	captive	wild
0 - 1	30	35 (10)
1 - 2	5	12 (4)
adult	5	8 (3)

In order to test the sensitivity of tree kangaroo populations to measurement uncertainty in mortality rate estimates, alternative models were developed in which adult mortalities were increased to 10% and/or juvenile female mortality was increased to 40%.

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 an annual probability of occurrence and a pair of severity factors describing their impact on mortality (across all age-sex classes) and the proportion of females successfully breeding in a given year. These factors range from 0.0 (maximum or absolute effect) to 1.0 (no effect), and are imposed during the single year of the catastrophe, after which time the demographic rates rebound to their baseline values.

Five catastrophic events were identified which may have risk implications for tree kangaroo populations across Papua New Guinea: volcanic activity, earthquake and associated tsunami, drought, fire and disease. Information from published sources and discussions with landowners, veterinarians, biologists and other participants at the workshop suggested that these catastrophic events were in order of expected decreasing effect on the population: drought, fire, disease, volcanic activity, earth quake and tsunami.

#### *Drought*

Data/knowledge suggests that drought is not usually a significant problem for Matschie's tree kangaroo. Annual frequency of the incidence of severe drought has been estimated from participants' observations at about 2% (i.e. one event every 50 years on average). However, during severe drought events (for example the El Niño of 1997/1998) a significant effect is more likely. During severe drought, reduced food supplies increase the hunting pressures on local populations of tree kangaroos and may also increase pressure on more distant populations because villagers can travel more easily through the forest and frequency of hunting forays also may increase. Severe drought may also effect tree kangaroo populations by habitat reduction which concentrates populations and increases density and the potential for reductions in food resources for tree kangaroos. There is also a need to increase knowledge on the effect of this on population movements/migration.

#### *Fire*

Little information is available on the effects of forest fire on tree kangaroos. There is some evidence of the vulnerability of tree kangaroos in general to effects of forest fire (canopy vs. low burn forest floor). High burn canopy fires would be expected to cause high levels of local population mortality and potential for local extinctions.

#### *Disease*

There is little published information on tree kangaroo diseases. The main disease risk appears to be avian tuberculosis (*Mycobacterium avium complex*) (Joslin, 1990; Bush, see article in CBSG TK handbook) but various parasitic diseases and necrobacillosis have also been recorded.

##### *Mycobacterium avium*

The main disease source is wild birds but behavioural transmission is also possible, for example by aerosol inhalation or direct contact (Joslin, 1990). Lesions or wounds derived from intraspecific aggression may also be a source of transmission. The effect of this disease on individuals may be dependent on the immune status of individuals as well as the effects of stress. Males are more susceptible to mycobacteriosis than females (Busch, in press). The cause of this differential effect is unknown but it may relate to an increased susceptibility of males to a stress-related suppression of the immune system. At present there are no data on the incidence of mycobacteriosis or stress on wild populations of tree kangaroos.

##### *Parasites*

There is evidence of parasitic infection in tree kangaroos (Busch...) at similar levels of susceptibility to other marsupials and eutherians (Beveridge, 1993). Round worms, tapeworms, coccidiosis and toxoplasmosis have all been recorded (Ochs in Kloes and Goeltenboth, 1995). Toxoplasmosis and

Coccidiosis are unlikely to occur with any frequency, if at all, in wild populations because of lack of contact with domestic animals. Obviously juveniles are more susceptible to both protozoon diseases, Toxoplasmosis as well as Coccidiosis, than adults are (Ochs in Kloes and Goeltenboth, 1995).

#### *Necrobacillus*

Necrobacillosis or lumpy jaw, which causes dental problems in macropod marsupials, often occurs in captive tree kangaroos in the context of inappropriate diet and/or hygiene and may not play an important role in free ranging populations.

#### *Volcanic Eruption*

Historical records of volcanic ash cover over parts (~50%) of Matschie's range following volcanic eruption from Long Island of the north coast adjacent to the Huon Peninsula. Frequency estimate is probably 0.5% per annum. No data available during workshop on the area affected by ash nor the effects on tree kangaroo population. Low extinction risk for population.

#### *Earthquake and Tsunami*

Low incidence and extremely low risk to populations. Likely to be a local effect only with forest destruction from earthquake and no risk from tsunami because minimum elevation of tree kangaroo populations (except perhaps *Dendrolagus spadix*) considerably above the expected maximum level of a tsunami.

Data from and discussions with the participants at the workshop led to the construction of the following two catastrophic disease events:

Drought/Fire: 2% annual probability of occurrence; 50% reduction in survivorship; 10% reduction in reproduction (anoestrous?/testicular atrophy?)

Volcanic Eruption: 0.5% annual frequency, 75% reduction in survival

While there was considerable discussion around the possible diseases affecting wild tree kangaroo populations, the group was unable at this time to parameterize these events for the purposes of simulation modeling.

Initial Population Size: Information presented during this workshop on the distribution and conservation status of the various tree kangaroo taxa suggest that current population sizes across these taxa span a wide range. For example, the size of Scott's tree kangaroo population may be as small as 50 total individuals, while a minimum estimate for the size of Matschie's tree kangaroo population may be approximately 2500 mature individuals. Preliminary modeling suggests that mature individuals make up about 80-85% of the total population. As a result, a broad series of models were developed with initial population sizes equal to 50, 250, 500, 1000, and 3000 individuals.

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.

There are very little data on the ecological requirements of tree kangaroo populations in the wild and, by extension, the number of animals a given habitat could reasonably support. In the absence of these data, we made the assumption that, since hunting appears to be the major factor leading to tree kangaroo population decline, there is habitat available that currently does not support tree kangaroo populations. Therefore, we set the carrying capacity for a given set of models equal to twice the initial population size, i.e., 100, 500, 1000, 2000, and 6000 individuals.

Human Concerns: Many discussions during (and before) this workshop point to the conclusion that the primary threat to tree kangaroo populations throughout New Guinea is the removal of animals by local hunters. A risk assessment for this group of species, then, should include an analysis of the effects of hunting on tree kangaroo populations that are vulnerable to other intrinsic processes such as catastrophes and unpredictable demographic events that, when taken together, may result in population extinction. The following discussion is extracted from notes taken by a team of three researchers (J. Williams, P. Nyhus, and J. Borovansky) that visited rural Papua New Guinea before the workshop to obtain interview information from local landowners on their patterns of natural resource utilization.

*Hunting rate*

To derive the estimate for the number of tree kangaroos killed by hunters throughout the Huon Peninsula, the team began by talking to one of the landowners (Mambawe) over several hours to determine how many tree kangaroos he has killed or captured, the size of the area from which these were obtained, and the time it took him to kill them.

First, they found that in total, he killed a total of 17 tree kangaroos (10 males and 7 females) in a 6-7 year period. Two were juveniles (one male, one female). Nine of these were taken from his own land and the remaining 8 were taken from other people's land in the immediate area.

<u>Extraction Type</u>	<u>Male</u>	<u>Female</u>	<u>Total</u>
Killed on his land	5	1	6
Killed on other's land	4	2	6
Captured on his land	1	2	2
Captured other's land	0	2	3
<b>TOTAL</b>	<b>10</b>	<b>7</b>	<b>17</b>

Secondly, to derive an estimate of the number of households in his area that hunt, the team asked him to describe all the households in his village (a total of 41) and then the number that hunted (numbering 11). Four of the hunters were "serious hunters" and 7 were not serious hunters. The landowner being interviewed described himself as a "serious" hunter—and, in fact, probably one of the best. This information was used to estimate that approximately 25% of the village population are hunters. This was actually the same estimate derived from detailed household data from four different villages in the Tekadu area, gathered by the same team. Moreover, based on this study of four villages in the Tekadu area, the team concluded that the average household size was about 5 people. This estimate was used in general for the Huon area.

Thirdly, assuming that the 4 serious hunters mentioned above killed tree kangaroos at a similar rate as the landowner being interviewed (2/year), and the less-serious hunters killed only a quarter as many (0.5/year), we estimated an average of one tree kangaroo killed per hunter per year.

Total Households	41	
Serious Hunters	4	(est. 2 TK/year)
Less Serious Hunters	7	(est 0.5 TK/year)
Total Number of Hunters	11 (~25%)	(est 1 TK/hunter/year)

Fourthly, the team obtained an estimate from Will Betz and the interviewed landowner of how many villages in their area had forest cover that was suitable for tree kangaroos. Out of the seven villages listed, 3 (including Teptep) probably had no tree kangaroos in the forests surrounding them, 3 had adequate forest, and one had excellent habitat. When similar questions were posed to a second landowner, he estimated that

8 of 21 villages in his area were “close to bush.” The team used these figures to estimate that roughly half of the villages in the peninsula could be expected to have tree kangaroos in the surrounding forest habitat.

*Estimated extraction rate of Matschie’s tree kangaroo*

With the above data in hand, the team began deriving a way in which to estimate the rate of extraction of tree kangaroos from a particular habitat segment. For Matschie’s tree kangaroo, we assumed that only those villages situated above about 1,800m would be in or near suitable hunting habitat. Therefore, if the total human population in this area is known, the total number of hunters within that population can be calculated and, assuming a particular annual rate of tree kangaroo extraction per hunter, the total number of animals removed can be estimated.

N	=	Total population size >1,800m
Suitable Villages	=	0.5 (est that ½ villages suitable)
Households	=	0.2 (est 5 people/household)
Hunters	=	0.25 (proportion that are hunters)
Hunting rate high	=	1 (1TK/hunter/year)
Hunting rate low	=	0.5 (1 TK/hunter/2 years)

$$\begin{aligned} \text{High Extraction Rate} &= [N] \times [\text{Suitable Villages}] \times [\text{Households}] \times [\text{Hunters}] \times [\text{Rate}] \\ &= [N] \times [0.5] \times [0.2] \times [0.25] \times [1] \\ &= [N] \times 0.025 \end{aligned}$$

$$\begin{aligned} \text{Low Extraction Rate} &= [N] \times [0.5] \times [0.2] \times [0.25] \times [0.5] \\ &= [N] \times 0.0125 \end{aligned}$$

For example, if the total human population in the region of interest is 10,000, the annual number of tree kangaroos extracted from a particular population would be 250 per year.

Obviously, a critical piece of information required for this analysis is the total human population size in the region of interest. Unfortunately, we were unable to gather this information during the workshop. As a result, we are forced to make a more simple set of assumptions concerning the total rate of extraction of tree kangaroos from a given area. However, the discussion presented above provides a valuable set of guidelines that can serve as a starting point for extended analyses on the severity of hunting pressures on wild tree kangaroo populations throughout New Guinea.

To evaluate the effect of hunting on tree kangaroo populations, we assumed that adult females were preferentially removed from the population, primarily because they are slower when they are with joeys and therefore easier to catch. In addition, when a female is caught the joey that is with her is also removed from the population (i.e., either eaten or kept/sold as a pet). We assumed that the joeys were male or female with equal probability. Finally, we assumed that hunting resulted in an additional 2% mortality among adult females. Therefore, if the baseline adult female mortality rate is 8% in a non-hunting scenario, this rate becomes 10% when hunting is added to the model. The mortality rate for joeys also needs to be increased, but by more than just 2% since juvenile tree kangaroos (0-1 year old) make up only 15-20% of a typical tree kangaroo population (data from preliminary models). In other words, the removal of 3-4 adult females from a population of 200 animals in this age-sex class has a smaller impact than the same level of removal (assuming all hunted females are carrying a joey) from a total of about 80 joeys. We calculated that a 2% increase in adult female mortality will result in an increase in juvenile mortality (both male and female) of about 4%. Therefore, all hunting models included juvenile mortality equal to 39% instead of the baseline 35%.

Iterations and Years of Projection: All scenarios were simulated 500 times, with population projections extending for 100 years (this is roughly equivalent to about 20 effective tree kangaroo generations). Output results were summarized at 10-year intervals for use in the tables and figures that follow. All simulations were conducted using VORTEX version 8.03 (March 1998).

## **Results from Simulation Modeling**

### Output Table Information

The tables that follow present the numerical results from the 308 different models developed during this workshop. Within these tables, description of the variable input centers around changes made to the age of first reproduction for either females (AFR-♀) or males (AFR-♂), the maximum age of reproduction (or "age of last reproduction", ALR), and the proportion of the adult female population that breeds in a given year (% ♀ ♀). The results of the models are described in terms of the following:

$r_s$ (SD)	Mean (standard deviation) stochastic growth rate, calculated directly from the observed annual population sizes across the 500 simulations;
P(E)	The probability of population extinction, determined by the proportion of 500 simulated populations within a given model that become extinct during the model's 100-year time frame.
$N_{100}$ (SD)	Mean (standard deviation) population size across those simulated population which are not extinct at 100 years;
$H_{100}$	Expected heterozygosity (gene diversity) in the simulated populations after 100 years;
T(E)	The mean time to extinction for those populations becoming extinct during the simulation.

### Demographic Sensitivity Analysis

The demographic and environmental parameters discussed above were assembled in the VORTEX model to assess the status of a generic tree kangaroo population relatively free from human interference and consistent with historical data. The initial model that includes our best estimates of tree kangaroo demography is considered to be the general baseline population model.

#### *The Baseline Population Model*

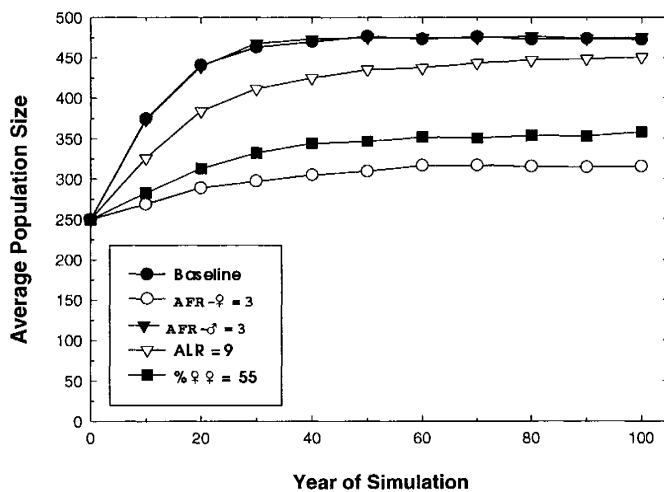
To review the characteristics of this baseline model:

- Polygynous mating system.
- Females and males begin breeding at 2 years of age; the maximum breeding age is 10 years.
- On average, 64% (SD = 10%) of adult females produce a single joey in a given year.
- All adult males are equally capable of breeding in a given year.
- Juvenile mortality is set at  $35 \pm 10\%$ , subadult at  $12 \pm 4\%$ , and adult at  $8 \pm 3\%$ .
- Initial population size was set (somewhat arbitrarily) at 250 individuals, with a carrying capacity of 500.
- Absent from this particular set of models: catastrophes, additional mortality caused by hunting.

Under these conditions, the baseline tree kangaroo model showed an annual population growth rate of  $r = 0.035$ . In other words, the set of demographic parameters listed above results in a simulated tree kangaroo population that has the capability of growing in size at a rate of about 3.5% per year. A population that is growing at this rate can be expected to double in size in about 20 years. It is important to remember, however, that this is a simple model that does not include other processes like catastrophes or hunting that will be assessed directly later on. These process will reduce the growth rate of simulated tree kangaroo

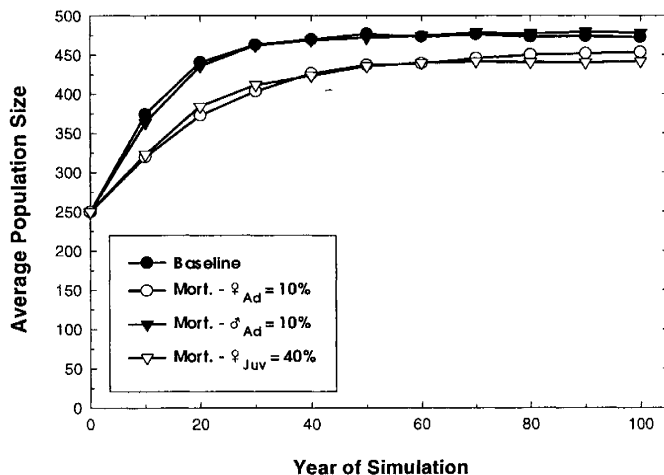
populations. This baseline model does, however, provide a starting point so that we can compare the results of other models using demographic sensitivity analysis. It is instructive to use the simulation modeling approach in an investigation of the relative sensitivities of the populations to changes in a range of demographic parameters. In other words, we can determine which parameters are most influential in impacting the future viability of tree kangaroo populations and utilize this information to, for example, help prioritize additional data collection. A total of seven parameters were chosen for study in this analysis: age of first reproduction in females, age of first reproduction in males, age of last reproduction, the percentage of adult females that breed successfully in a given simulation year, juvenile female mortality, adult female mortality, and adult male mortality. These parameters were chosen because a reasonable level of uncertainty exists concerning the best estimate we can make about their values in wild tree kangaroo populations. In total, the different combinations of these parameters resulted in construction of 128 different models.

A set of representative population trajectories is shown in Figure 1. (Tabular results for each sensitivity model were not included for the sake of brevity.) As expected, the baseline model increases in size from 250 animals to nearly 500 in about 25-30 years. When the age of first breeding among females is changed from 2 years to 3 years, the population growth rate decreases dramatically to  $r = 0.004$ . It is clear that this parameter has a strong overall influence on the growth rate of a tree kangaroo population under these model conditions. In contrast, an equivalent increase in the age of first breeding among males has virtually no effect on the growth rate. Since we assume here that tree kangaroos are polygynous, with one adult male breeding with more than one female per year, a simulated population will grow in size at the expected rate as long as there are some adult males available. However, the ability of a population to grow is strongly



**Figure 1.** Tree kangaroo demographic sensitivity analysis. Population projections under alternative values for breeding characteristics (*top*) and mortality (*bottom*). AFR, age of first reproduction; ALR, age of last reproduction. See text for additional details.

dependent on the total number of adult females present in the population, which is in turn a function of the age at which they become reproductively active.



Decreasing the maximum age of breeding from 10 years to 9 also reduces the growth rate, but not to the extent that we see when changes are made to first breeding ages. This is most likely a result of the fact that, because of annual adult mortality, there are simply fewer older adults in the population, so that there are fewer joeys produced which leads to a slower increase in population growth rate. Reducing the proportion of adult females producing joeys annually from 64% to 55% also has a noticeable impact on the population growth rate. This appears to be another important parameter in

determining tree kangaroo population growth dynamics.

In a similar manner, changes made to the annual mortality rates of females, both juveniles and adults, result in greater impacts to the simulated population compared to similar changes made to the annual mortality rate of adult males. This again is a likely consequence of the polygynous nature of the tree kangaroo breeding system. VORTEX may treat this breeding system with its potential social complexities a bit simplistically, but the conclusion nevertheless remains: the growth (or decline) of tree kangaroo populations appears to be most closely influenced by the breeding and mortality characteristics of females within that population.

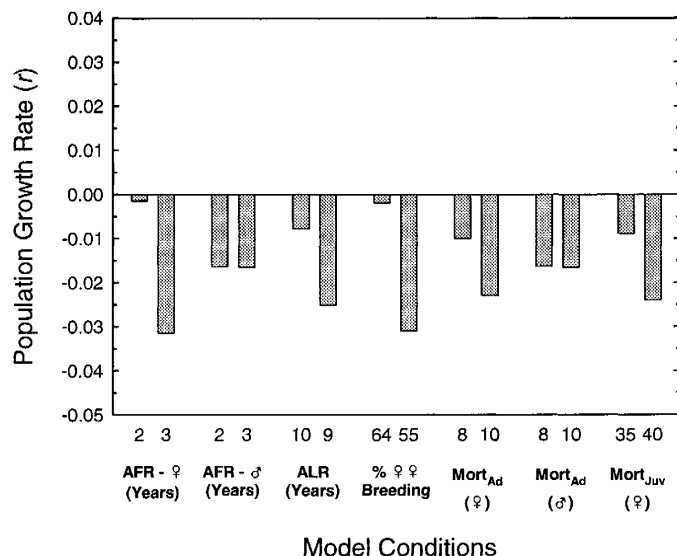
To further emphasize this point, a graphical summary of the results of our demographic sensitivity analysis is presented in Figure 2. The individual population growth rates resulting from all models with a given demographic parameter (for example, age of first female reproduction = 2 years) were averaged to obtain a mean growth rate for that particular parameter value. This procedure was repeated for each of the 14 alternative parameter values in order to compare the behavior of the simulated populations when changes to a particular parameter were made, with all other parameters held constant. It is very important to remember that, for this analysis, we are most interested in the relative differences between average population growth rates for a given demographic parameter and not the actual values of the average growth rates themselves. For example, it is not a particular cause for concern that all of the average growth rates shown in Figure 2 are negative, indicating a declining population. All of the alternative parameter values in the analysis were chosen somewhat arbitrarily and are expected to lead to a reduction in a population's rate of growth. The conclusion to be drawn from this summary analysis is that female breeding characteristics influence the growth of tree kangaroo populations to the greatest extent. Mortality rates among females are also quite important, with rates among juveniles

**Figure 2.** Demographic sensitivity analysis summary for simulated tree kangaroo populations. See text for methods and additional information.

perhaps slightly more influential than those for adults. The reason for this observation is similar to that given above in the discussion of breeding age effects: juveniles are expected to produce more offspring over their lifetime than are older adults that have a shorter relative lifespan.

Based on this sensitivity analysis, all subsequent risk assessment models described in this section will be run under alternative values of age of first reproduction among females (2 or 3 years), alternative proportions of annual female breeding success (64%, 55% or 73%), and alternative levels of adult mortality (8%, 6% or 10%). This will allow us to incorporate levels of "measurement uncertainty" into our risk assessments to provide a more comprehensive picture of tree kangaroo population viability under the scenarios discussed below.

### Risk Analysis I: Population Size and Catastrophes



The baseline demographic scenario was used as a starting point to develop 90 models that assess the risk of decline and extinction of populations of different sizes and under the influence of the catastrophic events presented earlier. The population sizes chosen for the modeling are thought to span the range of numbers likely to currently exist among tree kangaroo populations in Papua New Guinea. The smallest size, numbering just 50 individuals, is considered representative of the current population of Scott's tree kangaroo, while the largest simulated population of 3000 animals is considered close to (or perhaps a minimum estimate of) the current population of Matschie's tree kangaroo. There may be larger populations of other species, but this was taken as a reasonable maximum population size for this analysis.

The results from each of these models are listed in Tables 1 through 5. For each of the simulated populations, the baseline scenario (shown at the top line of each table) shows a population growth rate of about 0.025. This rate of growth is nearly 30% less than what would be expected for the same simulated population in the absence of catastrophes. This is borne out by the fact that the earlier sensitivity analysis baseline model, run in the absence of catastrophes, resulted in a growth rate of about 0.035 (see previous discussion of sensitivity analysis). The inclusion of volcanic activity and fire/drought clearly has a negative impact on the growth potential of tree kangaroo populations. Additional modeling would be necessary to evaluate the relative impact of the two events; the fire/drought event is likely to impact the simulated populations to a greater extent, primarily because it is more frequent in occurrence compared to the more severe, but very infrequent volcanic events.



**Table 1.** Tree kangaroo risk analysis under alternative demographic parameters. Initial population size is 50 individuals, while the carrying capacity (K) is set at 100 individuals. AFR, age of first reproduction; % ♀♀, average percentage of females breeding in a given year; Mort<sub>Ad</sub> - ♀, average annual mortality rate of adult females.

File#	AFR-♀	% ♀♀	Mort <sub>Ad</sub> - ♀	r <sub>s</sub> (SD)	P(E)	N <sub>100</sub> (SD)	H <sub>100</sub>	T(E)
301	2	64.0	8.0%	0.024 (0.139)	0.062	79 (26)	0.787	57
302	3			-0.011 (0.155)	0.348	43 (28)	0.683	58
303	2	55.0		-0.008 (0.156)	0.354	51 (31)	0.686	59
304	3			-0.035 (0.170)	0.794	20 (15)	0.566	57
305	2	73.0		0.047 (0.142)	0.022	88 (23)	0.799	52
306	3			0.012 (0.143)	0.136	74 (28)	0.787	60
307	2	64.0	10.0%	0.007 (0.153)	0.194	69 (30)	0.741	53
308	3			-0.023 (0.162)	0.584	30 (22)	0.633	58
309	2	55.0		-0.025 (0.164)	0.604	30 (25)	0.596	57
310	3			-0.047 (0.178)	0.914	15 (15)	0.425	49
311	2	73.0		0.033 (0.141)	0.058	84 (25)	0.785	54
312	3			0.001 (0.148)	0.208	61 (31)	0.744	63
313	2	64.0	6.0%	0.035 (0.140)	0.050	85 (23)	0.799	63
314	3			0.000 (0.151)	0.226	59 (32)	0.730	60
315	2	55.0		0.006 (0.145)	0.178	66 (30)	0.750	58
316	3			-0.024 (0.162)	0.580	29 (24)	0.585	61
317	2	73.0		0.061 (0.140)	0.010	91 (20)	0.813	53
318	3			0.023 (0.140)	0.052	80 (27)	0.795	59

Each of the models presented in the tables represents a possible fate of a real tree kangaroo population. Our uncertainty in the actual fate of a population rests largely on the fact that we are uncertain about the true demographic characteristics of the population in question. The baseline model may represent our best estimate of the likely fate of a real population given a specified set of conditions; using similar logic, we could construct the most optimistic model by setting the uncertain demographic parameters to their “best” value. The most pessimistic model is also constructed by setting the uncertain demographic parameters to their “worst” value. For example, for a population of 50 individuals, the most optimistic model shown in Table 1 includes a female breeding age of 2 years, 73.0% of females breeding on average every year, and 6% annual mortality among adult females. Under these conditions, the simulated population increases at a rate of about 6.1% per year with a very low risk of population extinction (Table 1, File#317).

**Table 2.** Tree kangaroo risk analysis. Initial population size is 250 individuals, while the carrying capacity (K) is set at 500 individuals. See Table 1 for definitions of column headings.

File#	AFR- ♀	% ♀ ♀	Mort <sub>Ad</sub> - ♀	r <sub>s</sub> (SD)	P(E)	N <sub>100</sub> (SD)	H <sub>100</sub>	T(E)
319	2	64.0	8.0%	0.025 (0.127)	0.000	411 (123)	0.951	—
320	3			-0.008 (0.136)	0.066	188 (144)	0.886	72
321	2	55.0		-0.005 (0.138)	0.052	216 (161)	0.889	70
322	3			-0.033 (0.147)	0.380	42 (45)	0.757	75
323	2	73.0		0.050 (0.13)	0.000	457 (94)	0.958	—
324	3			0.015 (0.126)	0.008	376 (149)	0.945	89
325	2	64.0	10.0%	0.011 (0.13)	0.016	342 (153)	0.934	66
326	3			-0.019 (0.136)	0.164	94 (89)	0.843	74
327	2	55.0		-0.020 (0.143)	0.190	101 (103)	0.822	76
328	3			-0.045 (0.155)	0.632	19 (16)	0.644	74
329	2	73.0		0.038 (0.123)	0.000	439 (111)	0.956	—
330	3			0.005 (0.127)	0.024	309 (166)	0.926	75
331	2	64.0	6.0%	0.039 (0.124)	0.000	448 (100)	0.958	—
332	3			0.005 (0.123)	0.012	317 (161)	0.933	67
333	2	55.0		0.010 (0.13)	0.010	340 (158)	0.934	66
343	3			-0.023 (0.142)	0.200	78 (85)	0.824	76
335	2	73.0		0.063 (0.132)	0.002	462 (90)	0.959	46
336	3			0.026 (0.125)	0.002	420 (123)	0.955	84

**Table 3.** Tree kangaroo risk analysis. Initial population size is 500 individuals, while the carrying capacity (K) is set at 1000 individuals. See Table 1 for definitions of column headings.

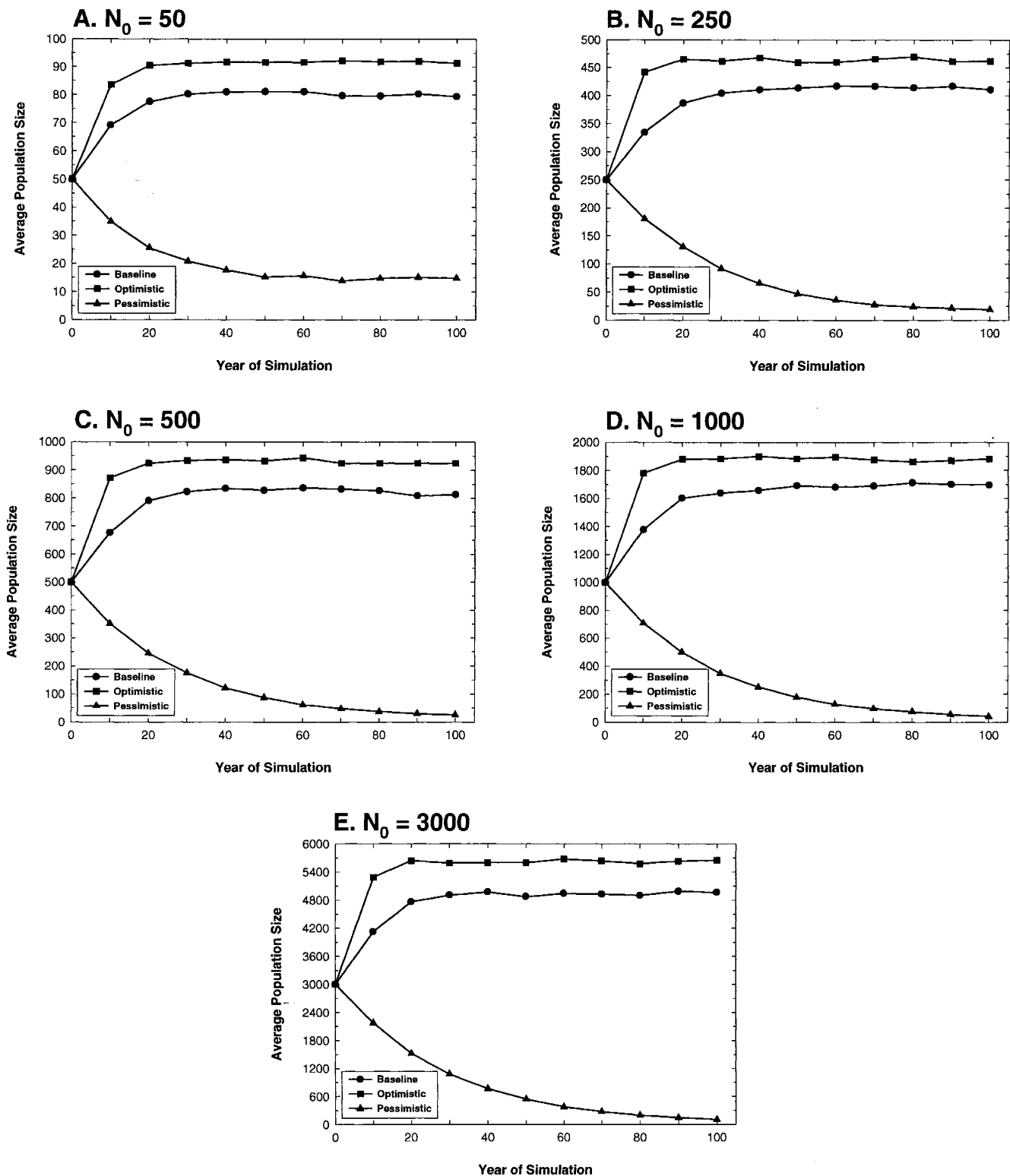
File#	AFR- ♀	% ♀ ♀	Mort <sub>Ad</sub> - ♀	r <sub>s</sub> (SD)	P(E)	N <sub>100</sub> (SD)	H <sub>100</sub>	T(E)
337	2	64.0	8.0%	0.024 (0.129)	0.006	813 (265)	0.975	79
338	3			-0.007 (0.127)	0.020	380 (289)	0.936	77
339	2	55.0		-0.003 (0.128)	0.016	444 (311)	0.943	62
340	3			-0.033 (0.141)	0.220	58 (59)	0.830	77
341	2	73.0		0.051 (0.125)	0.000	933 (163)	0.979	—
342	3			0.016 (0.123)	0.000	765 (291)	0.972	—
343	2	64.0	10.0%	0.011 (0.125)	0.008	693 (305)	0.966	45
344	3			-0.017 (0.131)	0.076	193 (186)	0.908	80
345	2	55.0		-0.019 (0.132)	0.090	188 (197)	0.892	81
346	3			-0.045 (0.151)	0.454	25 (25)	0.750	77
347	2	73.0		0.038 (0.126)	0.000	894 (210)	0.977	—
348	3			0.006 (0.124)	0.006	629 (318)	0.964	64
349	2	64.0	6.0%	0.039 (0.127)	0.000	897 (204)	0.978	—
350	3			0.006 (0.123)	0.004	634 (321)	0.965	73
351	2	55.0		0.010 (0.130)	0.004	674 (318)	0.964	97
352	3			-0.020 (0.132)	0.078	159 (167)	0.893	80
353	2	73.0		0.063 (0.134)	0.000	924 (186)	0.980	—
354	3			0.026 (0.126)	0.002	839 (243)	0.976	50

**Table 4.** Tree kangaroo risk analysis. Initial population size is 1000 individuals, while the carrying capacity (K) is set at 2000 individuals. See Table 1 for definitions of column headings.

File#	AFR- ♀	% ♀ ♀	Mort <sub>Ad</sub> - ♀	r <sub>s</sub> (SD)	P(E)	N <sub>100</sub> (SD)	H <sub>100</sub>	T(E)
355	2	64.0	8.0%	0.027 (0.122)	0.000	1696 (477)	0.988	—
356	3			-0.006 (0.123)	0.004	775 (584)	0.970	69
357	2	55.0		-0.003 (0.125)	0.006	924 (637)	0.966	64
358	3			-0.032 (0.132)	0.120	100 (109)	0.895	80
359	2	73.0		0.050 (0.127)	0.000	1813 (404)	0.990	—
360	3			0.016 (0.121)	0.004	1566 (562)	0.986	85
361	2	64.0	10.0%	0.012 (0.126)	0.000	1409 (609)	0.982	—
362	3			-0.018 (0.131)	0.026	313 (325)	0.938	81
363	2	55.0		-0.018 (0.132)	0.024	339 (376)	0.932	82
364	3			-0.043 (0.136)	0.230	41 (46)	0.819	82
365	2	73.0		0.038 (0.127)	0.000	1772 (436)	0.989	—
366	3			0.005 (0.124)	0.006	1296 (661)	0.981	89
367	2	64.0	6.0%	0.039 (0.126)	0.000	1790 (431)	0.989	—
368	3			0.005 (0.126)	0.000	1240 (658)	0.979	—
369	2	55.0		0.010 (0.128)	0.002	1353 (640)	0.981	91
370	3			-0.020 (0.128)	0.030	287 (319)	0.932	81
371	2	73.0		0.064 (0.127)	0.000	1882 (323)	0.990	—
372	3			0.027 (0.124)	0.000	1656 (526)	0.989	—

**Table 5.** Tree kangaroo risk analysis. Initial population size is 3000 individuals, while the carrying capacity (K) is set at 6000 individuals. See Table 1 for definitions of column headings.

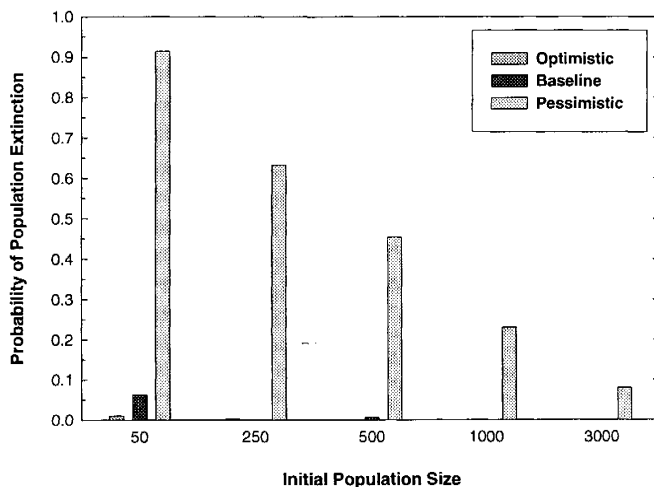
File#	AFR- ♀	% ♀ ♀	Mort <sub>Ad</sub> - ♀	r <sub>s</sub> (SD)	P(E)	N <sub>100</sub> (SD)	H <sub>100</sub>	T(E)
373	2	64.0	8.0%	0.025 (0.127)	0.000	4966 (1533)	0.996	—
374	3			-0.006 (0.126)	0.000	2343 (1842)	0.987	—
375	2	55.0		-0.003 (0.127)	0.002	2749 (1951)	0.989	96
376	3			-0.031 (0.130)	0.028	281 (321)	0.949	86
377	2	73.0		0.051 (0.126)	0.000	5571 (1024)	0.997	—
378	3			0.016 (0.123)	0.000	4647 (1721)	0.995	—
379	2	64.0	10.0%	0.012 (0.124)	0.000	4246 (1766)	0.994	—
380	3			-0.017 (0.126)	0.004	1067 (1156)	0.976	68
381	2	55.0		-0.016 (0.123)	0.006	1116 (1126)	0.977	96
382	3			-0.042 (0.129)	0.080	105 (158)	0.899	88
383	2	73.0		0.037 (0.126)	0.000	5263 (1355)	0.996	—
384	3			0.004 (0.127)	0.000	3592 (1992)	0.993	—
385	2	64.0	6.0%	0.039 (0.128)	0.000	5267 (1316)	0.996	—
386	3			0.006 (0.119)	0.000	3884 (1904)	0.994	—
387	2	55.0		0.009 (0.131)	0.000	3966 (1926)	0.993	—
388	3			-0.019 (0.126)	0.002	859 (932)	0.973	99
389	2	73.0		0.063 (0.128)	0.000	5653 (934)	0.997	—
390	3			0.027 (0.123)	0.000	5076 (1440)	0.996	—



**Figure 3.** Average size of simulated tree kangaroo populations over time for each of the five initial population sizes discussed in the text. Optimistic and pessimistic scenarios refer to those models that included the combination of the “best” and “worst” values, respectively, of the three demographic parameters singled out for risk analysis: age of first breeding in females, average percentage of adult females breeding in a given year, and adult female mortality.

However, the most pessimistic scenario—with females breeding at 3 years of age, 55.0% of adult females breeding on average annually, and 10% annual adult female mortality—the population declines at a rate of 4.7% annually with a very high probability of extinction (91.4%) within about 50-60 years from the onset of the simulation (Table 1, File#310). The actual fate of a small tree kangaroo population under conditions similar to those modeled here will likely fall within this range, and most likely will fall relatively close to the baseline model results discussed above.

Figure 3 shows simulated population size for the baseline, pessimistic and optimistic scenarios under each initial population size. Each population trajectory looks very similar, regardless of how big the population actually is. The baseline model shows strong growth towards the carrying capacity, the optimistic scenario grows even more rapidly towards this population ceiling, and the pessimistic scenario declines at a roughly equivalent rate for each of the starting population sizes. Inspection of Tables 1 through 5, however, shows that the risk of population extinction is much higher for the smallest population. It is important to appreciate that with all other parameters being equal, a small population of tree kangaroos may become extinct from detrimental and unpredictable impacts such as catastrophes, and it is precisely this small size that puts it at such a high risk. A graphical representation of the relationship between the probability of extinction of a population and its size is shown in Figure 4. The importance of considering chance events in population persistence is shown in the Figure by the fact that, for the smallest population of 50 individuals, even the most optimistic model has a non-zero probability of extinction, and the baseline model with an annual growth rate of more than 2% shows an extinction risk of more than 6%. In addition, the amount of genetic variation or heterozygosity retained in a population is directly related to its size: the smaller the population, the greater the loss of genetic variation due to inbreeding and the random loss of genes from one generation to the next (genetic drift). This loss of genetic variation may lead to a reduction in the immediate viability of the population as well as to a decreased capacity for the population to adapt to changing environmental conditions in the long term.



**Figure 4.** Probability of simulated tree kangaroo population extinction as a function of initial population size and demographic characteristics.

## Risk Analysis II: Effects of Hunting

An additional set of 90 models was constructed in a manner very similar to those developed for the population size/catastrophe analysis just described. The feature separating these models is that adult female mortality was increased by 2% and juvenile mortality was increased by 4% in all scenarios to simulate the potential impact of hunting on tree kangaroo populations of differing sizes.

**Table 6.** Tree kangaroo risk analysis with inclusion of hunting. Initial population size is 50 individuals, while the carrying capacity (K) is set at 100 individuals. See Table 1 for definitions of column headings.

File#	AFR- ♀	% ♀ ♀	Mort <sub>Ad</sub> - ♀	$r_s$ (SD)	P(E)	N <sub>100</sub> (SD)	H <sub>100</sub>	T(E)
401	2	64.0	8.0%	-0.006 (0.158)	0.338	54 (31)	0.691	56
402	3			-0.032 (0.169)	0.762	23 (18)	0.542	58
403	2	55.0		-0.034 (0.171)	0.790	22 (16)	0.531	55
404	3			-0.057 (0.181)	0.972	12 (7)	0.334	43
405	2	73.0		0.021 (0.144)	0.096	77 (26)	0.775	53
406	3			-0.011 (0.152)	0.332	45 (31)	0.672	60
407	2	64.0	10.0%	-0.022 (0.165)	0.596	37 (28)	0.598	57
408	3			-0.044 (0.176)	0.900	16 (12)	0.515	51
409	2	55.0		-0.049 (0.185)	0.938	13 (11)	0.373	49
410	3			-0.064 (0.178)	0.986	12 (5)	0.486	40
411	2	73.0		0.006 (0.147)	0.208	68 (31)	0.738	58
412	3			-0.022 (0.157)	0.564	32 (25)	0.609	59
413	2	64.0	6.0%	0.008 (0.151)	0.170	68 (30)	0.741	55
414	3			-0.022 (0.164)	0.548	28 (21)	0.610	60
415	2	55.0		-0.021 (0.165)	0.566	34 (26)	0.613	59
416	3			-0.044 (0.172)	0.900	15 (11)	0.486	53
417	2	73.0		0.037 (0.138)	0.040	85 (23)	0.799	50
418	3			0.000 (0.146)	0.222	60 (31)	0.742	63

The tabulated results of these models are presented in Tables 6 through 10. When comparing these results to those scenarios in Tables 1-5, in which hunting pressure is absent, it is clear that the additional mortality caused by hunting in these simulations is highly detrimental to tree kangaroo populations. Population growth rates in most cases involving hunting are negative, indicating populations that are in decline and headed towards eventual extinction if the additional mortality threat is not reduced. As a consequence of this reduced growth rate, population sizes at the end of the simulations are greatly reduced, the extent of population genetic diversity retained is decreased, and the risk of population extinction within the 100-year time frame of the simulations is, particularly with the smaller populations, greatly increased.

**Table 7.** Tree kangaroo risk analysis with inclusion of hunting. Initial population size is 250 individuals, while the carrying capacity (K) is set at 500 individuals. See Table 1 for definitions of column headings.

File#	AFR-♀	%♀♀	Mort <sub>Ad</sub> - ♀	r <sub>s</sub> (SD)	P(E)	N <sub>100</sub> (SD)	H <sub>100</sub>	T(E)
419	2	64.0	8.0%	-0.003 (0.139)	0.058	234 (164)	0.895	68
420	3			-0.029 (0.141)	0.286	47 (49)	0.771	74
421	2	55.0		-0.031 (0.147)	0.344	47 (53)	0.751	75
422	3			-0.055 (0.160)	0.810	12 (12)	0.570	68
423	2	73.0		0.024 (0.128)	0.008	412 (127)	0.947	63
424	3			-0.008 (0.135)	0.068	192 (149)	0.885	76
425	2	64.0	10.0%	-0.016 (0.137)	0.144	127 (124)	0.842	76
426	3			-0.042 (0.156)	0.586	23 (23)	0.690	73
426	2	55.0		-0.045 (0.153)	0.642	19 (17)	0.653	72
428	3			-0.068 (0.168)	0.938	7 (4)	0.498	60
429	2	73.0		0.010 (0.129)	0.014	339 (155)	0.933	74
430	3			-0.019 (0.138)	0.136	98 (103)	0.840	75
431	2	64.0	6.0%	0.012 (0.133)	0.018	352 (160)	0.936	64
432	3			-0.018 (0.136)	0.134	104 (101)	0.850	77
433	2	55.0		-0.017 (0.141)	0.160	129 (127)	0.847	76
434	3			-0.044 (0.154)	0.602	20 (21)	0.680	73
435	2	73.0		0.037 (0.131)	0.000	436 (113)	0.954	—
436	3			0.005 (0.126)	0.008	308 (156)	0.932	58

**Table 8.** Tree kangaroo risk analysis with inclusion of hunting. Initial population size is 500 individuals, while the carrying capacity (K) is set at 1000 individuals. See Table 1 for definitions of column headings.

File#	AFR-♀	%♀♀	Mort <sub>Ad</sub> - ♀	r <sub>s</sub> (SD)	P(E)	N <sub>100</sub> (SD)	H <sub>100</sub>	T(E)
437	2	64.0	8.0%	-0.002 (0.133)	0.016	462 (319)	0.939	80
438	3			-0.030 (0.136)	0.192	76 (91)	0.838	80
439	2	55.0		-0.031 (0.142)	0.214	79 (108)	0.832	79
440	3			-0.054 (0.151)	0.680	14 (10)	0.685	77
441	2	73.0		0.024 (0.131)	0.002	803 (280)	0.970	68
442	3			-0.006 (0.124)	0.018	401 (300)	0.940	84
443	2	64.0	10.0%	-0.016 (0.134)	0.076	231 (222)	0.903	73
444	3			-0.042 (0.145)	0.384	30 (33)	0.768	79
445	2	55.0		-0.046 (0.149)	0.488	29 (31)	0.730	77
446	3			-0.065 (0.157)	0.854	9 (7)	0.606	69
447	2	73.0		0.011 (0.128)	0.008	687 (305)	0.967	71
448	3			-0.018 (0.132)	0.056	184 (200)	0.898	77
449	2	64.0	6.0%	0.013 (0.130)	0.002	733 (297)	0.965	80
450	3			-0.017 (0.134)	0.070	191 (184)	0.906	77
451	2	55.0		-0.015 (0.132)	0.076	242 (231)	0.917	76
452	3			-0.042 (0.145)	0.384	31 (33)	0.754	78
453	2	73.0		0.040 (0.123)	0.000	894 (208)	0.979	—
454	3			0.005 (0.127)	0.008	628 (321)	0.960	94

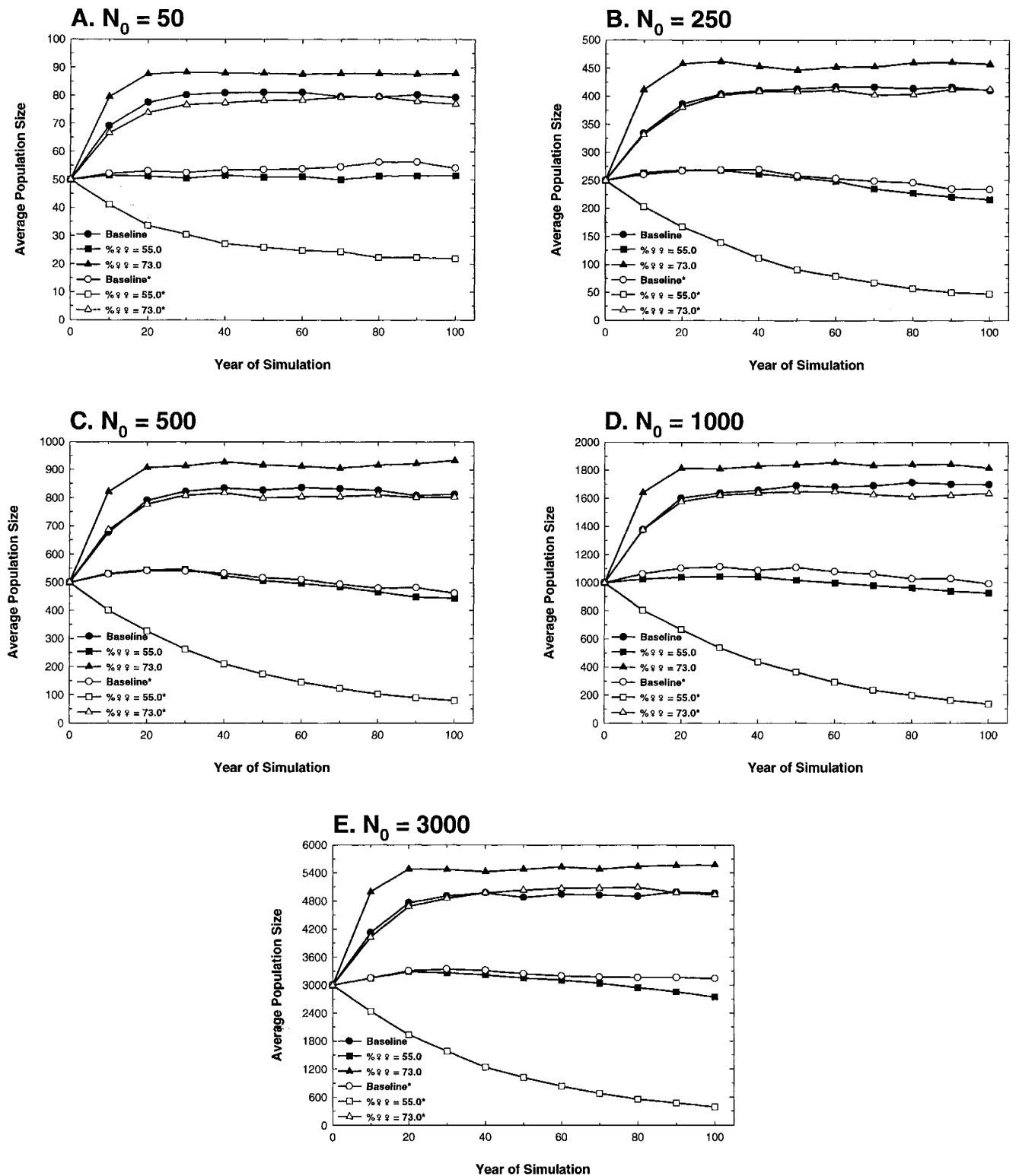
**Table 9.** Tree kangaroo risk analysis with inclusion of hunting. Initial population size is 1000 individuals, while the carrying capacity (K) is set at 2000 individuals. See Table 1 for definitions of column headings.

File#	AFR-♀	%♀♀	Mort <sub>Ad</sub> -♀	r <sub>s</sub> (SD)	P(E)	N <sub>100</sub> (SD)	H <sub>100</sub>	T(E)
455	2	64.0	8.0%	-0.001 (0.128)	0.004	989 (646)	0.970	78
456	3			-0.028 (0.132)	0.09	140 (174)	0.906	80
457	2	55.0		-0.031 (0.138)	0.120	135 (157)	0.888	82
458	3			-0.054 (0.145)	0.476	21 (22)	0.744	80
459	2	73.0		0.025 (0.127)	0.000	1633 (523)	0.986	—
460	3			-0.007 (0.130)	0.008	731 (600)	0.964	78
461	2	64.0	10.0%	-0.014 (0.126)	0.028	472 (469)	0.946	82
462	3			-0.041 (0.138)	0.212	48 (52)	0.843	83
463	2	55.0		-0.046 (0.146)	0.340	43 (53)	0.806	80
464	3			-0.065 (0.153)	0.726	13 (12)	0.660	76
465	2	73.0		0.011 (0.127)	0.002	1401 (630)	0.980	96
466	3			-0.016 (0.122)	0.020	368 (367)	0.945	76
467	2	64.0	6.0%	0.013 (0.127)	0.002	1432 (601)	0.983	49
468	3			-0.016 (0.128)	0.010	377 (388)	0.936	77
469	2	55.0		-0.014 (0.126)	0.014	451 (443)	0.944	87
470	3			-0.042 (0.140)	0.222	46 (50)	0.819	85
471	2	73.0		0.039 (0.124)	0.000	1790 (416)	0.989	—
472	3			0.005 (0.127)	0.008	1250 (653)	0.979	88

**Table 10.** Tree kangaroo risk analysis with inclusion of hunting. Initial population size is 3000 individuals, while the carrying capacity (K) is set at 6000 individuals. See Table 1 for definitions of column headings.

File#	AFR-♀	%♀♀	Mort <sub>Ad</sub> -♀	r <sub>s</sub> (SD)	P(E)	N <sub>100</sub> (SD)	H <sub>100</sub>	T(E)
473	2	64.0	8.0%	0.000 (0.126)	0.000	3142 (1973)	0.991	—
474	3			-0.028 (0.128)	0.014	380 (446)	0.955	88
475	2	55.0		-0.029 (0.129)	0.032	387 (535)	0.946	76
476	3			-0.053 (0.136)	0.230	44 (44)	0.861	87
477	2	73.0		0.025 (0.124)	0.000	4936 (1537)	0.995	—
478	3			-0.004 (0.119)	0.000	2538 (1833)	0.990	—
479	2	64.0	10.0%	-0.014 (0.128)	0.006	1395 (1384)	0.976	74
480	3			-0.040 (0.130)	0.066	121 (132)	0.915	85
481	2	55.0		-0.045 (0.137)	0.130	90 (116)	0.888	86
482	3			-0.065 (0.147)	0.442	17 (17)	0.766	83
483	2	73.0		0.012 (0.128)	0.000	4177 (1854)	0.994	—
484	3			-0.018 (0.128)	0.010	1044 (1147)	0.974	80
485	2	64.0	6.0%	0.014 (0.127)	0.000	4427 (1769)	0.994	—
486	3			-0.017 (0.125)	0.004	1027 (1099)	0.977	80
487	2	55.0		-0.013 (0.126)	0.002	1337 (1343)	0.982	81
488	3			-0.041 (0.130)	0.066	112 (134)	0.910	85
489	2	73.0		0.039 (0.122)	0.000	5374 (1267)	0.996	—
490	3			0.006 (0.123)	0.000	3869 (2023)	0.993	—

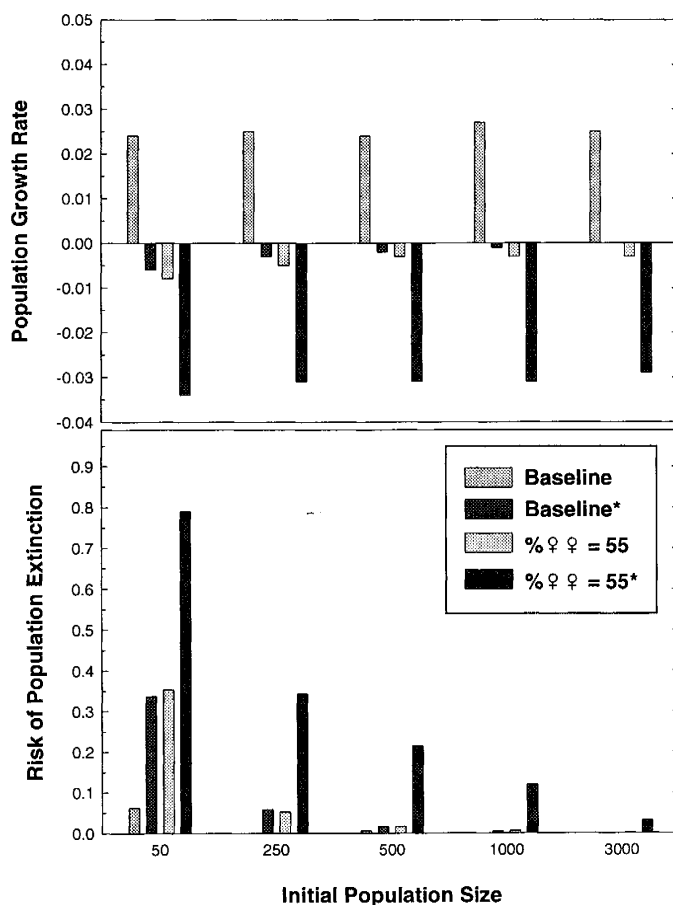




**Figure 5.** Average size of simulated tree kangaroo populations over time for each of the five initial population sizes ( $N_0$ ) discussed in the text. Trajectories show the impact of variable female reproductive success (defined as the percentage of adult females that breed in a given year) and additional mortality of adult females and juveniles of both sexes resulting from hunting by local human populations (hunting scenarios are designated by an asterisk in the figure legends). Hunting-based mortality of adult females is increased by 2% over the non-hunting scenarios, and juvenile mortality is increased by 4%. See text for additional details.

Figure 5 shows representative population trajectories under hunting and non-hunting scenarios. In addition, the figure includes scenarios in which demographic uncertainty in the extent of female breeding success is added. Note that the scenarios chosen for this figure are roughly intermediate between the optimistic and pessimistic scenarios displayed in Figure 3. Of particular note are those scenarios that show a shift from positive population growth to negative growth (decline) when additional hunting mortality is added. For example, the baseline scenario for each initial population size shows a growth rate of about 2.5% per year when hunting is absent, but the addition of hunting results in these same populations declining in size over time. It is important to appreciate that an additional 2% mortality added to the adult female population is not a particularly large increase in terms of total numbers of animals removed. For example, in a population of about 250 total animals, the total number of adult females is about 100. Therefore, an additional mortality of 2% means the annual removal of only 2 extra adult females.

If the degree of adult female breeding success is slightly less than the baseline value, the effect of additional hunting mortality is also quite severe. In particular, the risk of population extinction becomes significantly greater under these model conditions. Figure 6 shows summary information of population growth rate and extinction risk under conditions of alternative female breeding success and the addition of hunting-based mortality. The figure shows the dramatic rate of population decline when hunting is imposed and female breeding success is reduced below the estimated baseline value; moreover, the risk of population extinction is shown to be considerably increased, especially at smaller population sizes. This simulation modeling analysis graphically demonstrates the potential detrimental impacts suffered by tree kangaroo populations subjected to hunting by local human populations. It is important to remember, however, that the extent of this impact is critically dependent on the growth



**Figure 6.** Population growth rate (*top*) and probability of extinction (*bottom*) for simulated tree kangaroo populations under alternative levels of female breeding success (defined as the percentage of adult females that breed in a given year) and additional mortality of adult females and juveniles of both sexes resulting from hunting by local human populations (hunting scenarios are designated by an asterisk in the figure legend). Hunting-based mortality of adult females is increased by 2% over the non-hunting scenarios, and juvenile mortality is increased by 4%. See text for additional details.

rate of the population in the absence of hunting pressure. A tree kangaroo population growing at a rate of 4% per year in the absence of hunting can withstand a greater loss of animals than a population growing at just 2% per year. Unfortunately, we currently do not have the ability to make precise estimates of “actual” growth rates of wild tree kangaroo populations. Consequently, we cannot determine the maximum rate of hunting that would still allow for a population to continue to increase. Despite this limitation, we can conclude that hunting may have very serious consequences, particularly for very small populations, when unpredictable events such as catastrophes or random changes in a population’s demographic characteristics are also considered. In addition, our sensitivity analysis suggests that if hunting is to occur, a population will be able to sustain removal of males much more easily than removal of females. In order to make more precise estimates of the maximum sustainable rate of hunting, detailed information on the demographic characteristics of wild tree kangaroo populations is necessary.

## Conclusions

1. Demographic sensitivity analysis focused on tree kangaroo reproductive characteristics (age of first and last breeding, proportional female breeding success) and annual rates of mortality of both joeys and adults. The models demonstrated that, based on the VORTEX stochastic modeling exercise described in this section, estimates of tree kangaroo population growth dynamics is affected most profoundly by uncertainty in estimates of female breeding characteristics, especially early in a given female’s reproductive lifetime. In contrast, uncertainty in male breeding parameters has comparatively little impact on those growth estimates, primarily due to the supposed polygynous nature of the tree kangaroo breeding system. If age at first breeding for females is increased from 2 to 3yr, the resulting population growth rate ( $r$ ) was substantially reduced. In females, although there was a measurable effect of increasing adult mortality from 8 to 10%, the combined effects of an increase in the first age of breeding in females and increased mortality rates were considerably greater. In males, similar changes in age for first breeding and adult mortality rates had no real effect on underlying growth rates.
2. Current observations suggest that the some tree kangaroo populations may become fragmented as a result of human activities. The resultant populations may also become quite small as local human populations utilize tree kangaroo habitat for their own purposes. The consequences of small tree kangaroo population size are severe: they are more susceptible to further declines resulting from unpredictable demographic events (e.g., highly skewed sex ratio among joeys produced in a given year) and from catastrophic environmental change such as severe drought and resulting fire. Additional pressures on such populations from hunting make them even more vulnerable to rapid decline and eventual extinction.
3. Two critically endangered tree kangaroo species (Scott’s Tree Kangaroo, *Dendrolagus scottae* and Golden-mantled Tree Kangaroo, *Dendrolagus goodfellowi pulcherrimus*) exist as small and isolated populations. Any changes which reduce or restrict carrying capacity and/or increase mortality rates of females in these populations will increase the probability of population extinction. Immediate actions are needed to reduce the extent or impact of these parameters and ensure the continue survival of these important endangered subspecies.
4. A considerable amount of uncertainty exists with respect to our understanding of the population biology and ecology of wild tree kangaroo populations. As a result, our analyses are to be treated as useful from the standpoint of evaluating comparisons between alternative models instead of as specific, quantitative predictions of future wild population dynamics. We hope that this exercise stimulates the collection of additional demographic and environmental data that are suitable for refining the input to population modeling tools.

## Recommendations

**1. Obtain more detailed information on the genetics, age structure and breeding characteristics of wild populations.**

Establish a protocol to collect samples (e.g. mandibles for molar progression studies, hair, skulls) from hunted animals and ceremonial ornaments to provide age- and sex-specific data from tree kangaroos. This would help to monitor differences in tree kangaroo population structure from different areas – e.g., sex ratio and age structure of hunted animals, adult mortality rates.

Additional information on the biology of wild tree kangaroo populations can be derived from long-term field studies specifically designed for this purpose. We recognize the difficulty in obtaining direct information on the life history of such a cryptic group of species but this difficulty should not inhibit the development of novel research programs.

**2. Obtain more accurate information on local home ranges, seasonal activity patterns, migration patterns, and individual response to habitat alteration. This will increase our ability to estimate tree kangaroo population densities and the spatial characteristics of tree kangaroo habitat.**

A satellite-based radiotracking study should be employed. Ideally, a program like this should aim for following 10-20 animals, of both sexes and different ages, for 2 years. University research and associated grant programs (ideally within the region) are most appropriate for this task.

**3. Make increased use of information on tree kangaroo populations from information provided by local hunters (e.g., changes in population numbers over time, current hunting rates, additional information on species biology).**

The existing program of hunter surveys can be extended and/or revised to provide specific information suitable for future population viability modeling. In addition, a centralized location for storing this information must be identified and funding made available for its establishment and maintenance. To encourage this flow of information from local human populations, a fund should be developed to compensate individuals for their donation of time and material. A project of this type could be undertaken by researchers in any number of academic fields such as zoology, anthropology, sociology, ethnology, or environmental science.

**4. Explore methods of directing hunting pressure away from females**

It would be important to make local hunters more aware of the deleterious impact of removing adult females, particularly those with joeys, from tree kangaroo populations. This type of information can be integrated into a survey program of resource use behaviors among local human populations. However, recognition of the practical difficulties of modifying traditional behaviors among local human populations must be made.

**5. Develop more specific population models which allow us to determine sustainable levels of hunting in wild tree kangaroo populations**

This can be accomplished primarily through the collection of more detailed demographic information as described above in previous recommendation statements.

**6. Careful considerations should be given by the government to ensure that the most appropriate forestry and agricultural practices are used in tree kangaroo habitat**

Determine the short and long term impact of clearfelling logging practices on tree kangaroo populations. This could be achieved in part by consulting with the PNG Department of Forests and appropriate NGOs and by collaborating with Department of Environment and Conservation.

Examine the effects of government monitoring on the outcome of clear felling operations in tree kangaroo habitat and, if necessary, establish an independent monitoring facility to achieve this.

**Possible direction for future research**

Developing techniques that enable us to use fecal samples to investigate size structure within populations (as well as for further investigations like reproductive endocrinology, disease and parasitology).

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## References

- Akçakaya, H.R. 1997. RAMAS Metapop: Viability Analysis for Stage-Structured Metapopulations. Version 2.0. Applied Biomathematics, Setauket, New York.
- Bach, 1998. Birth Date Determination in Australasian Marsupials. First edition. Sydney, Australia: Australasian Regional Association of Zoological Parks and Aquaria.
- Beveridge, 1993
- Flannery, T.F., R. Martin, and A. Szalay. 1996. Tree Kangaroos: A Curious Natural History. Reed Books Australia, Melbourne.
- Joslin, 1990
- Kloes and Goeltenboth, 1995
- Wagi, S. 1997. A Brief Report on the Interview Survey of the Komba area of Kabwum District Concerning Matchie's Tree Kangaroo. Lae, Papua New Guinea: University of Papua New Guinea.
- Wilcken, Bigilale, Rodden & van Wees, 1998. Tree Kangaroos in Captivity: Studbook and Population Analysis 1998. Sydney, Australia: Australasian Regional Association of Zoological Parks and Aquaria.

## Sample VORTEX Input File

```
MATC301.OUT      ***Output Filename***
Y      ***Graphing Files?***
N      ***Each Iteration?***
500    ***Simulations***
100    ***Years***
10     ***Reporting Interval***
0      ***Definition of Extinction***
1      ***Populations***
N      ***Inbreeding Depression?***
Y      ***EV concordance between repro and surv?***
2      ***Types Of Catastrophes***
P      ***Monogamous, Polygynous, or Hermaphroditic***
2      ***Female Breeding Age***
2      ***Male Breeding Age***
10     ***Maximum Breeding Age***
0.500000 ***Sex Ratio***
1      ***Maximum Litter Size (0 = normal distribution) *****
N      ***Density Dependent Breeding?***
64.00  **breeding
10.00  **EV-breeding
35.000000 *FMort age 0
10.000000 ***EV
12.000000 *FMort age 1
4.000000 ***EV
8.000000 *Adult FMort
3.000000 ***EV
35.000000 *MMort age 0
10.000000 ***EV
12.000000 *MMort age 1
4.000000 ***EV
8.000000 *Adult MMort
3.000000 ***EV
0.500000 ***Probability Of Catastrophe 1***
1.000000 ***Severity--Reproduction***
0.250000 ***Severity--Survival***
2.000000 ***Probability Of Catastrophe 2***
0.500000 ***Severity--Reproduction***
0.900000 ***Severity--Survival***
Y      ***All Males Breeders?***
Y      ***Start At Stable Age Distribution?***
50     ***Initial Population Size***
100    ***K***
0.000000 ***EV--K***
N      ***Trend In K?***
N      ***Harvest?***
N      ***Supplement?***
Y      ***AnotherSimulation?***
```

## Sample VORTEX Output File

VORTEX 8.03 -- simulation of genetic and demographic stochasticity

MATC301.OUT

Mon Sep 28 15:04:41 1998

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

Extinction is defined as no animals of one or both sexes.

No inbreeding depression

First age of reproduction for females: 2 for males: 2

Maximum breeding age (senescence): 10

Sex ratio at birth (proportion males): 0.50000

Population 1:

Polygynous mating; all adult males in the breeding pool.

64.00 percent of adult females produce litters.

EV in % adult females breeding = 10.00 SD

Of those females producing litters, ...

100.00 percent of females produce litters of size 1

35.00 percent mortality of females between ages 0 and 1

EV in % mortality = 10.000000 SD

12.00 percent mortality of females between ages 1 and 2

EV in % mortality = 4.000000 SD

8.00 percent mortality of adult females (2<=age<=3)

EV in % mortality = 3.000000 SD

35.00 percent mortality of males between ages 0 and 1

EV in % mortality = 10.000000 SD

12.00 percent mortality of males between ages 1 and 2

EV in % mortality = 4.000000 SD

8.00 percent mortality of adult males (2<=age<=3)

EV in % mortality = 3.000000 SD

EVs may be adjusted to closest values possible for binomial distribution.

EV in reproduction and mortality will be concordant.

Frequency of type 1 catastrophes: 0.500 percent

with 1.000 multiplicative effect on reproduction

and 0.250 multiplicative effect on survival

Frequency of type 2 catastrophes: 2.000 percent

with 0.500 multiplicative effect on reproduction

and 0.900 multiplicative effect on survival

Initial size of Population 1: 50  
(set to reflect stable age distribution)

Age	1	2	3	4	5	6	7	8	9	10	Total	
	4	4	3	3	2	2	2	2	2	1	25	Males
	4	4	3	3	2	2	2	2	2	1	25	Females

Carrying capacity = 100



## Sample VORTEX Output File (Contd.)

EV in Carrying capacity = 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 = 0.028      lambda = 1.028      R0 = 1.159  
Generation time for: females = 5.32      males = 5.32

Stable age distribution:	Age class	females	males
	0	0.104	0.104
	1	0.066	0.066
	2	0.056	0.056
	3	0.050	0.050
	4	0.044	0.044
	5	0.039	0.039
	6	0.035	0.035
	7	0.031	0.031
	8	0.028	0.028
	9	0.025	0.025
	10	0.022	0.022

Ratio of adult ( $\geq 2$ ) males to adult ( $\geq 2$ ) females: 1.000

### Population 1

#### Year 10

N[Extinct] = 3, P[E] = 0.006  
N[Surviving] = 497, P[S] = 0.994  
Population size = 69.14 ( 0.97 SE, 21.60 SD)  
Expected heterozygosity = 0.966 ( 0.001 SE, 0.012 SD)  
Observed heterozygosity = 0.988 ( 0.001 SE, 0.014 SD)  
Number of extant alleles = 45.88 ( 0.43 SE, 9.50 SD)

#### Year 20

N[Extinct] = 4, P[E] = 0.008  
N[Surviving] = 496, P[S] = 0.992  
Population size = 77.50 ( 1.15 SE, 25.51 SD)  
Expected heterozygosity = 0.942 ( 0.001 SE, 0.026 SD)  
Observed heterozygosity = 0.964 ( 0.001 SE, 0.028 SD)  
Number of extant alleles = 30.70 ( 0.36 SE, 7.97 SD)

#### Year 30

N[Extinct] = 6, P[E] = 0.012  
N[Surviving] = 494, P[S] = 0.988  
Population size = 80.19 ( 1.15 SE, 25.46 SD)  
Expected heterozygosity = 0.919 ( 0.002 SE, 0.044 SD)  
Observed heterozygosity = 0.941 ( 0.002 SE, 0.037 SD)  
Number of extant alleles = 23.40 ( 0.30 SE, 6.61 SD)

#### Year 40

N[Extinct] = 9, P[E] = 0.018  
N[Surviving] = 491, P[S] = 0.982  
Population size = 80.96 ( 1.15 SE, 25.44 SD)  
Expected heterozygosity = 0.899 ( 0.003 SE, 0.056 SD)  
Observed heterozygosity = 0.918 ( 0.002 SE, 0.053 SD)  
Number of extant alleles = 19.08 ( 0.25 SE, 5.52 SD)

## Sample VORTEX Output File (Contd.)

Year 50

N[Extinct] = 13, P[E] = 0.026  
N[Surviving] = 487, P[S] = 0.974  
Population size = 81.11 ( 1.16 SE, 25.58 SD)  
Expected heterozygosity = 0.879 ( 0.004 SE, 0.082 SD)  
Observed heterozygosity = 0.896 ( 0.004 SE, 0.088 SD)  
Number of extant alleles = 16.10 ( 0.21 SE, 4.55 SD)

Year 60

N[Extinct] = 17, P[E] = 0.034  
N[Surviving] = 483, P[S] = 0.966  
Population size = 81.10 ( 1.12 SE, 24.64 SD)  
Expected heterozygosity = 0.860 ( 0.003 SE, 0.072 SD)  
Observed heterozygosity = 0.880 ( 0.003 SE, 0.075 SD)  
Number of extant alleles = 13.88 ( 0.18 SE, 3.98 SD)

Year 70

N[Extinct] = 20, P[E] = 0.040  
N[Surviving] = 480, P[S] = 0.960  
Population size = 79.66 ( 1.20 SE, 26.29 SD)  
Expected heterozygosity = 0.841 ( 0.004 SE, 0.083 SD)  
Observed heterozygosity = 0.859 ( 0.004 SE, 0.091 SD)  
Number of extant alleles = 12.16 ( 0.16 SE, 3.49 SD)

Year 80

N[Extinct] = 23, P[E] = 0.046  
N[Surviving] = 477, P[S] = 0.954  
Population size = 79.58 ( 1.16 SE, 25.26 SD)  
Expected heterozygosity = 0.822 ( 0.004 SE, 0.094 SD)  
Observed heterozygosity = 0.839 ( 0.005 SE, 0.102 SD)  
Number of extant alleles = 10.88 ( 0.14 SE, 3.16 SD)

Year 90

N[Extinct] = 27, P[E] = 0.054  
N[Surviving] = 473, P[S] = 0.946  
Population size = 80.27 ( 1.15 SE, 24.98 SD)  
Expected heterozygosity = 0.805 ( 0.004 SE, 0.097 SD)  
Observed heterozygosity = 0.820 ( 0.005 SE, 0.103 SD)  
Number of extant alleles = 9.87 ( 0.13 SE, 2.89 SD)

Year 100

N[Extinct] = 31, P[E] = 0.062  
N[Surviving] = 469, P[S] = 0.938  
Population size = 79.36 ( 1.18 SE, 25.55 SD)  
Expected heterozygosity = 0.787 ( 0.005 SE, 0.105 SD)  
Observed heterozygosity = 0.805 ( 0.005 SE, 0.117 SD)  
Number of extant alleles = 8.99 ( 0.12 SE, 2.65 SD)

In 500 simulations of Population 1 for 100 years:  
31 went extinct and 469 survived.

This gives a probability of extinction of 0.0620 (0.0108 SE),  
or a probability of success of 0.9380 (0.0108 SE).

31 simulations went extinct at least once.

Of those going extinct,

mean time to first extinction was 56.77 years (5.06 SE, 28.18 SD).

**Sample VORTEX Output File (Contd.)**

Mean final population for successful cases was 79.36 (1.18 SE, 25.55 SD)

Age 1	Adults	Total	
6.65	33.24	39.89	Males
6.63	32.84	39.48	Females

Across all years, prior to carrying capacity truncation,  
mean growth rate (r) was 0.0236 (0.0006 SE, 0.1388 SD)

Final expected heterozygosity was 0.7874 ( 0.0048 SE, 0.1050 SD)  
Final observed heterozygosity was 0.8055 ( 0.0054 SE, 0.1175 SD)  
Final number of alleles was 8.99 ( 0.12 SE, 2.65 SD)

\*\*\*\*\*

## **Appendix: Simulation Modeling and Population Viability Analysis**

A model is any simplified representation of a real system. We use models in all aspects of our lives, in order to: (1) extract the important trends from complex processes, (2) permit comparison among systems, (3) facilitate analysis of causes of processes acting on the system, and (4) make predictions about the future. A complete description of a natural system, if it were possible, would often decrease our understanding relative to that provided by a good model, because there is "noise" in the system that is extraneous to the processes we wish to understand. For example, the typical representation of the growth of a wildlife population by an annual percent growth rate is a simplified mathematical model of the much more complex changes in population size. Representing population growth as an annual percent change assumes constant exponential growth, ignoring the irregular fluctuations as individuals are born or immigrate, and die or emigrate. For many purposes, such a simplified model of population growth is very useful, because it captures the essential information we might need regarding the average change in population size, and it allows us to make predictions about the future size of the population. A detailed description of the exact changes in numbers of individuals, while a true description of the population, would often be of much less value because the essential pattern would be obscured, and it would be difficult or impossible to make predictions about the future population size.

In considerations of the vulnerability of a population to extinction, as is so often required for conservation planning and management, the simple model of population growth as a constant annual rate of change is inadequate for our needs. The fluctuations in population size that are omitted from the standard ecological models of population change can cause population extinction, and therefore are often the primary focus of concern. In order to understand and predict the vulnerability of a wildlife population to extinction, we need to use a model which incorporates the processes which cause fluctuations in the population, as well as those which control the long-term trends in population size (Shaffer 1981). Many processes can cause fluctuations in population size: variation in the environment (such as weather, food supplies, and predation), genetic changes in the population (such as genetic drift, inbreeding, and response to natural selection), catastrophic effects (such as disease epidemics, floods, and droughts), decimation of the population or its habitats by humans, the chance results of the probabilistic events in the lives of individuals (sex determination, location of mates, breeding success, survival), and interactions among these factors (Gilpin and Soulé 1986).

Models of population dynamics which incorporate causes of fluctuations in population size in order to predict probabilities of extinction, and to help identify the processes which contribute to a population's vulnerability, are used in "Population Viability Analysis" (PVA) (Lacy 1993/4). For the purpose of predicting vulnerability to extinction, any and all population processes that impact population dynamics can be important. Much analysis of conservation issues is conducted by largely intuitive assessments by biologists with experience with the system. Assessments by experts can be quite valuable, and are often contrasted with "models" used to evaluate population vulnerability to extinction. Such a contrast is not valid, however, as *any* synthesis of facts and understanding of processes constitutes a model, even if it is a mental model within the mind of the expert and perhaps only vaguely specified to others (or even to the expert himself or herself).

A number of properties of the problem of assessing vulnerability of a population to extinction make it difficult to rely on mental or intuitive models. Numerous processes impact population dynamics, and many of the factors interact in complex ways. For example, increased fragmentation of habitat can make it more difficult to locate mates, can lead to greater mortality as individuals disperse greater distances across unsuitable habitat, and can lead to increased inbreeding which in turn can further reduce ability to attract mates and to survive. In addition, many of the processes impacting population dynamics are intrinsically probabilistic, with a random component. Sex determination, disease, predation, mate acquisition -- indeed,

almost all events in the life of an individual -- are stochastic events, occurring with certain probabilities rather than with absolute certainty at any given time. The consequences of factors influencing population dynamics are often delayed for years or even generations. With a long-lived species, a population might persist for 20 to 40 years beyond the emergence of factors that ultimately cause extinction. Humans can synthesize mentally only a few factors at a time, most people have difficulty assessing probabilities intuitively, and it is difficult to consider delayed effects. Moreover, the data needed for models of population dynamics are often very uncertain. Optimal decision-making when data are uncertain is difficult, as it involves correct assessment of probabilities that the true values fall within certain ranges, adding yet another probabilistic or chance component to the evaluation of the situation.

The difficulty of incorporating multiple, interacting, probabilistic processes into a model that can utilize uncertain data has prevented (to date) development of analytical models (mathematical equations developed from theory) which encompass more than a small subset of the processes known to affect wildlife population dynamics. It is possible that the mental models of some biologists are sufficiently complex to predict accurately population vulnerabilities to extinction under a range of conditions, but it is not possible to assess objectively the precision of such intuitive assessments, and it is difficult to transfer that knowledge to others who need also to evaluate the situation. Computer simulation models have increasingly been used to assist in PVA. Although rarely as elegant as models framed in analytical equations, computer simulation models can be well suited for the complex task of evaluating risks of extinction. Simulation models can include as many factors that influence population dynamics as the modeler and the user of the model want to assess. Interactions between processes can be modeled, if the nature of those interactions can be specified. Probabilistic events can be easily simulated by computer programs, providing output that gives both the mean expected result and the range or distribution of possible outcomes. In theory, simulation programs can be used to build models of population dynamics that include all the knowledge of the system which is available to experts. In practice, the models will be simpler, because some factors are judged unlikely to be important, and because the persons who developed the model did not have access to the full array of expert knowledge.

Although computer simulation models can be complex and confusing, they are precisely defined and all the assumptions and algorithms can be examined. Therefore, the models are objective, testable, and open to challenge and improvement. PVA models allow use of all available data on the biology of the taxon, facilitate testing of the effects of unknown or uncertain data, and expedite the comparison of the likely results of various possible management options.

PVA models also have weaknesses and limitations. A model of the population dynamics does not define the goals for conservation planning. Goals, in terms of population growth, probability of persistence, number of extant populations, genetic diversity, or other measures of population performance must be defined by the management authorities before the results of population modeling can be used. Because the models incorporate many factors, the number of possibilities to test can seem endless, and it can be difficult to determine which of the factors that were analyzed are most important to the population dynamics. PVA models are necessarily incomplete. We can model only those factors which we understand and for which we can specify the parameters. Therefore, it is important to realize that the models probably underestimate the threats facing the population. Finally, the models are used to predict the long-term effects of the processes presently acting on the population. Many aspects of the situation could change radically within the time span that is modeled. Therefore, it is important to reassess the data and model results periodically, with changes made to the conservation programs as needed.

### **The VORTEX Population Viability Analysis Model**

For the analyses presented here, the VORTEX computer software (Lacy 1993a) for population viability

analysis was used. VORTEX models demographic stochasticity (the randomness of reproduction and deaths among individuals in a population), environmental variation in the annual birth and death rates, the impacts of sporadic catastrophes, and the effects of inbreeding in small populations. VORTEX also allows analysis of the effects of losses or gains in habitat, harvest or supplementation of populations, and movement of individuals among local populations.

Density dependence in mortality is modeled by specifying a carrying capacity of the habitat. When the population size exceeds the carrying capacity, additional mortality is imposed across all age classes to bring the population back down to the carrying capacity. The carrying capacity can be specified to change linearly over time, to model losses or gains in the amount or quality of habitat. Density dependence in reproduction is modeled by specifying the proportion of adult females breeding each year as a function of the population size.

VORTEX models loss of genetic variation in populations, by simulating the transmission of alleles from parents to offspring at a hypothetical genetic locus. Each animal at the start of the simulation is assigned two unique alleles at the locus. During the simulation, VORTEX monitors how many of the original alleles remain within the population, and the average heterozygosity and gene diversity (or “expected heterozygosity”) relative to the starting levels. VORTEX also monitors the inbreeding coefficients of each animal, and can reduce the juvenile survival of inbred animals to model the effects of inbreeding depression.

VORTEX is an individual-based model. That is, VORTEX creates a representation of each animal in its memory and follows the fate of the animal through each year of its lifetime. VORTEX keeps track of the sex, age, and parentage of each animal. Demographic events (birth, sex determination, mating, dispersal, and death) are modeled by determining for each animal in each year of the simulation whether any of the events occur. Events occur according to the specified age and sex-specific probabilities. Demographic stochasticity is therefore a consequence of the uncertainty regarding whether each demographic event occurs for any given animal.

VORTEX requires a lot of population-specific data. For example, the user must specify the amount of annual variation in each demographic rate caused by fluctuations in the environment. In addition, the frequency of each type of catastrophe (drought, flood, epidemic disease) and the effects of the catastrophes on survival and reproduction must be specified. Rates of migration (dispersal) between each pair of local populations must be specified. Because VORTEX requires specification of many biological parameters, it is not necessarily a good model for the examination of population dynamics that would result from some generalized life history. It is most usefully applied to the analysis of a specific population in a specific environment.

Further information on VORTEX is available in Lacy (1993a) and Lacy et al. (1995).

### **Dealing with Uncertainty**

It is important to recognize that uncertainty regarding the biological parameters of a population and its consequent fate occurs at several levels and for independent reasons. Uncertainty can occur because the parameters have never been measured on the population. Uncertainty can occur because limited field data have yielded estimates with potentially large sampling error. Uncertainty can occur because independent studies have generated discordant estimates. Uncertainty can occur because environmental conditions or population status have been changing over time, and field surveys were conducted during periods which may not be representative of long-term averages. Uncertainty can occur because the environment will change in the future, so that measurements made in the past may not accurately predict future conditions.

Sensitivity testing is necessary to determine the extent to which uncertainty in input parameters results in uncertainty regarding the future fate of the modeled population. If alternative plausible parameter values result in divergent predictions for the population, then it is important to try to resolve the uncertainty with better data. Sensitivity of population dynamics to certain parameters also indicates that those parameters describe factors which could be critical determinants of population viability. Such factors are therefore good candidates for efficient management actions designed to ensure the persistence of the population.

The above kinds of uncertainty should be distinguished from several more sources of uncertainty about the future of the population. Even if long-term average demographic rates are known with precision, variation over time caused by fluctuating environmental conditions will cause uncertainty in the fate of the population at any given time in the future. Such environmental variation should be incorporated into the model used to assess population dynamics, and will generate a range of possible outcomes (perhaps represented as a mean and standard deviation) from the model. In addition, most biological processes are inherently stochastic, having a random component. The stochastic or probabilistic nature of survival, sex determination, transmission of genes, acquisition of mates, reproduction, and other processes preclude exact determination of the future state of a population. Such demographic stochasticity should also be incorporated into a population model, because such variability both increases our uncertainty about the future and can also change the expected or mean outcome relative to that which would result if there were no such variation. Finally, there is “uncertainty” which represents the alternative actions or interventions which might be pursued as a management strategy. The likely effectiveness of such management options can be explored by testing alternative scenarios in the model of population dynamics, in much the same way that sensitivity testing is used to explore the effects of uncertain biological parameters.

## Results

Results reported for each scenario include:

Deterministic r -- The deterministic population growth rate, a projection of the mean rate of growth of the population expected from the average birth and death rates. Impacts of harvest, inbreeding, and density dependence are not considered in the calculation. When  $r = 0$ , a population with no growth is expected;  $r < 0$  indicates population decline;  $r > 0$  indicates long-term population growth. The value of  $r$  is approximately the rate of growth or decline per year.

The deterministic growth rate is the average population growth expected if the population is so large as to be unaffected by stochastic, random processes. The deterministic growth rate will correctly predict future population growth if: the population is presently at a stable age distribution; birth and death rates remain constant over time and space (i.e., not only do the probabilities remain constant, but the actual number of births and deaths each year match the expected values); there is no inbreeding depression; there is never a limitation of mates preventing some females from breeding; and there is no density dependence in birth or death rates, such as a Allee effects or a habitat “carrying capacity” limiting population growth. Because some or all of these assumptions are usually violated, the average population growth of real populations (and stochastically simulated ones) will usually be less than the deterministic growth rate.

Stochastic r -- The mean rate of stochastic population growth or decline demonstrated by the simulated populations, averaged across years and iterations, for all those simulated populations that are not extinct. This population growth rate is calculated each year of the simulation, prior to any truncation of the population size due to the population exceeding the carrying capacity. Usually, this stochastic  $r$  will be less than the deterministic  $r$  predicted from birth and death rates. The stochastic  $r$  from the simulations will be close to the deterministic  $r$  if the population growth is steady and robust. The stochastic  $r$  will be notably less than the deterministic  $r$  if the population is subjected to large fluctuations due to environmental variation, catastrophes, or the genetic and demographic instabilities inherent in small populations.

P(E) -- the probability of population extinction, determined by the proportion of, for example, 500 iterations within that given scenario that have gone extinct in the simulations. "Extinction" is defined in the VORTEX model as the lack of either sex.

N -- mean population size, averaged across those simulated populations which are not extinct.

SD(N) -- variation across simulated populations (expressed as the standard deviation) in the size of the population at each time interval. SDs greater than about half the size of mean N often indicate highly unstable population sizes, with some simulated populations very near extinction. When SD(N) is large relative to N, and especially when SD(N) increases over the years of the simulation, then the population is vulnerable to large random fluctuations and may go extinct even if the mean population growth rate is positive. SD(N) will be small and often declining relative to N when the population is either growing steadily toward the carrying capacity or declining rapidly (and deterministically) toward extinction. SD(N) will also decline considerably when the population size approaches and is limited by the carrying capacity.

H -- the gene diversity or expected heterozygosity of the extant populations, expressed as a percent of the initial gene diversity of the population. Fitness of individuals usually declines proportionately with gene diversity (Lacy 1993b), with a 10% decline in gene diversity typically causing about 15% decline in survival of captive mammals (Ralls et al. 1988). Impacts of inbreeding on wild populations are less well known, but may be more severe than those observed in captive populations (Jiménez et al. 1994). Adaptive response to natural selection is also expected to be proportional to gene diversity. Long-term conservation programs often set a goal of retaining 90% of initial gene diversity (Soulé et al. 1986). Reduction to 75% of gene diversity would be equivalent to one generation of full-sibling or parent-offspring inbreeding.

### **Literature Cited**

- Gilpin, M.E., and M.E. Soulé. 1986. Minimum viable populations: processes of extinction. Pp. 19-34, in *Conservation Biology: The Science of Scarcity and Diversity* (M.E. Soulé, ed.). Sinauer, Sunderland, Massachusetts, 584 pp.
- Jiménez, J.A., K.A. Hughes, G. Alaks, L. Graham, and R.C. Lacy. 1994. An experimental study of inbreeding depression in a natural habitat. *Science* 266:271-273.
- Lacy, R.C. 1993a. VORTEX: A computer simulation model for population viability analysis. *Wildlife Research* 20:45-65.
- Lacy, R.C. 1993b. Impacts of inbreeding in natural and captive populations of vertebrates: implications for conservation. *Perspectives in Biology and Medicine* 36:480-496.
- Lacy, R.C. 1993/1994. What is Population (and Habitat) Viability Analysis? *Primate Conservation* 14/15:27-33.
- Lacy, R.C., P. Miller, K. Hughes, and T. Kreeger. 1995. VORTEX Users Manual, Version 7. A Stochastic Simulation of the Extinction Process. IUCN SSC Conservation Breeding Specialist Group, Apple Valley, Minnesota.
- Ralls, K., J.D. Ballou, and A. Templeton. 1988. Estimates of lethal equivalents and the cost of inbreeding in mammals. *Conservation Biology*, 2:185-193.
- Shaffer, M.L. 1981. Minimum population sizes for species conservation. *BioScience* 1:131-134.
- Soulé, M., M. Gilpin, W. Conway, and T. Foose. 1986. The millennium ark: How long a voyage, how many staterooms, how many passengers? *Zoo Biology* 5:101-113.





**CONSERVATION ASSESSMENT AND MANAGEMENT PLAN  
FOR THE TREE KANGAROOS OF PAPUA NEW GUINEA**  
*and*  
**POPULATION AND HABITAT VIABILITY ASSESSMENT FOR  
MATSCHIE'S TREE KANGAROO**

**Lae, Papua New Guinea  
31 August – 4 September 1998**

**Final Report**

**Section 4  
Distribution and Status Working Group Report**





# Distribution and Status of Tree Kangaroos in Papua New Guinea

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Currently there are 10 taxa (species and subspecies) of tree kangaroos recognized in Papua New Guinea (Flannery, 1996). The taxonomy is not based on molecular biology (DNA), and a complete revision based on biochemical techniques urgently is needed to evaluate conservation/management practices and priorities. Distribution and population data is fragmentary for most of these taxa as well, and conclusions listed below should be open to re-examination when new data become available.

The CAMP process places 2 taxa (*D. scottae* and *D. goodfellowi pulcherrimus\**) as Critically Endangered, 6 taxa as Vulnerable (*D. matschie*, *D. inustus finschi\**, *D. goodfellowi buergersi*, *D. dorianus notatus*, *D. dorianus stellarum\** and *D. goodfellowi goodfellowi*), 1 taxon as Lower Risk: Near Threatened (*D. spadix*), and 1 taxa as Lower Risk (*D. dorianus dorianus*). (\* denotes PNG populations only considered for this classification from taxa extending significantly into Irian Jaya).

Principal causes of population decline for tree kangaroos include the following human induced factors: overexploitation by hunting meat for personal consumption, logging operations, human population growth leading to clearing forest for garden areas, and expansion of plantation agriculture (oil palm and rubber). Natural disasters independent of humans include drought, fire, landslide, volcano, and hurricanes and all the above are potentially more problematic as geographic ranges decline to very small or fragmented areas.

## Recommendations for Research and Conservation Management

1. A PNG national survey for presence/absence distribution for all taxa.
  - a. Comprehensive compilation of historical records from literature, museums, zoos, private collections transferred to GIS computer databases for mapping of distributions. DEC and National Museum and Art Gallery have a biodiversity mapping exercise already underway and tree kangaroos will be given high priority for earliest possible databasing/mapping. Contacts are Ilaiah Bigilale, Frank Bonaccorso, Mick Raga
  - b. Questionnaires/Interviews -- survey local knowledge through schools, churches, village hunters, and people bringing tree kangaroos for sale to zoos. Programs underway or planned include Will Betz and Lisa Dabek (AZA TK-SSP) and Peter Clark.
2. Species listed in IUCN threatened categories should have intensive field research directed to learn about population trends, use of habitat and space, food requirements and other natural history factors.
3. Tissue collection for molecular systematics should receive immediate attention from many geographic points within the ranges of all taxa in PNG.
4. Evaluation of the impact on populations and habitat from hunting and cultural practices and to be correlated with population trends.
5. Further research on captive populations in order to understand basic biology and to include reproductive physiology, social structures, and activity patterns.

6. Recovery Program for Critically Endangered species initiated as soon as possible.
7. To insure that all stakeholders interested in tree kangaroos received continuous information input on social issues, management practices, and basic research, a bilingual (Tok Pisin and English) newsletter should be initiated. The newsletter should be both in paper and electronic forms. Mr. Sabati Eva of the National Museum and Art Gallery will coordinate this effort, but everyone is required to submit information as it becomes available.

**Conservation Assessment Management Plan**  
**Taxon Data Sheet for *Dendrolagus goodfellowi buergeri***  
**Date: September 2, 1998**

**PART ONE**

**1. Scientific Name** (With authority and date) *Dendrolagus goodfellowi buergeri* (Matschie, 1912)

1A. Synonyms: *D. g. shawmayeri* (Rothschild & Dollman, 1936)

1B. Family: **Macropodidae**

1C. Common name(s) with language: **Goodfellows, Ornate Tree Kangaroo (English), Yavah (Tekedu), Kile (Mamafu), Timboyok (Mianmin)**

1D. Taxonomic level of assessment: **Subspecies**

**2. Distribution of the taxon**

2A. Habit or life form (only plants): **N/A**

2B. Habitat of the taxon (use national or regional classifications): **Hill Forest to Upper Montane Forest**

2C. Habitat specificity (niche, elevation, etc.): **900 - 3,100 meters**

2D. Historical distribution (Global -- in past 100 years described by country): **Papua New Guinea only**

2E. Current distribution (listed by country): **Papua New Guinea - Endemic**

2F. Current regional distribution (country/ biogeographic region of assessment): **Central Highlands of New Guinea Island**

2G. Concentrated migration regions: **N/A**

**3. Approximate EXTENT OF OCCURENCE** of the taxon in and around the area of study/ sighting/ collection (Extent of occurrence is defined as the area contained within the shortest continuous imaginary boundary encompassing all known, inferred or projected sites of present occurrence of the taxon): (tick appropriate box)

< 100 km<sup>2</sup>       101 - 5,000 km<sup>2</sup>       5,001 - 20,000 km<sup>2</sup>       > 20,001 km<sup>2</sup>

**T. Flannery, 1996 - 40,000**

**4. Approximate AREA OF OCCUPANCY** of the taxon in and around the area of study/ sighting/ collection (Area of occupancy is defined as the area occupied by the taxon within the 'extent of occurrence'): (tick appropriate box)

< 10 km<sup>2</sup>       11 - 500 km<sup>2</sup>       501 - 2,000 km<sup>2</sup>       > 2,001 km<sup>2</sup> (Flannery, 1996)

**5. Number of Locations or Subpopulations** in which the taxon is distributed:

**1/4 of the population is in this range; likely to be some fragmentation due to human population but large, undisturbed habitat remains.**

5A. Are the locations or populations:  Contiguous       Fragmented       **Not known**

**6. Habitat status:**

6A. Is there any change in the habitat where the taxon occurs:  **Yes**       No  
If yes, Is it a:  **Decrease in area**       Increase in area       Stable in area       Unknown

6B. If Decreasing, what has been the decrease in habitat (approximately, in percent) over years?:  
 < 20%       > 20%       > 50%       > 80%      in the last **50** years

**Note: This is true overall, but some areas are relatively stable.**

6C. If Stable or Unknown, do you predict a decline in habitat (approximately, in percent) over years?:  
 < 20%       > 20%       > 50%       > 80%      in the next \_\_\_\_\_ years

6D. State primary cause of change: **Habitat loss due to expanding human population, cities, agriculture.**

6E. Is there any change in the quality of habitat where the taxon occurs:  Yes     No    **X Unknown**  
If yes,     Decrease in quality     Increase in quality     Stable in quality     Unknown

6F. State primary cause of change:

**7. Threats:**

7A. What are the threats to the taxon? (**present [P]** or **future (predicted) [F]**):

Harvest/ Hunting **[P]** **[F]**

Harvest for food **[P]** **[F]**

Harvest for timber **[F]**

Loss of habitat **[P]** **[F]**

Habitat fragmentation **[F]**

El Nino **[P]** **[F]**

Drought **[P]** **[F]**

Fire **[F]**

**Others (please specify):**

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7B. Are these threats resulting in (perceived or inferred) or may result in (predicted) population decline?:  
**X Yes**     No

**8. Trade:**

8A. Is the taxon in trade?: **X Yes**     No  
If yes, is it:    **X Local**            **X Domestic**             Commercial             International

8B. Parts in trade:     Skin     Bones     Fur     Hair     Horn     Organs  
 Glands    **X Meat**     Taxidermy models    **X Live animal**     Products  
**X Others, please specify: Clothing ornament for traditional dress and artifacts sold at markets**

8C. Which form of trade (specified form) is resulting in a perceived or inferred population decline?:  
**Meat**

**9. Population numbers:**

9A. Global population: **unknown**

9B. Regional population (No. of subpopulations): **unknown**

9C. Number of **Mature Individuals** (in all populations):  < 50     < 250     < 2,500    **X > 2,500**  
based on estimated size of home ranges and available habitat.

9D. Generation time (Defined here as the average age of parents in population): **6.1 years (based on captive data)**

**10. Population trends:**

10A. Is the population size/ numbers of the taxon:

**X Declining in majority of habitat, except in areas of very low human population density or areas with social or religious (i.e. Seventh Day Adventist Church) taboos on hunting tree kangaroos/ mammals."**

Increasing

**X Stable in Crater Mountain area where Adventist is predominant religion; believe tree roo is an unclean animal and do not use for food or ornamentation**

Unknown

**NOTE: Populations in Crater Mt. are Stable (due to religious "no hunting" beliefs). Populations declining Takedu due to hunting.**

10B. If Declining, what has been the rate of population decline perceived or inferred:

< 20%   **X > 20%**    > 50%    > 80%   in the last 25 years

10C. If Stable or Unknown, do you predict a future decline in the population.    Yes    No

If yes, please specify rate and factors e.g. habitat loss, threats, trade, etc. \_\_\_\_\_

< 20%    > 20%    > 50%    > 80%   in the next \_\_\_\_\_ years/ generations

**11. Data Quality:**

11A. Are the above estimates based on:

- Census or monitoring    General field study   **X Informal field sighting**   **X Literature**
- Indirect information such as from trade, etc.   **X Museum/ records**   **X Hearsay/ popular belief**
- X Formal interviews with landowners**   **X Information from Landowner participants**

**12. Recent field studies** (in the last 10 years). Indicate year of study not year of publication.

Researcher names	Location	Dates	Topics
Lisa Dabek/Will Betz	Crater Mt. - WMA	1997-98	General survey

**PART TWO**

**13. Status:**

13A. IUCN: **Vulnerable**   IUCN Criteria based on: **A1, C1**

13B. CITES: **Not listed**

13C. National Wildlife Legislation: **PNG Fauna Protection Act**

13D. National Red Data Book:

13E. International Red Data Book:

13F. Other legislation (please specify): **None**

13G. Known presence in protected areas (please list): **Crater Mt. - WMA**

13H. National or regionally endorsed protection plan: **None**

**PART THREE**

**14. Supporting Research** recommended for the taxon:   **X Yes**    No   If yes, is it

**X Survey**   **X Genetic research**   **X Taxonomic research**   **X Life history studies**

Limiting factor research   **X Epidemiology (Avian TB)**   **X Trade**

**X Others** (taxon specific): **Feeding/Nutritional studies** (e.g. David Christophel, University of Adelaide, Lisa Dabek, Will Betz); **DNA studies** with Dr. Tom Husband, (Molecular Mammalogy Laboratory, University of Rhode Island); **Female Reproductive Physiology and Behavior** studies by Maria Franke.

14A. Is **Population and Habitat Viability Assessment** recommended:    Yes   **X No**    Pending



15. Management recommendations for the taxon:

Habitat management     Wild population management     Monitoring     Translocation  
 Sustainable utilization     Public awareness     Genome Resource Banking  
 Limiting factor management     Ex situ breeding     Work in local communities  
 Address policy makers; refer to needs of local people and landowner associations (i.e. RCF, Crater Mt. WMA)

16. If Ex situ management is recommended, is it for:

Species recovery     Education     Reintroduction     Benign introduction  
 Research     Husbandry     Preservation of live genome

Note: This taxon is the best analog species for research regarding *Dendrologus scottae*.

17. Do Ex situ stocks already exist:     Yes     No    If yes,

17A. Names of facilities: **Rainforest Habitat, Zenag (Phillip Leahy's), National Capital Botanical Gardens, Wau Ecology, Currumbin Sanctuary, Taronga Zoo and Melbourne Zoo.**

17B. Number in captivity: **5 Males; 11 Females; 1 Unsexed; Total 27**

17C. Does a coordinated **Species Management Program** exist for this species:  Yes     No    If yes, which countries/regions (if country, which institutions): **AZA, ARAZPA, EEP**

17D. Is a coordinated **Species Management Program** recommended for the range country(ies) ?  
 Yes     No (please specify countries): **PNG programs**

18. Level of ex situ management recommended:

A. Ongoing ex situ program intensified or increased     B. Ongoing ex situ program decreased  
 C. Initiate ex situ program within 3 years     D. Initiate ex situ program in 3 years

19. Are techniques established to propagate the taxon:

Techniques known for this taxon or similar taxon     Some techniques known for taxon or similar taxa     Techniques not known at all     Information not available with this group of compilers

20. Other

comments: \_\_\_\_\_  
\_\_\_\_\_

**PART FOUR**

21. Sources: **T. Flannery 1996, W. Betz, Local Landowners - Miffa Mionzing and Mambawe**

22. Compilers: **Will Betz, Frank Bonaccorso, Maria Franke, Alex Moses, Peter Uyepango, Kanlovo Ulaeahava**

**Conservation Assessment Management Plan**  
**Taxon Data Sheet for *Dendrolagus dorianus dorianus***  
**Date: September 3, 1998**

**PART ONE**

**1. Scientific Name** (With authority and date): *Dendrolagus dorianus dorianus* (Ramsay, 1883)

1A. Synonyms: *D.d. aureus* (Rothschild & Dollman, 1936), *D.d. palliceps* (Troughton & Le Souef, 1936), *D.d. profugus* (Troughton & Le Souet, 1936)

1B. Family: **Macropodidae**

1C. Common name(s) with language: **Doria's Tree Kangaroo; Dipolo (Tavade, Central Province)**

1D. Taxonomic level of assessment: **Subspecies**

**2. Distribution of the taxon**

2A. Habit or life form (only plants): **N/A**

2B. Habitat of the taxon (use national or regional classifications): **Hill Forest?? - Subalpine forest**

2C. Habitat specificity (niche, elevation, etc.): **600(?) - 3,600 meters**

2D. Historical distribution (Global -- in past 100 years described by country): **Papua New Guinea**

2E. Current distribution (listed by country): **Papua New Guinea**

2F. Current regional distribution (country/ biogeographic region of assessment): **Southeastern peninsula of New Guinea Island**

2G. Concentrated migration regions: **N/A**

**3. Approximate EXTENT OF OCCURENCE** of the taxon in and around the area of study/ sighting/ collection (Extent of occurrence is defined as the area contained within the shortest continuous imaginary boundary encompassing all known, inferred or projected sites of present occurrence of the taxon): (tick appropriate box)

< 100 km<sup>2</sup>       101 - 5,000 km<sup>2</sup>       **5,001 - 20,000 km<sup>2</sup>**       > 20,001 km<sup>2</sup>  
**15,000 km<sup>2</sup> (Flannery 1996)**

**4. Approximate AREA OF OCCUPANCY** of the taxon in and around the area of study/ sighting/ collection (Area of occupancy is defined as the area occupied by the taxon within the 'extent of occurrence'): (tick appropriate box)

< 10 km<sup>2</sup>       11 - 500 km<sup>2</sup>       501 - 2,000 km<sup>2</sup>       **> 2,001 km<sup>2</sup>**

**5. Number of Locations or Subpopulations** in which the taxon is distributed: One

5A. Are the locations or populations:  **Contiguous**       Fragmented       Not known

**6. Habitat status:**

6A. Is there any change in the habitat where the taxon occurs:  **Yes**       No  
If yes, Is it a:  **Decrease in area**       Increase in area       Stable in area       Unknown

6B. If Decreasing, what has been the decrease in habitat (approximately, in percent) over years?:  
 **< 20%**       > 20%       > 50%       > 80%      in the last **20** years

6C. If Stable or Unknown, do you predict a decline in habitat (approximately, in percent) over years?:  
 < 20%       > 20%       > 50%       > 80%      in the next \_\_\_ years

6D. State primary cause of change: **Increased human population and increase in garden areas.**

6E. Is there any change in the quality of habitat where the taxon occurs:  Yes  No If yes,  
 Decrease in quality  Increase in quality  Stable in quality  Unknown

6F. State primary cause of change:

**7. Threats:**

7A. What are the threats to the taxon? (Circle **present [P]** or **future (predicted) [F]** threats below):

Harvest/ Hunting **[P] [F]**

Harvest for food **[P] [F]**

Drought **[P] [F]**

**Others (please specify):** \_\_\_\_\_

7B. Are these threats resulting in (perceived or inferred) or may result in (predicted) population decline?:

**X Yes**  No

**8. Trade:**

8A. Is the taxon in trade?: **X Yes**  No If yes, is it:  
**X Local** **X Domestic**  Commercial  International

8B. Parts in trade:  Skin  Bones  Fur  
 Hair  Horn  Organs  Glands  
**X Meat**  Taxidermy models  Live animal  Products

**X Others**, please specify: **Meat sold as whole body**

8C. Which form of trade (specified form) is resulting in a perceived or inferred population decline?:

**Trade is probably not contributing to population decline.**

**9. Population numbers:**

9A. Global population: **>10,000**

9B. Regional population (No. of subpopulations): **Unknown**

9C. Number of **Mature Individuals** (in all populations):  < 50  < 250  < 2,500 **X >10,000**

9D. Generation time (Defined here as the average age of parents in population): **6.1 years (based on captive data)**

**10. Population trends:**

10A. Is the population size/ numbers of the taxon:

**X Declining**  Increasing  Stable  Unknown

**Assuming that human populations increase and hunting rates remain the same.**

10B. If Declining, what has been the rate of population decline perceived or inferred:

**X < 20%** > 20%  > 50%  > 80% in the last **25** years

10C. If Stable or Unknown, do you predict a future decline in the population.  Yes  No

If yes, please specify rate and factors e.g. habitat loss, threats, trade, etc. \_\_\_\_\_

< 20%  > 20%  > 50%  > 80% in the next \_\_\_\_ years/ generations

**11. Data Quality:**

11A. Are the above estimates based on:

**X Guess and extrapolation from known increase in population**

- Census or monitoring     General field study     Informal field sighting     Literature  
 Indirect information such as from trade, etc.     Museum/ records     Hearsay/ popular belief  
 Formal interviews with landowners     Based on resource use trends

12. **Recent field studies** (in the last 10 years). Indicate year of study not year of publication.  
**None**

## PART TWO

13. **Status:**

- 13A. IUCN: **Lower risk**    IUCN Criteria based on:  
 13B. CITES: **Not listed**  
 13C. National Wildlife Legislation: **PNG Fauna Protection Act**  
 13D. National Red Data Book:  
 13E. International Red Data Book:  
 13F. Other legislation (please specify): **None**  
 13G. Known presence in protected areas (please list): **None**  
 13H. National or regionally endorsed protection plan: **None**

## PART THREE

14. **Supporting Research** recommended for the taxon:     **Yes**     No    If yes, is it  
 **Survey**     **Genetic research**     **Taxonomic research**     **Life history studies**  
 Limiting factor research     Epidemiology     Trade  
 **Others** (taxon specific): Include large scale landowner surveys.

14A. Is **Population and Habitat Viability Assessment** recommended:     Yes     No     **Pending**

15. **Management recommendations** for the taxon:

- Habitat management (set up WPA)**     Wild population management     **Monitoring**  
 Translocation     **Sustainable utilization**     **Public awareness**     Genome Resource Banking  
 Limiting factor management     Ex situ breeding     **Work in local communities**  
 **Address policy makers; refer to needs of local people and landowners associations**

16. If **Ex situ management** is recommended, is it for:

- Species recovery     Education     Reintroduction     Benign introduction  
 Research     Husbandry     Preservation of live genome

17. Do **Ex situ stocks** already exist:     **Yes**     No    If yes,

17A. Names of facilities: PNG National Museum holds 1.1.0 animals and National Capital Botanical Gardens holds 1.0.2 animals.

17B. Number in captivity: **1 Males, 1 Females, 0 Unsexed; Total: 2**

17C. Does a coordinated **Species Management Program** exist for this species:     Yes     **No**  
 If yes, which countries (if country, which institutions):

17D. Is a coordinated **Species Management Program** recommended for the range country(ies) ?  
 **Yes**     No (please specify countries): **In PNG and if found in Irian Jaya, also by Indonesia.**

18. **Level of ex situ management recommended:**

- A. Ongoing ex situ program intensified or increased     B. Ongoing ex situ program decreased  
 C. Initiate ex situ program within 3 year     D. Initiate ex situ program in 3 years

**19. Are techniques established to propagate the taxon:**

- Techniques known for this taxon or similar taxon
- Some techniques known for similar taxa (D. goodfellowi and D. matschei)**
- Techniques not known at all
- Information not available with this group of compilers

**20. Other comments:** There is virtually no information, even anecdotal, about the presence/absence of the animal throughout its range. We believe that habitat loss might not be a major problem but, apart from Flannery's comment "hunting is probably slight", we have little information about hunting pressure.

**PART FOUR**

**21. Sources:** *Mammals of New Guinea*, 2nd ed. T. Flannery 1995; *Tree Kangaroos - A Curious Natural History*, Flannery, Martin and Szalay; *Tree Kangaroos in Captivity, Studbook and Population Analysis*

**22. Compilers:** Frank Bonaccorso, Will Betz

**Conservation Assessment Management Plan**  
**Taxon Data Sheet for *Dendrolagus inustus finschi* (PNG population only)**  
**Date: September 3, 1998**

**PART ONE**

**1. Scientific Name** (With authority and date): *Dendrolagus inustus finschi* (Matschie, 1916a)

1A. Synonyms: *Dendrolagus schoedei* (Matschie, 1916b)

1B. Family: **Macropodidae**

1C. Common name(s) with language: **Finsch's tree kangaroo, Grizzled tree kangaroo (English); Yonqui (Olo, Sandaun Province)**

1D. Taxonomic level of assessment: **Subspecies**

**2. Distribution of the taxon**

2A. Habit or life form (only plants): **N/A**

2B. Habitat of the taxon (use national or regional classifications): **Lowland rainforest - lower montane**

2C. Habitat specificity (niche, elevation, etc.): **Forest, not swamp; 100m to 1400m**

2D. Historical distribution (Global -- in past 100 years described by country): **Papua New Guinea and Irian Jaya**

2E. Current distribution (listed by country): **North coast of Papua New Guinea and north coast of Irian Jaya**

2F. Current regional distribution (country/ biogeographic region of assessment): **Northern coastal plain and north slope of north coastal ranges from the border to Wewak area.**

2G. Concentrated migration regions: **N/A**

**3. Approximate EXTENT OF OCCURENCE** of the taxon in and around the area of study/ sighting/ collection (Extent of occurrence is defined as the area contained within the shortest continuous imaginary boundary encompassing all known, inferred or projected sites of present occurrence of the taxon): (tick appropriate box) **IN PNG:**

< 100 km<sup>2</sup>      **X 101 - 5,000 km<sup>2</sup>**       5,001 - 20,000 km<sup>2</sup>       > 20,001 km<sup>2</sup>

**4. Approximate AREA OF OCCUPANCY** of the taxon in and around the area of study/ sighting/ collection (Area of occupancy is defined as the area occupied by the taxon within the 'extent of occurrence'): (tick appropriate box)

< 10 km<sup>2</sup>       11 - 500 km<sup>2</sup>      **X 501 - 2,000 km<sup>2</sup>**       > 2,001 km<sup>2</sup>

**5. Number of Locations or Subpopulations** in which the taxon is distributed:

5A. Are the locations or populations:     Contiguous    **X Fragmented (initial stages, due to logging, resettlement schemes)**     Not known

**6. Habitat status:**

6A. Is there any change in the habitat where the taxon occurs:    **X Yes**     No    If yes, Is it a  
**X Decrease in area**     Increase in area     Stable in area     Unknown

6B. If Decreasing, what has been the decrease in habitat (approximately, in percent) over years?:  
 < 20%    **X > 20%**     > 50%     > 80%    in the last **20** years

6C. If Stable or Unknown, do you predict a decline in habitat (approximately, in percent) over years?:  
 < 20%     > 20%     > 50%     > 80%    in the next \_\_\_ years

6D. State primary cause of change: **Logging, resettlement and increased gardening.**

6E. Is there any change in the quality of habitat where the taxon occurs: **X Yes**    No    If yes,  
**X Decrease in quality**     Increase in quality     Stable in quality     Unknown

6F. State primary cause of change: **Logging, resettlement**

**7. Threats:**

7A. What are the threats to the taxon? (Circle **present [P]** or **future (predicted) [F]** threats below):

Harvest/ Hunting **[P]** **[F]**

El Nino **[P]** **[F]**

Harvest for food **[P]** **[F]**

Loss of habitat **[P]** **[F]**

Habitat fragmentation **[P]** **[F]**

**Others (please specify):**

---

7B. Are these threats resulting in (perceived or inferred) or may result in (predicted) population decline?:

**X Yes**     No

**The most serious threats are land clearing for timber and rubber plantation. Could result in an additional >20% loss of habitat in the next 25 years.**

**8. Trade:**

8A. Is the taxon in trade?: **X Yes (in the past bartered for other items; unknown now)**     No

If yes, is it    **X Local**    **X Domestic**     Commercial     International

8B. Parts in trade:     Skin     Bones     Fur  
 Hair     Horn     Organs     Glands  
**X Meat (dried, smoked)**     Taxidermy models     Live animal     Products  
**X Others, please specify: Clothing ornament for traditional dress and artifacts sold at markets**

8C. Which form of trade (specified form) is resulting in a perceived or inferred population decline?:

**Meat for local consumption**

**9. Population numbers:**

9A. Global population: **Unknown**

9B. Regional population (No. of subpopulations): **Unknown**

9C. Number of **Mature Individuals** (in all populations):     < 50     < 250     < 2,500    **X > 2,500**  
 > 10,000.

9D. Generation time (Defined here as the average age of parents in population): **6.1 years (based on captive data)**

**10. Population trends:**

10A. Is the population size/ numbers of the taxon:

**X Declining**     Increasing     Stable     Unknown

10B. If Declining, what has been the rate of population decline perceived or inferred:

< 20%    **X > 20%**     > 50%     > 80%    in the last **25** years

10C. If Stable or Unknown, do you predict a future decline in the population.  Yes  No  
If yes, please specify rate and factors e.g. habitat loss, threats, trade, etc. \_\_\_\_\_  
 < 20%  > 20%  > 50%  > 80% in the next \_\_\_\_ years/ generations

**11. Data Quality:**

11A. Are the above estimates based on:

- Census or monitoring  General field study  Informal field sighting  **Literature**  
 Indirect information such as from trade, etc.  Museum/ records  **Hearsay/ popular belief**  
 Formal interviews with landowners  **Based on resource use trends**

**12. Recent field studies** (in the last 10 years). Indicate year of study not year of publication.  
**None**

**PART TWO**

**13. Status:**

- 13A. IUCN: **Vulnerable** IUCN Criteria based on: **A; B1, 2ab; C1**  
13B. CITES: **Not listed**  
13C. National Wildlife Legislation: **PNG Fauna Protection Act**  
13D. National Red Data Book:  
13E. International Red Data Book: **Not previously listed as a subspecies, recommended that it is listed by subspecies in future.**  
13F. Other legislation (please specify): **None**  
13G. Known presence in protected areas (please list): **None**  
13H. National or regionally endorsed protection plan: **None**

**PART THREE**

**14. Supporting Research** recommended for the taxon:  **Yes**  No If yes, is it  
 **Survey**  **Genetic research**  **Taxonomic research**  **Life history studies**  
 Limiting factor research  Epidemiology  Trade  Others (taxon specific):

14A. Is **Population and Habitat Viability Assessment** recommended:  **Yes**  No  Pending

**15. Management recommendations** for the taxon:

- Habitat management**  Wild population management  **Monitoring**  Translocation  
 **Sustainable utilization**  **Public awareness**  Genome Resource Banking  
 Limiting factor management  **Ex situ breeding in future if present trend continues**  
 Work in local communities  **Address policy makers ref needs of local people**  
 Others:

**16. If Ex situ management** is recommended, is it for:

- Species recovery  Education  Reintroduction  Benign introduction  
 Research  Husbandry  Preservation of live genome

**17. Do Ex situ stocks** already exist:  **Yes**  No If yes,

17A. Names of facilities: **Phillip Leahy; Jacksonville Zoological Gardens; Gladys Porter Zoo, Brownsville, Texas; San Antonio Zoo and Aquarium, San Antonio, Texas.**



17B. Number in captivity: Male ; Female ; Unsexed ; Total **5**

17C. Does a coordinated Species Management Program exist for this species:  Yes  **No** If yes, which countries (if country, which institutions):

17D. Is a coordinated **Species Management Program** recommended for the range country(ies) ?  
 **Yes**  No (please specify countries):

**18. Level of ex situ management recommended:**

A. Ongoing ex situ program intensified or increased  B. Ongoing ex situ program decreased  
 **C. Initiate ex situ program within 5 years**  D. Initiate ex situ program in 3 years

**19. Are techniques established to propagate the taxon:**

Techniques known for this taxon or similar taxon  **Some techniques known for taxon or similar taxa**  
 Techniques not known at all  Information not available with this group of compilers

**20. Other comments: This subspecies has a large distribution in Irian Jaya, Indonesia. Although probably less threatened than in PNG, Irian populations maybe declining due to logging, transmigration settlements and associated forest clearing due to subsistence and plantation agriculture.**

**PART FOUR**

**21. Sources: T. Flannery 1996; Matschie, 1916a; Rothschild and Rothschild 1898**

**22. Compilers: Frank Bonaccorso, Maria Franke, Chris Talie, Will Betz**

**Conservation Assessment Management Plan**  
**Taxon Data Sheet for *Dendrolagus goodfellowi goodfellowi***  
**Date: September 3, 1998**

**PART ONE**

**1. Scientific Name** (With authority and date): *Dendrolagus goodfellowi goodfellowi* (Thomas, 1908)

1A. Synonyms: **None**

1B. Family: **Macropodidae**

1C. Common name(s) with language: **Gimabulu (Suau-Samarai), Milne Bay Province, Dagon (Mt. Victory Area, Milne Bay Province), Goodfellows tree kangaroo.**

1D. Taxonomic level of assessment: **Subspecies**

**2. Distribution of the taxon**

2A. Habit or life form (only plants): **N/A**

2B. Habitat of the taxon (use national or regional classifications): **Hill forest to Mid-montane forest**

2C. Habitat specificity (niche, elevation, etc.): **Found primarily in oak forest (*Castanopsis* spp.) but ranging in elevation from 600-2400 meters.**

2D. Historical distribution (Global -- in past 100 years described by country): **Papua New Guinea - New Guinea Island endemic**

2E. Current distribution (listed by country): **Papua New Guinea - New Guinea Island endemic**

2F. Current regional distribution (country/ biogeographic region of assessment): **Papua New Guinea – Milne Bay, Central, Oro, Morobe Provinces**

2G. Concentrated migration regions: **N/A**

**3. Approximate EXTENT OF OCCURENCE** of the taxon in and around the area of study/ sighting/ collection (Extent of occurrence is defined as the area contained within the shortest continuous imaginary boundary encompassing all known, inferred or projected sites of present occurrence of the taxon): (tick appropriate box)

< 100 km<sup>2</sup>       101 - 5,000 km<sup>2</sup>       **5,001 - 20,000 km<sup>2</sup> (~10,000)**       > 20,001 km<sup>2</sup>

**4. Approximate AREA OF OCCUPANCY** of the taxon in and around the area of study/ sighting/ collection (Area of occupancy is defined as the area occupied by the taxon within the 'extent of occurrence'): (tick appropriate box)

< 10 km<sup>2</sup>       11 - 500 km<sup>2</sup>       501 - 2,000 km<sup>2</sup>       **> 2,001 km<sup>2</sup>**

**5. Number of Locations or Subpopulations** in which the taxon is distributed:

5A. Are the locations or populations:     Contiguous     Fragmented     **Not known**

**6. Habitat status:**

6A. Is there any change in the habitat where the taxon occurs:     **Yes**       No      If yes, Is it a

**Decrease in area**       Increase in area       Stable in area       Unknown

6B. If Decreasing, what has been the decrease in habitat (approximately, in percent) over years?:  
 < 20%     > 20%     > 50%     > 80%    in the last **20** years

6C. If Stable or Unknown, do you predict a decline in habitat (approximately, in percent) over years?:  
 < 20%     > 20%     > 50%     > 80%    in the next \_\_\_ years

6D. State primary cause of change: **Oil palm plantation, logging, human population increase/  
gardening/hunting.**

**Cape Rodney Center - Oil Palm**

**Oro, Popondetta - Oil Palm**

**Margarida district, Central Province - Logging**

**Sagarai Gala - Modewa - Logging**

6E. Is there any change in the quality of habitat where the taxon occurs:     Yes     No    If yes,  
 Decrease in quality     Increase in quality     Stable in quality     Unknown

6F. State primary cause of change:

## 7. Threats:

7A. What are the threats to the taxon? (Circle **present [P]** or **future (predicted) [F]** threats below):

Harvest/ Hunting [P] [F]

Drought [P] [F]

Harvest for food [P] [F]

Hurricane [F]

Loss of habitat [F]

Volcano [F] (**Mt. Lamington - last eruption in 1950s**)

**Others (please specify):** \_\_\_\_\_

7B. Are these threats resulting in (perceived or inferred) or may result in (predicted) population decline?:  
 Yes     No

## 8. Trade:

8A. Is the taxon in trade?:     Yes (**in the past bartered for other items; unknown now**)     No  
If yes, is it

Local

Domestic

Commercial

International

8B. Parts in trade:

Skin

Bones

Fur

Hair

Horn

Organs

Glands

Meat

Taxidermy models

Live animal

Products

Others, please specify:

8C. Which form of trade (specified form) is resulting in a perceived or inferred population decline?:  
**Hunting for meat of possible importance in population decline.**

## 9. Population numbers:

9A. Global population: **Unknown**

9B. Regional population (No. of subpopulations): **Unknown**

9C. Number of **Mature Individuals** (in all populations):     < 50     < 250     < 2,500     > 2,500  
 > 10,000.

9D. Generation time (Defined here as the average age of parents in population): **6.1 years (based on captive data)**

**10. Population trends:**

10A. Is the population size/ numbers of the taxon:

**Declining**                       Increasing                       Stable                       Unknown

10B. If Declining, what has been the rate of population decline perceived or inferred:

< 20%                       > 20%                       > 50%                       > 80%                      in the last \_\_\_ years/ generations

10C. If Stable or Unknown, do you predict a future decline in the population.  Yes                       No

If yes, please specify rate and factors e.g. habitat loss, threats, trade, etc. \_\_\_\_\_

< 20%                       > 20%                       > 50%                       > 80%                      in the next \_\_\_ years/ generations

**11. Data Quality:**

11A. Are the above estimates based on:

Census or monitoring     General field study     Informal field sighting     **Literature**  
 Indirect information such as from trade, etc.     **Museum/ records**                       Hearsay/ popular belief  
 Formal interviews with landowners                       Based on resource use trends

**12. Recent field studies** (in the last 10 years). Indicate year of study not year of publication.

None

**PART TWO**

**13. Status:**

13A. IUCN: **Vulnerable**                      IUCN Criteria based on: **A1c**

13B. CITES: **Not listed**

13C. National Wildlife Legislation: **PNG Fauna Protection Act**

13D. National Red Data Book:

13E. International Red Data Book:

13F. Other legislation (please specify): **None**

13G. Known presence in protected areas (please list):

13H. National or regionally endorsed protection plan:

**PART THREE**

**14. Supporting Research** recommended for the taxon:     **Yes**                       No                      If yes, is it

**Survey**     **Genetic research**                       **Taxonomic research**                       **Life history studies**

Limiting factor research                       Epidemiology                       Trade

Others (taxon specific): **Impact of hunting**

14A. Is **Population and Habitat Viability Assessment** recommended:  Yes     No

**Pending survey data**

**15. Management recommendations** for the taxon:

**Habitat management (set up WMA)**                       Wild population management                       Monitoring

Translocation     **Sustainable utilization**     **Public awareness**                       Genome Resource Banking

Limiting factor management                       Ex situ breeding                       Work in local communities

**Address policy makers ref needs of local people**

Others:

16. If **Ex situ management** is recommended, is it for:

- Species recovery    Education    Reintroduction    Benign introduction  
 Research    Husbandry    Preservation of live genome

17. Do **Ex situ stocks** already exist:    Yes    **No**   If yes,

17A. Names of facilities:

17B. Number in captivity: **None**

17C. Does a coordinated **Species Management Program** exist for this species:  Yes    **No**   If yes, which countries (if country, which institutions):

17D. Is a coordinated **Species Management Program** recommended for the range country(ies) ?  
 Yes    **No** (please specify countries): **Not in immediate future**

18. **Level of ex situ management recommended:**

- A. Ongoing ex situ program intensified or increased    B. Ongoing ex situ program decreased  
 C. Initiate ex situ program within 5 years    D. Initiate ex situ program in 3 years

19. **Are techniques established to propagate the taxon:**

- Techniques known for this taxon or similar taxon  
 **Some techniques known for similar taxa (D.g. buergesi)**  
 Techniques not known at all  
 Information not available with this group of compilers

20. **Other comments:**

## PART FOUR

21. **Sources:** T. Flannery 1996

22. **Compilers:** Frank Bonaccorso, Ilaiah Bigilale, Will Betz

Conservation Assessment Management Plan  
Taxon Data Sheet for *Dendrolagus matschiei*  
Date: September 1, 1998

**PART ONE**

**1. Scientific Name** (With authority and date) *Dendrolagus matschiei* (Forster and Rothschild, 1907)

1A. Synonyms: *Dendrolagus deltae*, Troughton & Le Souef, 1936; *Dendrolagus matschiei flavidor*, Matschie, 1912; *Dendrolagus matschiei xanthotis*, Rothschild & Dollman, 1936.

1B. Family: **Macropodidae**

1C. Common name(s) with language: **Matschie's tree kangaroo or Huon tree kangaroo (English); Peset (Pindiu area: Burmum, Kuat, Mung, Dedun, languages; Sivam (Indagen village); Klappaman (Kewang and Yupno languages); Torgap (Dangwitgamen); Yemda (Nankina area).**

1D. Taxonomic level of assessment: **Species**

**2. Distribution of the taxon**

2A. Habit or life form (only plants): **N/A**

2B. Habitat of the taxon (use national or regional classifications):

**Lower montane - Subalpine (Ziegler 1997) 1,000 - 3,300 meters**

**Note: The altitudinal range according to landowners is ~1800-3400m (Mambawe and Keweng landowners, Keweng 1 village, Kabwum District, Morobe Province). In the Mindik/Ogeranang region, Finschafen District, Morobe Province, the animal was known from ~1500m in the past, but has now been pushed up to higher altitudes (i.e. 2200m) due to human population expansion land clearance for gardens.**

2C. Habitat specificity (niche, elevation, etc.): **Forested habitat or adjacent subalpine meadow from 1,800 - 3,400m according to landowners, 1998. Will use partially disturbed forests, does not use extensive grassland or clear cut areas.**

2D. Historical distribution (Global -- in past 100 years described by country): **See Will Betz and Mambawe; Historical distribution was larger, but due to local extinctions and habitat destruction there appears to be an upward shift in the lower limit of distribution (see 2B above).**

2E. Current distribution (listed by country): **Papua New Guinea endemic**

2F. Current regional distribution (country/ biogeographic region of assessment): **Huon Peninsula, New Guinea Island. There are populations, probably introduced, on Umboi Island (Koopman, 1979), and in the Mt. Agulupella area of West New Britain Province (John Namuno, personal communication); however, no recent surveys have been undertaken to confirm the current status of either of the latter two populations.**

2G. Concentrated migration regions: **N/A**

**3. Approximate EXTENT OF OCCURENCE** of the taxon in and around the area of study/ sighting/ collection (Extent of occurrence is defined as the area contained within the shortest continuous imaginary boundary encompassing all known, inferred or projected sites of present occurrence of the taxon): (tick appropriate box)

< 100 km<sup>2</sup>

101 - 5,000 km<sup>2</sup>

5,001 - 20,000 km<sup>2</sup>

> 20,001 km<sup>2</sup>

**5,000 km<sup>2</sup> according to Flannery, 1996; landowners predict that it is lower than 5,000 km<sup>2</sup> due to more restricted altitude range (see 2B); In Morobe province the maximum possible area is 3,000 km<sup>2</sup>.**

4. Approximate **AREA OF OCCUPANCY** of the taxon in and around the area of study/ sighting/ collection (Area of occupancy is defined as the area occupied by the taxon within the 'extent of occurrence'): (tick appropriate box)

< 10 km<sup>2</sup>                       11 - 500 km<sup>2</sup>                       501 - 2,000 km<sup>2</sup>                       > 2,001 km<sup>2</sup>

5. **Number of Locations or Subpopulations** in which the taxon is distributed: **3 possible populations: the Huon Peninsula on New Guinea Island is the natural distribution and contains by far the majority of the total wild population; Umboi may have a small and probably introduced population; Mt. Agulupella, New Britain Island may have a small introduced population (see 2F above).**

5A. Are the locations or populations:     **Contiguous (for the major population source within the Huon Peninsula)**     Fragmented     Not known

**6. Habitat status:**

6A. Is there any change in the habitat where the taxon occurs:     **Yes**                       No                      If yes, is it a  
 **Decrease in area**                       Increase in area                       Stable in area                       Unknown

6B. If Decreasing, what has been the decrease in habitat (approximately, in percent) over years?:  
 **< 20%**                       > 20%                       > 50%                       > 80%                      in the last **20** years  
This is true overall, but some areas are relatively stable.

6C. If Stable or Unknown, do you predict a decline in habitat (approximately, in percent) over years?:  
 < 20%                       > 20%                       > 50%                       > 80%                      in the next \_\_\_\_\_ years

6D. State primary cause of change: **expanding human population; the increase in number of gardens replacing tree kangaroo habitat.**

6E. Is there any change in the quality of habitat where the taxon occurs:     Yes                       **No**                      If yes,  
 Decrease in quality     Increase in quality                       **Stable in quality**                       Unknown  
**There were severe brush fires in 1997 but there has been abundant new growth and the habitat quality is well into recovery.**

6F. State primary cause of change:

**7. Threats:**

7A. What are the threats to the taxon? (Circle **present [P]** or **future (predicted) [F]** threats below):

Harvest/ Hunting [P] [F]

Drought [P] [F]

El Nino [P] [F]

Harvest for food [P] [F]

Fire [F]

Harvest for timber [F]

Loss of habitat [P] [F]

Habitat fragmentation [F]

Volcano [F]

**Others (please specify):**  
\_\_\_\_\_

7B. Are these threats resulting in (perceived or inferred) or may result in (predicted) population decline?:  
 **Yes**     No

**8. Trade:**

8A. Is the taxon in trade?:  **Yes**     No    If yes, is it  
 **Local**     **Domestic**     Commercial     International

8B. Parts in trade:     Skin     Bones     Fur  
 Hair     Horn     Organs     Glands  
 **Meat**     Taxidermy models     **Live animal**     Products  
 Others, please specify

8C. Which form of trade (specified form) is resulting in a perceived or inferred population decline?:  
**Trade is incidental; occurs but is not a threat to population. The threat is hunting for personal consumption.**

**9. Population numbers:**

9A. Global population: **Unknown**

9B. Regional population (No. of subpopulations): **Unknown**

9C. Number of **Mature Individuals** (in all populations):  < 50     < 250     < 2,500     > 2,500  
**based on estimated size of home ranges and available habitat (0.25km<sup>2</sup>, Stirling in Flannery, 1996).**

9D. Generation time (Defined here as the average age of parents in population): **6.1 years (based on captive data)**

**10. Population trends:**

10A. Is the population size/ numbers of the taxon:

**Declining**     Increasing     Stable     Unknown

10B. If Declining, what has been the rate of population decline perceived or inferred:

**< 20%**     > 20%     > 50%     > 80%    in the last **25** years

10C. If Stable or Unknown, do you predict a future decline in the population.     Yes     No

If yes, please specify rate and factors e.g. habitat loss, threats, trade, etc. \_\_\_\_\_

< 20%     > 20%     > 50%     > 80%    in the next \_\_\_\_\_ years/ generations

**11. Data Quality:**

11A. Are the above estimates based on:

Census or monitoring     General field study     **Informal field sighting**     **Literature**  
 Indirect information such as from trade, etc.     Museum/ records     **Hearsay/ popular belief**  
 **Formal interviews with landowners**

**12. Recent field studies** (in the last 10 years). Indicate year of study not year of publication.

Researcher names	Location	Dates	Topics
Liam Sterling	Indagen, Huon Peninsula	1991	Radiocollars on <i>Dendrolagus matschiei</i> , Oxford Expedition
Lisa Dabek/Will Betz	Kewieng, Huon Peninsula	1996-98	<i>Dendrolagus matschiei</i> ecology and natural history



## PART TWO

### 13. Status:

- 13A. IUCN: **Vulnerable** IUCN Criteria based on: **B2c**  
13B. CITES: **Not listed**  
13C. National Wildlife Legislation: **PNG Fauna Protection Act**  
13D. National Red Data Book:  
13E. International Red Data Book:  
13F. Other legislation (please specify): **None**  
13G. Known presence in protected areas (please list): **None**  
13H. National or regionally endorsed protection plan: **None**

## PART THREE

14. **Supporting Research** recommended for the taxon:  **Yes**  **No** If yes, is it

**Survey**  **Genetic research**  **Taxonomic research**  **Life history studies**  
 **Limiting factor research**  **Epidemiology (Avian TB)**  **Trade**

**NOTE: Include survey of possible populations on Umboi and New Britain Island.**

**X Others (taxon specific): Feeding/Nutritional studies (e.g. Lisa Shipley , David Christophel, Lisa Dabek, Will Betz, DNA work with Tom Husband, Female Reproductive Physiology and Behavior work by Maria Franke.**

14A. Is Population and Habitat Viability Assessment recommended:  **Yes**  **No**  **Pending**  
**PHVA results are reported in this volume.**

15. **Management recommendations** for the taxon:

**Habitat management**  **Wild population management**  **Monitoring**  **Translocation**  
 **Sustainable utilization**  **Public awareness**  **Genome Resource Banking**  
 **Limiting factor management**  **Ex situ breeding**  **Work in local communities**  
 **Address policy makers ref needs of local people**

**X Others: Encourage the formation of Wildlife Management Areas (WMA) in Matschie tree kangaroo areas. Heightened awareness programmes and protected areas may result in this species being classified in a lower risk category in the future. The Lutheran Church should be approached as a possible leader in awareness and WMA campaigns.**

16. If **Ex situ management** is recommended, is it for:

**Species recovery**  **Education**  **Reintroduction**  **Benign introduction**  
 **Research**  **Husbandry**  **Preservation of live genome**

**Note: Existing ex situ programmes of AZA, ARAZPA and EEP should be continued.**

17. Do **Ex situ stocks** already exist:  **Yes**  **No** If yes,

17A. Names of facilities: **See International Studbook - 33 Facilities**

17B. Number in captivity: **(As of Dec, 97) Male: 49; Female: 63; Unsexed: 5; Total: 117**

17C. Does a coordinated **Species Management Program** exist for this species:  **Yes**  **No** If yes, which countries/regions (if country, which institutions): **AZA in North America, ARAZPA in Australia and Papua New Guinea, and EEP in Europe.**

17D. Is a coordinated **Species Management Program** recommended for the range country(ies) ?  
**X Yes**  No (please specify countries): **ARAZPA members in PNG participate in a regional species management program.**

**18. Level of ex situ management recommended:**

- X A. Ongoing ex situ program intensified or increased**  B. Ongoing ex situ program decreased  
 C. Initiate ex situ program within 3 years  D. Initiate ex situ program in 3 years

**Note: the existing captive breeding program should be intensified and strengthened within PNG institutions.**

**19. Are techniques established to propagate the taxon:**

- Techniques known for this taxon or similar taxon  
**X Some techniques known for taxon or similar taxon**  
 Techniques not known at all  
 Information not available with this group of compilers

**20. Other comments:**

**PART FOUR**

**21. Sources: T. Flannery, W. Betz, Lisa Dabek, Ziegler 1997, Local Landowners - Miffa and Mambawe**

**22. Compilers: Will Betz, Frank Bonaccorso, Maria Franke, Miffa Mionsing, Kaulobo Ulahaeava, Ilaiah Bigilale, Collin Aurere, Badi Joshua, Mambawe, Gert Skipper, Gary Slater**



**Conservation Assessment Management Plan**  
**Taxon Data Sheet for *Dendrolagus goodfellowi pulcherrimus***  
**Date: September 3, 1998**

**PART ONE**

**1. Scientific Name** (With authority and date): *Dendrolagus goodfellowi pulcherrimus* (Flannery, 1993)

1A. Synonyms: **None**

1B. Family: **Macropodidae**

1C. Common name(s) with language: **Golden-mantled Tree Kangaroo, Waimanke (Olo), Waiman (Sibilanga area) - both in Torricelli Mts., Sandaun (West Sepik Province)**

1D. Taxonomic level of assessment: **Subspecies**

**2. Distribution of the taxon**

2A. Habit or life form (only plants): **N/A**

2B. Habitat of the taxon (use national or regional classifications): **Mid - Montane Forest**

2C. Habitat specificity (niche, elevation, etc.): **Mid - Montane Oak forest, 680 - 1120 meters elevation**

2D. Historical distribution (Global -- in past 100 years described by country): **Papua New Guinea (possible sight record in Foja Mountains, Irian Jaya Province, Indonesia).**

2E. Current distribution (listed by country): **Papua New Guinea (?? Indonesia)**

2F. Current regional distribution (country/ biogeographic region of assessment): **Papua New Guinea (Torrecelli Mountains, East Sepik Province)**

2G. Concentrated migration regions: **N/A**

**3. Approximate EXTENT OF OCCURENCE** of the taxon in and around the area of study/ sighting/ collection (Extent of occurrence is defined as the area contained within the shortest continuous imaginary boundary encompassing all known, inferred or projected sites of present occurrence of the taxon): (tick appropriate box)

**X < 100 km<sup>2</sup>**                       101 - 5,000 km<sup>2</sup>                       5,001 - 20,000 km<sup>2</sup>                       > 20,001 km<sup>2</sup>  
**Possible best case = 300 km<sup>2</sup>**

**4. Approximate AREA OF OCCUPANCY** of the taxon in and around the area of study/ sighting/ collection (Area of occupancy is defined as the area occupied by the taxon within the 'extent of occurrence'): (tick appropriate box)

< 10 km<sup>2</sup>                       **X 11 - 500 km<sup>2</sup>**                       501 - 2,000 km<sup>2</sup>                       > 2,001 km<sup>2</sup>  
**(20 - 200 km<sup>2</sup> IS PROBABLE)**

**5. Number of Locations or Subpopulations** in which the taxon is distributed: One

5A. Are the locations or populations:                       **X Contiguous**                       Fragmented                       Not known

**Only one small population remains due to earlier habitat fragmentation**

**6. Habitat status:**

6A. Is there any change in the habitat where the taxon occurs:                       **X Yes**                       No                      If yes, Is it a

**X Decrease in area**                       Increase in area                       Stable in area                       Unknown

6B. If Decreasing, what has been the decrease in habitat (approximately, in percent) over years?:  
 < 20%       > 20%       > 50%       > 80%      in the last 20 years

6C. If Stable or Unknown, do you predict a decline in habitat (approximately, in percent) over years?:  
 < 20%       > 20%       > 50%       > 80%      in the next \_\_\_ years

6D. State primary cause of change: **Increased human population (leads to population decline from hunting).**

6E. Is there any change in the quality of habitat where the taxon occurs:     Yes       No      If yes,  
 Decrease in quality     Increase in quality       Stable in quality       Unknown

6F. State primary cause of change:

**7. Threats:**

7A. What are the threats to the taxon? (Circle **present [P]** or **future (predicted) [F]** threats below):

Harvest/ Hunting [P] [F]  
Drought [P] [F]  
El Nino [P] [F]  
Harvest for food [P] [F]  
Hurricane [F]  
Volcano [F]  
Overexploitation [P] [F]

**Others (please specify):** \_\_\_\_\_

7B. Are these threats resulting in (perceived or inferred) or may result in (predicted) population decline?:  
 Yes     No

**8. Trade:**

8A. Is the taxon in trade?:  Yes (in the past bartered for other items; unknown now)     No  
If yes, is it

Local      Domestic       Commercial       International

8B. Parts in trade:       Skin       Bones       Fur  
 Hair       Horn       Organs       Glands  
 Meat       Taxidermy models       Live animal       Products  
 Others, please specify:

8C. Which form of trade (specified form) is resulting in a perceived or inferred population decline?:  
**Any reduction of population for trade is critical.**

**9. Population numbers:**

9A. Global population: <250

9B. Regional population (No. of subpopulations): **One region - two sites near each other.**

9C. Number of **Mature Individuals** (in all populations):  < 50     < 250     < 2,500     > 2,500

9D. Generation time (Defined here as the average age of parents in population): **6.1 years (based on captive data)**

**10. Population trends:**

10A. Is the population size/ numbers of the taxon:

Declining       Increasing       Stable       Unknown

10B. If Declining, what has been the rate of population decline perceived or inferred:  
 < 20%       > 20%       > 50%       > 80%-95%      in the last 60 years

10C. If Stable or Unknown, do you predict a future decline in the population.  Yes       No  
If yes, please specify rate and factors e.g. habitat loss, threats, trade, etc. \_\_\_\_\_  
 < 20%       > 20%       > 50%       > 80%      in the next \_\_\_\_ years/ generations

### 11. Data Quality:

11A. Are the above estimates based on:

- Census or monitoring       **General field study**       Informal field sighting       **Literature**  
 Indirect information such as from trade, etc.       **Museum/records**       Hearsay/ popular belief  
 Formal interviews with landowners       Based on resource use trends

12. **Recent field studies** (in the last 10 years). Indicate year of study not year of publication.

Researcher names	Location	Dates	Topics
Flannery, Seri, Kula, German	Torricelli Mts.	1990	Mammalian faunal survey

## PART TWO

### 13. Status:

- 13A. IUCN: **Critically Endangered**      IUCN Criteria based on: **C2b**  
13B. CITES: **Not listed**  
13C. National Wildlife Legislation: **1966 PNG Fauna Protection Act**  
13D. National Red Data Book:  
13E. International Red Data Book:  
13F. Other legislation (please specify): **None**  
13G. Known presence in protected areas (please list): **None**  
13H. National or regionally endorsed protection plan: **None**

## PART THREE

14. **Supporting Research** recommended for the taxon:       **Yes**       No      If yes, is it

- Survey**       **Genetic research**       **Taxonomic research**       **Life history studies**  
 Limiting factor research       Epidemiology       Trade  
 Others (taxon specific):

14A. Is Population and Habitat Viability Assessment recommended:       **Yes**       No  
**Pending survey data**

15. **Management recommendations** for the taxon:

- Habitat management (set up WMA)**       **Wild population management**       Monitoring  
 Translocation       **Sustainable utilization**       **Public awareness**       Genome Resource Banking  
 Limiting factor management       **Ex situ breeding**       **Work in local communities**  
 **Address policy makers ref needs of local people**  
 Others: **Planning and implementation of immediate Recovery plan and total hunting moratorium needed.**

16. If **Ex situ management** is recommended, is it for:

- Species recovery**       Education       Reintroduction       Benign introduction  
 **Research**       Husbandry       **Preservation of live genome**

17. Do **Ex situ stocks** already exist:  Yes  **No** If yes,

17A. Names of facilities:

17B. Number in captivity: **None**

17C. Does a coordinated **Species Management Program** exist for this species:  Yes  **No**  
If yes, which countries (if country, which institutions):

17D. Is a coordinated **Species Management Program** recommended for the range country(ies) ?  
 **Yes**  No (please specify countries): **In PNG and if found in Irian Jaya, also by Indonesia.**

18. **Level of ex situ management recommended:**

A. Ongoing ex situ program intensified or increased

B. Ongoing ex situ program decreased

**C. Initiate ex situ program within 1 year**

D. Initiate ex situ program in 3 years

19. **Are techniques established to propagate the taxon:**

Techniques known for this taxon or similar taxon

**Some techniques known for similar taxa (*Dendrolagus goodfellowi buergesi*)**

Techniques not known at all

Information not available with this group of compilers

20. **Other comments:**

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#### **PART FOUR**

21. **Sources:** T. Flannery 1996

22. **Compilers:** Frank Bonaccorso, Ilaiah Bigilale, Will Betz

**Conservation Assessment Management Plan**  
**Taxon Data Sheet for *Dendrolagus spadix***  
**Date: September 3, 1998**

**PART ONE**

**1. Scientific Name** (With authority and date): *Dendrolagus spadix* (Troughton & Le Souef, 1936)

1A. Synonyms: *Dendrolagus matschiei spadix* (Groves, 1982) *Dendrolagus goodfellowi spadix* (Menzies, 1991)

1B. Family: **Macropodidae**

1C. Common name(s) with language: **Lowland Tree Kangaroo, Wagisa (Waro Village, Southern Highland Province)**

1D. Taxonomic level of assessment: **Species**

**2. Distribution of the taxon**

2A. Habit or life form (only plants): **N/A**

2B. Habitat of the taxon (use national or regional classifications): **Primary rainforest**

2C. Habitat specificity (niche, elevation, etc.): **Sea level to 800m**

2D. Historical distribution (Global -- in past 100 years described by country): **Papua New Guinea only**

2E. Current distribution (listed by country): **Papua New Guinea - Endemic**

2F. Current regional distribution (country/ biogeographic region of assessment): **Restricted to Gulf, Southern Highlands, and Western Provinces**

2G. Concentrated migration regions: **N/A**

**3. Approximate EXTENT OF OCCURENCE** of the taxon in and around the area of study/ sighting/ collection (Extent of occurrence is defined as the area contained within the shortest continuous imaginary boundary encompassing all known, inferred or projected sites of present occurrence of the taxon): (tick appropriate box)

< 100 km<sup>2</sup>                       101 - 5,000 km<sup>2</sup>                       5,001 - 20,000 km<sup>2</sup>                       > 20,001 km<sup>2</sup>

**4. Approximate AREA OF OCCUPANCY** of the taxon in and around the area of study/ sighting/ collection (Area of occupancy is defined as the area occupied by the taxon within the 'extent of occurrence'): (tick appropriate box)

< 10 km<sup>2</sup>                       11 - 500 km<sup>2</sup>                       501 - 2,000 km<sup>2</sup>                       >2,001 km<sup>2</sup>

**5. Number of Locations or Subpopulations** in which the taxon is distributed: **There are only seven locations verified for the presence of this very poorly known species.**

5A. Are the locations or populations:  Contiguous                       Fragmented                       **Not known**

**6. Habitat status:**

6A. Is there any change in the habitat where the taxon occurs:     **Yes**                       No                      If yes, Is  
it a  
 **Decrease in area**                       Increase in area                       Stable in area                       Unknown



6B. If Decreasing, what has been the decrease in habitat (approximately, in percent) over years?:  
 < 20%       > 20%       > 50%       > 80%      in the last 20 years

**Note: There is a large timber company that has moved in which will affect the habitat and therefore decline of numbers in the future is predicted. Also a rubber plantation. Predict a larger than 20% decrease in the future.**

6C. If Stable or Unknown, do you predict a decline in habitat (approximately, in percent) over years?:  
 < 20%       > 20%       > 50%       > 80%      in the next \_\_\_\_\_ years

6D. State primary cause of change: **Timber industry, clear cutting forests for veneer products and clearing for rubber plantation.**

6E. Is there any change in the quality of habitat where the taxon occurs:     Yes    No    If yes,  
 Decrease in quality     Increase in quality    **X Stable in quality**     Unknown

6F. State primary cause of change:

### 7. Threats:

7A. What are the threats to the taxon? (Circle **present [P]** or **future (predicted) [F]** threats below):

Harvest/ Hunting **[P]** **[F]**  
Drought **[P]** **[F]**  
El Nino **[P]** **[F]**  
Harvest for food **[P]** **[F]**  
Fire **[P]** **[F]**  
Loss of habitat **[P]** **[F]**

**Others (please specify):**  
\_\_\_\_\_

7B. Are these threats resulting in (perceived or inferred) or may result in (predicted) population decline?:

**X Yes**     No

**The most serious threats are land clearing for timber and rubber plantation. Could result in >20% loss of habitat in the next 25 years.**

### 8. Trade:

8A. Is the taxon in trade?:    **X Yes**     No    If yes, is it  
**X Local**     Domestic     Commercial     International

8B. Parts in trade:     Skin     Bones    **X Fur**  
 Hair     Horn     Organs     Glands  
**X Meat**     Taxidermy models    **X Live animal**     Products  
**X Others, please specify: Clothing ornament for traditional dress and artifacts sold at markets**

8C. Which form of trade (specified form) is resulting in a perceived or inferred population decline?:  
**Trade for this species is of very minor impact**

### 9. Population numbers:

9A. Global population: **Unknown**

9B. Regional population (No. of subpopulations): **Unknown**

9C. Number of **Mature Individuals** (in all populations):  < 50  < 250  < 2,500  > 2,500  
 > 10,000. **There are believed to be more than 2500 mature individuals but, because of the large area and low population density, this is a very rough estimate based on guessing.**

9D. Generation time (Defined here as the average age of parents in population): **6.1 years (based on captive data)**

#### 10. Population trends:

10A. Is the population size/ numbers of the taxon:

Declining  Increasing  Stable  **Unknown**

10B. If Declining, what has been the rate of population decline perceived or inferred:

< 20%  > 20%  > 50%  > 80% in the last \_\_\_ years/ generations

10C. If Stable or Unknown, do you predict a future decline in the population.  **Yes**  **No**

Factors responsible for the predicted future decline include: degradation/loss of habitat (due to mining, logging, agricultural expansion), and presumed increase in hunting pressure.

< 20%  > 20%  > 50%  > 80% in the next 50 years

#### 11. Data Quality:

11A. Are the above estimates based on:

Census or monitoring  General field study  Informal field sighting  **Literature**  
 Indirect information such as from trade, etc.  **Museum/ records**  **Hearsay/ popular belief**  
 Formal interviews with landowners

12. **Recent field studies** (in the last 10 years). Indicate year of study not year of publication.

**None**

### PART TWO

#### 13. Status:

13A. IUCN: **Lower risk - Near Threatened** IUCN Criteria based on:

13B. CITES: **Not listed**

13C. National Wildlife Legislation: **PNG Fauna Protection Act**

13D. National Red Data Book:

13E. International Red Data Book:

13F. Other legislation (please specify): **None**

13G. Known presence in protected areas (please list): **None**

13H. National or regionally endorsed protection plan: **None**

### PART THREE

14. **Supporting Research** recommended for the taxon:  **Yes**  **No** If yes, is it

**Survey**  **Genetic research**  **Taxonomic research**  **Life history studies**

Limiting factor research

Epidemiology

Trade

Others (taxon specific):

14A. Is Population and Habitat Viability Assessment recommended:  **Yes**  **No**  **Pending**

**results of recommended survey research**

**15. Management recommendations for the taxon:**

- Habitat management**     Wild population management     Monitoring     Translocation  
 **Sustainable utilization**     **Public awareness**     Genome Resource Banking  
 Limiting factor management     Ex situ breeding     Work in local communities  
 **Address policy makers in regard to the needs of local people**  
 Others:

**16. If Ex situ management is recommended, is it for:**

- Species recovery     **Education and public awareness**     Reintroduction     Benign introduction  
 **Research**     Husbandry     **Preservation of live genome**

**17. Do Ex situ stocks already exist:**     **Yes**     No    If yes,

17A. Names of facilities: **One individual at National Capital Botanical Gardens**

17B. Number in captivity: **Male 1; Female 0; Unsexed 0; Total 1**

17C. Does a coordinated **Species Management Program** exist for this species:  Yes     **No**    If yes, which countries (if country, which institutions):

17D. Is a coordinated **Species Management Program** recommended for the range country(ies) ?  
 Yes     **No** (please specify countries): **A program may be recommended depending on results of recommended survey research.**

**18. Level of ex situ management recommended:**

- A. Ongoing ex situ program intensified or increased     B. Ongoing ex situ program decreased  
 C. Initiate ex situ program within 3 years     D. Initiate ex situ program in 3 years  
 **E. Initiate ex situ program in 3 years**

**19. Are techniques established to propagate the taxon:**

- Techniques known for this taxon or similar taxon  
 Some techniques known for taxon or similar taxa  
 **Techniques not known at all**  
 Information not available with this group of compilers  
 Techniques are not known for spadix but this species is closely related to *d. matschiei* and *d. goodfellowi* and techniques may be similar.

**20. Other**

**comments:** \_\_\_\_\_  
\_\_\_\_\_

**PART FOUR**

**21. Sources:** T. Flannery 1996; J. Menzies, 1991; Sabati Eva, personal observations; Groves, 1982; Troughton and LeSouef, 1936; unpublished museum records, pers. comm. F. Bonaccorso.

**22. Compilers:** Frank Bonaccorso, Maria Franke, Sabati Eva, Will Betz



6B. If Decreasing, what has been the decrease in habitat (approximately, in percent) over years?:  
 < 20%       > 20%       > 50%       > 80%      in the last \_\_\_ years

6C. If Stable or Unknown, do you predict a decline in habitat (approximately, in percent) over years?:  
 < 20%       > 20%       > 50%       > 80%      in the next 20 years

6D. State primary cause of change: **Gold/copper mining/mining exploration.**

6E. Is there any change in the quality of habitat where the taxon occurs:  Yes       No      If yes,  
 Decrease in quality       Increase in quality       Stable in quality       Unknown

6F. State primary cause of change:

## 7. Threats:

7A. What are the threats to the taxon? (Circle **present [P]** or **future (predicted) [F]** threats below):

Harvest/ Hunting  **[P]**  **[F]**

Drought  **[P]**  **[F]**

Harvest for food  **[P]**  **[F]**

Loss of habitat  **[F]**

**Others (please specify):**

---

7B. Are these threats resulting in (perceived or inferred) or may result in (predicted) population decline?:

**Yes (Hunting)**       No

## 8. Trade:

8A. Is the taxon in trade?:  **Yes** (in the past bartered for other items; unknown now)       No      If yes, is it  
 **Local**       Domestic       Commercial       International

8B. Parts in trade:       Skin       Bones       **Fur**  
 Hair       Horn       Organs       Glands  
 **Meat**       Taxidermy models       **Live animal**       Products  
 Others, please specify:

8C. Which form of trade (specified form) is resulting in a perceived or inferred population decline?:

**Unknown; All trade is at unknown levels relative to sustainability.**

## 9. Population numbers:

9A. Global population: **Unknown**

9B. Regional population (No. of subpopulations): **Unknown**

9C. Number of **Mature Individuals** (in all PNG populations):

< 50       < 250       < 2,500       **> 2,500**       > 10,000.

9D. Generation time (Defined here as the average age of parents in population): **6.1 years (based on captive data)**

## 10. Population trends:

10A. Is the population size/ numbers of the taxon:  
 **Declining**       Increasing       Stable       Unknown

10B. If Declining, what has been the rate of population decline perceived or inferred:

**≤ 20%**       > 20%       > 50%       > 80%      in the last 10 years

10C. If Stable or Unknown, do you predict a future decline in the population.  Yes  No  
 If yes, please specify rate and factors e.g. habitat loss, threats, trade, etc. \_\_\_\_\_  
 < 20%  > 20%  > 50%  > 80% in the next \_\_\_\_ years/ generations

**11. Data Quality:**

11A. Are the above estimates based on:

- Census or monitoring  **General field study**  Informal field sighting  **Literature**  
 Indirect information such as from trade, etc.  Museum/ records  Hearsay/ popular belief  
 Formal interviews with landowners  Based on resource use trends

**12. Recent field studies** (in the last 10 years). Indicate year of study not year of publication.

Researcher names	Location	Dates	Topics
Flannery and Seri	West Sepik province	1990	Mammal distribution
Flannery	New Guinea	1996	Tree Kangaroos: A Curious Natural History (book)

**PART TWO**

**13. Status:**

- 13A. IUCN: **Vulnerable** IUCN Criteria based on: A1d, B2c,e, C1  
**[The PNG population is vulnerable due to limited range, large hunting effort etc., but it appears to be quite secure in the less inhabited regions of Irian Jaya. Flannery, pers.comm.]**  
 13B. CITES: **Not listed**  
 13C. National Wildlife Legislation: **PNG Fauna Protection Act**  
 13D. National Red Data Book:  
 13E. International Red Data Book:  
 13F. Other legislation (please specify): **None**  
 13G. Known presence in protected areas (please list): **None**  
 13H. National or regionally endorsed protection plan: **None**

**PART THREE**

**14. Supporting Research** recommended for the taxon:  **Yes**  No If yes, is it

- Survey  **Genetic research**  **Taxonomic research**  Life history studies  
 Limiting factor research  Epidemiology  Trade  Others (taxon specific):

14A. Is Population and Habitat Viability Assessment recommended:  Yes  **No**  Pending

**15. Management recommendations** for the taxon:

- Habitat management  Wild population management  Monitoring  Translocation  
 **Sustainable utilization**  **Public awareness**  Genome Resource Banking  
 Limiting factor management  Ex situ breeding  Work in local communities  
 **Address policy makers in regard to needs of local people**  
 Others:

**16. If Ex situ management** is recommended, is it for:

- Species recovery  Education  Reintroduction  Benign introduction  
 Research  Husbandry  Preservation of live genome

17. Do **Ex situ stocks** already exist:  Yes  **No** If yes,

17A. Names of facilities:

17B. Number in captivity: **None**

17C. Does a coordinated **Species Management Program** exist for this species:  Yes  **No** If yes, which countries (if country, which institutions):

17D. Is a coordinated **Species Management Program** recommended for the range country(ies) ?  
 Yes  **No** (please specify countries): **Not in immediate future**

**18. Level of ex situ management recommended:**

A. Ongoing ex situ program intensified or increased

B. Ongoing ex situ program decreased

C. Initiate ex situ program within 5 years

D. Initiate ex situ program in 3 years

**19. Are techniques established to propagate the taxon:**

Techniques known for this taxon or similar taxon

Some techniques known for taxon or similar taxa

**Techniques not known at all**

Information not available with this group of compilers

**20. Other comments: This subspecies has a large distribution in Irian Jaya, Indonesia, but it has been exterminated in parts of its range there such as the regions near Wamena and Ok Sibil (Flannery, 1996).**

**PART FOUR**

**21. Sources: T. Flannery 1996, Flannery and Seri, 1990**

**22. Compilers: Frank Bonaccorso, Chris Talie, Will Betz**

**Conservation Assessment Management Plan**  
**Taxon Data Sheet for *Dendrolagus dorianus notatus***  
**Date: September 2, 1998**

**PART ONE**

**1. Scientific Name** (With authority and date) *Dendrolagus dorianus notatus* (Matschie, 1916)

1A. Synonyms: *Dendrolagus notatus* (Matschie, 1926)

1B. Family: **Macropodidae**

1C. Common name(s) with language: **Ifola (Kuni, Chimbu Prov.), Yu (Pawia, Chimbu Province), Ugwa (Daribi, Chimbu) Flannery, 1996; Landowners: Tmnga (Takedu), Kama (Maimafu Crater Mt.), Ngalugi (Wau, Kuper range)**

**Alex and Peter (Landowners) present the following information: There are two different morphs associated with different names in the Takedu area; Tmnaya is the largest of the two and has a light colored ring around base of the tail. Tmnga is the smaller with no colored ring around base of the tail. They report that these two morphs represent sexual dimorphism with the male being larger and the female and both sexes of the juveniles representing the second morph (no light tail ring). Landowners from the Kuper Range (Wau area) say that there is only one kind of animal in their area with no sexual dimorphism.**

1D. Taxonomic level of assessment: **Subspecies**

**2. Distribution of the taxon**

2A. Habit or life form (only plants): **N/A**

2B. Habitat of the taxon (use national or regional classifications): **Hill Forest to Upper Montane Forest**

2C. Habitat specificity (niche, elevation, etc.): **900 - 3,100 meters**

2D. Historical distribution (Global -- in past 100 years described by country): **Papua New Guinea only**

2E. Current distribution (listed by country): **Papua New Guinea - Endemic**

2F. Current regional distribution (country/ biogeographic region of assessment): **Central mountain ranges of New Guinea Island**

2G. Concentrated migration regions: **N/A**

**3. Approximate EXTENT OF OCCURENCE** of the taxon in and around the area of study/ sighting/ collection (Extent of occurrence is defined as the area contained within the shortest continuous imaginary boundary encompassing all known, inferred or projected sites of present occurrence of the taxon): (tick appropriate box)

< 100 km<sup>2</sup>

101 - 5,000 km<sup>2</sup>

5,001 - 20,000 km<sup>2</sup>

> 20,001 km<sup>2</sup>

**T. Flannery, 1996 - 40,000**

**4. Approximate AREA OF OCCUPANCY** of the taxon in and around the area of study/ sighting/ collection (Area of occupancy is defined as the area occupied by the taxon within the 'extent of occurrence'): (tick appropriate box)

< 10 km<sup>2</sup>

11 - 500 km<sup>2</sup>

501 - 2,000 km<sup>2</sup>

> 2,001 km<sup>2</sup>

**(Flannery, 1996)**



5. Number of Locations or Subpopulations in which the taxon is distributed: **Because the central highlands holds a dense human population with many urban and rural developments, the populations of this taxon are likely to be highly fragmented and this process will increase. However, there still are large areas of undisturbed habitat remaining.**

5A. Are the locations or populations: Contiguous  Fragmented  **X Not known**

6. Habitat status:

6A. Is there any change in the habitat where the taxon occurs: **X Yes**  No  
If yes, Is it a **X Decrease in area**  Increase in area  Stable in area  Unknown

6B. If Decreasing, what has been the decrease in habitat (approximately, in percent) over years?:  
 < 20% **X > 20%**  > 50%  > 80% in the last 50 years

**Note: This is true overall, but some areas are relatively stable.**

6C. If Stable or Unknown, do you predict a decline in habitat (approximately, in percent) over years?:  
 < 20%  > 20%  > 50%  > 80% in the next \_\_\_\_\_ years

6D. State primary cause of change: **Habitat loss due to expanding human population, cities, agriculture.**

6E. Is there any change in the quality of habitat where the taxon occurs: **Unknown**  Yes  No If yes,  
 Decrease in quality  Increase in quality  Stable in quality  Unknown

6F. State primary cause of change:

7. Threats:

7A. What are the threats to the taxon? (Circle **present [P]** or **future (predicted) [F]** threats below):

- Harvest/ Hunting **[P]** **[F]**
- Drought **[P]** **[F]**
- El Nino **[P]** **[F]**
- Harvest for food **[P]** **[F]**
- Fire **[P]** **[F]**
- Harvest for timber **[P]** **[F]**
- Loss of habitat **[P]** **[F]**
- Habitat fragmentation **[P]** **[F]**

**Others (please specify):**  
\_\_\_\_\_

7B. Are these threats resulting in (perceived or inferred) or may result in (predicted) population decline?:  
**X Yes**  No

8. Trade:

8A. Is the taxon in trade?: **X Yes**  No If yes, is it  
**X Local** **X Domestic**  Commercial  International

8B. Parts in trade:  Skin  Bones  Fur  
 Hair  Horn  Organs  Glands  
**X Meat**  Taxidermy models **X Live animal**  Products  
**X Others, please specify: Clothing ornament for traditional dress and artifacts sold at markets**

8C. Which form of trade (specified form) is resulting in a perceived or inferred population decline?:  
**Meat**

**9. Population numbers:**

9A. Global population: **Unknown**

9B. Regional population (No. of subpopulations): **Unknown**

9C. Number of **Mature Individuals** (in all populations):  < 50     < 250     < 2,500     > 2,500  
**based on estimated size of home ranges and available habitat.**

9D. Generation time (Defined here as the average age of parents in population): **6.1 years (based on captive data for a similar taxon)**

**10. Population trends:**

10A. Is the population size/ numbers of the taxon:

**Declining**                     Increasing                     Stable                     Unknown

**NOTE: Populations in Crater Mt. are Stable (due to religious "no hunting" beliefs – Seventh Day Adventist church bans eating wild meat). Populations are declining in the Takedu area due to hunting for meat.**

10B. If Declining, what has been the rate of population decline perceived or inferred:

< 20%     > 20%     > 50%     > 80%    in the last **50** years

10C. If Stable or Unknown, do you predict a future decline in the population.     Yes     No

If yes, please specify rate and factors e.g. habitat loss, threats, trade, etc. \_\_\_\_\_  
 < 20%     > 20%     > 50%     > 80%    in the next \_\_\_\_\_ years/ generations

**11. Data Quality:**

11A. Are the above estimates based on:

Census or monitoring     General field study     **Informal field sighting**     **Literature**  
 Indirect information such as from trade, etc.     **Museum/ records**     **Hearsay/ popular belief**  
 **Formal interviews with landowners**

**12. Recent field studies** (in the last 10 years). Indicate year of study not year of publication.

Researcher names	Location	Dates	Topics
Lisa Dabek/Will Betz	Crater Mt. - WMA	1997 – 1998	General survey

**PART TWO**

**13. Status:**

13A. IUCN: **Vulnerable** IUCN Criteria based on: **A1, C1**

13B. CITES: **Not listed**

13C. National Wildlife Legislation: **PNG Fauna Protection Act**

13D. National Red Data Book:

13E. International Red Data Book: **This tree kangaroo taxon (subspecies) not listed in 1996 IUCN Red List Book; requires addition as a subspecies in next edition.**

13F. Other legislation (please specify): **None**

13G. Known presence in protected areas (please list): **Crater Mt. – Wildlife Management Area**

13H. National or regionally endorsed protection plan: **None**

**PART THREE**

**14. Supporting Research** recommended for the taxon:     **Yes**     No    If yes, is it

**Survey**     **Genetic research**     **Taxonomic research**     **Life history studies**

Limiting factor research                       Epidemiology(Avian TB)    **X Trade**  
**X Others (taxon specific): Feeding/Nutritional studies (eg. David Christophel, Lisa Dabek, Will Betz, DNA work with Thomas Husband, Female Reproductive Physiology and Behavior work by Maria Franke**

14A. Is Population and Habitat Viability Assessment recommended:     Yes    **X No**     Pending

**15. Management recommendations for the taxon:**

**X Habitat management**    **X Wild population management**    **X Monitoring**     Translocation  
**X Sustainable utilization**    **X Public awareness**                       Genome Resource Banking  
 Limiting factor management     Ex situ breeding    **X Work in local communities**  
**X Address policy makers ref needs of local people AND LANDOWNERS ASSOCIATIONS (ie; RCF, Crater Mt. WMA)**  
**X Others: Laise with landowner association**

**16. If Ex situ management is recommended, is it for:**

Species recovery                      **X Education**     Reintroduction     Benign introduction  
**X Research**                                  **X Husbandry**    **X Preservation of live genome**

**17. Do Ex situ stocks already exist:**    **X Yes**                       No                      If yes,

17A. Names of facilities: **Only in PNG: Rainforest Habitat, Zenag (Phillip Leahy's), Wau Ecology**

17B. Number in captivity: **Male: 5; Female: 4; Unsexed: 1; Total: 10**

17C. Does a coordinated **Species Management Program** exist for this species: **X Yes**     No    If yes, which countries/regions (if country, which institutions): **ASMP of ARAZPA through PNG member institution**

17D. Is a coordinated **Species Management Program** recommended for the range country(ies) ?  
**X Yes**     No (please specify countries): **PNG programs**

**18. Level of ex situ management recommended:**

**X A. Ongoing ex situ program intensified or increased**     B. Ongoing ex situ program decreased  
 C. Initiate ex situ program within 3 years                       D. Initiate ex situ program in 3 years

**19. Are techniques established to propagate the taxon:**

Techniques known for this taxon or similar taxon  
 Some techniques known for taxon or similar taxa  
**X Techniques not known at all**  
 Information not available with this group of compilers

**20. Other**

**comments:** \_\_\_\_\_  
\_\_\_\_\_

**PART FOUR**

**21. Sources:** T. Flannery 1996, W. Betz, Local Landowners - Miffa Mionzing and Mambawe

**22. Compilers:** Will Betz, Frank Bonaccorso, Maria Franke, Alex Moses, Peter Uyepango, Kanulobo Ulahaeava

**Conservation Assessment Management Plan**  
**Taxon Data Sheet for *Dendrolagus scottae***  
**Date: September 2, 1998**

**PART ONE**

**1. Scientific Name** (With authority and date): *Dendrolagus scottae* (Flannery and Seri, 1990)

1A. Synonyms: **None**

1B. Family: **Macropodidae**

1C. Common name(s) with language: **Scott's Tree Kangaroo, Tenkile (Mt. Somoro, Lumi District, East Sepik Province), Fiwo (Mt. Menawa, Sandaun Province)**

1D. Taxonomic level of assessment: **Species**

**2. Distribution of the taxon**

2A. Habit or life form (only plants): **N/A**

2B. Habitat of the taxon (use national or regional classifications): **Lowland Rainforest and Hill Forest**

2C. Habitat specificity (niche, elevation, etc.): **300 - 1200 meters elevation (Chris Talie)**  
**900-1520m (Flannery, 1996)**  
**Fiwo 1500-2000m (Flannery, 1996)**

2D. Historical distribution (Global -- in past 100 years described by country): **Extent of occurrence 50 years ago is estimated to be 500 km<sup>2</sup>**

2E. Current distribution (listed by country): **Papua New Guinea endemic**

2F. Current regional distribution (country/ biogeographic region of assessment): **Torricelli Mountains of East Sepik and Sandaun Provinces.**

2G. Concentrated migration regions: **N/A**

**3. Approximate EXTENT OF OCCURENCE** of the taxon in and around the area of study/ sighting/ collection (Extent of occurrence is defined as the area contained within the shortest continuous imaginary boundary encompassing all known, inferred or projected sites of present occurrence of the taxon): (tick appropriate box)

**X < 100 km<sup>2</sup> (~30 km<sup>2</sup> for Tenkile, ~40 for Fiwo)**     101 - 5,000 km<sup>2</sup>     5,001 - 20,000 km<sup>2</sup>  
 > 20,001 km<sup>2</sup>

**4. Approximate AREA OF OCCUPANCY** of the taxon in and around the area of study/ sighting/ collection (Area of occupancy is defined as the area occupied by the taxon within the 'extent of occurrence'): (tick appropriate box)

< 10 km<sup>2</sup>                       **X 11 - 500 km<sup>2</sup> (~20-30 km<sup>2</sup>)**     501 - 2,000 km<sup>2</sup>     > 2,001 km<sup>2</sup>

**5. Number of Locations or Subpopulations** in which the taxon is distributed: **Two disjunct populations each in very small areas, a third population believed to have undergone extinction in last 10 years.**

5A. Are the locations or populations:  **Contiguous**     **X Fragmented**     **Not known**  
**A small population on Mt. Somoro is in serious decline. A population on Mt. Menawa, Sandaun Province has not been surveyed for 10 years. A population formerly in the Wilbeti-Wigote area, East Sepik Province, now is believed by local people to be extinct.**

**6. Habitat status:**

6A. Is there any change in the habitat where the taxon occurs:  Yes  No If yes, is it a

Decrease in area  Increase in area  Stable in area  Unknown

6B. If Decreasing, what has been the decrease in habitat (approximately, in percent) over years?:  
 < 20%  > 20%  > 50% (~60%)  > 80% in the last 20 years

**Note: Eight years ago, animals at Mt. Somoro were found along a 20 km transect of mountains, but now are believed to occur only along a 10 km transect, in part due to vegetation clearing according to local landowners.**

6C. If Stable or Unknown, do you predict a decline in habitat (approximately, in percent) over years?:  
 < 20%  > 20%  > 50%  > 80% in the next \_\_\_ years

6D. State primary cause of change: **Increased human population (~3%/year); habitat loss.**

6E. Is there any change in the quality of habitat where the taxon occurs:  Yes  No If yes,  
 Decrease in quality  Increase in quality  Stable in quality  Unknown

6F. State primary cause of change:

**7. Threats:**

7A. What are the threats to the taxon? (Circle **present [P]** or **future (predicted) [F]** threats below):

Harvest/ Hunting **[P]** **[F]**

Drought **[P]** **[F]**

El Nino **[P]** **[F]**

Fire **[P]** **[F]**

Harvest for food **[P]** **[F]**

Loss of habitat **[P]** **[F]**

**Others (please specify): Deforestation results in a change in climate; up to 3 months without rain.**

7B. Are these threats resulting in (perceived or inferred) or may result in (predicted) population decline?:

Yes  No

**8. Trade:**

8A. Is the taxon in trade?:  Yes  No

If yes, is it

Local  Domestic  Commercial  International

8B. Parts in trade:  Skin  Bones  Fur  
 Hair  Horn  Organs  Glands  
 Meat  Taxidermy models  Live animal  Products  
 Others, please specify:

8C. Which form of trade (specified form) is resulting in a perceived or inferred population decline?:

**9. Population numbers:**

9A. Global population: <200; **Note: This includes most optimistic guess for combined populations at Mt. Somoro and Mt. Menawa and assumes that the Wilbeti population is extinct.**

9B. Regional population (No. of subpopulations): <200; **Note: About half the population is at Mt. Somoro and half at disjunct Mt. Menawa.**

9C. Number of **Mature Individuals** (in all populations):  < 50  < 250  < 2,500  > 2,500

9D. Generation time (Defined here as the average age of parents in population): **6.1 years (based on captive data for D. matschei)**

**10. Population trends:**

10A. Is the population size/ numbers of the taxon:

**Declining**                       Increasing                       Stable                       Unknown

10B. If Declining, what has been the rate of population decline perceived or inferred:

< 20%       > 20%       > 50%                       > 80%-95%      in the last \_\_\_\_ years/ generations

10C. If Stable or Unknown, do you predict a future decline in the population.     Yes               No

If yes, please specify rate and factors e.g. habitat loss, threats, trade, etc. \_\_\_\_\_

< 20%       > 20%                       > 50%                       > 80%      in the next \_\_\_\_ years/ generations

**11. Data Quality:**

11A. Are the above estimates based on:  **Good quality landowner information**

Census or monitoring               General field study                       Informal field sighting               **Literature**

Indirect information such as from trade, etc.     Museum/records                       Hearsay/ popular belief

Formal interviews with landowners                       Based on resource use trends

**12. Recent field studies** (in the last 10 years). Indicate year of study not year of publication.

<b>Researcher names</b>	<b>Location</b>	<b>Dates</b>	<b>Topics</b>
<b>Flannery</b>	<b>Mt. Somoro</b>	<b>1990-1992</b>	<b>Movements and food habits</b>

**PART TWO**

**13. Status:**

13A. IUCN: **Critically Endangered**                      IUCN Criteria based on: **B1, B2abce, C2b**

13B. CITES: **Not listed**

13C. National Wildlife Legislation: **1966 PNG Fauna Protection Act applies to all tree kangaroos**

13D. National Red Data Book:

13E. International Red Data Book: **Not listed in 1996 IUCN Red Data Book because of recent discovery, this species should be given listing in the next edition**

13F. Other legislation (please specify): **None**

13G. Known presence in protected areas (please list): **None**

13H. National or regionally endorsed protection plan: **None**

**PART THREE**

**14. Supporting Research** recommended for the taxon:     **Yes**                       No                      If yes, is it

**Survey**                       **Genetic research (there may be 2 subspecies, Flannery 1996)**

Taxonomic research                       Life history studies                       Limiting factor research                       Epidemiology

Trade                       Others (taxon specific): **Genome resource banking**

14A. Is Population and Habitat Viability Assessment recommended:  **Yes**                       No

**15. Management recommendations** for the taxon: **Full ban on hunting (very specific regulations required)**

**Habitat management**                       **Wild population management**                       **Monitoring**

Translocation     Sustainable utilization     Public awareness     Genome Resource Banking  
 Limiting factor management     Ex situ breeding     Work in local communities

Address policy makers in regard to needs of local people

Others: **IMMEDIATE ACTION NEEDED; captive breeding for reintroduction is needed but will not be accepted without education, public awareness and financial compensation. Need to stop expansion of gardening into Tenkile habitat.**

16. If **Ex situ management** is recommended, is it for:

Species recovery     Education and awareness     Reintroduction     Benign introduction  
 Research     Husbandry     Preservation of live genome

17. Do **Ex situ stocks** already exist:     Yes     No    If yes,

17A. Names of facilities:

17B. Number in captivity:

**Note: There is a single individual juvenile animal held by a local family in Waunulu, this animal might become part of a captive breeding project in the local area as all remaining live animals are important to the population.**

17C. Does a coordinated **Species Management Program** exist for this species:  Yes     No  
If yes, which countries (if country, which institutions):

17D. Is a coordinated **Species Management Program** recommended for the range country(ies) ?

Yes     No (please specify countries): **Papua New Guinea should establish a captive program with at least two separate populations, preferably one population should be at a center developed in the Mt. Somoro local area, and at least one other captive population established at an established institution with a record of husbandry and breeding of tree kangaroos.**

18. **Level of ex situ management recommended:**

A. Ongoing ex situ program intensified or increased     B. Ongoing ex situ program decreased  
 C. Initiate ex situ program within 1 year     D. Initiate ex situ program in 3 years

19. **Are techniques established to propagate the taxon:**

Techniques known for this taxon or similar taxon  
 Some techniques known for similar taxa (D.g.b) buergesi)  
 Techniques not known at all

**Techniques for this species not known at all, but information and techniques from *D. dorianus*, *D. matschiei* and *D. goodfellowi* should be a starting basis for developing precise techniques.**

20. **Other comments:** See Action Plan to Protect Scott's Tree Kangaroo (Section 8 of this document).

## PART FOUR

21. **Sources:** Chris Talie (interview)

22. **Compilers:** Frank Bonaccorso, Will Betz, Chris Talie

**CONSERVATION ASSESSMENT AND MANAGEMENT PLAN  
FOR THE TREE KANGAROOS OF PAPUA NEW GUINEA**  
*and*  
**POPULATION AND HABITAT VIABILITY ASSESSMENT FOR  
MATSCHIE'S TREE KANGAROO**

**Lae, Papua New Guinea  
31 August – 4 September 1998**

**Final Report**

**Section 5  
Socio-economic Issues  
Working Group Report**







# Socio-economic Issues Working Group Report

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This working group consolidated issues identified by the stakeholder groups into five working issues to be discussed during the workshop. Three issues were addressed in detail - assessing environmental awareness, environmental education and technical training, and addressing social needs - while the other two issues - funding and human impacts on the environment - were addressed and incorporated as components of this and other working groups' recommendations. Each issue was defined and possible strategies for addressing these issues were listed. Recommendations and action steps were identified for those strategies that were considered of highest concern and implementable for this group.

## Issues, Needs, and Recommendations

### Issue 1: Assessing Existing Levels of Community Environmental Awareness

**We need to determine the existing level of awareness amongst the people of PNG (including local people, resource developers, urban dwellers, expatriates) of conservation issues in general and those relevant to tree kangaroos in particular.**

- Conduct a literature search to determine if data about existing levels of environmental awareness already exists.
- Approach the National Research Institute, DEC, the National Museum, academic institutions and others to collect data on current levels of environmental awareness.
- Utilize students in colleges and other academic institutions to carry out research and surveys on environmental issues and tree kangaroos in particular.

#### *Recommendation:*

Research into existing environmental awareness should be encouraged, but that in a climate of limited resources, we should focus on programs to raise environmental awareness as it seems likely that current awareness levels are low. Co-ordination of current projects and information dissemination is suggested.

### Issue 2: Raising Environmental Awareness

**We need to develop student and community education programs to increase environmental awareness amongst the people of PNG with the aim of protecting tree kangaroos and their habitats.**

#### *Recommendation A:*

**Create an education program to be distributed to villages throughout tree kangaroo habitats with the aim of involving children in data collection whilst raising their awareness of conservation issues surrounding tree kangaroos.**

A survey sheet was developed during the course of the conference (see Appendix I) in draft format which will be distributed throughout villages in PNG. It is designed to raise village awareness of tree kangaroo conservation through involving school children in an exercise to collect data on tree kangaroos in their area. At the same time the data will be useful for scientists attempting to study tree kangaroos in the field. The survey forms will be accompanied by brochures outlining the need to conserve tree kangaroos. Both surveys and brochures will be printed in English and in Pidgin for greater relevance to village people.

When the survey forms are returned by the children to the Rainforest Habitat in Lae, Peter Clarke will send back to the respondent further information on tree kangaroos and other native animals which are very popular with children in villages (information passed on by Landowners).

During the conference the Landowners made repeated and passionate pleas for the other members of the conference to provide them with some information to be able to take back to their villages as they leave the conference. It was assumed that this was important for their credibility in the eyes of their village people. Therefore a model of the survey and of the information in the brochure was provided to all landowners and delegates in either English or Pidgin.

<b>Further actions required:</b>	<b>Responsibility</b>
Create a combined survey, species identification and conservation brochure for use by children in the ranges of PNG's tree kangaroo species, eg. Tenkile in the Torricelli Mountains.	<b>Peter Clark and Tony Jupp</b> to work on together.
Professional production of the survey form and brochure.	<b>Tony Jupp</b>
Australian Zoos to send project sheets, stickers, colouring-in sheets or other educational materials to Peter Clark in Lae.	<b>Tony Jupp/Gert Skipper</b> to request this of other Australian Zoos.
Create a colouring-in sheet on tree kangaroos for children to accompany survey form and brochure.	<b>Peter Clark and Tony Jupp</b> to work on together.
Distribute* final versions of surveys, brochures and colouring-in sheets to schools throughout tree kangaroo habitat.	<b>Peter Clark</b>
Link villages with other villages through letters and poster exchange.	<b>Peter Clark</b>
Include churches and women's groups in this outreach program.	<b>Landowner representatives</b>

\*Note: The initial distribution of surveys will be through out the established network of teachers in Morobe province, and to landowners who were present at the workshop. They will then be used as a resource to distribute as needed to encourage participation from a broader range of areas.

By bringing draft materials produced at the workshop to their villages, landowners at the workshop agreed to encourage church and other community groups in their areas to participate in conservation outreach programs.

***Recommendation B:***

**School programs in Environmental Education should be expanded through teacher training.**

There is presently a program given at Rainforest Habitat, with support of University of Technology, for teachers from Morobe province. The National Government is starting an educational program in a couple of off-shore island communities. Support is needed to expand teacher training to all areas of PNG. Wildlife Conservation Society is currently supporting the existing Rainforest Habitat project.

Landowner representatives will encourage their local teachers to contact Peter Clark if they are interested in the teacher in-service program.

***Recommendation C:***

**Provide training/knowledge transfer opportunities for care-takers/keepers of tree kangaroos between those within PNG (both in captivity and in the wild) and outside PNG.**

Wildlife management area (WMA) managers as well as PNG captive facilities identified the need for training. Several participants in the workshop agreed to pursue various options. It is suggested that

collaborations between several national and international institutions will insure long-term support and training. Potential collaborators include: University of PNG, Rainforest Habitat, the National Museum and Art Gallery, Zenag project, University of Technology, WMA committee members, district officers, and local churches. Will Meikle (Taronga Zoo), Mitch Bush (Smithsonian) and Frank Bonaccorso (National Museum and Art Gallery, PNG) have agreed to investigate training agreements.

**Actions** - Training in wild and captive management for community leaders, wildlife management area committee members, and district officers with regard to conservation values.

**Responsibilities** - Taronga Zoo may be able to make commitment to the development of a wildlife management training course in PNG. Taronga Zoo will apply for funding from AusAid (Australia) for the training program - **Will Meikle**.

The Conservation and Research Center of the NOAHS, the Smithsonian Institution, is a possibility for support of a training program. The start would be a very basic course in wildlife biology and captive management (see draft proposal below). The training would then expand into field work including such activities as radio tracking. Work with the stakeholders to develop specific training programs tailored to local needs - **Mitchell Bush**.

### **TRAINING PROGRAM FOR PNG BIOLOGIST IN CONSERVATION BIOLOGY** (FIRST DRAFT PROPOSAL FOR DISCUSSION PURPOSES ONLY)

This is a proposed collaborative program **between conservation-based organizations and interested Australian institutions** and the Conservation and Research Center, Smithsonian Institution, Front Royal Virginia to offer a structured and staged long term training program in the broad field of wildlife conservation and management training program. The initial phase will consist of an intensive 3 to 4 week of lectures demonstrations and "hands-on" training exercises in PNG. Training will focus upon commonly encountered The program will provide for at least 4 follow-up visits during the first 24 months after initial training to continue new training exercises, and to evaluate the progress of the program since the previous visit. The first workshop is proposed for late 1999. The second phase of this program is to invite selected zoo veterinarians from PNG to participate in a structured advanced training program in the United States to be conducted at various zoological parks and veterinary schools.

#### **Issue 3 – Funding for Conservation Initiatives**

**How could funds be raised within and outside PNG to support tree kangaroo conservation *in situ* in PNG? Which of these methods are appropriate and which are inappropriate? Once raised, how should these funds be utilised?**

#### ***Strategies:***

- Selling/leasing tree kangaroos for profit
- Identifying national and international sponsors
- Setting up trusts and foundations
- Approaching non-renewable resource developers

Funding of projects is a universal problem. Ways of securing funds to support sustainable conservation programs must be sought. Recommendations for funding have been incorporated throughout the report as needed.

#### **Issue 4 - Conservation and Development**

**We need to address the identified problem that local people would like to develop conservation programs but they have other problems they perceive as more important or urgent - i.e. insufficient health services, inadequate education & lack (or high cost) of transportation. If these services were improved, it would increase the likelihood of success with conservation programs.**

Due to a lack of development of most urgent services and infrastructure, communities may be reluctant to give priority to conservation programs unless infrastructure and social services are equally considered.

#### ***Strategies:***

- Integrate conservation programs with socio-economic development programs to increase their effectiveness.
- Encourage consumption of alternative sources of protein, such as livestock, rather than eating tree kangaroos.
- Encourage and support ecologically sustainable commerce and industry activities in order to create alternative sources of cash and employment.
- Create benefits to communities involved in conservation programs.
- Involve communities in decision-making through local level political institutions.

#### ***Recommendation A:***

**In order to link conservation and development, local communities need to have access to alternatives for generating income and meeting other priority social needs (school fees, transportation fees, health, nutrition).**

#### **Actions**

Possible actions and needs are identified in order to offer options to villages. It is recognized that all projects must be initiated at the village level. There is a great potential for zoos and other NGOs to help villages develop conservation projects that address local needs through partnerships. The International Studbook Keepers for tree kangaroos have agreed to contact all institutions holding tree kangaroos about forming partnerships with villages. If a village or wildlife committee would like a partner institution, they can contact Ilaiah Bigilale at the National Museum-PNG.

#### **1. Ecotourism**

##### *Potential Services*

- Encourage local communities to set up guest houses to provide infrastructure for ecotourism to take advantage of the unique flora and fauna of PNG.
- Additional services can be offered in the villages, such as cooking of meals, guide services into the nearby bush, cultural activities (e.g., sing-sings) and sale of other objects (books, photographs, local crafts).
- User fees were suggested as another form of income from tourism.
- TPA (tourism promotion authority) maintains inventory of guest houses. Encourage villages to list their guest houses with these authorities.

##### *Possible users villages can attract/Categories of ecotourism:*

- Research fees with regard to research stations
- Government officers going into village may stay at guest house
- Companies (timber and mining, purchase crafts)

*Needs identified by the villages to help with ecotourism are:*

- Support and marketing of guest houses and village tourism services. (The Village Development Trust is trying to develop these services.)
- Link villages with organizations or institutions that can provide additional services. (e.g., transportation to the village).
- Education programs (identified in issue 2) in the local villages can help to train local villagers as guides.

## **2. Sources of protein and nutrition**

It is recommended that attempts be made to supplement other forms of protein that may be more easily derived than hunting tree kangaroos, and will support local health and nutrition. For example:

- Poultry farming (For example, companies like Zenag will contract with villages.)
- Domestic pigs
- Fisheries (aquaculture)
- Rabbits
  - University of Technology has an experimental development program in progress.
  - Villages are invited to send representatives for training.
- Sheep was brought up at a possibility, but according to participants, in previous attempts (Edward Hallstrom) this hasn't been viable.

## **3. Eco-Forestry**

Some communities may choose to develop community forestry concepts for selected timber products, following the work of selected NGOs.

- Finchafen is a model program, utilizing walk-about sawmills.
- FPCD (Foundation for People and Community Development)
- Pacific Heritage Foundation
- Greenpeace (Green Timber)

## **4. Other source of income**

It is recommended that each village inventory its locality and come up with a list of other sources of income to address health care needs. These may include:

- Butterfly Farming
- Identify other non-timber forest products (e.g., betel-nut, gold, coffee, berries, nuts, orchids, mushrooms, medicinal plants)
- Support Women's activities (i.e. sewing, cooking, baking, traditional arts, & agriculture).
- NGOs can help in the development of markets for local products (e.g., partner zoos selling products in their gift shops).

## **5. Further needs with regard to services**

The lack of infrastructure to support villages in PNG is an urgent and difficult problem. While many issues are beyond the scope of this workshop to address, it is necessary that these problems are recognized when addressing conservation in PNG. Specific issues discussed by this group include health and transportation.

### **Health Issues**

- There are many needs associated with the shortage of medical supplies, accessibility of aid posts. There is a need for support of maternal and children's health, with specific concerns regarding malaria.

- This is a responsibility of government not being met in many villages. Conservation programs may help support obtaining of higher quality of trained personnel and services.
- It is recommended that Women's Councils be involved in conservation and link projects to their concerns of improving local health conditions, through improvements in sanitation, water, diet, and care.
- In some cases, while medical supplies are available, the transport for them is not. A specific need that can be addressed by NGOs is help in transporting medical supplies.

### **Transportation needs**

- Lack of access/infrastructure: transportation and communication. "This is the major problem of rural areas of Papua New Guinea."
- Recommendations here are difficult to make as they are so location specific. Further the development of roads, necessary for village transport, may have extremely negative effects on the local forest unless there is effective environmental education prior to road construction.

### ***Recommendation B: Seek sources of national and international funding to support conservation and development programs***

Since there are incremental costs to supporting integrated conservation and development programs and the government of PNG does not have adequate funding available, these initiatives may be best supported by funding from outside PNG. Such biodiversity programs are eligible for support from the World Bank and through the GEF, the Global Environmental Fund. It is proposed to prepare a proposal and explore the possibility of obtaining World Bank support for the preparation of a GEF proposal to support the biodiversity of the unique endangered fauna of PNG, including Tree Kangaroos. In addition, national sources of funding should be investigated, for example, mining and timber companies.

1. Gather information about possible international and national grants/funding sources (e.g., GEF funds or World Bank).
  - John Williams
  - Chris Talie
2. Seek PNG NGO cooperation and apply for grants.
  - Mike Raga, DEC
  - Karol Kisokau, Village Development Trust

### **Issue 5 – Human Populations and Resource Use**

**A) We need to know why, how and when tree kangaroos are hunted (i.e. cultural reasons) and how this may be changing over time. This also applies to the use of other forest resources such as other fauna, timber etc.**

**B) How do changes in population growth rates affect tree kangaroos and what are the links between this growth and resource use?**

#### ***Strategies:***

- Develop ways to measure the impact of people on tree kangaroos and habitat.
- Incorporate this into education and conservation programs.
- Explore historical information on traditional lifestyles.

- Understand that even though populations may be growing, people are sometimes turning to alternative activities to hunting such as gold panning.
- Recognise that one possible consequence of increased human population is increased competition for resources that may lead to increased conflict (e.g. legal actions, fighting, war.)
- Steps taken to reduce the rate of human population growth need to occur far in advance. Action is required today to reduce population growth 20 years in the future. To wait until the population places strain on local resources in 20 years time, and then act to slow population growth, the decline will not really start until an additional twenty years has gone by, by which time, the number of households in the community may have nearly doubled.

***Actions:***

**Information on extraction rates, habitat and population growth was shared by landowners and incorporated in the CAMP data sheets and Vortex model.**

All of the strategies identified are suggested research questions that would help to better understand the interactions between wildlife populations, habitat and human populations.

***Working group participants:*** Mambawe, Tony Jupp, Badi Joshua, Banak Gamui, Alex Moses, Peter Uyepango, Mitch Bush, Kaulobo Ulahaeava, Sakias Huho, John Williams, Philip Nyhus, Peter Clark, Rick Bein, Sam Sogeri, Chris Talie, Miffa Mionzing, Nalu Wabu, Kausa Ilao, Dex Matu, Karol Kisakau, Jenna Borovansky.





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**Section 6  
Government and Legislation  
Working Group Report**





# Government and Legislation Working Group Report

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Initial issues handed to the Government and Legislation Working Group following stakeholder group discussions were:

- A. People are not following community laws; we (landholders) need enforcement of laws and/or stronger laws.
- B. People outside the community are using the land and taking wildlife; we (landholders) need to be able to enforce boundaries.
- C. Other issues take priorities over conservation (health and transpiration) leaving little incentive to abide by wildlife protection laws; we (landholders) need improved services.
- D. Zoos in PNG and elsewhere have some resources and would like to contribute to tree-kangaroo conservation but do not know what best to do; we (zoo representatives need advisement from the Department of Environment and Conservation).

## ISSUES A, B and C

Following general discussion of issues a, b and c, the group developed the following broad assessment of attitudes and problems and concluded that these would need to be addressed in any objectives or actions for the conservation of Tree-kangaroos.

### Local people

- Why should I worry about Tree Kangaroo/Wildlife?
- Why do we need all these laws?
- How will I/my community benefit if we work to manage wildlife?

### Wildlife Management Area Committees

- What laws should we create?
- How can we enforce these laws without ongoing assistance (from government or other agency)?

### Police/District Officers

- Why should we take wildlife laws seriously?
- Why should we work to enforce wildlife laws when we are very busy with general law enforcement?

### DEC

- How can we help with enforcement when we don't have enough resources?

## Issue A

### The uncontrolled use of firearms in Wildlife Management Areas

#### Objectives/Needs

- All Wildlife Management Area Committees need to establish laws and penalties in relation to firearm use in their Wildlife Management Areas.
- Wildlife Management Area Committees need national government support for enforcement of laws in relation to firearm use in Wildlife Management Areas

### **Actions**

1. Include the endorsement of the relevant Wildlife Management Area Committee as a requirement for annual firearm license renewal (Mick Raga to pursue through DEC)
2. Produce a handout that advises Wildlife Management Area Committees on options for creating firearm laws (this might be appropriate in the Wildlife Management Area Newsletter suggested under Action 19).
3. Establish dialogue between Wildlife Management Area Committee and district office to inform them about the Wildlife Management Area and associated laws.

## **Issue B**

### **People are not following existing laws in Wildlife Management Areas**

#### **Background**

Wildlife Management Area Committees establish the laws intended to protect wildlife within the designated area. Committee members are empowered under national legislation, the Fauna (Protection and Control) Act, to enforce these laws. Landholders sometimes experience difficulties enforcing the laws within their community and often want local court officials to adjudicate on their behalf. Problems associated with accessibility and lack of resources mean that the limited number of police offices and other courts officials often can not provide the necessary assistance in a timely way. The lawbreakers recognize this problem and exploit the situation.

Committee members are entitled to receive Wildlife Rangers Cards which help to demonstrate their authority. Wildlife Rangers are empowered to arrest and prosecute lawbreakers and take them to the police. Wildlife Rangers Cards have not been distributed for some time due to the lack of available funds and law enforcement training courses have not been conducted, also due to a lack of funds.

#### **Objectives/Needs**

- Create stronger and enforceable laws.
- Educate local communities on national and local laws
- Enlist national government enforcement support at local levels
- Enlist church support
- Enlist NGO and other support of Wildlife Management Area committees
- Stop outside people using/abusing Wildlife Management Area's

### **Actions**

4. Create a handout to advise Wildlife Management Area Committees on possible options to consider when making the laws, such as the establishment of quotas (this may be appropriate as an inclusion in the Wildlife Management Area Newsletter suggested under Action 19).
5. Implement the PNG Department of Environment and Conservation's existing Wildlife Ranger Card system. Mick Raga (DEC) estimated that this will cost an estimated 3,000K.
6. Resume the PNG Department of Environment and Conservation's training workshops for Wildlife Rangers.
7. Create and distribute to local communities, material such as leaflets and posters (written in pidgin) on
  - Why local people should worry about Tree-kangaroos and other wildlife
  - Why laws are needed to protect Tree-kangaroos and other wildlife
  - The Fauna (Protection and Control) Act, its content and purpose
  - Local community wildlife protection laws (and penalties)
  - All species protected under the Act (not just Tree-kangaroos)

8. Advise local communities of the potential benefits they could pursue (e.g. eco-tourism) if they actively protect their land/wildlife. This may be appropriate as an inclusion in the Wildlife Management Area Newsletter suggested under Action 19.

### **Issue C**

#### **Other issues take priority over the need for conservation of Tree Kangaroo and wildlife protection laws (for example health, education, services, etc.).**

#### **Objectives/Needs**

- Tangible links between wildlife conservation efforts (including those for Tree-kangaroos) and the provision of much needed village services.
- Improved services to communities operating Wildlife Management Areas.
- Communication of the need and value of Wildlife Management Areas to villages
- Support for communities that develop Wildlife Management Areas from the national government, NGOs, the church, the local and international captive community and corporations.
- The repair or replacement of failed alliances.

#### **Actions**

9. Create a handout stating why Tree-kangaroo should be considered important by local communities.
10. Link Tree-kangaroo and wildlife protection with benefits to the local communities.
  - Gather information on existing eco-tourism facilities including Wildlife Management Areas (Mick Raga from DEC will pursue; Peter Clark will send information that he has to Mick).
  - Provide a forum for existing facilities (including Wildlife Management Areas) to meet and link their activities (Christine Hopkins will approach AusAid and Australian Ecotourism Assoc. for funds).
  - Approach PNG Tourism Promotion Authority to investigate markets for nature tours (Peter Clark will pursue).
  - Approach Earthwatch regarding feasibility of support for Tree-kangaroo projects (Gary Slater will pursue).
  - Consider fund-generating options (eg. Sale of artifacts, butterfly farming, orchids and other non timber forest products, payment for facilitating research, sale/leasing of Tree-kangaroos overseas).

### **Issue D**

#### **Determining the role of captive animals and the captive community in contributing to the conservation of Tree-kangaroos**

#### **Background discussions**

Any export of Tree-kangaroos needs to be linked with benefits directed back to PNG and preferably local communities. With regard to zoos outside of PNG, the demand for Tree-kangaroos is limited to periodic import into regionally managed populations. The PNG government intends to retain ownership of any exported Tree-kangaroos.

There are currently selected PNG species that are exported as part of commercial operations. (including crocodile, butterflies and giant clams) and the government may consider other species when more data is available.

## Objectives/Needs

- A contract/agreement process that obligates zoos to provide support and recognizes PNG ownership of endemic Tree-kangaroos.
- Indication of which species/subspecies require captive management.
- Tree-kangaroo husbandry standards.

## Actions

11. ARAZPA to provide a copy of the "Australian Ambassador Species Agreement" to the PNG Department of Environment and Conservation for consideration. (Christine Hopkins to pursue with Mike Raga)
12. ARAZPA and DEC representatives to brief Frank Antram and Hank Jerkins (of the DEC Strengthening Program) on the "Australian Ambassador Species Agreement" during zoo standards meeting on 8-9 September 1998.
13. ARAZPA to contact the Wildlife Protection Unit of Environment Australia to see if they can arrange a meeting with the appropriate DEC officials to discuss their experiences with the "Australian Ambassador Species Agreement". (Christine Hopkins to pursue by the end of September).
14. ARAZPA to contact other zoo regional associations managing captive Tree-kangaroos (AZA and EAZA) asking them to survey their zoos regarding the idea of returning the ownership of all Tree-kangaroos to PNG. Christine Hopkins to report back to the DEC secretary by the end of October.
15. Tree Kangaroo International Studbook Group to document support, resources and projects already funded in PNG by facilities holding Tree-kangaroos and report to the DEC secretary by the end of the year.
16. Mick Raga to give the Tree Kangaroo International Studbook Group the complete list of protected areas within PNG, together with specific contact details by the end of September.
17. The Tree Kangaroo International Studbook Group is to send the document (referred to in Action.6) back to all facilities holding Tree-kangaroos together with an invitation to consider further support. The following partnership arrangement is recommended.

Structured partnerships between PNG Protected areas (including Wildlife Management Areas) and Tree-kangaroo facilities outside PNG, are proposed. Under each partnership, the local community will accommodate wildlife conservation in its land management practices and the supporting partner will provide an agreed range of support. Support may include the marketing of artifacts, the provision of supplies to schools, supply of other materials, provision of domesticated animals as a potential alternative meat source, establishment of in-situ research project, training and technology transfer.

18. Explore the potential of limited and controlled farming and exportation of selected wildlife at both the village level and other centralized facilities within PNG. The benefits derived would be directed back to the Wildlife Management Area and to improving the village services and conditions.
19. Develop a scheme whereby a Newsletter is published that provides a link between the Wildlife Management Area Committees. Undertaken as a joint partnership with the PNG Department of Environment and Conservation.
20. Facilities holding Tree-kangaroos are to be informed of captive research priorities identified at this meeting. These are
  - Husbandry studies (including reproductive biology and manipulation, veterinary issues, dietary studies and behavioural studies) on Doria's as an analogue for Scott's.
  - Continued husbandry studies on *D. g. buergersi* as an analogue for *D. g. pulcherrimus*
  - Collection of base data for taxonomic studies (with an emphasis on Goodfellow's and Doria's)
  - Development of techniques to extract DNA from faecal samples
  - Collection of biological material for a genome resource bank to facilitate studies into storage and retrieval techniques and to allow the use of this material in relevant studies in the future.

21. PNG facilities holding or planning to hold Tree-kangaroos are to be informed of the captive management priorities identified at this meeting. These are
  - To continue to opportunistically acquire any species or sub-species of Tree-kangaroo to use in captive research, advocacy and education.
  - To investigate the feasibility of actively acquiring specimens of *D. g. pulcherrimus* and Scott's Tree-kangaroo in order to establish insurance populations as part of a structured conservation program.
22. Facilities holding or planning to hold Tree kangaroos outside of PNG are to be informed of the captive management priorities identified at this meeting. These are:
  - To continue to manage existing captive populations of Goodfellow's tree kangaroo (*D. g. buergersi*) and Matchie's tree kangaroo (*D. matschiei*) to facilitate captive research, advocacy and education and in conjunction with the transfer of skills and resources to PNG.
  - To investigate the feasibility of establishing a captive population of Doria's to serve of a research analogue for Scott's Tree kangaroo.
23. Existing and potential Tree kangaroo facilities to be fully utilized with regard to captive research, advocacy, education and the management of insurance populations.
24. In line with the opening remarks of the Wari Iamo, DEC Secretary, DEC will strive to facilitate the work of those PNG facilities with a good track record of Tree kangaroo husbandry and research (notably Phillip Leahy's facility at Zeneg and the Rainforest Habitat at Lae). This requires that those facilities received the permits/licenses they require to legally hold Tree kangaroos. It may also require approval to periodically export approved scientific products (samples) or live Tree kangaroos in support of approved breeding programs. Mick Raga to pursue within DEC. Specifically, Mick will attempt to ensure that the Zenag facility is licensed to hold protected species within the month.
25. Will Meikle to ask the group of DEC representatives and zoo representatives meeting next week to consider PNG Zoo standards to also consider specific conditions/requirements for holding protected species such as Tree kangaroos and Birds-of-Paradise.

**Working group participants:** Mau Au, Ilaiah Bigilale, Robert Bino, Mitch Bush, Peter Clark, Christine Hopkins, Sakias Huho, Karol Kisokau, Mambawe, Will Meikle, Alex Moses, Mick Raga, Bing Siza, Gary Slater, Sam Sogeri.





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**Lae, Papua New Guinea  
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**Section 7  
Landowner Issues Review Report**





# Landowners Issue Review Report

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The landowners were asked to reconvene their stakeholder group to evaluate whether the issues and needs identified on the first day of this workshop had been addressed to their satisfaction and to surface any remaining concerns. Results of that meeting are reported below:

Most of the landowner representatives present agreed that all the issues and needs discussed so far have addressed their concerns.

However the following two new issues were raised:

1. Wau Ecology Institute (Sam Sogeri)
  - a. Wau Ecology Institute is interested in captive breeding of tree kangaroos and they have facilities to look after tree kangaroos, but do not have any money.  
**Action:** ARAZPA to give one (1) year complementary membership to Wau Ecology Institute. (C. Hopkins)
  - b. The Institute has administrative management problems. There is concern that these problems will hinder any conservation and facilitation efforts.
2. The biggest concern by most of the representatives present was that after the workshop is over there should be a coordinating body that will coordinate/facilitate the recommendations.  
**Recommendation:** Establish a committee within PNG to record and report on implementation of PHVA recommendations.  
**Action:** Committee established; made up of representatives from:  
Department of Environment and Conservation (Mr. Mick Raga and Mr. Mau Au)  
National Museum and Art Gallery (Dr. Frank Bonaccorso and Mr. Ilaiah Bigilale)  
As responsible parties complete recommended actions, they are responsible for notifying the National Museum and Art Gallery and/or DEC.

**Report submitted by Ilaiah Bigilale**



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**Section 8  
Tenkile Working Group Report**





**CBSG Tree-kangaroo Conference**  
**Lae, Papua New Guinea, September 1998**  
**Action Plan to Protect Scott's Tree-kangaroo**  
*Dendrolagus scottae*

**Background**

The tenkile or Scott's tree kangaroo, *Dendrolagus scottae*, was only discovered by scientists in 1989. At that time it already had a very limited distribution in the Torricelli Mountains in north-western PNG and was already under the threat of extinction. From discussions held at the CBSG Tree Kangaroo CAMP/PHVA conference with Chris Talie, a prominent land owner of the region, it became evident that the known populations of this species had suffered alarmingly in the time since its discovery. It is possible that there has been as much as a 75% reduction in range in the past nine years, and it appears that the known range of the species is now restricted to the southern face of Mount Somoro in an area estimated to be 20-30 square kilometres. From this information a total population for the species of 10 -100 individuals was estimated and a IUCN Conservation Status category of Critically Endangered was assigned. It is considered that without immediate action the species may be extinct within two years. The good news, however, is that the local villagers are aware of the fact that the Tenkile is in trouble and are requesting assistance to rectify the situation.

**Response**

A small working group was established at the conference to develop an action plan to recommend immediate and medium term courses of action. The group consisted of Chris Talie (Landowner and local community leader), Jonathan Wilcken (ARAZPA), Gary Slater (Melbourne Zoo), Frank Bonaccorso (PNG Museum), Ilaiah Bigilale (PNG Museum), Tony Jupp (Perth Zoo), Maria Franke (Zenag/Toronto Zoo), Will Betz (Field Researcher/Tree Kangaroo SSP) and Peter Clarke (Rainforest Habitat, Lae)

The proposal developed by this team was presented to a plenary session of the Tree kangaroo workshop. The recommended course of action, which consisted of an immediate response to the situation and a medium term strategy was endorsed by the workshop participants. It was agreed that this the immediate response should occur within 30 days of funding being identified. Note: Due to heavy rains and logistical difficulties, Team Tenkile now plans to make its first visit to the Mt. Somoro area in February 1999.

**Immediate Recommended Response**

The workshop determined the membership of the "Team Tenkile" to undertake an immediate field trip for initial assessment and to negotiate an immediate moratorium on hunting of Tenkile. The team membership was determined on the basis of :

A representative of the Sumoro people, and team leader	Chris Talie
A representative of the PNG Department of Environment and Conservation	Mick Raga, Mau Au or Lester Seri
A representative of the PNG Captive Community	Phillip Leahy (Zenag) or Peter Clark (RFH)
A representative of the PNG Scientific community	Robert Bino (RCF)
A representative of another area in PNG who has had experience with implementing a hunting moratorium	Mambwe (Keweng1)



To enable the rapid response of the “Team Tenkile” Melbourne Zoo and Taronga Zoo agreed to underwrite the expedition. A funding commitment from the International Zoo community would be sought to partner Melbourne and Taronga to finance the expedition. It is anticipated that the funds required will be in the vicinity of \$3,000 US. Funding for this first stage of the project, the Team Tenkile expedition, will be co-ordinated by Frank Bonaccorso, Vice President of ARAZPA, PNG.

The group also noted that the implications of establishing a conservation program in this area will require a long term commitment. Though the group is not able to specify timelines at this point, indications are that any social/conservation program will require greater than a ten year commitment.

### Team Tenkile: Outcomes

A report will be produced immediately on the Team Tenkile's return. This report will be distributed, via regional zoo associations, to all participating organisations and those organisations indicating potential future support.

The report will encompass:

- The outcome of the proposed moratorium on Tenkile hunting.
- Identification of an appropriate community support program.
- Outline strategies for implementation of the community support program
- Identification of an initial site for commencing a captive program.
- Identification of an interim committee to establish structures to implement the next stages of the project.
- Outline responsibilities, actions and timelines for the interim committee.
- Resulting outcome regarding the current captive male Tenkile.
- Comments from those contacted before and during the process of the assessment.

**The following table outlines the objectives, actions and responsibilities initially determined by the workshop task group.**

<b>The Objectives</b>	<b>Action</b>	<b>Responsibility</b>
To demonstrate a commitment from this conference, to comply with the request from the local village for help.	Send in a assessment team of 4-5 people led by Chris Talie to assess the situation ASAP.	Conference
To confirm and extend current information on the known Tenkile population	Survey villagers	Team Tenkile
To determine what the highest priority needs are of the people in the local villages.	Hold village meetings to determine these needs	Team Tenkile
To determine the nature and complexity of a current Tenkile ownership dispute between the villages.	Village meetings with elders, elected members, church leaders etc	Team Tenkile
To negotiate and implement a moratorium on further hunting.	At village meetings present the evidence and consequences of continued hunting.	Team Tenkile
Ensure all possible stakeholders are informed/consulted	Include/inform DEC, Police, Coffee Companies (?) in/of all activities.	FB/IB
	Seek comment and support from Tim Flannery	JW
	Contact local MP in Port Moresby	CT
	Alert AZA, ARAZPA, EEP, TK SSP, IUCN Marsupial Specialist Group	JW
To assess the situation of the single captive male.	Discuss options for the male with the villagers concerned; collect hair samples for taxonomic studies	Team Tenkile

### **Tenkile Conservation Program: possible future**

The task group identified future strategies and actions that would need to be undertaken in the medium term, following the return and report of Team Tenkile. Much of the future development of this program will depend on the resulting recommendations from the expedition report. On the assumption that the report will recommend ongoing action of some kind the Task group identified areas of future work and issues that will need to be addressed.

To ensure a planned, consistent and equitable long term program be established, it is recommended that:

1. A Tenkile recovery team is established
2. Appropriate members required for the establishment of a Tenkile Recovery Team are identified.
3. A funds management mechanism for the long term support of the program be established.

### **Stage 2**

- The group agreed that the establishment of a captive breeding population is essential to act as an insurance against wild population extinction, and to provide captive-bred animals to supplement or re-establish the wild population in the future. The group considered this to be an urgent requirement, to be initiated as ASAP (see below for options to be put to conference and villagers). Criteria for assessing early success or failure of such a program need developing, as well as protocols for monitoring progress (in records keeping and husbandry issues).
- Surveys need to be conducted of other possible ranges within the Torricelli and Prince Alexander Mountain Ranges habitats to determine if any extra-limital populations of Tenkile exist. This should include the site where Flannery speculates as to the existence of a possible unnamed subspecies. In addition to surveying for the presence of Tenkile, the habitat should also be assessed for suitability for future possible reintroductions.
- Implement a local community assistance program as determined by the Team Tenkile.
- Follow up on in-situ program i.e. the protection of the existing wild population at Somoro with ideas deemed appropriate by the meetings between the Team Tenkile and the villagers e.g. monitoring of the moratorium on hunting, education programs in local schools and villagers.

NB: as with the immediate response, all of the above medium term plans need to be developed in consultation with villagers.

- Identify the potential members of a recovery team and develop a formal Tenkile Recovery Plan, endorsed by all parties, to include potential sources of long term funding.

**The group suggests that these medium term plans be fully operational within 12 months of the completion of the immediate response visit.**

### **Options for the Captive Breeding Population**

A number of options were discussed for the potential locations of the captive breeding population. It was agreed that the best solution was for the program to be developed in two stages including one site at Mt Somoro and one elsewhere but within PNG. The group did not decide at this stage which of the two sites should come first. This issue needs further and wider consultation and contemplation. The identified benefits of a two sites approach include a combination of the benefits of programs at each site as listed below.

Having a site at Mt Somoro allows for;

- Increased local support and involvement including local employment, education programs and a base for any *in-situ* field work.
- Taking advantage of providing the animals with the right climate and diet.
- Less stress for the captive animals during transportation to the facility.

Having a site elsewhere in PNG allows for;

- Safeguarding against local catastrophes which have the potential to wipe out wild and local captive populations.
- The greater availability of other tree kangaroo species as analogues and surrogate mothers should pouch swapping joeys be attempted.
- Taking advantage of existing infrastructure.
- Management may be less constrained by the potential for escalation of any local disputes.
- Better access to veterinary and other professional care.

**What is required:**

1. Partner organisations to join Melbourne Zoo and Taronga Zoo in funding the initial Team Tenkile expedition.
2. An indication from those organisations wishing to expand their current involvement in conservation projects in PNG.
3. An indication from those organisations that are interested in becoming involved in a long term PNG conservation project.

## Tenkile (*D. scottae*) Recovery Project: Information and Background

Villages falling within former (10 years ago) species range:

Sumoro constituency

*East:* Fatima Parish (ordered east to west)

Wilbeite - ward 12  
Meiwaute - ward 12  
Wabute - ward 11  
Rawete - ward 10

*West:* Yauluwape Parish (ordered east to west)

Youngite - ward 9  
Wannulu\* - ward 9  
Minate (soulette)- ward 9  
Maiwetem - ward 8

Distribution bounded by river Wei, and mountains Sumoro  
Used to be distributed as far Sibilangia (anecdotal)

Maximum possible current distribution: EW ~10km  
river ~2-3 km

10 years ago EW ~20 km?

Currently hunted. Last reported hunting trip involved 6-7 people camping for 2 weeks, during which time 2 animals were captured. Formerly, hunting parties captured approximately 10 tree kangaroos in 1 week. Hunting frequency is approximately 1 or 2 times per year but was more frequent in the past.

Maximum annual harvest currently removed from the population is as many as 5 - 6 animals, although Chris Talie does not know of a successful recent hunting trip, apart from above.

Disputed ownership of animals: based on cultural interpretations of tree kangaroo behavior (it is believed that daily migration behavior is linked to particular places. Since direction of migration is disputed, the place of origin (to the east or west) is also disputed.

Villagers want conservation measures and propose economic benefits be connected to these measures

Human population growth rate is 3% and is dependent on the coffee and cocoa crop (with cultivation occurring in the eastern part of the range, but little cultivation to the west). There is a large number of guns in area and small-scale goldpanning takes place in the river.

Wilbeite - owners of lake, formerly taboo for hunting (Flannery). Chris Talie suggests that this area can not have been important, as no tree kangaroo vegetation.

Wilbeite & Meiwaute already have a facility built (Tenkile Guest-house, where result of latest hunting trip were held).

Churches run health services

Population: Lumi area ~30,000?  
Fatima Prish: ~6,000 - 7,000

### **Management Options**

Management options to benefit local people and Scott's tree kangaroo are:

1. A total hunting moratorium linked with economic incentives to protect tree kangaroos. The economic incentives should be linked through wider community development projects and involve local political leaders and church leaders.
2. A captive breeding programme for Scott's tree kangaroo should consider:
  - a. A local breeding project in the Mt. Somoro area with most staff drawn from local villages will provide local economic benefits to the people "owning" the wild tree kangaroos and habitat as well as allow husbandry research where local food stocks and climate can be studied to further husbandry. The local breeding center can double as a more general research center to benefit field research on Scott's tree kangaroos and other fauna and flora as well.
  - b. An additional distant breeding center perhaps located in Lae or Zenag (or both) within Papua New Guinea provides insurance that a population of animals is not subject to any local catastrophic disaster such as drought, fire, vandalism or failure of the hunting moratorium. A breeding center with an urban environment provides better access to high technology for research and access of large numbers of people for education and research.

**CONSERVATION ASSESSMENT AND MANAGEMENT PLAN  
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MATSCHIE'S TREE KANGAROO**

**Lae, Papua New Guinea  
31 August – 4 September 1998**

**Final Report**

**Section 9  
List of Participants**





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**Section 10  
Workshop Presentations**





**CONSERVATION ASSESSMENT AND MANAGEMENT PLAN  
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and  
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**Lae, Papua New Guinea  
31<sup>st</sup> August - 4<sup>th</sup> September 1998**

**NOTES FOR OPENING SPEECH  
by The Secretary, Dr Wari Iamo  
Department of Environment and Conservation**

DEC welcomes this very important workshop and hopes that the results of it will assist DEC in determining appropriate strategies, policies and legislative measures for promoting the conservation of, not only tree kangaroos, but also other species of conservation concern or economic significance.

The six species of tree kangaroo in PNG are all endemic to the island of New Guinea. Three of these are restricted to small geographic ranges totally within PNG, while the other three have larger distributions including Irian Jaya.

Tree kangaroos used to be, and in some areas still are, important food species for local people. They also are culturally significant in some areas.

Unfortunately, populations of tree kangaroos are declining, due to habitat loss and other factors, possibly including over-hunting. Tree kangaroos are now considered to be threatened species.

The effective conservation of tree kangaroos and all the other components of biological diversity in PNG will ultimately depend on the ability of the national Government to implement, in cooperation with the provincial administrations and local communities, effective policies and programs to conserve essential natural habitats.

Failure to do so may result in disappearance of many species, particularly those species which are habitat specialists and which are confined to restricted and/or fragile habitats.

Given the system of traditional land tenure and resource ownership that exists in PNG, it is doubtful that DEC will be able to establish a sufficiently extensive network of protected areas throughout the country in which all important and threatened habitat types are represented and legally protected.

In any event, management of protected areas is costly, and effective conservation of biological diversity is unlikely to be achieved solely through establishment of protected areas. The demands placed on natural resources to meet the needs of an increasing human population, which is anxious for economic development, often conflict with the interests of wildlife conservation.

The utilisation of wild fauna and flora, for both subsistence and commercial purposes, is necessary and inevitable in PNG. The challenge is to find ways of ensuring that this utilisation is ecologically and economically sustainable, and that the landowners derive financial benefit. The potential importance of sustainable use of wild fauna and flora as a complementary adjunct to conservation through protected areas must be recognised.

Careful strategic planning is required in order to ensure sustainable development which does not compromise the conservation of wildlife resources and land systems, or future options for their use. The Minister for Environment and Conservation is ultimately responsible for ensuring that the provisions of nature conservation legislation are enforced. DEC is responsible for resource conservation policy formulation and coordination, and implementing wildlife conservation management programs in the country. DEC is also responsible for ensuring that the PNG Government fulfils its obligations under international treaties relating to conservation and the environment. In order to achieve these in the long-term, it is essential that effective communication linkages are established between DEC and other relevant Central Government departments, the provincial administrations, scientific community and local communities. Workshops, such as this one, are very useful in bringing together the stakeholders.

PNG has been identified as a centre of major biological diversity. There have been numerous biological surveys conducted in PNG which have resulted in a body of information about the biological resources extant in the country. Nevertheless, the distribution and abundance of many taxa remain generally poorly understood. Furthermore, although there are some well-known examples of traditional and commercial use of wildlife in PNG (*eg* crocodiles, birdwing butterflies and certain birds of paradise), there is similarly a poor understanding of the full extent of wildlife use, particularly subsistence uses.

Resources currently available to DEC necessitate a strategic approach to developing a national program for the conservation and management of native fauna and flora in PNG. Research and management activities directed to quantifying the biological diversity of PNG should therefore be prioritised. Biodiversity surveys may be prioritised according to vegetation types that are known to be important habitats for native fauna and flora. In remote regions where extensive areas of undisturbed habitat remain, biodiversity inventories may not be as urgent as in areas where development has resulted in destruction and fragmentation of natural habitats. Alternatively, survey priorities can be determined according to whether the species is economically important or a concern exists for its conservation.

There are three primary pieces of legislation, administered by DEC, which relate to species management in PNG. These are:

- *Fauna (Protection and Control) Act*
- *International Trade (Fauna and Flora) Act*
- *Crocodile Trade (Protection) Act*

The *Fauna (Protection and Control) Act* provides for a list of nationally protected species, and the establishment of Sanctuaries, Protected Areas and Wildlife Management Areas. The *International Trade (Fauna and Flora) Act* enables PNG to implement its responsibilities as a Party to CITES. The *Crocodile Trade (Protection) Act* was enacted specifically to administer management controls on the crocodile industry. Two other pieces of legislation -the *Conservation Areas Act* and the *National Parks Act* -have applicability to species management only in certain areas.

The *Fauna (Protection and Control) Act* is the principal legal framework underpinning DEC's domestic policies and programs for the conservation, management and use of native wild fauna.

DEC is presently reviewing all its species management legislation and policies. The current legislation and policies have not been updated since the 1970s and, apart from being out-of-date, are deficient in many areas.

Consideration is being given to widening of the scope of the Fauna Protection Act to protect native flora. However, although there is merit in broadening the scope of the Act to apply to flora, there are cross-jurisdictional issues with the *Forestry Act* concerning the use of non-timber forest plants that must first be resolved. Similar jurisdictional confusion exists with regard to certain marine species. DEC's legal and policy advisers are currently working with the PNG Forest Authority and the National Fisheries Authority on these issues.

Nationally protected species, listed under the Fauna Protection Act, may be utilised for traditional purposes, but are effectively prohibited from commercial use. The only exception being the birdwing butterflies for which special provision was made to enable them to be traded commercially.

The present list of nationally protected species was compiled many years ago and it is now unclear what criteria were applied in formulating the list. The list of protected species does not have any meaningful relevance in the context of wildlife conservation in PNG, and may indeed have the potential to seriously constrain the application of effective conservation strategies that are based on commercial use.

DEC is proposing to review the current list of protected species with the objective of replacing it with lists of species which have more relevance, socially and culturally, to PNG.

I have recently written to the Provincial Governments about the legislative review, and have explained that one element of the review entails the abandoning of the current list of protected species, and the compilation of two new lists comprising:

- species for which there is a demonstrable conservation concern, and
- species of economic importance as export commodities or traditional use by indigenous communities.

In the spirit of the Organic Law, it is intended to approach the task of compiling these lists from the provincial level. By adopting this collaborative approach with the Provincial Governments, national lists of species will be developed that reflect provincial priorities and have relevance to the sustainable economic development of the Provinces.

Implicit in this approach is the recognition in legislation of species in need of specific management action to enhance their conservation prospects.

Different levels of protection should apply to the species on the two lists. Species such as birdwing butterflies which are currently protected under the Fauna Protection Act, but for which special provision has been made to allow commercial trade, might be more appropriately classified as taxa of economic importance and managed accordingly. Full legal protection should be reserved for taxa which are critically endangered. Action (or recovery) plans will need to be developed for endangered species, and that is why I am particularly interested in the ideas and outcomes of this workshop on tree kangaroos.

Provision will need to be made in the legislation for the lists to be dynamic and able to be amended readily in light of increased knowledge and understanding of the conservation status of wildlife resources in PNG, derived over time from surveys and inventories. Present activities within DEC, such as the BIORAP program, can be used to good effect in developing a scientific basis for the lists of species.

Changes to legislation and policy will also need to include provision for management plans for species which are of economic importance. All commercial harvesting of wild fauna or flora in PNG should be



subject to the approval of a documented program for the sustainable management of the species. This is particularly important for species listed under CITES. It is essential for PNG to be able to demonstrate to the international community that the export trade in particular species is sustainable. Failure to do so, may result in trade sanctions against PNG.

Regulations to the Fauna Protection Act will need to specify matters which should be considered when deciding whether to approve a proposal to harvest wild fauna or flora. The sort of matters which are appropriate for consideration are:

- the distribution of the species, and its national and regional status and abundance
- the harvest methods and likely effects of the harvest on the local population of the species
- the existence of other harvesting activities, locally and regionally, for the species
- the proposed nature and extent of trade, and
- the returns to landowners

The legislation will need to enable conditions of approval to be imposed, such as reporting requirements or a quota on the number of specimens which may be harvested. Furthermore the legislative provisions will need to include the ability to terminate an approved program if it becomes apparent that management is not complying with the approved regime.

Finally, the amendments to the Fauna Protection Act will need to address the keeping and exhibiting of live animals. The Act already provides the legal basis for regulating the capture and keeping of protected fauna, but does not specify the criteria for approval or the minimum standards necessary for keeping and exhibiting animals. Approval of requests to exhibit live animals is likely to require consideration of such matters as:

- the conservation status of the species
- the number and source of specimens
- access to qualified veterinary services
- the type of food and reliability of supply
- the enclosure construction (security and welfare of the exhibited specimens).

I like to take this opportunity to show my gratitude to these national and international agencies for organising and sponsoring this international workshop on tree kangaroos at University of Technology, Lae, Papua New Guinea. *They include the Conservation Breeding Specialist Group (SSC/IUCN), the Rainforest Habitat (University of Technology), National Museum and Art Gallery, for making the workshop happen, and acknowledging the support of the Adelaide, Melbourne, Taronga, Columbus and Perth Zoos, and Currumbin Sanctuary.*

**American Association of Zoos and Aquariums' Tree Kangaroo Species Survival Plan:  
Tree Kangaroo In-Situ Conservation Project  
PHVA Workshop Statement  
July 1998**

**Lisa Dabek and Will Betz**

Tree kangaroo conservation research in Papua New Guinea (PNG) is not simply a matter of funding an expedition and collecting data. Conservation is about people, and it is no more true than in PNG. Since over 90% of the land is privately owned by the local people, researchers must work directly with the landowners. In our project we spent the first year talking with local landowners to secure a field site. Working on one family's land is not a simple matter. The village consists of several family lines and consideration must be taken to involve other family lines in a project or else jealousy and resentment will arise. For our project site at Dendawang (on the Huon Peninsula near Teptep; home of *Dendrolagus matschiei*), we have been working on the land belonging to the family of Mambawe from Kewieng 1 village for three years. This year we are negotiating with the family Tapmambok, family of Mot and Sawang, from Kewieng 3 village to set up a field site on their land to extend our censusing and interviewing of hunters and elders. To set up a site it is first necessary to visit the bush with the landowner and hunting dogs to confirm that there are tree kangaroos in the area. Once this is confirmed, the bush must be surveyed to determine if the terrain is feasible for cutting transects and censusing.

We now have field sites at two locations in PNG – the Keweng area near Teptep on the Huon Peninsula for *D. matschiei*, and the village of Maimafu in the Crater Mountain Wildlife Management Area for *D. goodfellowi* and *D. dorianus*.

What we have accomplished so far:

1. Confirmed methodology for censusing tree kangaroos using Distance Sampling, a statistical method for estimating populations of hard-to-observe animals. We use dung samples as evidence of animals. This method can provide detailed information on populations of tree kangaroos within the study areas.
2. Interview methodology for documenting information from landowners, hunters, and elders regarding hunting practices and changes in tree kangaroo populations over time. This method provides general trends over larger geographical areas. Interviews are done in the villages surrounding the study site areas.
3. Involvement of students from the University of PNG (UPNG). Presently we have 3 students working on the project, Kasbeth Evei, Russel Terry, and Som. Kasbeth and Russel are working at Crater Mountain. Both of them grew up in the Eastern Highlands Province where Crater is located. Som is interviewing hunters, etc. in the Teptep region. He is from close to the area. Kasbeth will be graduating in 1998 and will join the project full-time to work at Crater Mountain. This is a real boost for the project since he is a direct link to the landowners and has promise as a field biologist. We just returned from the bush at Crater and the landowners are very pleased with Kasbeth and Russel. There is certainty of long term conservation research here; it is a stable research area in that it is managed by a landowner association and the Research and Conservation Foundation of PNG (RCF).
4. Will Betz is working on his Masters thesis on the population ecology of tree kangaroos and will complete his degree in 1999.
5. Maria Franke is following up Lisa Dabek's reproductive biology work on *D. matschiei* and is doing her Masters thesis research on the reproductive biology and behavior of *D. matschiei*, *D. goodfellowi*, *D. inustus* and *D. dorianus* at the home of Dr. Phillip Leahy in Zenag, PNG. The methodology being used

is fecal steroid assays and behavioral observations. Samples are also being collected for *D. goodfellowi* at the San Diego Zoo, coordinated by Valerie Thompson.

6. Study of food plants of tree kangaroos. Although tree kangaroos are considered to be generalists, no previous work has been done on the feeding ecology of the New Guinea species of tree kangaroos. We are collecting food plants specimens based on traditional knowledge (we have over 80 species for the Teptep, Huon Peninsula area) and are having these plants identified to the family, genus, or species level at The National Herbarium at Lae and at Kew Gardens in London. We are also collecting fecal samples for a study on diet; stomata patterns from undigested leaf cuticle in the feces can identify food plants and be used as confirmation of traditional knowledge. Dr. David Cristophel, a botanist from the University of Adelaide is collaborating on this project.
7. DNA analysis of tree kangaroos from fecal samples. We are collecting fresh tree kangaroo dung as part of our census to be analyzed to the species level as confirmation of tree kangaroo presence. We also hope to analyze these samples down to the individual level in order to document home range size in tree kangaroos and follow individual animals.
8. New methodology in 1998. Trailmaster trip cameras are being used this year to provide further confirmation of tree kangaroo presence, document other mammal species, and for some tree kangaroo species be used as a photo censusing method. Studies in other parts of the world have shown this method to be successful with hard to observe animals, e.g., tigers (R. Tilson, personal communication). Preliminary results are hopeful that this method is useful for PNG. Trip cameras could potentially be used in areas where radiocollaring is not feasible.
9. Conservation education is another facet of the project's work. Tree kangaroo posters funded by U.S. zoos and produced by Conservation International have been distributed in villages and schools in the areas that we have worked. Our hope is to distribute these posters to community schools nationwide along with surveys to be filled out by students and teachers. A sister school exchange between PNG and US (and hopefully Australian) students is being organized partially based on the model from RCF used in the Crater Mountain Area. We hope to collaborate with the teacher workshops run through Rainforest Habitat.

## **FUTURE WORK**

1. Other areas and/or species we are considering: lowland areas of Crater Mountain WMA for *D. spadix*; Lake Triste (SE of Wau) for *D. goodfellowi* and *D. dorianus*; Landslide Gap and Indagen (E. Huon Peninsula) for *D. matschiei*. Based upon a reconnaissance flight that we did in 1996, and from local landowner interviews we would like to organize a wilderness expedition using helicopters to unpopulated/unhunted sections of the largely unstudied Finisterre Range.
2. We would like to collaborate with other groups either by sharing our methodology or by having people work at our field sites. Dr. Dabek offers to be a coordinator and/or information source for field research. She is the Research Coordinator for the Tree Kangaroo Species Survival Plan (N. America) and Research and Conservation Director at the Roger Williams Park Zoo in Providence, Rhode Island, USA.
3. We would like to share any information about tree kangaroos with other researchers in PNG. This includes anecdotal information from researchers studying other subjects!
4. Would a field station be useful at the Dendawang research site (Huon Peninsula) for other scientists, and for visitors who wish to see tree kangaroo habitat? At least two U.S. zoos are interested in running adventure travel trips to PNG in association with our project.

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**Appendix I  
Tree Kangaroo Education Brochure**

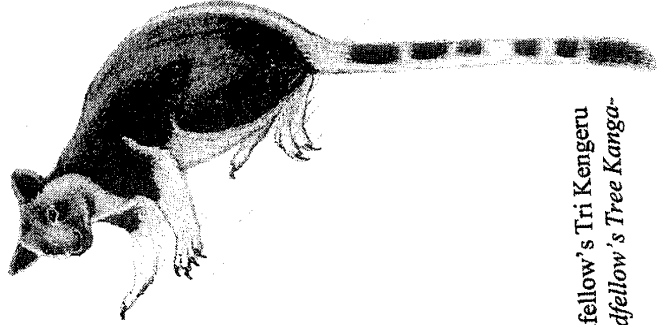




# Lukautim Ol Tri Kengeru



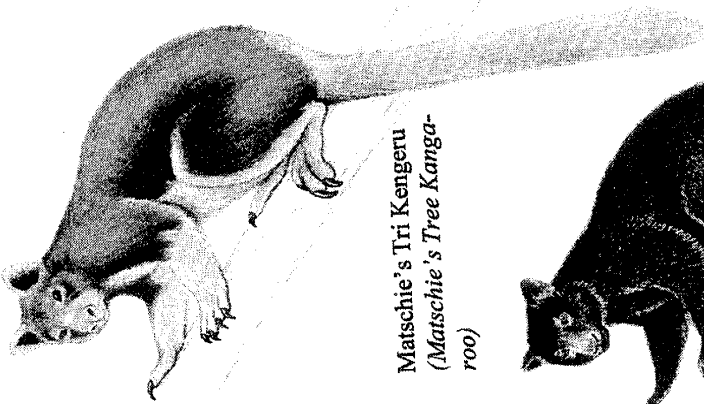
Doria's Tri Kengeru  
(*Doria's Tree Kangaroo*)



Goodfellow's Tri Kengeru  
(*Goodfellow's Tree Kangaroo*)



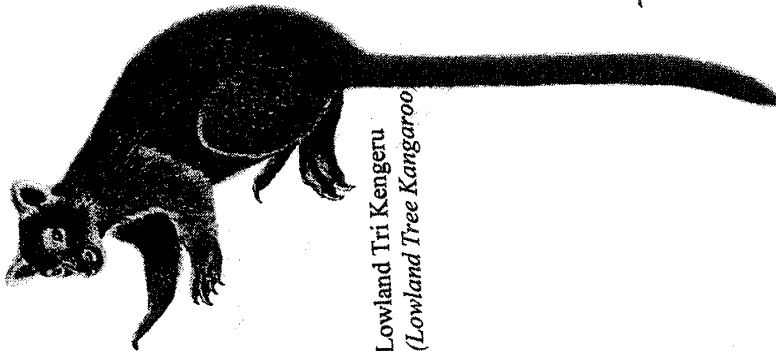
Grizzled Tri Kengeru  
(*Grizzled Tree Kangaroo*)



Matschie's Tri Kengeru  
(*Matschie's Tree Kangaroo*)



Scott's Tri Kengeru  
(*Scott's Tree Kangaroo*)



Lowland Tri Kengeru  
(*Lowland Tree Kangaroo*)

## Why should we protect tree kangaroos?

Your Papua New Guinea is like no other place on earth. It is a very special country and you are its caretaker.

It is one of the last places where large areas of rainforest remain. The forests of PNG contain many special animals that are found nowhere else on earth such as the Blue Bird of Paradise and Matschie's and Scott's Tree Kangaroos.

All animals and plants in the forest depend on each other for survival. The plants provide food and homes for the animals and in return the animals help the plants by pollinating their flowers, ridding them of pests and distributing their seeds so that new plants can grow in areas away from their parents.

If some plants or animals are lost to extinction and gone forever, then others which depended on them will also suffer and may themselves become extinct and so on. Therefore the extinction of one species can mean the loss of many.

The people who live in the forest depend on it for their survival as much as the animals. If the animals and plants of the forest disappear, the people will have nowhere left to live. This would be a disaster for the people of Papua New Guinea and the people of the world.

To prevent this, we must protect the forest and the animals in it. To do this means to only take from it as much as it can naturally replace.

So if we kill more tree kangaroos than can be replaced each year, their numbers will decline until they eventually become extinct. Once they are extinct they can never return.

This is the same if we destroy their forest faster than it can regrow. If all the tree kangaroos disappear then part of what makes Papua New Guinea unique will be lost forever.

But this doesn't have to happen and you can help prevent it! You can protect tree kangaroos and all the other animals and plants in the forest by ensuring you only take as much from the forest as can be naturally replaced. This means that the forest and the tree kangaroos in it, will live on for our children, grandchildren and future generations to enjoy. This is why you are the caretakers of the forest and of the future of Papua New Guinea.

## Bilong wonem bai yuni mas lukautim tri kengeru

Papua Niugini em ino olsem narapela ples long ples giraun. Em i wanpela spesel kantri. Em i wanpela laspela ples long ples giraun igat yet ol gupela bikpela hap bus ol i kolim "rainforest" istap yet. Ol bus bilong PNG igat plenti kainkain wel abus, pisin, binatang na diwai istap we yu no inap long painim long narapela hap long ples giraun. Dispela em ol abus olsem blu-pela kumul, Matschie's na Scott's Tri Kengeru.

Olgeta abus na diwai insait long bus i needim ol narapela long istap laip yet. Ol diwai i kamapim kaikai na haus bilong ol abus na ol abus i bekim dispela taim ol i halivim diwai long karim pikinini, klinim ol diwai long binatang nogut, na karim pikinini diwai igo longwei long mama diwai so em i ken gro na kamap gut.

Sapos sampela abus o diwai i pinis olgeta long ples giraun, ol narapela abus o diwai husat i needim ol long istap laip bai bungim bikpela hevi. Ol dispela abus o diwai bai iken bihainim ol tu na dai pinis. Olsem na pinis bilong wanpela samting bai iken kamapim arere bilong plenti ol narapela samting tu.

Ol manmeri husat isave stap insait long bikpela bus i save needim tri dispela bus long istap olsem tasol ol abus i needim bus long istap laip yet. Sapos ol dispela abus na diwai i dai olgeta, bai nogat narapela ples ken bilong istap long em. Dispela bai bagarapim sindaun bilong ol pipel bilong Papua Niugini na ol narapela ples long ples giraun tu.

Long stopim dispela hevi long kamap, yumi mas lukatim gut bus na ol kainkain abus we istap insait long em. Long kamapim strong dispela tingting, yumi mas rausim tasol inap samting long bus we bus em yet i inap long putim bek ken.

Dispela em i wankain tu long yumi bagarapim bus na ples bilong Tri Kengeru hariap moa long em i ken gro bek ken. Sapos olgeta Tri Kengeru i pinis, wanpela long ol samting i save mekim Papua Niugini igat nem bai lus olgeta.

Tasol dispela bai imas noken kamap. Taim yumi lukautim gut Tri Kengeru na ol narapela diwai na abus long bus na yumi rausim inap tasol long mak we bus em yet inap long bekim bek, ol dispela samting bai istap yet long longpela taim ikam long ol pikinini na pikinin bilong ol long lukim na hamamas.

Tri kengeru imas kaikai olsem yu kaikai, long stap gut. Tokim mipela long wanem samting yu ting ol i save kaikai. *(Like you, tree kangaroos need food to survive. Tell us what you think they eat)*

Ol tri kengeru imas igat ples bilong istap, bai ol istap gut olgeta taim. Yu save stap long haus. Ol tri kengeru i save stap long diwai. Ol man i save katim ol diwai igo daun long bus klostu long ples bilong yu o nogat? *(As well as food, tree kangaroos also need homes to survive. You live in a house. Tree kangaroos live in trees. Are trees ever cut down from the forest near your home?)*

Sapos ansa bilong yu emi yes, bilong wanem? Givim tupela as (If yes, give two reasons why)

1) \_\_\_\_\_

2) \_\_\_\_\_

<p>Yu o famili bilong yu ibin lukim wampela bilong dispela tri kengeru bilong yu or nogat? <i>(Have you or your family ever seen any of the tree kangaroos on the front of this paper in your area?)</i></p> <p>Pinisim dispela bokis tamblö long wanim kain kengeru yu gat. <i>(Complete the table below for the ones you've seen.)</i></p>	<p>Nem bilong em; <i>(Their names are)</i></p>	<p>Nem bilong tokples long tri kengeru: <i>(Local name)</i></p>	<p>Yu o famili bilong yu lukim hamas olgeta? <i>(How many have you or your family ever seen?)</i></p>	<p>Hamas bilong ol igat pikinini? <i>(How many of these had babies that you could see?)</i></p>	<p>Yu save lukim long wanem taim - monin, apinun or long bik nait? <i>(When do you usually see them?)</i></p>
<p><input type="checkbox"/> Doria's Tri Kengeru <i>(Doria's Tree Kangaroo)</i></p>					
<p><input type="checkbox"/> Matschie's Tri Kengeru <i>(Matschie's Tree Kangaroo)</i></p>					
<p><input type="checkbox"/> Goodfellow's Tri Kengeru <i>(Goodfellow's Tree Kangaroo)</i></p>					
<p><input type="checkbox"/> Scott's Tri Kengeru <i>(Scott's Tree Kangaroo)</i></p>					
<p><input type="checkbox"/> Grizzled Tri Kengeru <i>(Grizzled Tree Kangaroo)</i></p>					
<p><input type="checkbox"/> Lowland Tri Kengeru <i>(Lowland Tree Kangaroo)</i></p>					



Ol man i save painim (hantim) tri kengeru long ples bilong yu o nogat?  
(Are tree kangaroos ever hunted by people in your village?) \_\_\_\_\_

Sapos yes, hamas pela taim? (If yes, how often?)

Wanpela taim long 1-pela wik (Once a week )

Wanpela taim long 1-pela mun (Once a month)

Wanpela taim long 6-pela mun (Once every 6 months)

Wanpela taim long 1-pela yia (Once every year)

Taim ol man i kilim ol tri kengeru, ol i save yusim olsem wanem?  
(Once killed, what are the tree kangaroos used for?) \_\_\_\_\_

Plis, raitim daun tu sampela samting moa yu save long ol tri kengeru.  
(Please write down for us what else you know about tree kangaroos.) \_\_\_\_\_

Tenkyu long pinisim dispela askim. Halivim bilong yu bai i halivim ol tri kengeru long istap gut olgeta taim bilong yu, ol pikinini bilong yu na ol tumbuna bilong yu long lukim long bihain taim.  
(Thank you for completing this survey. Your help will help the tree kangaroos to survive for you, your children and your grandchildren to see in the future.)

Yu ken holim narapela hap pepa, tasol  
salim dispela pepa ikam bek long: **Rainforest Habitat**  
(Please keep the outside page but **Unitech, UDC Office,**  
but send this one to:) **Private Mail Bag**  
**LAE, Morobe Province, PNG**

Mipela bai traिम salim sampela fri posta bilong tri kengeru na ol arapela bikpela toktok long ol arapela abus bilong PNG na arapela ol kantri long dispela graun. (We will try to send you a free poster of tree kangaroos and other special

# Lukautim ol Tri Kengeru

Ol Tri Kengeru I save stap long Papua Niugini Irian Jaya na liklik hap bilong Australia tasol.

(Tree Kangaroos are only found in New Guinea and a very small part of Australia.)

Yumi no gat bikpela save long wokabout bilong ol long bus. Ol saintis bilong PNG na ovasis iwok long stadi long ol Tri Kengeru long bus bilong Papua Niugini na oli laikim yu long helpim ol long painim out moa long ol Tri Kengeru. Dipela emi sans bilong yu.

(Very little is known about them in the wild. Scientists from PNG and abroad are studying tree kangaroos in the wild in Papua New Guinea and would like your help in finding out more about them. This is your chance!)

Nem (Name): \_\_\_\_\_

Krismas (Age): \_\_\_\_\_ Man/meri (Sex): \_\_\_\_\_

Skul (School): \_\_\_\_\_

Liklik ples (Village): \_\_\_\_\_

Provins (Province): \_\_\_\_\_

Day (Day): \_\_\_\_\_ Mun (Month): \_\_\_\_\_ Yia (Year): \_\_\_\_\_

**CONSERVATION ASSESSMENT AND MANAGEMENT PLAN  
FOR THE TREE KANGAROOS OF PAPUA NEW GUINEA  
*and*  
POPULATION AND HABITAT VIABILITY ASSESSMENT FOR  
MATSCHIE'S TREE KANGAROO**

**Lae, Papua New Guinea  
31 August – 4 September 1998**

**Final Report**

**Appendix II  
Follow-up Report on  
Tenkile Working Group**





# **Scotts Tree kangaroo Expedition**

## **Report on Field Trip**

### **4-14<sup>th</sup> December 1998**

**Steve Hamilton**  
**Conservation Projects Officer**  
**Australian Conservation Training Institute (ACTI)**  
**Taronga Zoo**

#### **Background**

As an outcome of the Tree Kangaroo (TR) PHVA held in September 98, a field expedition to ascertain the status of the Tenkile was to be undertaken. Steve Hamilton was nominated by the Marsupial and Monotreme TAG co ordinator to participate as an Australian Representative in the initial expedition to the Torricelli Mountains in Saundau Province PNG.

Areas identified for investigation included the following:

- Potential for a Tenkile hunting moratorium
- Confirm and extend the current information on the known Tenkile population.
- Determine priority needs of villagers
- Identify appropriate community support programs
- Outline strategies for implementation of support program
- Determine nature and extent of Tenkile ownership dispute
- Assess captive animal and take samples
- Identification of a site for a captive program
- Identification of interim committee with responsibilities, actions and timeliness.

The role in the field team was to determine the logistical implications of a captive program under a range of scenarios.

1. Captive program in-situ
2. Captive program part in-situ part in other areas of PNG
3. Captive program wholly in other parts of PNG

Things to consider under these scenarios were:

- The views of the villagers on each scenario
- Views of the dominant churches in the area
- Views of DEC on each scenario
- Village and church views on requirements for successful reintroduction's of animals
- Logistics of transporting Animals
- Long term husbandry of collection - feeding and maintenance
- Potential for expansion
- Access to veterinary services
- Costs of establishment
- Existing facilities and their utilisation
- Management of a facility
- Potential for reintroduction of animals
- Potential as a field base for reintroduction
- Communications in country and overseas
- Other agencies operating in the area
- Roles other agencies could assist with

## **Outcomes**

The undertaking of this initial survey was to occur within 30 days of the September PHVA workshop. I arrived in PNG on the 4<sup>th</sup> December to assist preparations for the field expedition. On Sunday 6<sup>th</sup> December after many efforts to rectify a range of problems the decision was made to postpone the trip until early next year. The decision to postpone the field expedition was seen as vital to the long-term success of the project and improving the fragility of relations with DEC.

The team was unable to reach the field destination due to the following combination of problems:

1. AID helicopter, for transport to the site, was unavailable due to bureaucratic problems.
2. Heavy rainfall in the area of Lumi Village
3. Government department strikes in PNG affecting basic services including communication between PNG based team members
4. Problems with internal communications in DEC.

Only a few of the desired outcomes could be achieved without a visit to the site.

### **1. Department of Environment and Conservation**

Meetings with Lester Seri (DEC wildlife section) and Frank Antram (Environment Australia-wildlife population biologist, representative for Aus AID DEC strengthening project) revealed a high level of disinterest in the tree kangaroo project, but more specifically zoos involvement in the process. Neither of them were aware of the planned expedition - only Mick Raga, they advised, who also attended the PHVA, had any awareness of the project. Mick had been away from the office most of the preceding week and was not able to be contacted.

Although both Lester and Frank attended the recent ARAZPA workshop on PNG exhibit guidelines, it appears they are still refusing to acknowledge zoo capabilities and roles in conservation. Although it is vital that DEC play a key role in this process, progression without their involvement at the moment could lead to further damaging of relations between the international zoo community and DEC. Good communication of our activities through the Museum, Rainforest Habitat or Botanical Gardens to DEC may suffice at the moment.

The expected support from an Environment Australia's representative was not forthcoming. This was disappointing given the understanding various senior administrators within EA have of zoos (i.e. Anitra Wendon in the International Programs Office).

### ***Recommendation***

There may be a role for some domestic meetings with EA to firm up our position in PNG and EA and ensure that any future liaison with DEC are through the most appropriate channels and supported by EA.

### **2. Member for Lumi**

Meetings with Chris Talie at Parliament (Member from Lumi) who also attended the PHVA were very positive (despite the problems he had with organising the helicopter) this was largely due to communication problems within PNG. Chris is still very enthusiastic about assisting with and participating in the field trip.

### ***Recommendation***

A follow up letter be sent to Chris Talie expressing the continued plans and proposed date for the next expedition.

### 3. Tree Roo Hair Samples

Whilst at the Rainforest Habitat and in Port Moresby, hair samples were collected for phylogenetic work from:

- |                                   |                 |
|-----------------------------------|-----------------|
| 1. <i>D. dorianus notatus</i>     | RFH             |
| 2. <i>D. dorianus dorianus</i>    | PNG Museum      |
| 3. <i>D. dorianus dorianus</i>    | PNG Bot Gardens |
| 1. <i>D. spadix</i>               | PNG Bot Gardens |
| 6. <i>D. matschiei</i>            | RFH             |
| 1. <i>D. goodfellowi bergersi</i> | RFH             |

As the opportunity presented itself, hair samples from 4 long beaked echidnas and 1 short beaked echidna were also collected for phylogenetic work in the future (visually there appears quite some variation within these species).

Equipment for tissue sampling (ear punching) was left with the RFH vet for future use for when a sampling protocol is developed and should the Tenkile expedition take place.

Further hair samples will be obtained from animals held in Bulolo and at a latter date from animals bought in for sale at RFH. The samples will be sent to Bronwyn Houlden once export and import permits are obtained. The samples were collected under the supervision of the RFH vet and as part of their work with tree roos.

### *Recommendation*

Undertake liaison with a student at Macquarie University currently undertaking *Dendrolagus* phylogeny using genetics will be initiated most likely through Bronwyn Houlden or Sandy Ingleby of the Australian Museum

### 4. Keeper Training at RFH

A keeper training session for staff at RFH was held and discussions on how to implement a training program appropriate for the staff of RFH held with RFH vet and Peter Clark. This included the agreement to place a trainer keeper for a minimum of 3 months at RFH to work alongside keepers (5 of them). ACTI is progressing with ways to support this training attachment. Other forms of formal face to face short-term training courses are inappropriate at this stage for the staff's career development.

### 5. Tenkile Resources for next trip

ACTI compiled a set of 11 folders intended for distribution to schools in the Lumi area. These were also left with RFH. They contained laminated colour photocopies of the tree roo species and information from Flannery's Tree roo book of the species found in the Torricelli mountains and a selection of photocopied species accounts from the Mammals of new guinea recorded or likely to occur in the area. A copy of David Attenborough's bird of paradise video and Tim Flannery's Tenkile video were left at RFH for staff and the Tenkile expedition team as part of training education programs. A copy of Flannery's Mammals of New Guinea donated by the Australian Museum was also left with RFH.

### Other Tree Kangaroos

During the 5 days spent at RFH, two Matschie's tree roos were bought in for sale (2 of about 50 per year) due to facility and financial constraints an adult male was turned away, but a young female was acquired for the collection. Data about both animals was recorded by RFH.

## **6. PNG National Capital Botanical Gardens**

Meetings with Justin Tachenko (deputy administrator, National Capital District Commission) and the National Capital Botanical Gardens and Phil Spence (Botanist orchid research centre) revealed they have undertaken 2 expeditions to the Torricellis (one in July the other in October this year) to do with orchid collecting and involvement of the local community. Whilst there, they filmed a documentary through Pacific Visuals about the expedition. They also saw and filmed a Tenkile being eaten. It would seem most logical to be more closely co ordinating with the Botanical Gardens expeditions into the area for our own purposes. According to the participants of the trip, there was some ill feeling remaining in the villages borne from Tim Flannery's presence in the area and the subsequent Tenkile documentary that was made.

I feel that the success of the Tenkile project and future expeditions to the area will be hampered by this legacy and may only succeed if we work with existing developments within the area with the Botanical Gardens and not independently of these. Anecdotal information passed on to me through them was that the villages claimed there were still tree kangaroos in the area (species unknown) as they could see ample evidence of their presence by the lack of orchids on tree trunks due to the animals feeding on them, this is probably fairly reliable given that the Gardens team were there to collect orchids.

Justin's position in PNG is fairly high and influential with very good relations with the current government. His achievements at the Gardens and the broader Moresby beautification program are substantial and working with him would be very beneficial. Justin is also on the board of trustees for the Museum.

Justin also confirmed that NCDC would be taking over Moitaka from DEC and planning to develop the site as its existing wildlife sanctuary role. Justin confirmed Botanical Gardens membership in ARAZPA (though he couldn't remember the acronym) and appeared enthusiastic about collaboration in the development of this facility.

### ***Recommendation***

Given the work the Botanical Gardens have been undertaking in the region, close communication and liaison should be maintained in increased considering joint expeditions/work in the area. This is vital from the local community's perspective to ensure that the two groups are working together. I will be speaking with Phil Spence, head Botanist to try and co ordinate future work in the area with the Botanical Gardens. They have built up a good rapport with the community and ironed out a lot of ill feeling that was hanging around from previous biologists in the area. We will then have the added advantage of an influential government department and figurehead in support of the project.

I have explained our situation to them and passed on information about the Tenkile team. Any future expeditions planned by the Botanical Gardens will endeavour to involve the Tenkile Team

## **7. Potential Collaborators (other than those already stated) working in PNG that may assist in the Tenkile implementation Phase.**

The following organisations all potentially could have something to offer a program, stitching this together will take time and much co ordination from a PNG based officer.

- \*PNG Research and Conservation Foundation
- \*Village Development Trust
- \*The Nature Conservancy
- \*Wildlife Conservation Society
- \*Conservation International
- \*Australian Overseas Service Bureau
- UK VSO

US Peace Corps  
CUSO (Canadian volunteers)  
German Development Organisation  
\*PNG National Botanical Gardens  
\*National Capital District Commission  
\*Community Development Scheme  
\*Australian Youth Ambassadors Scheme

\* organisations that there is an existing relationship developed or developing with ACTI which may significantly ease the way for Tenkile specific work.

## **Captive Program Investigation**

### **1. Captive program in-situ**

In the Torricelli's, plans for a road through the area (according to Phil Spence of the Botanical Gardens) extending from Jayapura will surely seal the fate of the Tenkile, a captive program seems likely given the time constraints required for changing community attitudes and stabilising the wild population let alone being able to monitor it.

I fear the difficulties involved (both social and logistically) in establishing a captive population in the village will overwhelm the possibility of success ultimately rendering the captive work a failure (something that cannot be afforded in PNG as reputations are at stake for any future work). Given the current state of tree kangaroo husbandry and success in zoos around the world, maintaining a captive population *in situ* would require at least as much careful management as would the existing zoo populations. This would require the placement of someone in the village with the appropriate skills. Given the remoteness of the villages and the rivalries that appear to exist between clans over the tree roo, this would be problematic for the person who was based in the village to implement the program. It would require long term placement of staff to achieve results. Communications from this area would be difficult and place considerable strain on that staff member as well as the added daily difficulties in food provisioning etc.

The idea of training a landowner to do this seems ideal, but I do not see it as being achievable without significant supervision, even then, the pressures on that landowner from others in the area would likely be high. PNG society is based more on how much you can acquire to give away rather than our own on how much you can acquire for yourself. This leads to constant problems whether it be with money or possessions in a western system of work or management. The payment of one individual for any work would most likely cause unrest. Provision of community support alone, does not give the responsibility of looking after the captive animals to any individual ultimately leading to problems of accountability. I have seen similar problems in the Crater Mountain Wildlife Management Area, which has had 20 years of development and a whole team of staff supporting it. Any village-based activities must take into account all the issues and even then, it can be complicated. The time factor and estimated remaining population play a large role in taking this stance on a village facility.

There may be a possibility that an *in situ* captive program could be initiated on neutral ground with the church. This to me would seem the only option for stand-alone *in situ* work at present.

### ***Recommendation***

Given the increased cost in establishing a breeding facility in the village, and the lack of funds available at this stage a captive program solely in the village would be difficult. It may be more realistic to involve the landowners in educational programs and provide on going support to local schools in terms of educational resources that may lead to protection of the Tenkile. The possibility of having a field researcher based there



undertaking work on some aspect of the animal or social science would aid in spreading the word on the Tenkile's fate. There are a number of ways this could be achieved through various avenues of aid, volunteering, NGOs, churches and wildlife organisations.

## **2. Captive program part in-situ part in other areas of PNG**

In order to overcome many of the foreseeable and unforeseeable problems associated with establishing, financing and staffing and running an *in situ* program solely based in the village, it appears more realistic to establish a population at several captive facilities in PNG that have the existing capacity to accommodate the animals. Currently these could only be the Rainforest Habitat and Phillip Leahy's facility. The Botanical Gardens does not have the current commitment to maintaining captive populations required, but this could be changed, Moitaka wildlife sanctuary could not keep animals alive for very long and the PNG museum does not have the capacity to house animals at the current point in time and the Wau Ecology Institute would require the basing of a permanent experienced staff member there. Budgets for the museum have been greatly cut and are effecting their ability to feed the current tree kangaroos they have. The museum would require extensive construction if it were to house a captive tree roo population. The RFH and Phillip Leahy's have the benefit of having a secure location, room for expansion, existing infrastructure to deal with captive tree kangaroos and sufficient commitment from existing staff to maintain the animals.

Future options may include the dispersal of captive animals to the remaining organisations at a time in the future where they were able to accommodate them or were supported to develop the required facilities.

As an educational tool, some captive animals could be maintained in the village, but these animals would have to be seen as surplus and I am not sure that their full reproductive potential could be met in the village.

This would be due to factors such as:

- Village dogs
- Village children
- Irregularity of food supply (unless closely supervised)
- Village politics
- No access to veterinary assistance (unless provided at considerable expense)
- Costs of maintaining village facility

### ***Recommendation***

Alongside appropriate village development measures, that steps be put in place for the Tenkile to be established in captivity at both the RFH and Phillip Leahy's facilities with skills support provided by experienced tree kangaroo keepers. This should immediately be followed by attempts to slow the decline of the wild population through a more comprehensive program of the Integrated Conservation and development type to investigate protecting the unique endemic fauna of the Torricellis whilst addressing community needs. The captive animals would serve as a back up population should the combined declining factors prove to be irreversible.

Attempt to initiate educational programs throughout the Tenkile's range, utilising a few captive animals that may already exist within the villages. Substantial effort will be required to co ordinate and fund both of the above activities (see notes below on trust) establishing protected area management of the scope required to preserve areas of the Torricellis will require enlisting the help and support of large international bodies and PNG based NGO's.

### **3. Captive program wholly in other parts of PNG**

Covered in part by points above.

The RFH and Phillip Leahys have the advantage of having vets on site, RFH also has the university with some capacity to provide lab services. Both localities are not too remote to hamper travel and communications. It would be desirable that there was some form of a small captive component in the village, but this could not be relied on to produce a breeding outcome. Utilising a more common species in the village may be a possibility to test this scenario.

#### ***Recommendation***

In effect through necessity and feasibility, the captive population will be almost entirely wholly in other parts of PNG at the early stages, barring a few animals maintained in villages for educational purposes. The recommendation is as for point 2. This is not to say that a village based program is not possible, but my opinion is that unless it is given considerable financial support and adequate care is taken to address local social issues, it is doomed.

#### **Tree Roo Trust/Foundation**

In order that as many of the PHVA recommendations as possible (including village based programs) are implemented, Peter Clark and myself considered the potential of establishing a Tree Kangaroo Trust/foundation to provide the finances needed to for such work. Although focussing on TR's the trust could address broader issues as well using the TR's as a flagship. These issues would include environmental education, ecotourism, village development, alternative food sources and providing a central body for the dissemination of information and co ordination of activities to do with the PHVA issues. These would potentially be of great assistance in the Tenkiles instance. Although not necessarily directing all of these activities, the trust/ foundation would endeavour to bring together interested parties and provide an option for all interested in TR's to work with. This is probably the only way that lasting change can be effected on some of the major issues confronting tree kangaroo conservation in PNG and would provide an avenue for external support to be channeled and co ordinated into outcomes for conservation and the people of PNG.

The TRT would endeavour over time to address the majority of recommendations in the PHVA document. The draft details of such a trust are under development and will be circulated for comment and input to all interested parties.

#### **Conclusion**

The remainder of my time I spent looking for ways that the PHVA recommendations could be implemented and attending to business for ACTI programs in PNG. In my opinion, although working closely with DEC is necessary, they will not pave the road forward at this stage, this is especially evident given the attitude towards zoos.

As with most environmental/conservation activities in PNG it appears the way forward for change on the ground will probably lie with NGO type organisations working with DEC. The capacity for DEC to deal with anything other their existing programs now seems limited by resources and staff. There is real potential with a recent GEF grant to The Nature Conservancy to support the development of NGO's in the country and establish a PNG Conservation Trust Fund. This has been supported with 5 million as a sink fund to establish with a further 10 million available to be on a dollar for dollar matching program. I have initiated the first steps of contact with The Nature Conservancy and will be approaching them with Peter for assistance with the Tree kangaroo trust.

This trip reaffirmed my previous opinion of conservation challenges in PNG. My four years experience working with PNG have shown that to make progress in these areas you have to carefully hold its hand all

the way through. The problems currently faced by all PNG government departments, with budgetary cuts, have severely hampered the capabilities of all services. Hence, we are dealing with a problem beyond that of internal DEC complications, which seems chronic now in PNG. To give credit where due I do know that individuals work very hard to make things succeed but are working in a difficult system.

The way ahead will most likely lie with a population of Tenkile held in an environment where the animals needs can be met in PNG. Issues of village development and Wildlife Management Areas are long term programs and I fear will not be in place quickly enough to precede the extinction of the Tenkile. A start can be made though if there is someone to keep it moving every step of the way. This may involve generating interest from international wildlife organisations to oversee an *in situ* program in the Torricellis or alternatively Australian Zoos finding a way to fund a position based in PNG to begin the process of co ordinating such activities.

**CONSERVATION ASSESSMENT AND MANAGEMENT PLAN  
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**POPULATION AND HABITAT VIABILITY ASSESSMENT FOR  
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**Lae, Papua New Guinea  
31 August – 4 September 1998**

**Final Report**

**Appendix III  
IUCN Policy Statements**





# IUCN Policy Statement on Captive Breeding

Prepared by the SSC Captive Breeding Specialist Group \*

Approved by the 22nd Meeting of the IUCN Council, Gland Switzerland, 4 September 1987

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**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 species are reduced to critically low numbers, and thereafter need to be co-ordinated internationally according to sound biological principles, with a view to the maintaining or re-establishment of viable populations in the wild.

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## PROBLEM STATEMENT

IUCN data indicate that about three 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 lost 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 lost first, but a wide range of other forms are also at risk. Conservation over the long term will require management to reduce risk, including ex situ populations which could support and interact demographically and genetically with wild populations.

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## 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, *Oryx leucoryx*).

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## 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.

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## SUGGESTED PROTOCOL

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

**WHEN:** The vulnerability of small populations has been consistently underestimated. 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 efforts 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 programmed should not encourage commercial ventures or trade. Whenever possible, captive programmed should be carried out in parallel with field studies and conservation efforts aimed at the species in its natural environment.

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**Notes:**

Currently the \*Conservation Breeding Specialist Group and the

\*\* World Conservation Monitoring Centre

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# IUCN GUIDELINES FOR THE PLACEMENT OF CONFISCATED LIVE ANIMALS<sup>1</sup>

## **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<sup>1</sup>; 2) to discourage further illegal or irregular<sup>2</sup> 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 exist.

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.

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.

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<sup>1</sup> 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.



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, or 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"<sup>1</sup> 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 in 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 will 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 and 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: 1) 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 in 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.

**1) 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 re-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 conspecifics 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 overstressed that euthanasia may frequently be the most feasible option available for economic, conservation and humane reasons. In 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. In 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 been 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.

These 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:

- 1) 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 alternative 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).

# IUCN/SSC Guidelines For Re-Introductions

Prepared by the SSC Re-introduction Specialist Group \*

Approved by the 41st Meeting of the IUCN Council, Gland Switzerland, May 1995

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## INTRODUCTION

These policy guidelines have been drafted by the Re-introduction Specialist Group of the IUCN's Species Survival Commission (1), in response to the increasing occurrence of re-introduction projects worldwide, 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 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 translocations 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. It should be noted that re-introduction is always a very lengthy, complex and expensive process.

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

This document has been written to encompass the full range of plant and animal taxa and is therefore general. It will be regularly revised. Handbooks for re-introducing individual groups of animals and plants will be developed in future.

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## CONTEXT

The increasing number of re-introductions and translocations led to the establishment of the IUCN/SSC Species Survival Commission's Re-introduction Specialist Group. A priority of the Group has been to update IUCN's 1987 Position Statement on the Translocation of Living Organisms, in consultation with IUCN's other commissions.

It is important that the Guidelines are implemented in the context of IUCN's broader policies pertaining to biodiversity conservation and sustainable management of natural resources. The philosophy for environmental conservation and management of IUCN and other conservation bodies is stated in key documents such as "Caring for the Earth" and "Global Biodiversity Strategy" which cover the broad themes of the need for approaches with community involvement and participation in sustainable natural resource conservation, an overall enhanced quality of human life and the need to conserve and, where necessary, restore ecosystems. With regards to the latter, the re-introduction of a species is one specific instance of restoration where, in general, only this species is missing. Full restoration of an array of plant and animal species has rarely been tried to date.

Restoration of single species of plants and animals is becoming more frequent around the world. Some succeed, many fail. As this form of ecological management is increasingly common, it is a priority for the Species Survival Commission's Re-introduction Specialist Group to develop guidelines so that re-introductions are both justifiable and likely to succeed, and that the conservation world can learn from each

initiative, whether successful or not. It is hoped that these Guidelines, based on extensive review of case - histories and wide consultation across a range of disciplines will introduce more rigour into the concepts, design, feasibility and implementation of re-introductions despite the wide diversity of species and conditions involved.

Thus the priority has been to develop guidelines that are of direct, practical assistance to those planning, approving or carrying out re-introductions. The primary audience of these guidelines is, therefore, the practitioners (usually managers or scientists), rather than decision makers in governments. Guidelines directed towards the latter group would inevitably have to go into greater depth on legal and policy issues.

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## 1. DEFINITION OF TERMS

**"Re-introduction"**: an attempt to establish a species<sup>(2)</sup> in an area which was once part of its historical range, but from which it has been extirpated or become extinct <sup>(3)</sup> ("Re-establishment" is a synonym, but implies that the re-introduction has been successful).

**"Translocation"**: deliberate and mediated movement of wild individuals or populations from one part of their range to another.

**"Re-inforcement/Supplementation"**: addition of individuals to an existing population of conspecifics.

**"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. This is a feasible conservation tool only when there is no remaining area left within a species' historic range.

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## 2. AIMS AND OBJECTIVES OF RE-INTRODUCTION

### a. Aims:

The principle aim of any re-introduction should be to establish a viable, free-ranging population in the wild, of a species, subspecies or race, which has become globally or locally extinct, or extirpated, in the wild. It should be re-introduced within the species' former natural habitat and range and should require minimal long-term management.

### b. Objectives:

The objectives of a re-introduction may 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 and/or restore natural biodiversity; to provide long-term economic benefits to the local and/or national economy; to promote conservation awareness; or a combination of these.

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## 3. MULTIDISCIPLINARY APPROACH

A re-introduction requires a multidisciplinary approach involving a team of persons drawn from a variety of backgrounds. As well as government personnel, they may include persons from governmental natural resource management agencies; non-governmental organisations; 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.

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## **4. PRE-PROJECT ACTIVITIES**

### **4a. BIOLOGICAL**

#### **(i) Feasibility study and background research**

- An assessment should be made of the taxonomic status of individuals to be re-introduced. They should preferably be of the same subspecies or race 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 as to individuals' taxonomic status. 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, intraspecific variation and adaptations to local ecological conditions, social behaviour, group composition, home range size, shelter and food requirements, foraging and feeding behaviour, predators and diseases. For migratory species, studies should include the potential migratory areas. 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 species, if any, that has filled the void created by the loss of the species concerned, should be determined; an understanding of the effect the re-introduced species will have on the ecosystem is important for ascertaining the success of the re-introduced population.
- The build-up of the released population should be modelled 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 and type**

- Site should be within the historic range of the species. For an initial re-inforcement there should be few remnant wild individuals. For a re-introduction, there should be no remnant population to prevent disease spread, social disruption and introduction of alien genes. In some circumstances, a re-introduction or re-inforcement 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.
- 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 and only when a significant contribution to the conservation of the species will result.
- 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 foreseeable future. The possibility of natural habitat change since extirpation must be considered. Likewise, a change in the legal/ political or cultural environment since species extirpation needs to be ascertained and evaluated as a possible constraint. 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, or reduction to a sufficient level, 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 re-introduction is carried out.

#### **(v) Availability of suitable release stock**

- It is desirable that source animals come from wild populations. If there is a choice of wild populations to supply founder stock for translocation, the source population should ideally be closely related genetically to the original native stock and show similar ecological characteristics (morphology, physiology, behaviour, habitat preference) to the original sub-population.
- 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.
- 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.
- 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 solely as a means of disposing of surplus stock.
- Prospective release stock, including stock that is a gift between governments, 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 non-endemic or contagious pathogens with a potential impact on population levels, 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.

#### **(vi) Release of captive stock**

- Most species of mammal and birds rely heavily on individual experience and learning as juveniles for their survival; they should be given the opportunity to acquire the necessary information to

enable survival in the wild, through training in their captive environment; a captive bred individual's probability of survival should approximate that of a wild counterpart.

- Care should be taken to ensure that potentially dangerous captive bred animals (such as large carnivores or primates) are not so confident in the presence of humans that they might be a danger to local inhabitants and/or their livestock.

#### **4b. SOCIO-ECONOMIC AND LEGAL REQUIREMENTS**

- 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 impacts, costs and benefits of the re-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 or alteration 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 minimise 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 provincial, national and international legislation and regulations, and provision of new measures and required permits 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 or when a re-introduced population can expand into other states, provinces or territories.
- If the species poses potential risk to life or property, these risks should be minimised 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.

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### **5. PLANNING, PREPARATION AND RELEASE STAGES**

- Approval of relevant government agencies and land owners, and coordination with national and international conservation organizations.
- Construction of a multidisciplinary team with access to expert technical advice for all phases of the programme.
- 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.

Monitoring the health of individuals, as well as the survival, is important; intervention may be necessary if the situation proves unforeseeably favourable.

- Appropriate health and genetic screening of release stock, including stock that is a gift between governments. Health screening of closely related species in the 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 as required to ensure health of released stock throughout the programme. This is to include adequate quarantine arrangements, especially where founder stock travels far or crosses international boundaries to the release site.
  - 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.
  - Determination of release strategy (acclimatization of release stock to release area; behavioural 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 the 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.
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## **6. POST-RELEASE ACTIVITIES**

- Post release monitoring is required 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 behavioural studies of released stock must be undertaken.
- 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.

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**Footnotes:**

1. Guidelines for determining procedures for disposal of species confiscated in trade are being developed separately by IUCN.
  2. The taxonomic unit referred to throughout the document is species; it may be a lower taxonomic unit (e.g. subspecies or race) as long as it can be unambiguously defined.
  3. A taxon is extinct when there is no reasonable doubt that the last individual has died
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**The IUCN/SSC Re-introduction Specialist Group**

The IUCN/SSC Re-introduction Specialist Group (RSG) is a disciplinary group (as opposed to most SSC Specialist Groups which deal with single taxonomic groups), covering a wide range of plant and animal species. The RSG has an extensive international network, a re-introduction projects database and re-introduction library. The RSG publishes a bi-annual newsletter RE-INTRODUCTION NEWS.

If you are a re-introduction practitioner or interested in re-introductions please contact:

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**CONSERVATION ASSESSMENT AND MANAGEMENT PLAN  
FOR THE TREE KANGAROOS OF PAPUA NEW GUINEA**  
*and*  
**POPULATION AND HABITAT VIABILITY ASSESSMENT FOR  
MATSCHIE'S TREE KANGAROO**

**Lae, Papua New Guinea  
31 August – 4 September 1998**

**Final Report**

**Appendix IV  
VORTEX Technical Reference**





## VORTEX: A Computer Simulation Model for Population Viability Analysis

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### 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,



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.

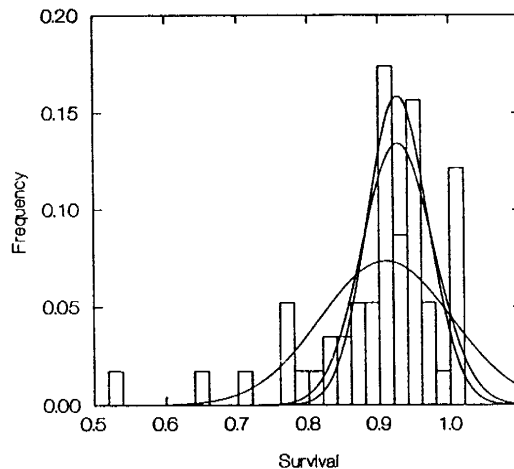
In this paper, I present the PVA program VORTEX and describe its structure, assumptions and capabilities. VORTEX is perhaps the most widely used PVA simulation program, and there are numerous examples of its application in Australia, the United States of America and elsewhere.

### 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 1980a, 1980b), 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 iterations.

(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

$$H_e = 1 - \sum(p_i^2),$$

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

$$f_{AB} = 0.5 \times (f_{MB} + f_{PB})$$

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  $f_{AA} = 0.5 \times (1 + F)$ . [See Ballou (1983) for a detailed description of this method for calculating inbreeding coefficients.]

(17) The survival of each animal is determined by comparing a random number to the survival probability for that animal. In the absence of inbreeding depression, the survival probability is given by the age and sex-specific survival rate for that year. If the Heterosis model of inbreeding depression is used and an individual is inbred, the survival probability is multiplied by  $e^{-bF}$  in which  $b$  is the number of lethal equivalents per haploid genome.

If the Recessive Lethals model is used, all offspring that are homozygous for a lethal allele are killed.

(18) The age of each animal is incremented by 1, and any animal exceeding the maximum age is killed.

(19) If more than one population is being modelled, migration among populations occurs stochastically with specified probabilities.

(20) If population harvest is to occur that year, the number of harvested individuals of each age and sex class are chosen at random from those available and removed. If the number to be removed do not exist for an age-sex class, VORTEX continues but reports that harvest was incomplete.

(21) Dead animals are removed from the computer memory to make space for future generations.

(22) If population supplementation is to occur in a particular year, new individuals of the specified age class are created. Each immigrant is assigned two unique alleles, one of which will be a recessive lethal in the Recessive Lethals model of inbreeding depression. Each immigrant is assumed to be genetically unrelated to all other individuals in the population.

(23) The population growth rate is calculated as the ratio of the population size in the current year to the previous year.

(24) If the population size ( $N$ ) exceeds the carrying capacity ( $K$ ) for that year, additional mortality is imposed across all age and sex classes. The probability of each animal dying during this carrying capacity truncation is set to  $(N-K)/N$ , so that the expected population size after the additional mortality is  $K$ .

(25) Summary statistics on population size and genetic variation are tallied and reported. A simulated population is determined to be extinct if one of the sexes has no representatives.

(26) Final population size and genetic variation are determined for the simulation.

(27) Summary statistics on population size, genetic variation, probability of extinction, and mean population growth rate, are calculated across iterations and printed out.

#### **Assumptions Underpinning VORTEX**

It is impossible to simulate the complete range of complex processes that can have an impact on wild populations. As a result there are necessarily a range of mathematical and biological assumptions that underpin any PVA program. Some of the more important assumptions in VORTEX include the following.

(1) Survival probabilities are density independent when population size is less than carrying capacity. Additional mortality imposed when the population exceeds  $K$  affects all age and sex classes equally.

(2) The relationship between changes in population size and genetic variability are examined for only one locus. Thus, potentially complex interactions between genes located on the same chromosome (linkage disequilibrium) are ignored. Such interactions are typically associated with genetic drift in very small populations, but it is unknown if, or how, they would affect population viability.

(3) All animals of reproductive age have an equal probability of breeding. This ignores the likelihood that some animals within a population may have a greater probability of breeding successfully, and breeding more often, than other individuals. If breeding is not at random among those in the breeding pool, then decay of genetic variation and inbreeding will occur more rapidly than in the model.

(4) The life-history attributes of a population (birth, death, migration, harvesting, supplementation) are modelled as a sequence of discrete and therefore seasonal events. However, such events are often continuous through time and the model ignores the possibility that they may be aseasonal or only partly seasonal.

(5) The genetic effects of inbreeding on a population are determined in VORTEX by using one of two possible models: the Recessive Lethals model and the Heterosis model. Both models have attributes likely to be typical of some populations, but these may vary within and between species (Brewer *et al.* 1990). Given this, it is probable that the impacts of inbreeding will fall between the effects of these two models. Inbreeding is assumed to depress only one component of fitness: first-year survival. Effects on reproduction could be incorporated into this component, but longer-term impacts such as increased disease susceptibility or decreased ability to adapt to environmental change are not modelled.

(6) The probabilities of reproduction and mortality are constant from the age of first breeding until an animal reaches the maximum longevity. This assumes that animals continue to breed until they die.

(7) A simulated catastrophe will have an effect on a population only in the year that the event occurs.

(8) Migration rates among populations are independent of age and sex.

(9) Complex, interspecies interactions are not modelled, except in that such community dynamics might contribute to random environmental variation in demographic parameters. For example, cyclical fluctuations caused by predator-prey interactions cannot be modelled by VORTEX.

## Discussion

### *Uses and Abuses of Simulation Modelling for PVA*

Computer simulation modelling is a tool that can allow crude estimation of the probability of population extinction, and the mean population size and amount of genetic diversity, from data on diverse interacting processes. These processes are too complex to be integrated intuitively and no analytic solutions presently, or are likely to soon, exist. PVA modelling focuses on the specifics of a population, considering the particular habitat, threats, trends, and time frame of interest, and can only be as good as the data and the assumptions input to the model (Lindenmayer *et al.* 1993). Some aspects of population dynamics are not modelled by VORTEX nor by any other program now available. In particular, models of single-species dynamics, such as VORTEX, are inappropriate for use on species whose fates are strongly determined by interactions with other species that are in turn undergoing complex (and perhaps synergistic) population dynamics. Moreover, VORTEX does not model many conceivable and perhaps important interactions among variables. For example, loss of habitat might cause secondary changes in reproduction, mortality, and migration rates, but ongoing trends in these parameters cannot be simulated with VORTEX. It is important to stress that PVA does not predict in general what will happen to a population; PVA forecasts the likely effects only of those factors incorporated into the model.

Yet, the use of even simplified computer models for PVA can provide more accurate predictions about population dynamics than the even more crude techniques available previously, such as calculation of expected population growth rates from life tables. For the purpose of estimating extinction probabilities, methods that assess only deterministic factors are almost certain to be inappropriate, because populations near extinction will commonly be so small that random processes dominate deterministic ones. The suggestion by Mace and Lande (1991) that population viability be assessed by the application of simple rules (e.g., a taxon be considered Endangered if the total effective population size is below 50 or the

total census size below 250) should be followed only if knowledge is insufficient to allow more accurate quantitative analysis. Moreover, such preliminary judgments, while often important in stimulating appropriate corrective measures, should signal, not obviate, the need for more extensive investigation and analysis of population processes, trends and threats.

Several good population simulation models are available for PVA. They differ in capabilities, assumptions and ease of application. The ease of application is related to the number of simplifying assumptions and inversely related to the flexibility and power of the model. It is unlikely that a single or even a few simulation models will be appropriate for all PVAs. The VORTEX program has some capabilities not found in many other population simulation programs, but is not as flexible as are some others (e.g., GAPPS; Harris *et al.* 1986). VORTEX is user-friendly and can be used by those with relatively little understanding of population biology and extinction processes, which is both an advantage and a disadvantage.

#### *Testing Simulation Models*

Because many population processes are stochastic, a PVA can never specify what will happen to a population. Rather, PVA can provide estimates of probability distributions describing possible fates of a population. The fate of a given population may happen to fall at the extreme tail of such a distribution even if the processes and probabilities are assessed precisely. Therefore, it will often be impossible to test empirically the accuracy of PVA results by monitoring of one or a few threatened populations of interest. Presumably, if a population followed a course that was well outside of the range of possibilities predicted by a model, that model could be rejected as inadequate. Often, however, the range of plausible fates generated by PVA is quite broad.

Simulation programs can be checked for internal consistency. For example, in the absence of inbreeding depression and other confounding effects, does the simulation model predict an average long-term growth rate similar to that determined from a life-table calculation? Beyond this, some confidence in the accuracy of a simulation model can be obtained by comparing observed fluctuations in population numbers to those generated by the model, thereby comparing a data set consisting of tens to hundreds of data points to the results of the model. For example, from 1938 to 1991, the wild population of whooping cranes had grown at a mean exponential rate,  $r$ , of 0.040, with annual fluctuations in the growth rate, SD ( $r$ ), of 0.141 (Mirande *et al.* 1993). Life-table analysis predicted an  $r$  of 0.052. Simulations using VORTEX predicted an  $r$  of 0.046 into the future, with a SD ( $r$ ) of 0.081. The lower growth rate projected by the stochastic model reflects the effects of inbreeding and perhaps imbalanced sex ratios among breeders in the simulation, factors that are not considered in deterministic life-table calculations. Moreover, life-table analyses use mean birth and death rates to calculate a single estimate of the population growth rate. When birth and death rates are fluctuating, it is more appropriate to average the population growth rates calculated separately from birth and death rates for each year. This mean growth rate would be lower than the growth rate estimated from mean life-table values.

When the simulation model was started with the 18 cranes present in 1938, it projected a population size in 1991 ( $N \pm SD = 151 \pm 123$ ) almost exactly the same as that observed ( $N = 146$ ). The large variation in population size across simulations, however, indicates that very different fates (including extinction) were almost equally likely. The model slightly underestimated the annual fluctuations in population growth [model SD ( $r$ ) = 0.112 v. actual SD ( $r$ ) = 0.141]. This may reflect a lack of full incorporation of all aspects of stochasticity into the model, or it may simply reflect the sampling error inherent in stochastic phenomena. Because the data input to the model necessarily derive from analysis of past trends, such retrospective analysis should be viewed as a check of consistency, not as proof that the model correctly describes current population dynamics. Providing another confir-

mation of consistency, both deterministic calculations and the simulation model project an over-wintering population of whooping cranes consisting of 12% juveniles (less than 1 year of age), while the observed frequency of juveniles at the wintering grounds in Texas has averaged 13%.

Convincing evidence of the accuracy, precision and usefulness of PVA simulation models would require comparison of model predictions to the distribution of fates of many replicate populations. Such a test probably cannot be conducted on any endangered species, but could and should be examined in experimental non-endangered populations. Once simulation models are determined to be sufficiently descriptive of population processes, they can guide management of threatened and endangered species (see above and Lindenmayer *et al.* 1993). The use of PVA modelling as a tool in an adaptive management framework (Clark *et al.* 1990) can lead to increasingly effective species recovery efforts as better data and better models allow more thorough analyses.

#### *Directions for Future Development of PVA Models*

The PVA simulation programs presently available model life histories as a series of discrete (seasonal) events, yet many species breed and die throughout much of the year. Continuous-time models would be more realistic and could be developed by simulating the time between life-history events as a random variable. Whether continuous-time models would significantly improve the precision of population viability estimates is unknown. Even more realistic models might treat some life-history events (e.g., gestation, lactation) as stages of specified duration, rather than as instantaneous events.

Most PVA simulation programs were designed to model long-lived, low fecundity (K-selected) species such as mammals, birds and reptiles. Relatively little work has been devoted to developing models for short-lived, high-fecundity (r-selected) species such as many amphibians and insects. Yet, the viability of populations of r-selected species may be highly affected by stochastic phenomena, and r-selected species may have much greater minimum viable populations than do most K-selected species. Assuring viability of K-selected species in a community may also afford adequate protection for r-selected species, however, because of the often greater habitat-area requirements of large vertebrates. Populations of r-selected species are probably less affected by intrinsic demographic stochasticity because large numbers of progeny will minimise random fluctuations, but they are more affected by environmental variations across space and time. PVA models designed for r-selected species would probably model fecundity as a continuous distribution, rather than as a completely specified discrete distribution of litter or clutch sizes; they might be based on life-history stages rather than time-increment ages; and they would require more detailed and accurate description of environmental fluctuations than might be required for modelling K-selected species.

The range of PVA computer simulation models becoming available is important because the different assumptions of the models provide capabilities for modelling diverse life histories. Because PVA models always simplify the life history of a species, and because the assumptions of no model are likely to match exactly our best understanding of the dynamics of a population of interest, it will often be valuable to conduct PVA modelling with several simulation programs and to compare the results. Moreover, no computer program can be guaranteed to be free of errors. There is a need for researchers to compare results from different PVA models when applied to the same analysis, to determine how the different assumptions affect conclusions and to cross-validate algorithms and computer code.

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## 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. (1980a). A simulation model for small populations of animals. *Creative Computing* 6, 116-21.
- Grier, J. W. (1980b). 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 penicillata* (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. Dobbs'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):

$$r = -0.001 \quad \lambda = 0.999 \quad RO = 0.997$$

Generation time for: females = 5·28 males = 5·28

*Note that the deterministic life-table calculations project approximately zero population growth for this population.*

Stable age distribution:	Age class	females	males
	0	0·119	0·119
	1	0·059	0·059
	2	0·053	0·053
	3	0·048	0·048
	4	0·043	0·043
	5	0·038	0·038
	6	0·034	0·034
	7	0·031	0·031
	8	0·028	0·028
	9	0·025	0·025
	10	0·022	0·022

Ratio of adult (>=2) males to adult (>=2) females: 1·000

Population 2:

*Input parameters for Population 2 were identical to those for Population 1.*

*Output would repeat this information from above.*

*Simulation results follow.*

Population1

Year 10

N[Extinct] = 0, P[E] = 0.000  
 N[Surviving] = 100, P[S] = 1.000  
 Population size = 4.36 (0.10 SE, 1.01 SD)  
 Expected heterozygosity = 0.880 (0.001 SE, 0.012 SD)  
 Observed heterozygosity = 1.000 (0.000 SE, 0.000 SD)  
 Number of extant alleles = 8.57 (0.15 SE, 1.50 SD)

*Population summaries given, as requested by user, at 10-year intervals.*

Year 100

N[Extinct] = 86, P[E] = 0.860  
 N[Surviving] = 14, P[S] = 0.140  
 Population size = 8.14 (1.27 SE, 4.74 SD)  
 Expected heterozygosity = 0.577 (0.035 SE, 0.130 SD)  
 Observed heterozygosity = 0.753 (0.071 SE, 0.266 SD)  
 Number of extant alleles = 3.14 (0.35 SE, 1.29 SD)

In 100 simulations of 100 years of Population1:

86 went extinct and 14 survived.

This gives a probability of extinction of 0.8600 (0.0347 SE),  
 or a probability of success of 0.1400 (0.0347 SE).

99 simulations went extinct at least once.

Median time to first extinction was 5 years.

Of those going extinct,

mean time to first extinction was 7.84 years (1.36 SE, 13.52 SD).

123 recolonisations occurred.

Mean time to recolonisation was 4.22 years (0.23 SE, 2.55 SD).

110 re-extinctions occurred.

Mean time to re-extinction was 54.05 years (2.81 SE, 29.52 SD).

Mean final population for successful cases was 8.14 (1.27 SE, 4.74 SD)

Age 1	Adults	Total	
0.14	3.86	4.00	Males
0.36	3.79	4.14	Females

During years of harvest and/or supplementation

mean growth rate (r) was 0.0889 (0.0121 SE, 0.4352 SD)

Without harvest/supplementation, prior to carrying capacity truncation,

mean growth rate (r) was -0.0267 (0.0026 SE, 0.2130 SD)

*Population growth in the simulation (r = -0.0267) was depressed relative to the projected growth rate calculated from the life table (r = -0.001) because of inbreeding depression and occasional lack of available mates.*

Note: 497 of 1000 harvests of males and 530 of 1000 harvests of females could not be completed because of insufficient animals.

Final expected heterozygosity was 0.5768 (0.0349 SE, 0.1305 SD)

Final observed heterozygosity was 0.7529 (0.0712 SE, 0.2664 SD)

Final number of alleles was 3.14 (0.35 SE, 1.29 SD)

Population2

*Similar results for Population 2, omitted from this Appendix, would follow.*

\*\*\*\*\* Metapopulation Summary \*\*\*\*\*

Year 10

N[Extinct] = 0, P[E] = 0.000  
 N[Surviving] = 100, P[S] = 1.000  
 Population size = 8.65 (0.16 SE, 1.59 SD)  
 Expected heterozygosity = 0.939 (0.000 SE, 0.004 SD)  
 Observed heterozygosity = 1.000 (0.000 SE, 0.000 SD)  
 Number of extant alleles = 16.92 (0.20 SE, 1.96 SD)

*Metapopulation summaries are given at 10-year intervals.*

Year 100

N[Extinct] = 79, P[E] = 0.790  
 N[Surviving] = 21, P[S] = 0.210  
 Population size = 10.38 (1.37 SE, 6.28 SD)  
 Expected heterozygosity = 0.600 (0.025 SE, 0.115 SD)  
 Observed heterozygosity = 0.701 (0.050 SE, 0.229 SD)  
 Number of extant alleles = 3.57 (0.30 SE, 1.36 SD)

In 100 simulations of 100 years of Metapopulation:

79 went extinct and 21 survived.

This gives a probability of extinction of 0.7900 (0.0407 SE),  
 or a probability of success of 0.2100 (0.0407 SE).

97 simulations went extinct at least once.

Median time to first extinction was 7 years.

Of those going extinct,

mean time to first extinction was 11.40 years (2.05 SE, 20.23 SD).

91 recolonisations occurred.

Mean time to recolonisation was 3.75 years (0.15 SE, 1.45 SD).

73 re-extinctions occurred.

Mean time to re-extinction was 76.15 years (1.06 SE, 9.05 SD).

Mean final population for successful cases was 10.38 (1.37 SE, 6.28 SD)

Age 1	Adults	Total	
0.48	4.71	5.19	Males
0.48	4.71	5.19	Females

During years of harvest and/or supplementation

mean growth rate ( $r$ ) was 0.0545 (0.0128 SE, 0.4711 SD)

Without harvest/supplementation, prior to carrying capacity truncation,

mean growth rate ( $r$ ) was -0.0314 (0.0021 SE, 0.1743 SD)

Final expected heterozygosity was 0.5997 (0.0251 SE, 0.1151 SD)

Final observed heterozygosity was 0.7009 (0.0499 SE, 0.2288 SD)

Final number of alleles was 3.57 (0.30 SE, 1.36 SD)

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