POPULATION AND HABITAT VIABILITY ANALYSIS WORKSHOP (PHVA)

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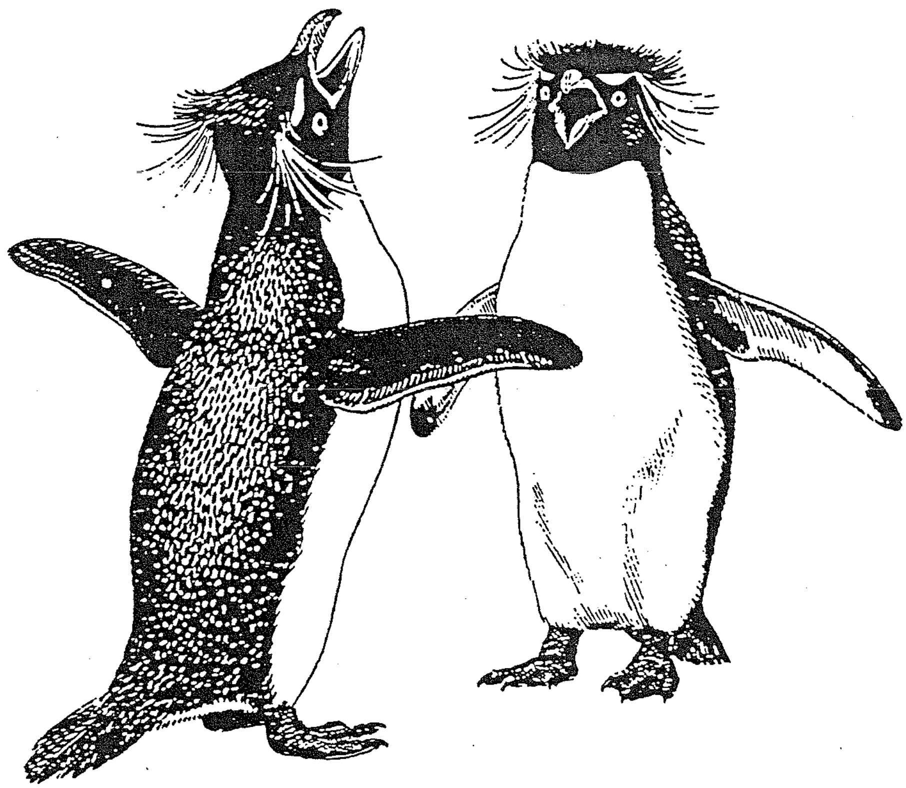

FOR NEW ZEALAND PENGUINS

HELD IN CHRISTCHURCH 20 - 21 AUGUST 1992

JOINT PROJECT BY:

- **ORANA PARK WILDLIFE TRUST**
- **DEPARTMENT OF CONSERVATION**
- **CAPTIVE BREEDING SPECIALIST GROUP (CBSG)**

SPONSOR - AORAKI CORPORATION LIMITED

NEW ZEALAND PENGUINS

POPULATION AND HABITAT VIABILITY ANALYSIS

WORKSHOP HELD IN CHRISTCHURCH

19-21 August 1992

FIRST DISCUSSION DRAFT

Compiled by U. S. Seal

NEW ZEALAND PENGUIN

PHVA WORKSHOP

27 August 1992

Dear Colleague,

The following document is the first discussion draft of results of the Population and Habitat Viability Analysis (PHVA) Workshop held in Christchurch, New Zealand, 19 - 21 August 1992. The purpose of this first draft is to provide Workshop participants and others contributing to the conservation and wildlife management in penguins in the New Zealand area, the opportunity of reviewing and refining the material discussed at this Workshop.

The organisers and participants of this Workshop together with this document compiler recognise the limitations of assembling such draft documents in a limited time frame but are encouraged to keep the momentum generated at the Workshop moving in a positive forward direction.

We respectively ask for your comments, questions, suggestions and criticisms of this draft and in particular ask you to provide, in written form, any additional data you feel may add substance and depth to the final product. It is recognised that the PHVA process is an on-going mechanism by which to continue the conservation evaluation of threatened TAXA and as such it is highly likely that additional workshops will be held to continue population modelling of various TAXA's of New Zealand penguins.

Please send all comments to PHVA Document Editors:

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OR

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Papanui
CHRISTCHURCH

We thank you in advance for your assistance in continuing the conservation assessment of New Zealand penguins and look forward to receiving your reply.

Acknowledgements

We wish to thank the Aoraki Corporated Limited for their forward thinking and support of this conference. Few corporations understand the need to prepare for changes in the natural world by planning for tomorrow. Aoraki Corporated has been generous financially and in addition, provided their facilities to make the Penguin Conservation Assessment and Management Plan possible. Orana Park, The New Zealand Department of Conservation, and CBSG planned this meeting. Individuals who were instrumental in the planning, were David Butler, Paul Garland, Sue Ellis-Joseph, Ian McLean and Ulysses Seal.

Many individuals who did not attend the workshop contributed to the final product by preparing taxon sheets, providing literature, and other support. This report was the work of all workshop attendees working collaboratively and reflects a team effort for the several species modelled. This discussion draft was not circulated to workshop participants prior to being published. It is intended to provide a summary of the preliminary models which were formulated as a reference for further analysis and data evaluation. It is anticipated that individual reports will be prepared for the respective species as further work is done.

Orana Park

A Joint Project of

NEW ZEALAND DEPARTMENT OF CONSERVATION

ORANA PARK WILDLIFE TRUST

CAPTIVE BREEDING SPECIALIST GROUP
IUCN/SPECIES SURVIVAL COMMISSION

The Aoraki Corporated Limited Supports Orana Park in Facilitating
This New Zealand Penguin CAMP/PVA Workshop

NEW ZEALAND PENGUINS

POPULATION AND HABITAT VIABILITY ANALYSIS

INITIAL WORKSHOP REPORT

FIRST DISCUSSION DRAFT

19-21 August 1992

Christchurch

SECTION 1

INTRODUCTION

AGENDA

POPULATION AND HABITAT VIABILITY ANALYSIS WORKSHOP

FOR NEW ZEALAND PENGUINS

PHVA

Wednesday, 19 August 1992

AFTERNOON 12.30 - 17.00

I. Introduction of PHVA Workshops - **Seal**

II. Problems of goals of the PHVA Workshop - **Seal**

III. Small population biology overview - **Seal**
- Demographic, environmental, and catastrophic effects on persistence of small populations.
- Genetics and Persistence of small populations
- VORTEX

IV. Overview of New Zealand Penguin Taxa including:
Life history patterns, census and population data, demographics (e.g. fecundity and mortality), disease problems and habitat utilisation.
- Rockhoppers - **Cunningham**
- Fiordland Crested - **McQueen**
- Yellow-eyed -**Darby**
- Little Blue - **Challis**
- Erect-crested - **Cunningham**
- Snares crested - **Tennison**

V. Introductory run with VORTEX

VI. Discussion of initial VORTEX results.

EVENING: 19.30 - 21.00 (At the Airport Gateway Motor Lodge)

VII. Establishment, overview, purpose, direction of working groups etc. - **Seal**

Thursday, 20 August 1992

MORNING : 8.30 - 12.00

I. Review of day 2 Minutes

II. Working groups convene, start refining model values, start working on reports.

III. Working group reports.

AFTERNOON 12.30 - 15.00

IV. Further working sessions and VORTEX simulations.

EVENING 19.30 - 21.00 (At Aoraki Corporation if required)

Friday, 21 August 1992

MORNING : 8.30 - 12.00

I. Working group sessions, refinement of reports and VORTEX simulations.

II. Working group reports.

III. Presentation of results from simulations and analyses - **Seal**

IV. Discussion of areas for future research.

V. Identification of conservation priorities and schedule of actions. Identification of major policy, politcal and financial constraints and effects on biological scenarios.

AFTERNOON ; 12.30 - 15.00

VI. Review of draft working group reports. Consensus language on the summary and recommendations. Note any items that are dependent on further date, analysis, and simulations to be completed after the workshop.

VII. Distribute final draft or working group reports for PHVA.

VIII. Close

PHVA Workshops

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

Relevant information includes data on (1) age of first reproduction for males and females, (2) inter-birth interval in the wild population, (3) neonatal and first year mortality, (4) sex ratio at hatching or fledging, (5) juvenile survival to the age of first reproduction, (6) adult sex ratio, (7) breeding strategy - monogamous or polygynous in a season, (8) adult mortality (by sex if available), (9) population size, (10) habitat carrying capacity and possible changes through time, (11) environmental variables influencing either reproduction or mortality, (12) potential catastrophic events and their frequency and possible severity in terms of effects upon reproduction or mortality in the year of occurrence, and (13) dispersal and movement of animals between breeeeding groups.

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

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

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

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

(2) the need for molecular taxonomic, genetic heterozygosity, and parentage studies,

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

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

(5) the potential uses of reproductive technology for the conservation of the species whether through assisted reproduction or genome banking,

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

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

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

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

NEW ZEALAND PENGUINS

POPULATION AND HABITAT VIABILITY ANALYSIS

INITIAL WORKSHOP REPORT

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Christchurch

SECTION 2

PENGUIN CAMP SUMMARY AND TABLES

PENGUIN CAMP EXECUTIVE SUMMARY

There are several natural and known perturbations that threaten penguins and call attention to the need for more intensive protection and management of these species in the wild. Penguins are vulnerable to a number of threats in both their marine and terrestrial habitats. Large size, flightlessness, tameness, and high site fidelity make penguins particularly negatively affected by habitat loss, marine perturbations, pollution, predators, and commerical fisheries.

Penguins are long lived, have delayed maturity, lay small clutches, have a restricted foraging area when they are feeding chicks, and spend considerable time at the sea air interface where pollutants such as petroleum, plastics, heavy metals and other chemicals get concentrated. These natural history traits of penguins make them more vulnerable than many seabirds that can fly and avoid natural marine alterations such as climate change or variability in marine systems associated with EL Nino Southern Oscillation (ENSO) events.
In this document, Penguins are reviewed on a taxon-by-taxon basis to assess their vulerability to extinction and to recommend conservation actions to improve the viability of their populations. The recommendations contained in the Penguin Conservation Assessment and Management Plan are based only on conservation criteria; adjustments for political and other constraints will be the responsibility of regional programs. The Penguin CAMP examined 17 species and 24 distinct taxa (forms, subspecies, or species if no subspecies are contained therein).

Where taxa occurred in two or more geographic regions, separate assessments and recommendations were made for each region. Eleven of the 26 taxa (45%) are assigned to one of three categories of threat, based on Mace-Lande criteria:

Critical	0
Endangered	3
Vulnerable	8

The three Endangered taxa were: *Eudyptes pachyrhychus* (Fiordland); *Megadyptes antipodes* (Yellow-eyed); and *Spheniscus humboldti* (Peruvian or Humboldt). 15 taxa were assigned to the Safe category, according to Mace-Lande criteria. Two forms of E. minor were not assigned to Mace-Lande categories (listed as Unknown) because of insufficient data.

16 of the 24 taxa (67%) were recommended for Population and Habitat Viability Assessment workshops. 11 of the 24 taxa (45%) are recommended for more intensive *in situ* management.

All 24 taxa are recommended for research:

13 taxa (54%) - Taxonomic research
21 taxa (87%) - Survey research
11 taxa (45%) - Other research
1 taxa (4%) - Husbandry research

More surveys are needed to better determine populations sizes and trends. Taxonomic work will better delineate subpopulations and evolutionarily active areas. The loss of penguin breeding habitat requires that habitat restoration efforts proceed and that attempts are made to reduce the effects of petroleum pollution, human disturbance, and commercial fisheries on penguin populations. The costs to proect penguins in the wild is much less than captivity and efforts for zoos to support conservation efforts in the wild should be given high priority.

Nine of the 24 Penguin taxa (37%) are recommended for one of four levels of captive programs (based in part on Mace-Lande criteria):

90/100 I	0
90/100 II	1
Nucleus I	1
Nucleus II	7
Pending PHVA findings	9

Five taxa were not recommended for captive programs.

Captive management should concentrate on managing Peruvian penguins so that they are self-sustaining and that no additional birds are removed from the wild. It was recommended that captive programs for Magellanic (*Spheniscus magellanicus*) penguin be eliminated because the space could be better used for Peruvian penguins (*S. humboldti*). The African penguin (*S. demersus*) should also be intensively managed because of the potential conservation need. Other penguin species presently in captivity should be managed as Nucleus II as their populations are not currently threatened in the wild.

SUMMARY OF PENGUIN CAMP WORKSHOP RESULTS.

A great deal of available data on distribution and abundance of Penguin species had been gathered and summarized in preparation for the meeting. During the workshop, each taxa was discussed individually, first by four working groups each focusing on one region or taxonomic group (Antarctic spp., *Eudyptes* spp., *Eudyptula* spp. and *Megadyptes*, *Spheniscus* spp. and *Aptenodytes patagonicus*) then by the assembled congress. Where sub-species occurred in two or more geographic units, each working group considered the status of that taxon within each geographic area.

All Penguin taxa were evaluated on a taxon-by-taxon basis in terms of their status and prospects in the wild to assign priorities for conservation action or information gathering activities. The workshop participants applied the proposals by Mace and Lande (1991) for the redefinition of the IUCN Red Data Categories (Section 4). The Mace-Lande scheme assesses threats in terms of a likelihood of extinction within a specified period of time (Table 1). The system defines three categories for threatened taxa:

Critical 50% probability of extinction within five years or two generations, whichever is longer.

Endangered 20% probability of extinction within 20 years or ten generations, whichever is longer.

Vulnerable 10% probability of extinction within 100 years.

Definitions of these categories and assessment of threat are based on population viability theory. A comparison of Mace-Lande and IUCN classification results for Penguins is presented in Table 1. A total of eight taxa were assigned as threatened in comparison with the three taxa listed as threatened in the 1990 Red List of Threatened Animals (IUCN, 1990). Five taxa assigned to Mace-Lande categories of threat are not listed in the 1990 IUCN Red List of Threatened Animals.

Table 1. Threatened Penguins - comparison of Mace-Lande and IUCN classification results.

IUCN / MACE-LANDE	END	VUL	RARE	INDET	K	NOT	TOTAL
Critical	0	0	0	0	0	0	0
Endangered	0	1	0	0	1	1	3
Vulnerable	0	0	0	0	1	6	7
TOTAL	0	1	0	0	2	7	10

Table 2. Management and research recommendations made for Penguins in relation to their category of threat assignment.

MACE-LANDE	PHVA	WILD MGMT	CAP PRGMS	NO CAP RECOMM	RESEARCH
Critical	0	0	0	0	0
Endangered	3	3	1	0	3
Vulnerable	7	5	1	2	7
Safe	4	3	7	1	11
Unknown	3	0	0	2	3
Pending PHVA	-	3	4	3	0
TOTAL	17	14	13	8	24

For taxa placed in a category of threat, recommendations were generated for the kinds of intensive action and information-gathering necessary, both in terms of wild and captive management. These recommendations, summarized in Table 2, were: Population and Habitat Viability Assessment workshops, more intensive in-situ management, more taxonomic research, more survey work, captive programs, and other kinds of research. The PHVA workshops provide a means of assembling available detailed biological information on the respective taxa, evaluating the threats to their habitat, development of management scenarios with immediate and 100-year time scales, and the formulation of adaptive management plans with the aid of simulation models. These workshops are conducted in the range countries of the respective taxa, at the invitation of and in collaboration with the wildlife agencies responsible for the taxa's management. In many cases, workshop participants felt that recommendations for conservation action could not be made prior to holding a PHVA workshop; in those cases, recommendations are listed as "pending PHVA."

CONSERVATION ASSESSMENT AND MANAGEMENT PLAN (CAMP) SPREADSHEET CATEGORIES (11 August 1992)

The Conservation Assessment and Management Plan (CAMP) spreadsheet is a working document that provides information that can be used to assess the degree of threat and recommend conservation action.

The first part of the spreadsheet summarizes information on the status of the wild and captive populations of each taxon. It contains taonomic, distributional, and demographic information useful in determining which taxa are under greatest threat of extinction. This information can be used to identify priorities for intensive management action for taxa.

TAXON

SCIENTIFIC NAME: Scientific names of extant taxa: genus, species, subspecies.

WILD POPULATION

BREEDING RANGE: Geographical area where a species and its subspecies occur.

EST # BREEDING PAIRS: Estimated numbers of breeding pairs in the wild. If specific numbers are unavailable, estimate the general range of the population size.

OF SUB-POPS: Number of populations within the taxonomic unit. Ideally, the number of populations is described in terms of boundary conditions as delineated by Mace-Lande (see attached information) and indicates the degree of fragmentation.

TREND: Indicates whether the natural trend of the species/subspecies/population is currently (over the past 3 generations) increasing (I), decreasing (D), or stable (S). Note that trends should NOT reflect supplimentation of wild populations. A + or - may be indicated to indicate a rapid or slow rate of change, respectively.

AREA: A quantification of a species' geographic distribution.

W = Widespread distribution; more than 1 biogeographic region

R = Regional distribution; 1 biogeographic region

r = Restricted distribution to single island group

M/L STS: Status according to Mace/Lande criteria (see attached explanation).

C = Critical

E = Endangered

V = Vulnerable

S= Safe

THREATS: Immediate or predicted events that are or may cause significant population declines.

A = Aircraft
C = Climate
D = Disease
F = Fishing
G = Genetic problems
H = Hunting for food or other purposes
Hyb = Hybridization
I = Human interference or disturbance
L = Loss of habitat
M = Marine perturbations, including ENSO and other shifts
P = Predation
Ps= Pesticides
Pl= Powerlines
Po= Poisoning
Pu= Pollution
S = Catastrophic events
  f: fire
  h: hurricane
T = Trade for the life animal market

PHVA: Is a Population and Habitat Viability Assessment Workshop recommended? Yes or No? NOTE**A detailed model of a species' biology is frequently not needed to make sound management decisions.

WILD MGMT: Should wild management be more intensive than is currently occurring? Yes or No?

RESEARCH

TAX/SRV/HUSB/OTHER: Is there a need for taxonomic clarification investions (TAX)? MORE quantitative survey work (SRV)? MORE husbandry research to permit success in captivity (HUSB)? Are there specific suggestions for research (OTHER)?

For example:
Hyb = research on extent and status of hybrid zone

CAPTIVE PROGRAM

NUM: Numbers in captivity.

CAP REC: Recommendation for level of captive program, defined by its genetic an demographic objectives and hence the target population requred to achieve these objectives.

90/100 I: Population sufficient to preserve 90% of the genetic diversity of a population for 100 years. Program should be developed within 5 years. This is an emergency program (like Whooping Crane program) based on the present availabilty of genetically diverse founders.

90/100 II: Same as "90/100 I", except program should be developed within 5 to 10 years. This is still an emergency program but designed in a less paniced state.

NUC I: Nucleus I. A cative nucleus of 50-100 individuals organized to always represent 98% of the wild gene pool. This program may require periodic importation of individuals from the wild population to maintain this high level of genetic diversity in a limited captive population. View this type of program as protection against potential extripation of wild populations.

NUC II: Nucleus II. A captive nucleus of 25-100 individuals for taxa of interest (not necessarily of conservation concern). The captive nucleus should be managed as well as possible.

E: Eliminate from captivity. The captive population should be managed to extinction.

NONE: No recommendation

PENGUIN CONSERVATION ASSESSMENT AND MANAGEMENT PLAN SPREADSHEET

TAXON			WILD POPULATION							RECS			CAP PRGMS	
	SCIENTIFIC NAME	SUBSPECIES OR (COMMON NAME)	BREEDING RANGE	EST # BREEDING PAIRS	SUB POP	TRND	AREA	M-L	THRTS	PHVA	WILD MGMT	TAX/ SRV/ HUSB /OTR	NUM	CAP REC
APTENODYTES	PATAGONICUS	(KING)	SO.OCEAN ISL-MACQUAR, FALKLD,STATEN,S.GRGIA,P. EDWARD,CROZET,MACQUARIE, KERGUELEN,HEARD,MARION ISL	>1,000,000	3?	I-	W	S	P,Pu,A	NO	YES	S	262	NUC II
APTENODYTES	FORSTERI	(EMPEROR)	ROSS SEA TO ANTARCTIC PENINSULA	195,000	?	S?	W	S	Pu,A, I	NO	NO	S	57	NUC II
PYGOSCELIS	PAPUA	(GENTOO)	SO.OCEAN ISL-P.EDWARD, CROZET,KERGUEL,HEARD, MACQUAR,STATN,FALKLD, S.GRGIA,S.ORKNY,S.SHETLD + ANTARCT. PENINSULA	314,000	?	I?	W	S	Pu,P	NO	NO	S,T	283	NUC II
PYGOSCELIS	ADELIAE	(ADELIE)	COASTAL ANTARCT+SO.OCEAN ISLS.SHETLD,S.ORKNY,BOUVET BALLENY,SCOTT,PETER ISL	>2,400,000	?	I	W	S	Pu,A, I	NO	NO	S	221	NUC II
PYGOSCELIS	ANTARCTICA	(CHINSTRAP)	SO.OCEAN ISLS-S.SANDWCH, S.ORKNY,S.SHETLD,S.GRGIA,B OUVET,BALLENY,PETER + ANTARC.PENINSULA	>7,400,000	?	I	W	S	Pu,F	NO	NO	S	161	NUC II
EUDYPTES	PACHYRHYNCHUS	(FIORDLAND)	SOUTH ISLAND OF NEW ZEALAND+STEWART ISL	<1,000	0	D	R	E	Pu,P, F	YES	YES	S,T	0	PEND
EUDYPTES	ROBUSTUS	(SNARES ISLAND)	SNARES ISLAND	23,000	1	S/I	r	V?	Pu,F	YES	NO	S,T	0	PEND
EUDYPTES	SCLATERI	(ERECT CRESTED)	NEW ZEALND ISLS- BOUNTY,ANTIPODES	300,000Antip 115,000Bount	1	D?	R	V?	Pu,F, A	YES	NO	S	0	PEND
EUDYPTES	CHRYSOCOME	FILHOLI (ROCKHOPPER)	MACQUAR,AUCKLD,CAMPBLL, BOUNTY,ANTIPDES,MCDONALD,C ROZET,P.EDWARD,MARION, KERGUEL,HEARD	826,000 (see Taxon sheet for geog. breakdown)	14	D locally S overall	W	V?	Pu,F, M	YES	YES	S	0	PEND

TAXON			WILD POPULATION							RECS			CAP PRGMS	
SCIENTIFIC NAME		SUBSPECIES OR (COMMON NAME)	BREEDING RANGE	EST # BREEDING PAIRS	SUB POP	TRND	AREA	M-L	THRTS	PHVA	WILD MGMT	TAX/ SRV/ HUSB /OTR	NUM	CAP REC
EUDYPTES	CHRYSOCOME	CHRYSOCOME (ROCKHOPPER)	ISL OFF TIERRA DEL FUEGO+STA.CRUZ,FLKLAND ISLS	2,500,000	?	S	-	S	L,Pu, F,M	NO	YES.	S	351	PEND
EUDYPTES	CHRYSOCOME	MOSELEYI (ROCKHOPPER)	TRISTAN DA CUNHA, ST. PAUL, AMSTERDAM,GOUGH ISL	>55,000	4	?	-	UNK	F,L,P Pu	YES?	PEND	T	14	PEND
EUDYPTES	SCHLEGELI	(ROYAL)	MACQUARIE,BISHOP+CLERK ISLANDS	850,000	1	S/I	r	S	Pu,F,A, P	YES	YES	T	0	PEND
EUDYPTES	CHRYSOLOPHUS	(MACARONI)	SO.OCEAN ISLS-FALKLD, S.GRGIA,S.SANDWCH,S.ORKNY, S.SHETLD,BOUVET,P.EDWARD, MARION,CROZET,KERGUEL, HEARD, ANTARC PEN, SO.CHILE	11,800,000	?	S	W	S	Pu,F	NO	NO	T?,S	131	NUC II
MEGADYPTES	ANTIPODES	(YELLOW-EYED)	NEW ZEAL-EAST+SO.COASTS SO.ISL.S OF OMARU+BANKS PENINSULA, STEWART,AUCKLAND, & CAMPBELL IS	1,420-1,670	3	D	R	E mnld+ Stew Is V Auck Camp	Pu,P,L, M,F	YES	YES	T,O	1	PEND
EUDYPTULA	MINOR	NOVAEHOLLANDIAE (BLUE)	SOUTHERN AUSTRAL-PERTH TO NSW,TASMANIA,SOUTHERN AUSTRALIAN ISLS	< 100,000	2	D	R	S?	P,M, Pu,L,F	YES	YES, pend PHVA	T,S, O	129	NUC II
EUDYPTULA	MINOR	MINOR (BLUE)	W.COAST OF SO.ISL. NEW ZEAL, S.COAST+E.COAST NORTH TO OMARU, STEWART ISL+OUTLIERS	15,000-20,000 ?	0	D mnld S isls	-	S? mnld S isls	P,M,Pu, L,F	YES	YES, pend PHVA	T,S, O	0	NONE

TAXON			WILD POPULATION							RECS			CAP PRGMS	
SCIENTIFIC NAME		SUBSPECIES OR (COMMON NAME)	BREEDING RANGE	EST # BREEDING PAIRS	SUB POP	TRND	AREA	M-L	THRTS	PHVA	WILD MGMT	TAX/ SRV/ HUSB /OTR	NUM	CAP REC
EUDYPTULA	MINOR	CHATHAMENSIS (BLUE)	CHATHAM ISLANDS	<10,000	0	D?main isl S outlying isl	-	V main isl S other isl	P,M,Pu, L,F	YES	YES, pend PHVA	T,S, O	0	NONE
EUDYPTULA	MINOR	IREDALEI (BLUE)	NORTHERN HALF OF N.ISLAND, NEW ZEAL	10,000 total population	0	UNK	-	UNK	P,M,Pu, F,L?	YES	YES, pend PHVA	T,S, O	0	NONE
EUDYPTULA	MINOR	VARIABILIS (BLUE)	COASTS+ISL OF S PART OF N.ISL NEW ZEAL;COASTS+ISL OF N PART OF S.ISL	UNKNOWN	0	UNK	-	UNK	P,M, Pu,F,L ?	YES	YES, pend PHVA	T,S, O	0	NONE
EUDYPTULA	MINOR	ALBOSIGNATA (BLUE)	MOTANAU ISLAND+BANKS PENINSULA,NEW ZEALAND	>500 Banks 1,250 Motanau	2	S Motanau I D Banks Penins	-	V/S	P,Pu,M, L,F	YES	YES	T,S, O	0	PEND
SPHENISCUS	DEMERSUS	(AFRICAN)	COASTS OF S.AFRICA + ISLANDS + NAMIBIA	50,000-80,000	0	D	R	V	M,L,P F,Pu	YES	YES	S,O	873	NUC I
SPHENISCUS	HUMBOLDTI	(PERUVIAN)	COASTS OF PERU+N.CHILE AND ISLANDS	5,000-8,000	0	D	R	E	M,L,HPu ,F	YES	YES	S,H, O	900	90/100
SPHENISCUS	MAGELLANICUS	(MAGELLANIC)	S.ARGENTINA+S.CHILE	1,000,000	3	D-?	R	S	M,Pu,F	NO	YES	S,O	405	ELIM
SPHENISCUS	MENDICULUS	(GALAPAGOS)	GALAPAGOS ISLANDS	1,000-3,000	0	VAR	r	V	M,Pu,F	YES	YES	S,O	0	NONE

NEW ZEALAND PENGUINS

POPULATION AND HABITAT VIABILITY ANALYSIS

INITIAL WORKSHOP REPORT

FIRST DISCUSSION DRAFT

19-21 August 1992

Christchurch

SECTION 3

YELLOW-EYED PENGUIN

from Chris Lalas

Yellow-eyed Penguin Leper Colony

Katiki Point Scientific Reserve

Summary

1. Breeding established at a new location:
   Breeding established with relocated, rehabilitated birds:
   Two nests in the 1991-92 breeding season.

2. July 1992 resident population: minimum 10 birds.

3. Possible behavioural and physiological anomalies
   with relocated / rehabilitated birds.

4. Chick captive-rearing: behavioural problems still unresolved.

5. Captive breeding to enhance natural populations:
   very expensive; trivial impact.

Implications for Yellow-eyed Penguin research

Rehabilitation

* Can work with most underweight moulters
* Doesn't work with many injured birds
* "Worming" is an important treatment
* Balanced diet (whole "fresh" fish) is necessary
* Presence of acclimatised resident penguins is advantageous
* Captive-rearing of chicks is still dubious

Relocation

* Can work with chicks, juveniles and (young?) adults
* A period of on-site acclimatisation in enclosures is necessary
* A long-term commitment to supplementary feeding is necessary

Manipulation of breeding

* Artificial nest sites are accepted
* Thorough screening of nests is necessary
* Screened nest sites can be closely packed (5m apart)
* Supplementary feeding of chicks works
* Chick transfer between nests can work

YELLOW-EYED PENGUIN MODELLING REPORT

The present situation is that over the past 9 years a decline in the adult population of 50% has been recorded and 3-4 events that can be evaluated as catastrophes in terms of effects upon chick and juvenile survival have occurred. Thus after the 1986 catastrophe, 100% of the chicks and all of the surviving 1985 juveniles died.

Richdale recorded a mean mortality of 15% over his study period of 18 years and recorded only a single catastrophe in that time. Richdale reported a reproductive output of 1.78 chicks per nest. Over the last 12 years the output has been lower, primarily as a result of predation. Experimental trapping in the breeding area has demonstrated that the reproductive output recorded by Richdale can be achieved. However, at present it is doubtful if the population achieves 1.5 chicks per year.

Some implications for management include:

1. What level of predation can be sustained if adult mortality continues at 15% per year for adults?

2. We believe that we can predict ENSO events within 2 weeks of egg laying.

Some management options include:

1. remove one or both eggs and release adults to the sea with the probability that we remove catastrophic events on adults - but continue to have catastrophic events on chicks and possibly the previous years cohorts.

2. Allow predation of chicks to occur?

Evaluation of mortality data over the past 12 years and comparison with the 18 years data of Richdale needs to consider each years data and to fit curves to the frequency distribution as a means of detecting outlier events that may need to treated as catastrophes. This may also allow separation of the components due to environmental variance and to demographic sampling. The 15% average mortality described by Richdale appears too high for a stable population given the reproductive output information.

An average annual adult mortality of 15% could result from a much lower annual mortality rate with occasional high mortality events. Separation of these high mortality years or events from the mean has an important impact on the risk of extinction of a population. It is possible for population which has been reduced 50% by an event to rapidly expand back to the original levels in the years between catastrophic events (the number of years required depends upon the annual rate of increase the population can achieve). The modelling results suggest that the population will decline if an annual

15% mortality is imposed upon the adults even at the highest levels of reproductive output.

About 86% of eggs laid hatch and 70% of hatched chicks fledged for a 59% fledging rate for eggs laid.

The reproductive output data indicate 1.50 - 1.78 chicks per nest at the time of fledging. Lower values were examined to test the effects of various levels of predation that might occur. The sex ratio at fledging was assumed to be 0.500. Adult sex ratio data indicate an increased skewing in favor of males with increasing age (1.38 at 6 years, 1.53 at 8-9 years, and 2.0 at 10-17 years). This implies a continuing differential mortality on the females. The birds are monogamous in a season but with about a 20% turnover between seasons. Age of first reproduction is 2-3 for females and 3-4 for males. We chose 3 and 4 respectively for the initial models since there was some question about chick survival with the 2 year old females. About 90% of adult females breed each year and males are not limiting.

It likely will be necessary to model each of the 3 subpopulations separately because there does not appear to be demographic reinforcement from one colony to the other. There may be a limited amount of gene flow.

The molecular genetic data indicate sufficient divergence between the colonies perhaps to warrant their classification as separate subspecies. At the very least each contains a significant separate fraction of the genetic diversity of the species. This genetic divergence, if sustained with further analysis, suggests the need for a separate management protocol for each colony and special concern for the future of the mainland colony which appears to have sustained the greatest losses and to be at the highest risk of extinction in the near term.

Given the considerations summarized above we have modelled 2 major types of scenarios based upon differences in adult mortalities and the occurrence of catastrophes. Chicks fledged has been held constant at 1.5 per female, but first year mortality has been varied within each group of scenarios. It was not possible to achieve a stable or growing population with an adult mortality of 15%.

```
YELLOW22.OUT     ***OutputFilename***
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1      ***TypesOfCatastrophes***
M      ***MonogamousOrPolygynous***
3      ***FemaleBreedingAge***
4      ***MaleBreedingAge***
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0.500000      ***SexRatio***
2      ***MaximumLitterSize***
N      ***DensityDependentBreeding?***
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30.000000      ***Population1:PercentLitterSize1***
60.000000      ***Population1:PercentLitterSize2***
12.500000      ***EV--Reproduction***
33.000000      ***FemaleMortalityAtAge0***
11.083020      ***EV--FemaleMortality***
17.000000      ***FemaleMortalityAtAge1***
6.000000      ***EV--FemaleMortality***
17.000000      ***FemaleMortalityAtAge2***
6.000000      ***EV--FemaleMortality***
6.750000      ***AdultFemaleMortality***
2.250000      ***EV--AdultFemaleMortality***
33.000000      ***MaleMortalityAtAge0***
11.083020      ***EV--MaleMortality***
10.000000      ***MaleMortalityAtAge1***
3.000000      ***EV--MaleMortality***
6.750000      ***MaleMortalityAtAge2***
2.250000      ***EV--MaleMortality***
6.75000      ***MaleMortalityAtAge3***
2.250000      ***EV--MaleMortality***
6.7500000      ***AdultMaleMortality***
2.250000      ***EV--AdultMaleMortality***
16.500000      ***ProbabilityOfCatastrophe1***
0.000000      ***Severity--Reproduction***
0.50000      ***Severity--Survival***
Y      ***AllMalesBreeders?***
Y      ***StartAtStableAgeDistribution?***
914      ***InitialPopulationSize***
2500      ***K***
0.000000      ***EV--K***
N      ***TrendInK?***
N      ***Harvest?***
N      ***Supplement?***
```

TAXON: MEGADYPTES ANTIPODES Yellow-eyed penguin

Status: **CITES Appendix** - not listed
Red Data Book - Vulnerable
Mace-Lande - Endangered (mainland and Stewart Island);
Vulnerable (Auckland and Campbell Islands)

Breeding Distribution: New Zealand - eastern and southern coasts of the South Island south of Oamaru. Banks Peninsula, Stewart, Auckland, and Campbell Islands.

Estimated wild population:
South Island - 320 Pairs; 274 Non-breeders; 914 Total individuals

Stewart - 300-400 Pairs; 257-342 Non-breeders; 857-1,142 Total individuals

Auckland - 350-450 Pairs; 300-385 Non-breeders; 1,000-1,285 Total individuals

Campbell - 450-500 Pairs; 385-428 Non-breeders; 1,285-1,428 Total individuals

TOTAL INDIVIDUALS - 4,056-4,769

The % of non breeders is probably to high and a more realistic figure is probably 15-20%. The above data estimates that nonbreeders represent 30% of the population.

Current/Ongoing field studies:
Predator-free island: Green Island Nature Reserve Otago - population dynamics (Lalas). Semi-captive group of relocated, rehabilitated birds at Katiki Point, Otago, are breeding (Jones,Lalas). Long term population studies (Darby), also brood reduction (natural and induced)(Edge), predator prey relations (Ratz), foraging and diet (Moore) and population study Banks Peninsula are being conducted.

Captive population: none listed in ISIS; one bird Marineland Napier, New Zealand

Concerns/Comments: On the South Island, population declines have been caused by the loss and overgrazing of breeding habitat and by predation of young by introduced stoats (*Mustela erminea*), ferrets (*Mustela putorius*), cats and dogs (Darby & Seddon, 1990). According to Darby, the Auckland, Campbell, and Mainland/Stewart Island populations maybe considered to be genetically discrete; See Triggs and Darby. Note also there are no records of birds from the subantartic and Codfish Island banded birds having been recovered in the northern breeding areas Primary concerns are for the mainland and Stewart Island (except for Codfish Island) populations that are subject to predation of chicks by introduced predators and mortality in set nets. The population on the South Island and elsewhere are sensitive to marine perturbations; the South Island population has decreased by half over the last five yearsand possibly 87% since the 1950's. Populations on islands are protected from adverse land use but not environmental effects. Populations are declining throughout the distribution. On the mainland, the population will decline precipitously if current management practices are not continued at the present level. In January 1990, something in the order of 30% (150 birds out of 240 breeding pairs) of the adult breeding birds on the Otago Peninsula died. The disease entity has not been identified (Gill & Darby, submitted for publication). Any threats that may be present on the subantarctic islands are difficult to address. Threats include fluctuating food supplies.

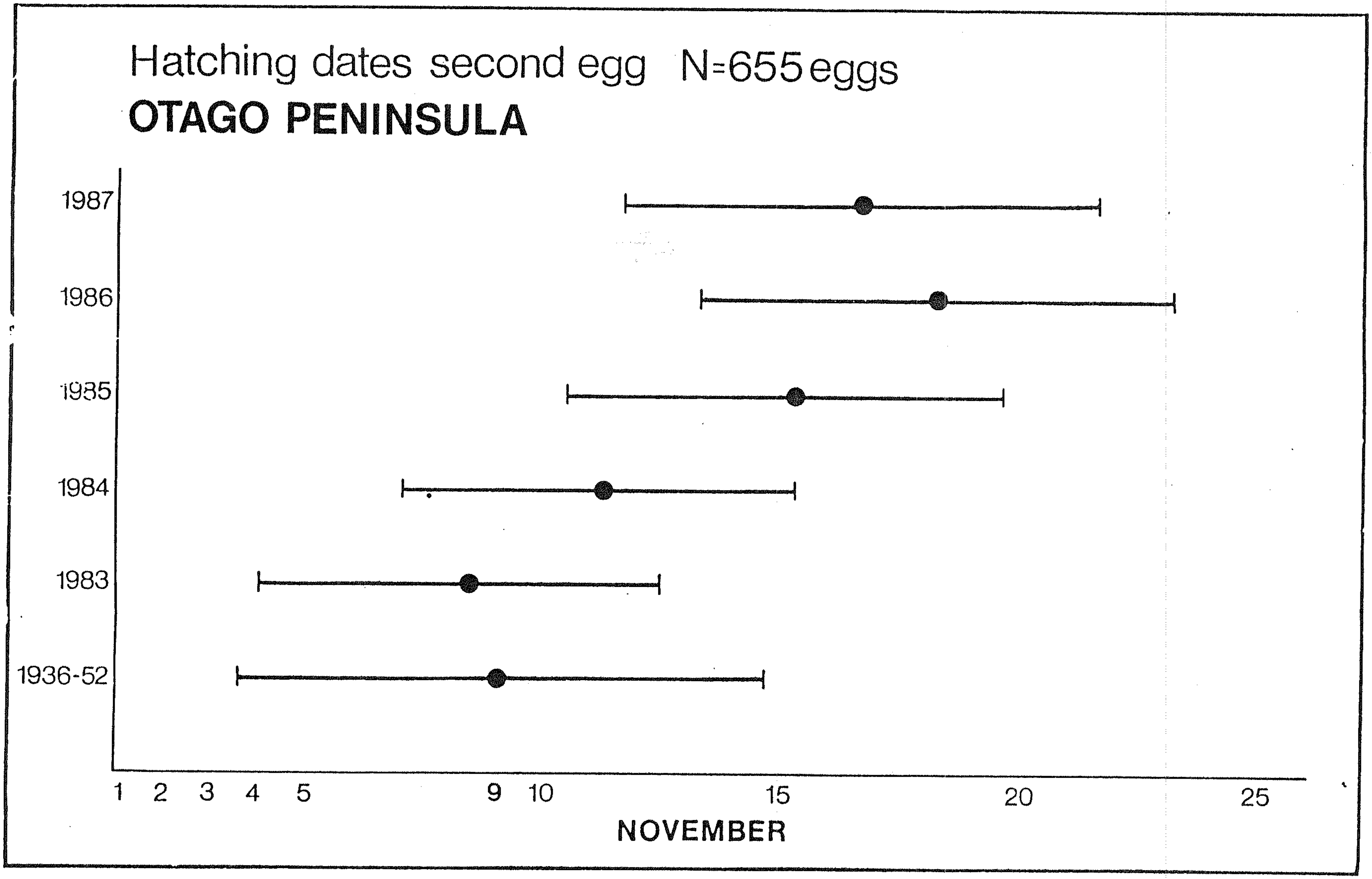
Recommendations:

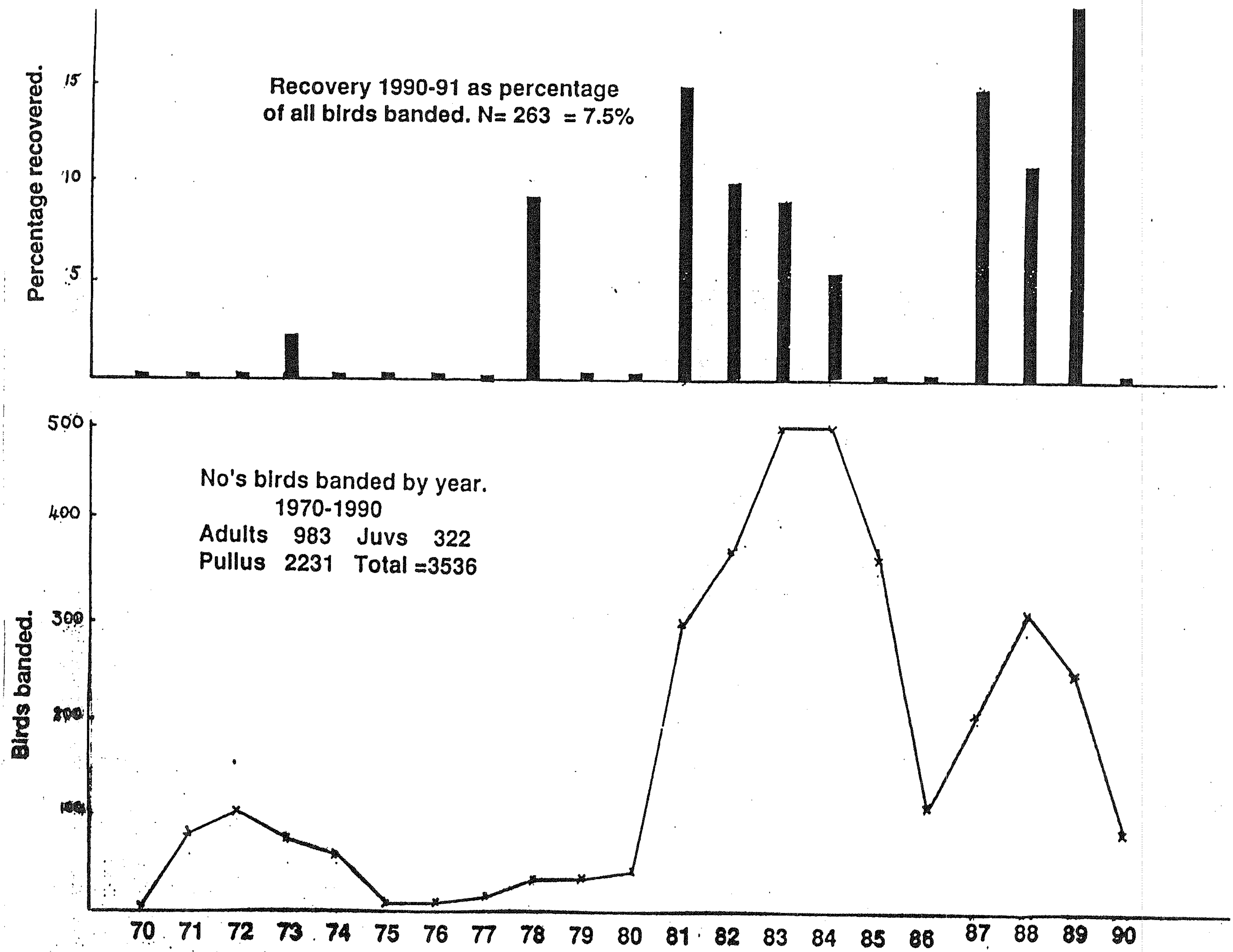
PHVA: Yes

More intensive wild management: Yes

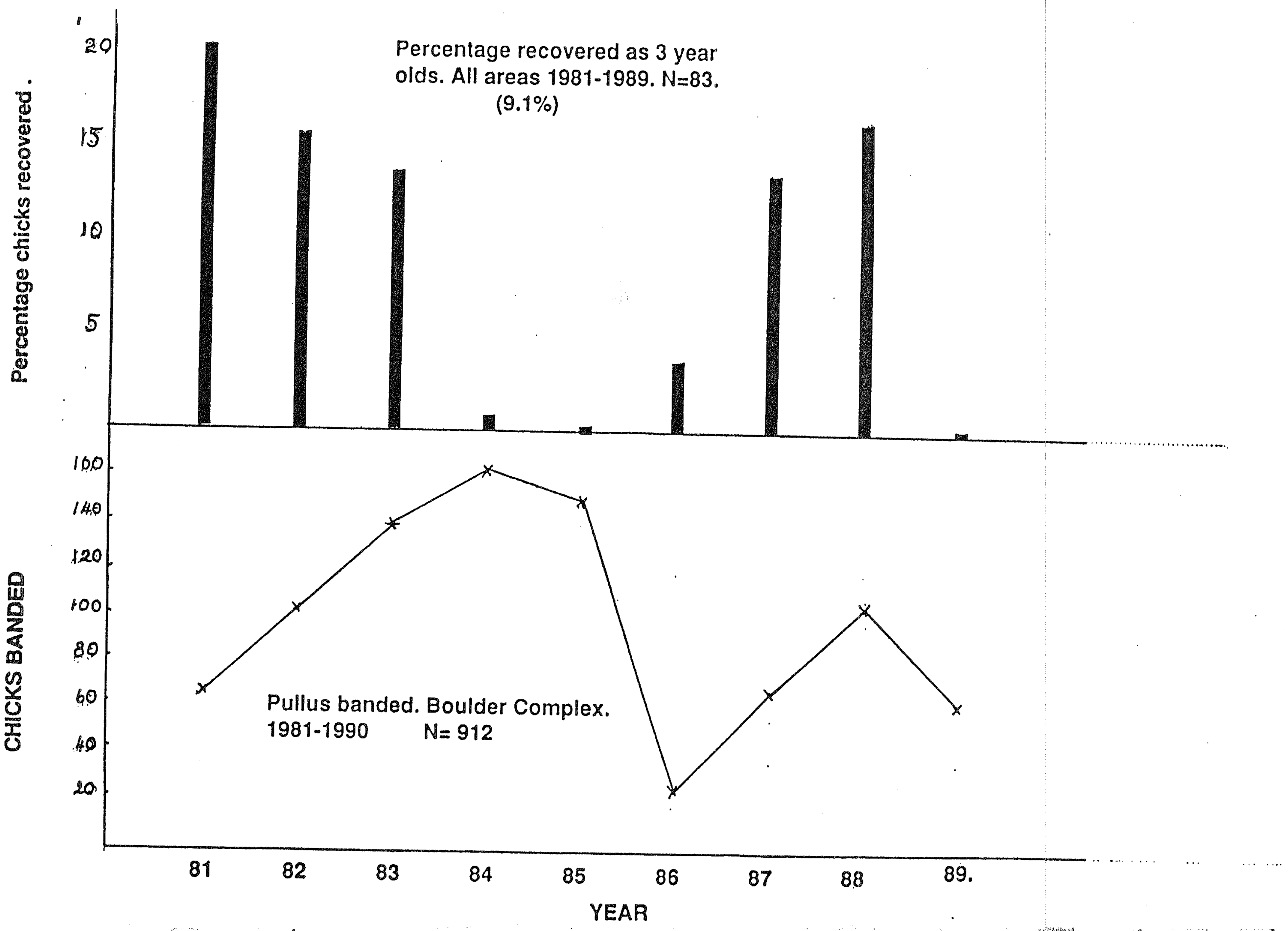
Captive program: Pending PHVA

Research: Taxonomy, Other
Most research needs are being met by ongoing projects. Additional research on marine environmental factors is required. Set nets should be banned off nesting sites. Recommend that research into release and survivability of captive-reared fledglings from a surrogate species such as *Eudyptes spp*. be undertakenbefore any consideration of placing this species into captivity, and that the current program at Kaitiki Point be evaulated before it is further expanded and developed.


Hatching dates second egg N=655 eggs
OTAGO PENINSULA
1987
1986
1985
1984
1983
1936-52
1 2 3 4 5 9 10 15 20 25
NOVEMBER

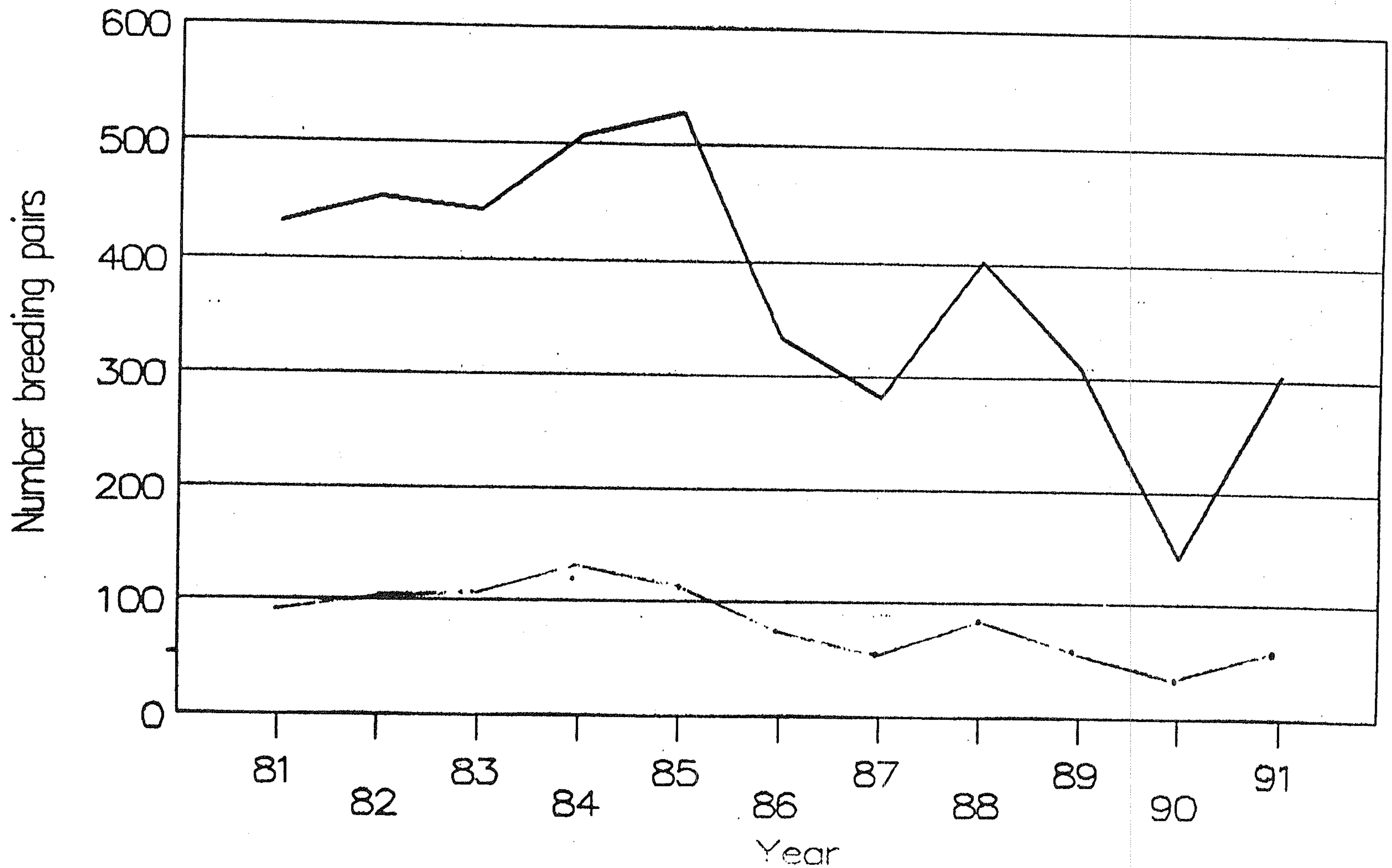


Percentage recovered.
15
10
5
Recovery 1990-91 as percentage
of all birds banded. N= 263 = 7.5%
Birds banded.
500
400
300
200
100
No's birds banded by year.
1970-1990
Adults 983 Juvs 322
Pullus 2231 Total =3536
70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90



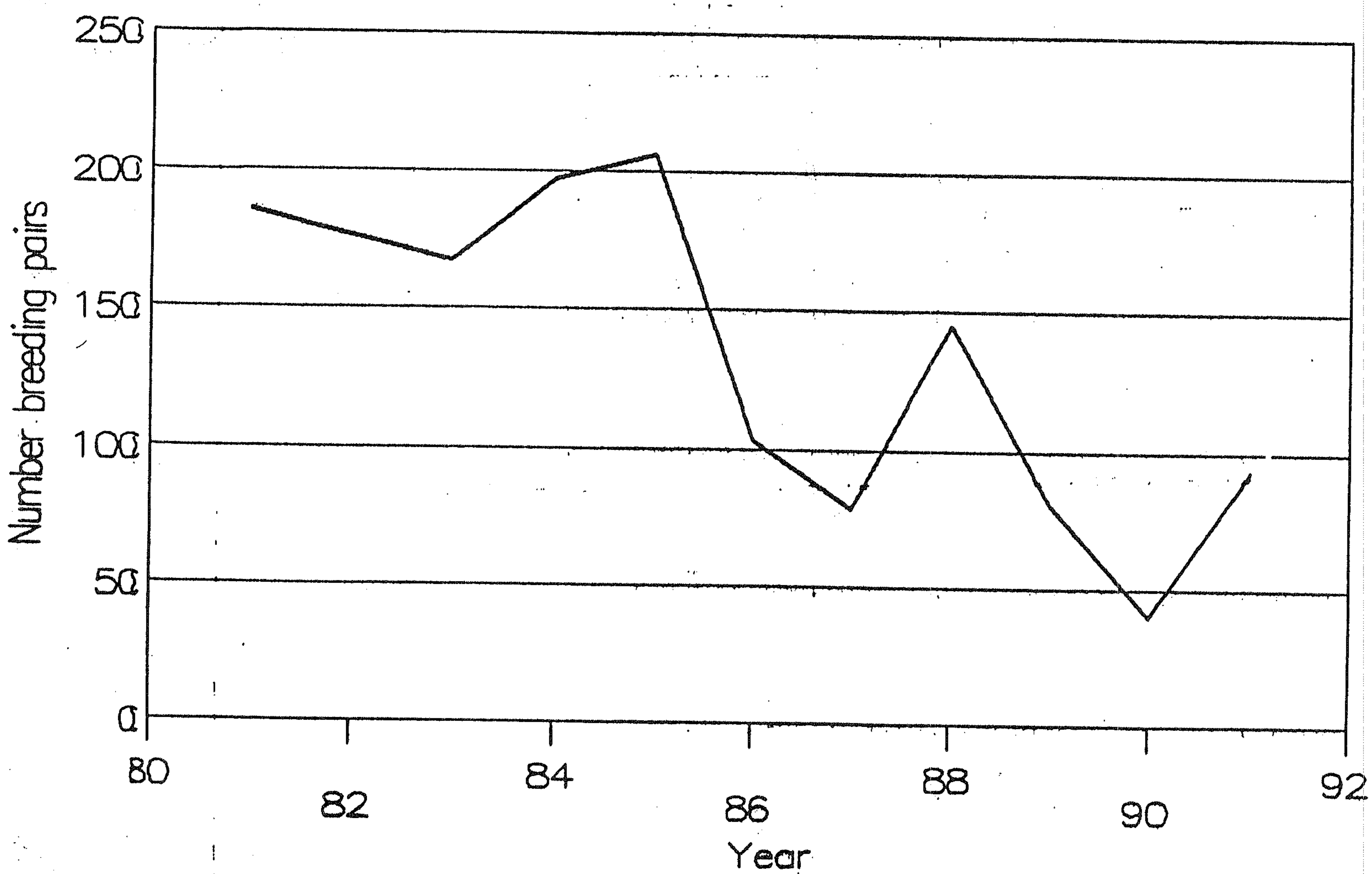
Percentage recovered as 3 year olds. All areas 1981-1989. N=83. (9.1%)
Percentage chicks recovered .
20
15
10
5
CHICKS BANDED
160
140
120
100
80
60
40
20
Pullus banded. Boulder Complex.
1981-1990 N= 912
81
82
83
84
85
86
87
88
89.
YEAR

Mainland
1981–1991.



Catlins.

1981–1991.



POPULATION VIABILITY ANALYSIS DATA FORM - BIRDS

Species: Megadyptes antipodes

Species distribution: South-east coast South Island, Stewart and Codfish Islands
Auckland and Campbell Islands

Study taxon (subspecies):

Study population location: Mostly Mainland New Zealand, but some information from Codfish Island, Auckland Island & Campbell Island.

Metapopulation - are there other separate populations? Are maps available?:
(Separation by distance, geographic barriers?)
Yes - See Triggs & Darby D.O.C. internal report - Campbell, Auckland and Mainland populations considered genetically discrete

Specialized requirements (Trophic, ecological):

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

a)Earliest: Females 2 years 48%; 3 years 100%
Males 2 years 8%; 3 years 35%; 4 years 80%

b)Mean:

Clutch size (N, mean, SD, range): N=662 (1215 eggs) mean 1.95 r 1 - 2

Number fertile: 13.58% (1029)

Number hatched: 1029

Number fledged: 713 (69.29%). of eggs laid 58.68%

Laying Season: 1981 - 1987

Laying frequency (interclutch interval): 12 months

Are multiple clutches possible? Definitely No

Duration of incubation: 38 - 54 days

Hatchling sex ratio: 50/50

Egg weights: N=90 137·8 s.d. 7.6 r 121 - 153

Hatchling weights (male and female): 95 - 100 g

Age(s) at fledging: 102 days

Adult sex ratio: 6 year olds. males : females 1.38 to 1
8 - 9 year olds. 1.53 to 1 10 - 17 year olds 2 : 1

Adult body weight of males and females:
June Males 5.62 kg; Females 5.17 kg

Reproductive life-span (Male & Female, Range):
3 Females 17+ years; 2 males 19+ years

Life time reproduction (Mean, Male & Female): Not known

Social structure in terms of breeding (random, pair-bonded, polygyny, polyandry, etc; breeding male and female turnover each year?):
Pair bonded about 20% turnover annually

Proportion of adult males and females breeding each year:
90% females; ? 60% males ?

Dispersal distance (mean, sexes): Generally no dispersal phase for adults - however evidence is coming through that some adults may disperse northwards during May - June as far as Cook Strait.

Migrations (months, destinations):
Fledglings migrate north February - October - November 700 k?

Territoriality (home range, season):
Adults on territories year round - Territory size varies with habitat
Forest about 1 pair/1.5 ha.
Scrub 4 pairs/ha - 14/ha mean about 2-3 /ha

Age of dispersal:
14 - 16 weeks - Juvenile only

Maximum longevity: Females 17 - 18 years; Males 19 - 20 years

Population census - most recent. Date of last census. Reliability estimate.:

4056 - 4769 ± 15%;

Projected population (5, 10, 50 years).:

Past population census (5, 10, 20 years - dates, reliability estimates):
10 years 4,666 - 6766 ± 50%; 150 years 8 - 10,000 ?

Population sex and age structure (young, juvenile, & adults) - time of year.:
May 70% adults; 30% Juveniles

Fecundity rates (by sex and age class): 25 nests 3-4 year olds 1.68 chicks/nest
MS = mixed sex 2 - 3 year olds 0.66 chicks/nest 33 nest 2 - 7 year olds 1.78 chicks/nest

Mortality rates and distribution (by sex and age) (neonatal, juvenile, adult);

?

Population density estimate. Area of population. Attach marked map.:

Variable to less than 1 pair/ha to 14 pairs per ha. mean 2 - 3/ha.

Sources of mortality-% (natural, poaching, harvest, accidental, seasonal?).:
Natural - highly variable from season to season for both adults and juveniles
Approximate adult 15% Natural 1 - 2% accidental set nets
80% Natural 1 - 2% " " "

Habitat capacity estimate (Has capacity changed in past 20, 50 years?).:
Yes - drastically - from 150 years ago to 50 years - loss about 60%. Of that approximately 95% lost in last 50 years - barely 1-2% remains on the Mainland . Other areas - overall about 10% loss

Present habitat protection status.:

5 years ago virtually nil - present 55 - 60% with some protection

Projected habitat protection status (5, 10, 50 years).:

10 - 50 years 100%

Environmental variance affecting reproduction and mortality (rainfall, prey, predators, disease, snow cover ?).:

Predators - mostly of concern on the Mainland - highly variable 10 - 90% per year of chicks. Predation of adults by Hookers Sealions may be significant

Is pedigree information available?:

Collected but not accessible

Attach Life Table if available.
Not available

Date form completed:
August 14th 1992

Correspondent/Investigator:

Name: John Darby

Address: Otago Museum, P.O. Box 6202, Dunedin New Zealand

Telephone: (03) 4772-372 ext. 815.

Fax: (03) 4775-993

Comments: Most of this work has been carried out on the South Island by the Senior Researcher in a part-time capacity.
The concerns expressed for the species have mainly been derived from that study, ie,suggesting that the Auckland and Campbell Island populations are relatively secure, but that the Mainland and Stewart Island birds are not.

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SCIENCE AND RESEARCH INTERNAL REPORT NO.43

GENETICS AND CONSERVATION OF YELLOW-EYED PENGUIN : AN INTERIM REPORT

By

Sue Triggs and John Darby

Science & Research Directorate,
Department of Conservation,
P.O. Box 10-420,
Wellington, New Zealand

January 1989

GENETICS AND CONSERVATION OF YELLOW-EYED PENGUIN

AN INTERIM REPORT

Sue Triggs[1] and John Darby[2]

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SUMMARY

Analysis of the genetics of yellow-eyed penguin populations in the subantarctic and South Island suggests that there are three discrete populations of yellow-eyed penguin. Recovery of penguin numbers in the South Island will have to be achieved without input from the subantarctic, as migration rates between subantarctic and mainland populations are very low. Migration between Campbell and Enderby Islands, although an order of magnitude higher than that between the subantarctic and mainland, is insufficient to prevent significant genetic differentiation between the two subantarctic populations. The present low numbers in the South Island and possibly in the Auckland Islands are likely to lead to loss of genetic variation within these populations and hence decreased long-term viability. Genetic variation in the Enderby Island population is already less than half that found on Campbell Island. Samples from Stewart and Codfish Islands are essential to complete this analysis of genetic structure in yellow-eyed penguins.

1. INTRODUCTION

Maintaining genetic diversity is an important component of conservation. Minimum population sizes of a few hundred to a few thousand are necessary to maintain natural levels of variation and hence levels of fitness and adaptability (Triggs 1988). Biochemical genetic techniques can be used to define discrete populations or management units and to assess genetic diversity within species by determining diversity among populations and genetic variation within populations. Genetic techniques provide a rapid and relatively inexpensive alternative to traditional banding methods for estimating migration (gene flow) between populations.

The yellow-eyed penguin *Megadyptes antipodes*, the world's rarest penguin and the sole representative of its genus, has a total population size of less than 3000 breeders (McKinlay in prep., P J Moore pers comm.). It is one of only three species of penguin to breed on the New Zealand mainland and thus has aroused considerable public interest. The present range of yellow-eyed penguins extends from southern New Zealand to the subantarctic. Since the arrival of humans to New Zealand yellow-eyed penguin numbers have decreased as a result of predation by introduced mammals, disturbance by humans and domestic animals, and habitat destruction. A dramatic decline in numbers from approximately 600 to 200 pairs has occurred on the southeast coast of the South Island since 1986, possibly as a result of a collapse in the marine food chain.

Low penguin numbers raise concern for the long-term genetic viability and the potential for population recovery in the South Island. The aim of the present research was to determine the potential role of immigration from the subantarctic in population recovery in the South Island, and to suggest strategies for maintaining genetic viability in yellow-eyed penguins based on an assessment of genetic structure and diversity within the species.

2. METHODS

The genetic structure of yellow-eyed penguin populations was determined by electrophoresis, a biochemical technique that estimates genetic variation from proteins in blood samples. (Research is also underway using mitochondrial DNA techniques to determine the genetic structure of yellow-eyed penguin populations. This work is being done by Dr Allan Baker of the Toronto Museum, Canada). Genetic variation was estimated at 29 protein loci for samples from two South Island and two subantarctic sites: Otago Peninsula (21 individuals), Catlins (24), Enderby Island, Auckland Islands (24), and Campbell Island (24).

The genetic variation within populations is estimated by the statistic H (heterozygosity). The amount of genetic differentiation between populations, or the genetic diversity, is given by F_{ST}. Samples that are part of a single inter-mixing population have $F_{ST} = 0$, whereas completely isolated populations have $F_{ST} = 1.0$. The number of migrants exchanged per generation, $N_e m$ (effective population size x migration rate), can also be estimated from F_{ST}, using the following equation:

$$F_{ST} = (4N_e m + 1)^{-1}$$

Estimation of effective population size N_e requires information on sex ratio, variance of reproductive success, generation time, and fluctuations in population size. For the purposes of this interim report N_e was assumed to be approximately equal to the minimum estimated number of breeders (N_B) for each population. The average of N_e for two populations x and y is given by the harmonic mean: $1/N_e = 0.5\ (1/N_{BX} + 1/N_{BY})$.

3. RESULTS

The level of genetic variation (heterozygosity, H) in yellow-eyed penguins averaged 0.03. This is lower than the average (H = 0.05), but within the known range, for other bird species. Enderby Island had the lowest level of variation (H = 0.02), possibly reflecting the small size of the Auckland Islands population (estimated at 150-200 pairs), whereas Campbell Island had the highest level of variation (H = 0.04).

Significant genetic differentiation was found among the four samples (Table 1). Enderby and Campbell Islands were significantly divergent from each other, as were Enderby and the South Island, and Campbell and the South Island. No significant genetic differences were found between the Catlins and Otago samples.

Table 1: Genetic structure and migration between populations of yellow-eyed penguin

[$N_e m$ is the actual number of migrants exchanged per generation (estimated from F_{ST}), N_e is the effective population size (estimated from censuses and historic information), and m is the migration rate, the proportion of the population exchanged, (estimated from $N_e m$)].

	F_{ST}	significant differentiation?	$N_e m$	N_e	m
Among all 4 samples	0.243	yes	0.8	570	0.001
Campbell I. vs South I.	0.138	yes	1.6	460	0.001
Enderby I. vs South I.	0.333	yes	0.5	1000	0.001
Campbell I. vs Enderby I.	0.052	yes	4.6	470	0.01
Catlins vs Otago	0.008	no	31	500	0.06

The amount of genetic differentiation (or genetic differences) between yellow-eyed penguin populations is an order of magnitude higher than that estimated for most other species of bird (F_{ST} averaged 0.022 for 15 geographically-widespread species of birds; Barrowclough 1983). The genetic differentiation between these populations is a natural population structure developed over thousands of years. Thus, F_{ST} and N_em estimates are valid for average population sizes over the past few thousand years. Recent declines in yellow-eyed penguin numbers, assuming that migration rates remain constant, will decrease N_em and lead to even greater divergence between populations.

Significant genetic differentiation between populations can only occur when either population size or migration rate or both are small (low N_em value). N_em is the actual number of migrants exchanged between locations per generation. When this value is greater than approximately 1-4 the locations sampled can be treated as a single management unit for genetic conservation (Varvio et al. 1986). Yellow-eyed penguins thus form at least two discrete populations (the subantarctic and South Island). Enderby and Campbell Islands are on the borderline of genetic isolation. Although migration between these two populations is an order of magnitude higher than between subantarctic and mainland populations, significant differences in gene frequency and amount of genetic variation between Enderby and Campbell Islands suggest that these two locations could be treated as discrete populations. This will be particularly true if penguin numbers decrease on either island in the future or have decreased substantially in the recent past. The large value of N_em between Catlins and Otago samples indicate that migration has, in the past, been more than sufficient to maintain these as a single genetic population. The decline of penguin numbers in the South Island by at least an order of magnitude in recent decades suggests that N_em may now be approximately 3 rather than 31, as given in Table 1. If so, the Catlins and Otago populations may soon begin to show effects of genetic isolation.

4. MANAGEMENT IMPLICATIONS

1. The genetic diversity within the species is high. Thus, each of the three discrete populations is an important component of the total genetic diversity to be conserved.

2. Immigration to the South Island from the subantarctic is very low and thus is unlikely to play a significant role in population recovery on the South Island.

3. The present population size of at least one of the three defined populations, the South Island, is lower than the recommended minimum of 500-1000 breeding individuals needed to maintain genetic variation within populations. In addition, low numbers in the South Island may result in genetic isolation between the Catlins and Otago Peninsula, thus disrupting the natural population structure of yellow-eyed penguins. Accurate census information is not available for the Auckland Islands, but present estimates suggest that numbers may be fewer than 500-1000 (McKinlay in prep.). Active management to increase numbers in the South Island and perhaps the Auckland Islands, if possible, is recommended.

4. Two major strategic breeding areas, Stewart Island and Codfish Island, have not as yet been sampled. Their large size and geographic position make them vital components of the analysis of genetic structure and diversity.

5. Calculations of effective population size are an important part of conservation genetics. An accurate census of the Auckland Island population, as well as an analysis of life history information, will be required before accurate estimates of N_e can be made.

5. ACKNOWLEDGMENTS

We are grateful to Lou Sanson and Andy Cox, Murihiku District DoC, for supporting this project at an early stage and arranging the collecting trip to the subantarctic. Peter Moore, Jeff Flavell, and Royal New Zealand Navy personnel helped with the collection of blood samples on Campbell and Enderby Islands and Nina Swift assisted with the electrophoresis. We thank Drs D R Towns, P J Moors, and R M Sadleir for commenting on the manuscript.

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Yellow 35   Darby 21/8/92.

No predation.
Breeding success 1·5 chicks fledged / pair
No catastrophes.
Average mortality = 15% per year for 100 years 10 runs.

10 populations 3 went extinct

Age related mortalities ~ same as for yellow 22

Basis of modelling is partly from Richdale who recorded mean annual mortality for 18 years as 15%. and recording only a single catastrophe for this period.

The present situation is that we have recorded a decline in adult population of 50% in 9 years which includes 3-4 catastrophes.
I consider it to be ~~[illegible]~~ to because the impact captured the cohort of chicks & 3 of adults, that is we lost 100% of all chicks in 4 years however one cygnus (the 1985 juveniles) died as a result of the 1986 catastrophe.

Reproductive output over that last 12 years has never equalled that of Richdale's 18 yrs study – mostly as a result of chick predation. Experimental trapping of breeding areas has demonstrated that R.O. recorded by Richdale can be achieved.

The scenario modelled for Yellow 35 is as close to the present situation (last 12 years) as possible.
However it is clear that our data is not as

robust as it should be – we have the data – but it has yet to ~~be~~ be extracted.
We particularly need better information on age ~~th~~ related death rates – especially as it concerns the age of first breeding of males & females in particular.

The reality of the present situation is ~~that~~ it is very doubtful that R.O. can equal 1·5 chicks/year

The implications for management are:

(1) What level of predation can be sustained if continue with a mean mortality of 15% for adults

(2) We believe ~~that~~ we can predict ENSO events ~~at the~~ within 2 weeks of egg laying.

Management options are.

a) to remove one or both eggs & release adults to the sea – with the probability that we remove catastrophic events on adults – but continue to have catastrophic events on chicks & possibly the previous (1) years cohorts.

b) Allow production of chicks to occur?

```
YELLOW30.OUT     ***OutputFilename***
Y      ***PlotterFiles?***
N      ***EachRun?***
10      ***Simulations***
100      ***Years***
10      ***ReportingInterval***
1      ***Populations***
Y      ***InbreedingDepression?***
H      ***HeterosisOrLethals***
1.000000      ***LethalEquivalents***
Y      ***EVcorrelation?***
2      ***TypesOfCatastrophes***
M      ***MonogamousOrPolygynous***
3      ***FemaleBreedingAge***
4      ***MaleBreedingAge***
25      ***MaximumAge***
0.500000      ***SexRatio***
2      ***MaximumLitterSize***
N      ***DensityDependentBreeding?***
10.000000      ***Population1:PercentLitterSize0***
30.000000      ***Population1:PercentLitterSize1***
60.000000      ***Population1:PercentLitterSize2***
5.000000      ***EV--Reproduction***
70.000000      ***FemaleMortalityAtAge0***
32.403703      ***EV--FemaleMortality***
30.000000      ***FemaleMortalityAtAge1***
10.000000      ***EV--FemaleMortality***
30.000000      ***FemaleMortalityAtAge2***
10.000000      ***EV--FemaleMortality***
15.000000      ***AdultFemaleMortality***
5.000000      ***EV--AdultFemaleMortality***
70.000000      ***MaleMortalityAtAge0***
32.403703      ***EV--MaleMortality***
30.000000      ***MaleMortalityAtAge1***
10.000000      ***EV--MaleMortality***
15.000000      ***MaleMortalityAtAge2***
5.000000      ***EV--MaleMortality***
15.000000      ***MaleMortalityAtAge3***
5.000000      ***EV--MaleMortality***
15.000000      ***AdultMaleMortality***
5.000000      ***EV--AdultMaleMortality***
16.500000      ***ProbabilityOfCatastrophe1***
1.000000      ***Severity--Reproduction***
1.000000      ***Severity--Survival***
0.000000      ***ProbabilityOfCatastrophe2***
Y      ***AllMalesBreeders?***
Y      ***StartAtStableAgeDistribution?***
914      ***InitialPopulationSize***
2000      ***K***
0.000000      ***EV--K***
N      ***TrendInK?***
N      ***Harvest?***
N      ***Supplement?***
N      ***AnotherSimulation?***
```

VORTEX -- simulation of genetic and demographic stochasticity

YELLOW30.OUT
Fri Aug 21 08:57:16 1992

1 population(s) simulated for 100 years, 10 runs

No inbreeding depression

First age of reproduction for females: 3 for males: 4
Age of senescence (death): 25
Sex ratio at birth (proportion males): 0.5000

Population 1:
Monogamous mating; 100.00 percent of adult males in the breeding pool.

Reproduction is assumed to be density independent.

10.00 (EV = 12.25 SD) percent of adult females produce litters of size 0
30.00 percent of adult females produce litters of size 1
60.00 percent of adult females produce litters of size 2

70.00 (EV = 22.91 SD) percent mortality of females between ages 0 and 1
30.00 (EV = 10.00 SD) percent mortality of females between ages 1 and 2
30.00 (EV = 10.00 SD) percent mortality of females between ages 2 and 3
15.00 (EV = 5.00 SD) percent annual mortality of adult females (3<=age<=25)
70.00 (EV = 22.91 SD) percent mortality of males between ages 0 and 1
30.00 (EV = 10.00 SD) percent mortality of males between ages 1 and 2
15.00 (EV = 5.00 SD) percent mortality of males between ages 2 and 3
15.00 (EV = 5.00 SD) percent mortality of males between ages 3 and 4
15.00 (EV = 5.00 SD) percent annual mortality of adult males (4<=age<=25)
EVs may have been adjusted to closest values
possible for binomial distribution.
EV in reproduction and mortality will be correlated.

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

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total	
	71	51	46	40	35	32	27	25	21	19	17	15	13	12	10	9	8	7	7	5	5	4	4	3	3	489	Males
	71	51	38	33	29	26	22	21	17	16	14	12	11	10	8	8	6	6	5	5	4	3	3	3	3	425	Females

Carrying capacity = 2000 (EV = 0.00 SD)

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

r = -0.039 lambda = 0.962 R0 = 0.718
Generation time for: females = 8.62 males = 9.52

Stable age distribution:

Age class	females	males
0	0.166	0.166
1	0.052	0.052
2	0.038	0.038
3	0.027	0.033
4	0.024	0.029
5	0.021	0.026
6	0.019	0.023

```
                7       0.017      0.020
                8       0.015      0.018
                9       0.013      0.016
               10       0.011      0.014
               11       0.010      0.012
               12       0.009      0.011
               13       0.008      0.010
               14       0.007      0.008
               15       0.006      0.008
               16       0.005      0.007
               17       0.005      0.006
               18       0.004      0.005
               19       0.004      0.005
               20       0.003      0.004
               21       0.003      0.004
               22       0.003      0.003
               23       0.002      0.003
               24       0.002      0.002
               25       0.002      0.002

Ratio of adult (>= 4) males to adult (>= 3) females: 1.064


Population1

Year 10
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =              781.70 ( 107.51 SE,   339.97 SD)
     Expected heterozygosity =        0.998 (   0.000 SE,    0.000 SD)
     Observed heterozygosity =        1.000 (   0.000 SE,    0.000 SD)
     Number of extant alleles =     652.10 (  35.84 SE,   113.33 SD)

Year 20
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =              554.00 ( 102.35 SE,   323.65 SD)
     Expected heterozygosity =        0.995 (   0.000 SE,    0.002 SD)
     Observed heterozygosity =        1.000 (   0.000 SE,    0.000 SD)
     Number of extant alleles =     362.90 (  40.43 SE,   127.85 SD)

Year 30
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =              478.90 ( 143.03 SE,   452.29 SD)
     Expected heterozygosity =        0.991 (   0.001 SE,    0.004 SD)
     Observed heterozygosity =        0.996 (   0.001 SE,    0.004 SD)
     Number of extant alleles =     224.70 (  40.08 SE,   126.74 SD)

Year 40
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =              364.10 ( 120.87 SE,   382.22 SD)
     Expected heterozygosity =        0.984 (   0.003 SE,    0.010 SD)
     Observed heterozygosity =        0.992 (   0.002 SE,    0.007 SD)
     Number of extant alleles =     152.50 (  33.73 SE,   106.67 SD)

Year 50
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =              367.50 ( 134.44 SE,   425.14 SD)
     Expected heterozygosity =        0.973 (   0.006 SE,    0.020 SD)
     Observed heterozygosity =        0.983 (   0.007 SE,    0.022 SD)
     Number of extant alleles =     114.50 (  27.85 SE,    88.07 SD)

Year 60
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =              259.60 (  81.62 SE,   258.11 SD)
```

```
      Expected heterozygosity =     0.952 (  0.015 SE,    0.048 SD)
      Observed heterozygosity =     0.983 (  0.007 SE,    0.024 SD)
      Number of extant alleles =    85.90 (  24.12 SE,    76.27 SD)

Year 70
      N[Extinct] =          2, P[E] = 0.200
      N[Surviving] =        8, P[S] = 0.800
      Population size =            283.75 (  96.59 SE,  273.19 SD)
      Expected heterozygosity =     0.962 (  0.014 SE,    0.039 SD)
      Observed heterozygosity =     0.984 (  0.004 SE,    0.011 SD)
      Number of extant alleles =    83.87 (  23.08 SE,    65.27 SD)

Year 80
      N[Extinct] =          3, P[E] = 0.300
      N[Surviving] =        7, P[S] = 0.700
      Population size =            202.71 (  69.71 SE,  184.42 SD)
      Expected heterozygosity =     0.972 (  0.005 SE,    0.012 SD)
      Observed heterozygosity =     0.989 (  0.005 SE,    0.013 SD)
      Number of extant alleles =    68.57 (  17.29 SE,    45.74 SD)

Year 90
      N[Extinct] =          3, P[E] = 0.300
      N[Surviving] =        7, P[S] = 0.700
      Population size =            149.29 (  62.33 SE,  164.92 SD)
      Expected heterozygosity =     0.957 (  0.008 SE,    0.021 SD)
      Observed heterozygosity =     0.983 (  0.007 SE,    0.019 SD)
      Number of extant alleles =    48.43 (  14.44 SE,    38.20 SD)

Year 100
      N[Extinct] =          3, P[E] = 0.300
      N[Surviving] =        7, P[S] = 0.700
      Population size =            120.57 (  82.71 SE,  218.83 SD)
      Expected heterozygosity =     0.927 (  0.018 SE,    0.048 SD)
      Observed heterozygosity =     0.984 (  0.010 SE,    0.026 SD)
      Number of extant alleles =    33.00 (  13.59 SE,    35.96 SD)

In 10 simulations of 100 years of Population1:
  3 went extinct and 7 survived.

This gives a probability of extinction of 0.3000 (0.1449 SE),
  or a probability of success of          0.7000 (0.1449 SE).

3 simulations went extinct at least once.
Of those going extinct,
    mean time to first extinction was 72.33 years (3.84 SE, 6.66 SD).

No recolonizations.

Mean final population for successful cases was 120.57 (82.71 SE, 218.83 SD)

   Age 1       2       3    Adults    Total
   12.14    1.43    9.43    41.14     64.14  Males
   13.29    0.71            42.43     56.43  Females

Without harvest/supplementation, prior to carrying capacity truncation,
  mean growth rate (r) was -0.0452 (0.0065 SE, 0.1956 SD)

Final expected heterozygosity was       0.9272 ( 0.0181 SE,   0.0478 SD)
Final observed heterozygosity was       0.9843 ( 0.0097 SE,   0.0256 SD)
Final number of alleles was              33.00 (  13.59 SE,    35.96 SD)
```

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

YEP35.IN
Fri Aug 21 14:34:34 1992


  1 population(s) simulated for 100 years, 10 runs

  HETEROSIS model of inbreeding depression
    with  0.00 lethal equivalents per diploid genome

  First age of reproduction for females: 3   for males: 6
  Age of senescence (death): 25
  Sex ratio at birth (proportion males): 0.5000


Population 1:
  Monogamous mating; all adult males in the breeding pool. 100.00 percent
of adult males in the breeding pool.

  Reproduction is assumed to be density independent.

    10.00 (EV = 3.00 SD) percent of adult females produce litters of size 0
    30.00 percent of adult females produce litters of size 1
    60.00 percent of adult females produce litters of size 2

   70.00 (EV = 20.49 SD) percent mortality of females between ages 0 and 1
   25.00 (EV = 8.00 SD) percent mortality of females between ages 1 and 2
   25.00 (EV = 8.00 SD) percent mortality of females between ages 2 and 3
   15.00 (EV = 5.00 SD) percent annual mortality of adult females
(3<=age<=25)
   70.00 (EV = 20.49 SD) percent mortality of males between ages 0 and 1
   25.00 (EV = 8.00 SD) percent mortality of males between ages 1 and 2
   15.00 (EV = 5.00 SD) percent mortality of males between ages 2 and 3
   15.00 (EV = 5.00 SD) percent mortality of males between ages 3 and 4
   15.00 (EV = 5.00 SD) percent mortality of males between ages 4 and 5
   15.00 (EV = 5.00 SD) percent mortality of males between ages 5 and 6
   15.00 (EV = 5.00 SD) percent annual mortality of adult males
(6<=age<=25)
    EVs may have been adjusted to closest values
        possible for binomial distribution.
    EV in reproduction and mortality will be correlated.

  Frequency of type 1 catastrophes: 1.000 percent
    with 0.000 multiplicative effect on reproduction
     and 0.000 multiplicative effect on survival

  Initial size of Population 1:
    (set to reflect stable age distribution)
 Age 1      2      3      4      5      6      7      8      9     10     11     12
13     14     15     16     17     18     19     20     21     22     23     24     25
 Total
   155    119    104     91     79     68     60     52     45     40     34     30
26     23     20     17     15     13     11     10      9      7      7      5      5
 1045  Males
   155    119     92     80     69     61     53     46     40     34     31     26
23     20     18     15     13     11     11      8      8      6      6      5      5
  955  Females

  Carrying capacity = 2000 (EV = 0.00 SD)

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

     r =  -0.034      lambda = 0.966      R0 =      0.753

   Generation time for:  females = 8.29     males = 11.02
```

Stable age distribution:

Age class	females	males
0	0.168	0.168
1	0.052	0.052
2	0.040	0.040
3	0.030	0.035
4	0.027	0.030
5	0.023	0.026
6	0.020	0.023
7	0.018	0.020
8	0.015	0.017
9	0.013	0.015
10	0.012	0.013
11	0.010	0.011
12	0.009	0.010
13	0.008	0.009
14	0.007	0.008
15	0.006	0.007
16	0.005	0.006
17	0.004	0.005
18	0.004	0.004
19	0.003	0.004
20	0.003	0.003
21	0.003	0.003
22	0.002	0.002
23	0.002	0.002
24	0.002	0.002
25	0.001	0.002

Ratio of adult (>= 6) males to adult (>= 3) females: 0.732

Population1

```
Year 10
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     10, P[S] = 1.000
     Population size =            993.80 (  72.17 SE,  228.23 SD)
     Expected heterozygosity =     0.999 (  0.000 SE,   0.000 SD)
     Observed heterozygosity =     1.000 (  0.000 SE,   0.001 SD)
     Number of extant alleles =  1121.10 (  58.43 SE,  184.76 SD)

Year 20
     N[Extinct] =        2, P[E] = 0.200
     N[Surviving] =      8, P[S] = 0.800
     Population size =            546.50 (  53.48 SE,  151.26 SD)
     Expected heterozygosity =     0.997 (  0.000 SE,   0.000 SD)
     Observed heterozygosity =     1.000 (  0.000 SE,   0.001 SD)
     Number of extant alleles =   508.00 (  32.00 SE,   90.51 SD)

Year 30
     N[Extinct] =        3, P[E] = 0.300
     N[Surviving] =      7, P[S] = 0.700
     Population size =            344.71 (  44.10 SE,  116.67 SD)
     Expected heterozygosity =     0.994 (  0.001 SE,   0.002 SD)
     Observed heterozygosity =     0.999 (  0.001 SE,   0.002 SD)
     Number of extant alleles =   270.57 (  26.01 SE,   68.81 SD)

Year 40
     N[Extinct] =        3, P[E] = 0.300
     N[Surviving] =      7, P[S] = 0.700
     Population size =            164.57 (  37.16 SE,   98.32 SD)
     Expected heterozygosity =     0.988 (  0.001 SE,   0.003 SD)
     Observed heterozygosity =     0.997 (  0.002 SE,   0.004 SD)
     Number of extant alleles =   132.71 (  18.22 SE,   48.21 SD)

Year 50
     N[Extinct] =        3, P[E] = 0.300
     N[Surviving] =      7, P[S] = 0.700
     Population size =            123.57 (  32.01 SE,   84.69 SD)
     Expected heterozygosity =     0.977 (  0.003 SE,   0.009 SD)
```

```
     Observed heterozygosity =    0.986 (  0.005 SE,   0.014 SD)
     Number of extant alleles =   81.00 ( 16.73 SE,   44.26 SD)

Year 60
     N[Extinct] =       4, P[E] = 0.400
     N[Surviving] =     6, P[S] = 0.600
     Population size =            79.83 ( 33.02 SE,   80.87 SD)
     Expected heterozygosity =    0.960 (  0.007 SE,   0.017 SD)
     Observed heterozygosity =    0.989 (  0.005 SE,   0.013 SD)
     Number of extant alleles =   47.00 ( 13.86 SE,   33.96 SD)

Year 70
     N[Extinct] =       4, P[E] = 0.400
     N[Surviving] =     6, P[S] = 0.600
     Population size =            58.33 ( 33.19 SE,   81.29 SD)
     Expected heterozygosity =    0.934 (  0.013 SE,   0.032 SD)
     Observed heterozygosity =    0.968 (  0.020 SE,   0.050 SD)
     Number of extant alleles =   31.83 ( 12.27 SE,   30.06 SD)

Year 80
     N[Extinct] =       6, P[E] = 0.600
     N[Surviving] =     4, P[S] = 0.400
     Population size =            44.25 ( 20.18 SE,   40.37 SD)
     Expected heterozygosity =    0.898 (  0.050 SE,   0.100 SD)
     Observed heterozygosity =    0.972 (  0.010 SE,   0.020 SD)
     Number of extant alleles =   27.00 ( 12.34 SE,   24.68 SD)

Year 90
     N[Extinct] =       7, P[E] = 0.700
     N[Surviving] =     3, P[S] = 0.300
     Population size =            28.00 ( 11.06 SE,   19.16 SD)
     Expected heterozygosity =    0.926 (  0.010 SE,   0.017 SD)
     Observed heterozygosity =    0.976 (  0.015 SE,   0.027 SD)
     Number of extant alleles =   19.00 (  2.89 SE,    5.00 SD)

Year 100
     N[Extinct] =       8, P[E] = 0.800
     N[Surviving] =     2, P[S] = 0.200
     Population size =            16.50 (  5.50 SE,    7.78 SD)
     Expected heterozygosity =    0.880 (  0.012 SE,   0.018 SD)
     Observed heterozygosity =    0.909 (  -NaN SE,    -NaN SD)
     Number of extant alleles =   12.50 (  3.50 SE,    4.95 SD)


In 10 simulations of 100 years of Population1:
  8 went extinct and 2 survived.

This gives a probability of extinction of 0.8000 (0.1265 SE),
  or a probability of success of         0.2000 (0.1265 SE).

8 simulations went extinct at least once.
Median time to first extinction was 74 years.
Of those going extinct,
    mean time to first extinction was 56.75 years (11.15 SE, 31.54 SD).

No recolonizations.

Mean final population for successful cases was 16.50 (5.50 SE, 7.78 SD)

   Age 1      2      3      4      5   Adults    Total
    1.00   2.00   1.50   0.00   0.00    4.50      9.00  Males
    1.00   1.50                         5.00      7.50  Females

Without harvest/supplementation, prior to carrying capacity truncation,
  mean growth rate (r) was -0.0664 (0.0067 SE, 0.1695 SD)

Final expected heterozygosity was      0.8802 ( 0.0124 SE,   0.0175 SD)
Final observed heterozygosity was      0.9091 (   -NaN SE,     -NaN SD)
Final number of alleles was             12.50 (   3.50 SE,     4.95 SD)
```

Yellow-eyed Penguin

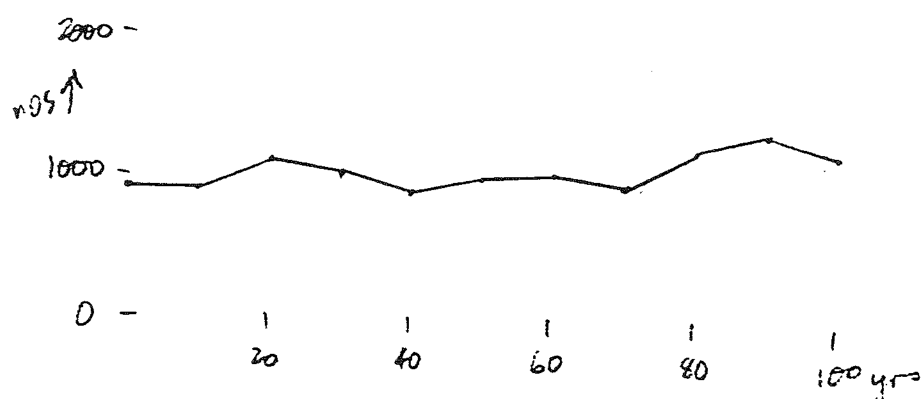
LALAS 21 AUG92

"YELLOW22" = a feasible catastrophe scenario & no human impact

YEP Otago N_{1992} = 914 individuals

YELLOW 22.

1. no predation breeding success = 1·5 chicks fledged per nest
2. 16·5 catastrophes per century
   - → zero breeding success
   - → 50% adult mortality
3. plus 6·75% adult mortality pa
   - → total adult mortality average 15% pa



10 populations : none went extinct

av. after 100 years = 1273 birds cf start 914

range in 10 pops @ 100 years ~ 86 → 2500

NB 2500 = holding capacity

ie cockup with upper limit for popN.

Yellow-eyed Penguins.

YELLOW 22
LALAB 21AUG99-

YELLOW 22 does not address "human impact"

PREDATION

YELLOW 22 Reproduction

Litter size 0 = 10 %
1 = 30 %
2 = 60 %

Result ie for NO PREDATION
nesting success average 1.5 fledglings per nest

Predation = chicks ONLY = reduction in fledgling rate
eg 33% predation ≡ av 1.0 fledglings per nest

HUMAN IMPACT (DEATH) ON FLEDGED BIRDS

assume impact is the same on all age classes (?)
ie add a constant to all mortality rates (?)
This would test effects of dog kills, set nets etc etc

LAND CLEARANCE / DESTRUCTION OF NESTING HABITAT

→ reduce "holding capacity" K
is this scenario work following up?

Yellow-eyed penguins.

YELLOW 22
LALAS 21 Au

* Vortex programming "problems"

1. Carring capacity K needs to be higher or "open ended" if we set it at "2500" – needs to be say "5000" or maybe "10 000"
2. "Catastrophe" → need an age-selective mortality.

---

* "Stable" population model (no predation, no human impact)

Adults — by definition we must match a long-term 15% pa mortality for adults

Our stable model = "YELLOW 22"
adult mortality = "intrinsic" 6.75% pa ⇒ 45% total mortal.
PLUS 50% @ each catastrophe ⇒ 55% total mortal

"Conclusion" catastrophes account for about/over half adult deat

---

Juveniles & Immatures ~~[illegible]~~ = age 0 ♀ ♂
age 1 ♀ ♂
age 2 ♀ ♂
age 3 ♂

by "definition" → without catastrophes, about 1/3 survive from fledging to breeding

→ with catastrophes, none survive

Catastrophes frequency deduced directly by extrapolation from numbe that occurred through combination of study periods by Richdale & Darby

```
YELLOW22.OUT        ***OutputFilename***
Y       ***PlotterFiles?***
N       ***EachRun?***
10       ***Simulations***
100       ***Years***
10       ***ReportingInterval***
1       ***Populations***
N       ***InbreedingDepression?***
Y       ***EVcorrelation?***
1       ***TypesOfCatastrophes***
M       ***MonogamousOrPolygynous***
3       ***FemaleBreedingAge***
4       ***MaleBreedingAge***
25       ***MaximumAge***
0.500000       ***SexRatio***
2       ***MaximumLitterSize***
N       ***DensityDependentBreeding?***
10.000000       ***Population1:PercentLitterSize0***
30.000000       ***Population1:PercentLitterSize1***
60.000000       ***Population1:PercentLitterSize2***
12.500000       ***EV--Reproduction***
33.000000       ***FemaleMortalityAtAge0***
11.083020       ***EV--FemaleMortality***
17.000000       ***FemaleMortalityAtAge1***
6.000000       ***EV--FemaleMortality***
17.000000       ***FemaleMortalityAtAge2***
6.000000       ***EV--FemaleMortality***
6.750000       ***AdultFemaleMortality***
2.250000       ***EV--AdultFemaleMortality***
33.000000       ***MaleMortalityAtAge0***
11.083020       ***EV--MaleMortality***
10.000000       ***MaleMortalityAtAge1***
3.000000       ***EV--MaleMortality***
6.750000       ***MaleMortalityAtAge2***
2.250000       ***EV--MaleMortality***
6.75000       ***MaleMortalityAtAge3***
2.250000       ***EV--MaleMortality***
6.7500000       ***AdultMaleMortality***
2.250000       ***EV--AdultMaleMortality***
16.500000       ***ProbabilityOfCatastrophe1***
0.000000       ***Severity--Reproduction***
0.50000       ***Severity--Survival***
Y       ***AllMalesBreeders?***
Y       ***StartAtStableAgeDistribution?***
914       ***InitialPopulationSize***
2500       ***K***
0.000000       ***EV--K***
N       ***TrendInK?***
N       ***Harvest?***
N       ***Supplement?***
```

VORTEX -- simulation of genetic and demographic stochasticity

YELLOW22.OUT
Thu Aug 20 19:42:00 1992

1 population(s) simulated for 100 years, 10 runs

No inbreeding depression

First age of reproduction for females: 3 for males: 4
Age of senescence (death): 25
Sex ratio at birth (proportion males): 0.5000

Population 1:
Monogamous mating; all adult males in the breeding pool. 100.00 percent of adult males in the breeding pool.

Reproduction is assumed to be density independent.

10.00 (EV = 12.25 SD) percent of adult females produce litters of size 0
30.00 percent of adult females produce litters of size 1
60.00 percent of adult females produce litters of size 2

33.00 (EV = 11.08 SD) percent mortality of females between ages 0 and 1
17.00 (EV = 6.00 SD) percent mortality of females between ages 1 and 2
17.00 (EV = 6.00 SD) percent mortality of females between ages 2 and 3
6.75 (EV = 2.25 SD) percent annual mortality of adult females (3<=age<=25)
33.00 (EV = 11.08 SD) percent mortality of males between ages 0 and 1
10.00 (EV = 3.00 SD) percent mortality of males between ages 1 and 2
6.75 (EV = 2.25 SD) percent mortality of males between ages 2 and 3
6.75 (EV = 2.25 SD) percent mortality of males between ages 3 and 4
6.75 (EV = 2.25 SD) percent annual mortality of adult males (4<=age<=25)
EVs may have been adjusted to closest values possible for binomial distribution.
EV in reproduction and mortality will be correlated.

Frequency of type 1 catastrophes: 16.500 percent
with 0.000 multiplicative effect on reproduction
and 0.500 multiplicative effect on survival

Initial size of Population 1:

(set to reflect stable age distribution)

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total	
	95	75	61	49	40	32	26	22	17	14	11	9	8	6	5	4	3	3	2	2	1	1	1	1	0	488	Males
	95	69	50	40	33	27	21	18	14	11	10	7	6	5	4	4	2	2	2	2	1	1	0	1	1	426	Females

Carrying capacity = 2500 (EV = 0.00 SD)

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

r = 0.053 lambda = 1.055 R0 = 1.503
Generation time for: females = 7.66 males = 8.60

Stable age distribution:

Age class	females	males
0	0.132	0.132
1	0.077	0.077
2	0.055	0.060
3	0.040	0.049
4	0.033	0.040
5	0.026	0.032
6	0.021	0.026
7	0.017	0.021
8	0.014	0.017
9	0.011	0.014
10	0.009	0.011
11	0.008	0.009
12	0.006	0.007
13	0.005	0.006
14	0.004	0.005
15	0.003	0.004
16	0.003	0.003
17	0.002	0.003
18	0.002	0.002
19	0.001	0.002
20	0.001	0.001
21	0.001	0.001
22	0.001	0.001
23	0.001	0.001
24	0.000	0.001
25	0.000	0.000

Ratio of adult (>= 4) males to adult (>= 3) females: 0.986

Population1

Year 10

```
      N[Extinct] =        0, P[E] = 0.000
      N[Surviving] =     10, P[S] = 1.000
      Population size =
                                 928.70 ( 247.16 SE,   781.60 SD)
      Expected heterozygosity =   0.997 (   0.001 SE,   0.003 SD)
      Observed heterozygosity =   1.000 (   0.000 SE,   0.001 SD)
      Number of extant alleles = 622.60 ( 130.18 SE,   411.68 SD)
   Year 20
      N[Extinct] =        0, P[E] = 0.000
      N[Surviving] =     10, P[S] = 1.000
      Population size =
                                1228.40 ( 279.30 SE,   883.23 SD)
      Expected heterozygosity =   0.994 (   0.001 SE,   0.004 SD)
      Observed heterozygosity =   0.998 (   0.001 SE,   0.002 SD)
      Number of extant alleles = 422.40 ( 100.34 SE,   317.29 SD)
   Year 30
      N[Extinct] =        0, P[E] = 0.000
      N[Surviving] =     10, P[S] = 1.000
      Population size =
                                1084.20 ( 313.73 SE,   992.10 SD)
      Expected heterozygosity =   0.990 (   0.002 SE,   0.006 SD)
      Observed heterozygosity =   0.996 (   0.001 SE,   0.005 SD)
      Number of extant alleles = 260.50 (  64.15 SE,   202.85 SD)
   Year 40
      N[Extinct] =        0, P[E] = 0.000
      N[Surviving] =     10, P[S] = 1.000
      Population size =
                                 923.80 ( 280.39 SE,   886.66 SD)
      Expected heterozygosity =   0.986 (   0.003 SE,   0.009 SD)
      Observed heterozygosity =   0.994 (   0.002 SE,   0.006 SD)
      Number of extant alleles = 197.60 (  53.15 SE,   168.07 SD)
   Year 50
      N[Extinct] =        0, P[E] = 0.000
      N[Surviving] =     10, P[S] = 1.000
      Population size =
                                1008.60 ( 270.56 SE,   855.59 SD)
      Expected heterozygosity =   0.980 (   0.005 SE,   0.015 SD)
      Observed heterozygosity =   0.987 (   0.003 SE,   0.009 SD)
      Number of extant alleles = 160.10 (  44.14 SE,   139.57 SD)
   Year 60
      N[Extinct] =        0, P[E] = 0.000
      N[Surviving] =     10, P[S] = 1.000
      Population size =
                                1080.80 ( 248.97 SE,   787.32 SD)
      Expected heterozygosity =   0.977 (   0.006 SE,   0.018 SD)
      Observed heterozygosity =   0.982 (   0.005 SE,   0.015 SD)
      Number of extant alleles = 137.80 (  35.09 SE,   110.97 SD)
   Year 70
      N[Extinct] =        0, P[E] = 0.000
      N[Surviving] =     10, P[S] = 1.000
      Population size =
                                1001.90 ( 267.54 SE,   846.03 SD)
      Expected heterozygosity =   0.973 (   0.007 SE,   0.023 SD)
      Observed heterozygosity =   0.978 (   0.005 SE,   0.017 SD)
      Number of extant alleles = 107.50 (  21.59 SE,    68.26 SD)
```

```
Year 80
     N[Extinct] =         0, P[E] = 0.000
     N[Surviving] =      10, P[S] = 1.000
     Population size =          1254.50 ( 299.32 SE,   946.54 SD)
     Expected heterozygosity =    0.971 (  0.007 SE,    0.024 SD)
     Observed heterozygosity =    0.970 (  0.008 SE,    0.025 SD)
     Number of extant alleles =   97.40 (  19.10 SE,    60.39 SD)

Year 90
     N[Extinct] =         0, P[E] = 0.000
     N[Surviving] =      10, P[S] = 1.000
     Population size =          1370.20 ( 302.03 SE,   955.10 SD)
     Expected heterozygosity =    0.968 (  0.008 SE,    0.024 SD)
     Observed heterozygosity =    0.970 (  0.009 SE,    0.027 SD)
     Number of extant alleles =   88.40 (  17.88 SE,    56.53 SD)

Year 100
     N[Extinct] =         0, P[E] = 0.000
     N[Surviving] =      10, P[S] = 1.000
     Population size =          1272.90 ( 310.40 SE,   981.58 SD)
     Expected heterozygosity =    0.964 (  0.008 SE,    0.025 SD)
     Observed heterozygosity =    0.971 (  0.007 SE,    0.022 SD)
     Number of extant alleles =   78.20 (  16.94 SE,    53.55 SD)
```

In 10 simulations of 100 years of Population1:
0 went extinct and 10 survived.

This gives a probability of extinction of 0.0000 (0.0000 SE),
or a probability of success of 1.0000 (0.0000 SE).

Mean final population for successful cases was 1272.90 (310.40 SE, 981.58 SD)

Age 1	2	3	Adults	Total	
107.00	105.70	83.00	391.70	687.40	Males
106.50	101.80		377.20	585.50	Females

Without harvest/supplementation, prior to carrying capacity truncation,
mean growth rate (r) was 0.0227 (0.0113 SE, 0.3587 SD)

Final expected heterozygosity was 0.9643 (0.0080 SE, 0.0252 SD)
Final observed heterozygosity was 0.9713 (0.0068 SE, 0.0216 SD)
Final number of alleles was 78.20 (16.94 SE, 53.55 SD)
****

NEW ZEALAND PENGUINS

POPULATION AND HABITAT VIABILITY ANALYSIS

INITIAL WORKSHOP REPORT

FIRST DISCUSSION DRAFT

19-21 August 1992

Christchurch

SECTION 4

CRESTED PENGUINS

NEW ZEALAND CRESTED PENGUINS

Introduction

There are five species of crested penguins breeding in the New Zealand area. Fiordland Crested Penguins (*Eudyptes pachyrhynchus*) breeds in the south-west of the South Island, Stewart Island and islands nearby. Snares Crested Penguin (*E robustus*) are confined to the Snares Islands 100km south of Stewart Island. Erect crested penguins (*E sclateri*) breed on Bounty and Antipodes Islands. Rockhopper penguins (*E chrysocome filholi*) breeed on Antipodes, Campbell, Auckland, and Macquarie Islands and other islands elsewhere in the southern ocean. Royal Penguins (*E schlegeli*) only breed on Macquarie Island.

Abundance

Fiordland Crested Penguins are considered threatened with perhaps less than 1000 breeding pairs. Snares crested Penguins have about 2000 breeding pairs. There are several hundred thousand breeding pairs of Erect crested Penguins but the estimates for the Antipodes population is at best an educated guess. There are probably 350,000-400,000 Rockhopper penguin breeding pairs in the New Zealand (including Macquarie Island), and about one million pairs of Royal Penguins. Fiordland crested and Rockhopper penguins have declined from a large population 50-100 years ago. Little is known about the former abundance of the other crested penguin species.

Population Biology

Studies have been carried out on the breeding biology of all crested penguins except Erect-crested Penguins. The best information has been collected for Royal and Rockhopper penguins and a few studies have been carried out on Snares and Fiordland-crested penguins. Life history and demographic studies are still needed for all species. The best information is recorded for Royal Penguins and some for Snares and Rockhopper Penguins. Very little or nothing is known for Fiordland and Erect-crested Penguins.

PVA Scenarios

Good statistically, robust, quantified data were lacking for all species. Aspects of breeding biology and life history were well known for some species and parameters examined. However, a complete set of information was not available for any one species to carry out a meaningful PVA analysis. Therefore a combination of factors that were known was used to test a typical crested penguin scenario.

The best single source of information we had was the Handbook of Australian, New Zealand, and Antarctic Birds.

Breeding Success

Fiordland-crested	0.5 chicks/nest/year
Snares-crested	0.5-0.8 chicks/nest/year
Erect-crested	No data
Rockhopper	0.5 chicks/nest/year
Royal	0.5 chicks/nest/year

Explanation
Breeding success ranged from 0.5-0.8 chicks/nest/year. We chose 0.6 as a representative scenario.

Mortality to Year 1

Fiordland-crested	No data
Snares-crested	85%
Erect-crested	No data
Rockhopper	No data
Royal	33%

Explanation
Mortality data was incomplete. The Snares-crested Penguin scenario (85%) was too high and led to extinctions in all runs. Band loss was probably and important but as yet unquantified factor. Little Blue Penguins had a 33% first-year mortality and so we chose 33% as our standard year-one mortality rate.

Mortality to Year 2

The only data available was for Royal and Snares-crested Penguins. This was 24% and 43% but seemed too high and so we chose 15% (about half of first-year mortality) to account for an expected increase in mortality around the time of the birds first moult.

Mortality to Year 3 to adult

New reliable information is available for any species. A set of data for Royal Penguins was modelled and was found to be erroneous/led to rapid extinction. If this data was used only 5% of fledglings would be alive by the time of first breeding at eight years - an unsustainable proposition. We therefore tested several adult mortality rates in the range expected for other long-lived seabirds, eg 5-10%. We found that 8% led to a decline whereas 7% maintained a stable or increasing population. We suspect that high band-loss has occurred in the natural populations studied to date. For example, Snares-crested had an annual mortality rate of 30% and Royals had a rate of 13%.

Age at first breeding

Information was available for Royal, Snares and Fiordland-crested Penguins. Some birds began nests at four years of age but breeding attempts by Royals was unsuccessful when the birds bred in their fifth and sixth years. Thee was also some evidence from Royal Penguins that male began breeding slightly later than females. We chose seven years as the mean age of first breeding for females and eight years for males.

Percentage of adult males in breeding pool

Penguins are essentially monogamous breeders. We tested scenarios of 80-90% of males in the breeding pool. This assumed a small percentage of males of breeding age would not be nesting or remain un-paired each year.

Other factors

We assumed no in-breeding depression, reproduction to be density independent, and carrying-capacity would not be limiting. We also assumed that all adults would not survive past 30 years, as the oldest known crested penguins are 20-25 years of age. We did not test harvest or supplementation scenarios or model for catastrophes.

Input summary

We ran a large number of PVA simulations with slight changes to the main factors; breeding success and age-related mortality (juvenile and adult). A stable population trend emerged at 60% chick production, first-year mortality of 33%, second-year 15%, and third year to adult mortality of 7%. This represented a hypothetical crested penguin species. For species of a known low chick production eg 50%, the mortality rates would need to be lower for the population size to remain stable.

At present all these modelled factors are producing a declining population in Rockhopper Penguins.

Alternative run options

Vary breeding success to test impact on the population. Look for occasional (one event in 25 years), small and large catastrophes. Look at inbreeding depression effects on the model. Increase adult life-expectancy to see if it is limiting population growth.

Recommendations for research/management

1. Distribution of Fiordland crested Penguins is still poorly known. Survey of this specie's breeding colonies is a high priority.

2. Population abundance of Erect-crested and Rockhopper Penguins is still poorly known on the Antipodes Island. A field survey and census is needed urgently. An aerial

survey of Erect-crested on the Bounty Islands is also required.

3. An analysis of banding data (recoveries) is need for Rockhopper Penguins.

4. A test is needed to establish the impact of band-loss and wear on the estimates of age-related mortality. Birds should be banded with both a specially designed leg-band and flipper-band to measure the extent of flipper-band loss.

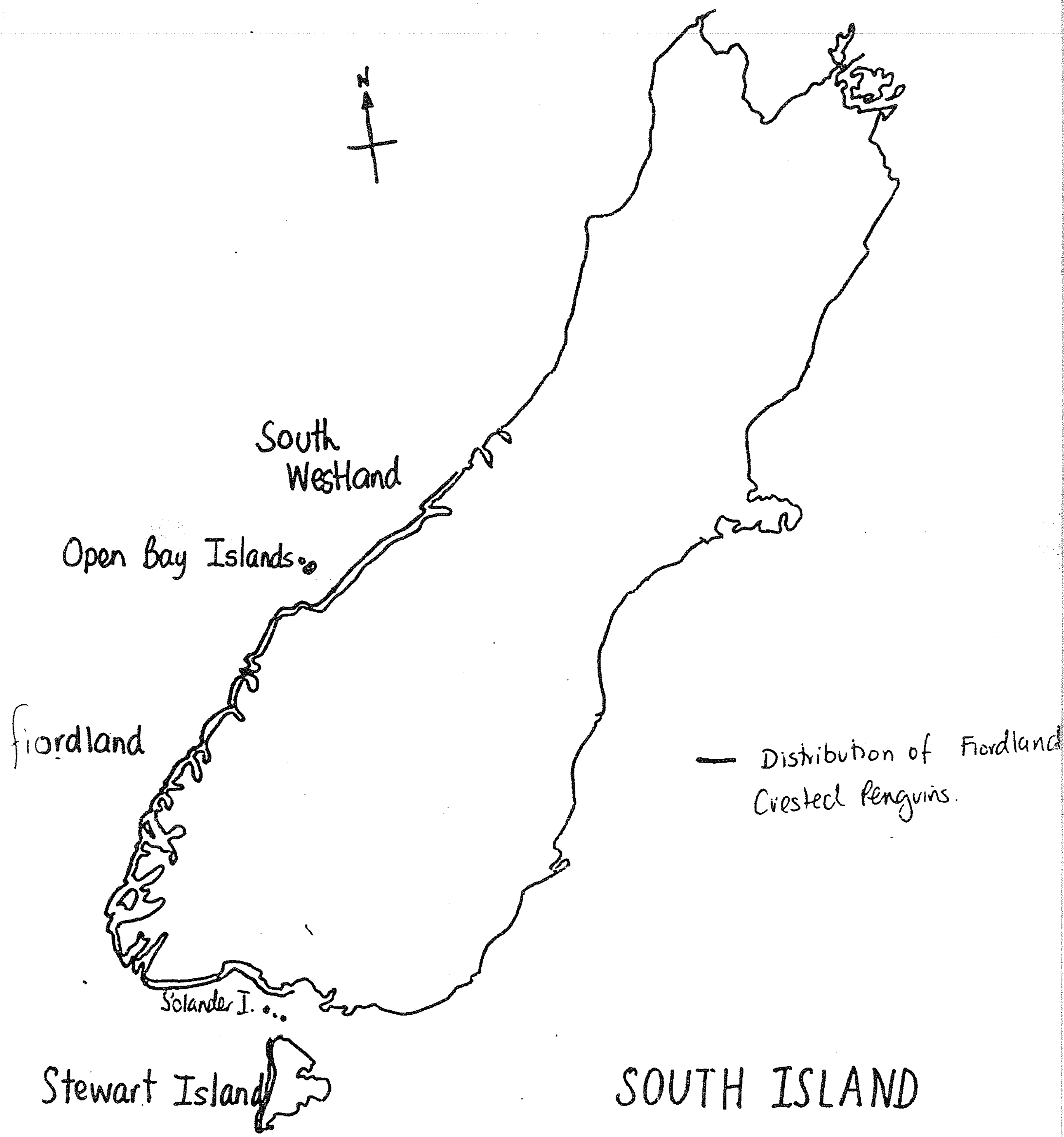
5. A detailed study of breeding biology and demography of Erect-crested Penguins is needed. This would best be done on Antipodes Island. The study would require a regular banding programme involving banding adults as well as banding large numbers of chicks.

6. A complete census of Snares-crested Penguins is needed just after the completion of egg-laying to establish a base-line of the breeding pairs. Previous counts were based on chick production.

7. A study of Fiordland crested Penguins breeding on both mainland and island (predator-free) sites is needed to compare breeding success at these different localities. A banding study if also needed to look at the demographic trends in this population.

Conclusion

The PVA has revealed the weakness of the data-set for most factors modelled, but in particular life-history parameters are poorly known. Age-related mortality was shown to have the most significant impact on the modelled penguin populations but this information was the least well known for all species. A one percent increase in annual adult mortality can be the difference between a stable and a decreasing population. Clearly several long-term studies using reliable banding techniques are urgently needed for both stable species and where the population is declining.


N
South Westland
Open Bay Islands
fiordland
Solander I.
Stewart Island
SOUTH ISLAND
— Distribution of Fiordland Crested Penguins.

TAXON: EUDYPTES PACHYRHYNCHUS Fiordland crested penguin

Status: **CITES Appendix** - not listed
Red Data Book - not listed
Mace-Lande - Endangered

Breeding Distribution: New Zealand, Stewart Island

Estimated wild population: < 1,000 pairs
Stewart Island - unknown
New Zealand -
Jackson Head - 100 breeding pairs (approximately)
Open Bay Islands, Taumaka Island - 300 - 400 breeding birds
Doubtful to Milford Sound - 283 birds
Dusky to Breaksea Sound - 106 birds (46 nests)

Current/Ongoing field studies: Monitoring of three sub-colonies on the west coast by New Zealand Department of Conservation, Private Bag. Monitoring is low-key. Surveys at the northern end of the breeding range due to commence during the 1992 breeding season, carried out by New Zealand Department of Conservation. Sub-fossil archeological surveys of previous sites would be useful.

Captive population: none listed in ISIS

Concerns/Comments: On the west coast, breeding sites are relatively accessible. Little information exists on population size or trends on the west coast. Historical data from Richard Henry (c.1890) reports "thousands;" Oliver (1955) has records of their breeding north up to the Cook Straights and perhaps on the southernmost part of the North Island. Question exists as to whether the current range may be refugia rather than optimal availability of the habitat. Tends to occur in small numbers in discrete locations throughout their range (McLean & Russ, 1991), and tend to nest in discrete groups rarely exceeding 10 nests in an area of less than 1 hectare. Largest breeding population is on Taumaka Island in the Open Bay Islands. Natural egg mortality is usually due to displacement or desertion; eggs and small chicks are also preyed upon by Wekas (*Gallirallus australis*). [Mainland Wekas are also threatened; see K-J. Wilson's pers. comm. under *Pygoscelis papua*.] McLean (1992) reported that 38% of egg mortality and 20% of mortality in young chicks was attributable to Weka predation at a study site at Taumaka; 38% of the chicks that hatched were alive at the end of the study, 6-8 weeks prior to fledging. Additionally, Weka uproot ground cover while foraging for insects and other prey. Older chick mortality most often results from starvation or exposure to bad weather or predation. Belinda Studholm noted an increase in chick predation over the last three years at Taumaka Island (Garland, pers.comm.).

In addition to predation by Weka, threats include human disturbance at nest sites, cars, and predation by introduced species such as dogs, stoats, and possibly cats. Fisheries are also a threat in that birds are caught in set nets. It is recommended that no set nets be allowed near breeding colonies of penguins. Moulting birds are especially susceptible to predation by dogs. Blood is available to deposit in Peter Stockdale's pathology registry at Massey University, New Zealand.

Recommendations:
PHVA: Yes
More intensive wild management: Yes
Captive program: Pending PHVA
Research: Survey, Taxonomy, Other
Priority is survey work and monitoring, including banding and/or injectable microchips for at least a 5-year period. Once birds are identified, it should be able to be shown if there is any genetic exchange between populations, and estimate juvenile and adult mortality rates. Identify former range and distribution and locate historical sites and determine if any birds are remaining in historical range. Identify components of high-grade sites and quality habitat and monitor these to establish trends. A Recovery/Management Plan needs to be developed. Studies into predation and the role predators play is not well understood; investigate effects of chick predation and compare with a predator-free colony as control. Of high priority is a detailed study of the effects of Wekas on the flora and fauna of the Open Bay Islands. Genetic exchange between small groups needs study. Dietary studies need to be carried out for the entire genus especially with regard to fisheries competition. (If *E. pachyrhynchus* is specializing on squid, then by analogy with other squid feeders they should have low reproductive rate but high adult survivorship (G. Taylor, pers.comm.). Also investigate diet changes in conjunction with climate changes, and examine fledging weights. A telemetry study is needed to determine foraging details. A baseline study is needed to establish normal physiological values.

VORTEX -- simulation of genetic and demographic stochasticity

FIORD18
Thu Aug 20 12:30:07 1992

1 population(s) simulated for 100 years, 10 runs

No inbreeding depression

First age of reproduction for females: 5 for males: 5
Age of senescence (death): 30
Sex ratio at birth (proportion males): 0.5000

Population 1:
Monogamous mating; 80.00 percent of adult males in the breeding pool.

Reproduction is assumed to be density independent.

25.00 (EV = 12.50 SD) percent of adult females produce litters of size 0
75.00 percent of adult females produce litters of size 1

70.00 (EV = 16.20 SD) percent mortality of females between ages 0 and 1
10.00 (EV = 3.00 SD) percent mortality of females between ages 1 and 2
5.00 (EV = 3.00 SD) percent mortality of females between ages 2 and 3
5.00 (EV = 3.00 SD) percent mortality of females between ages 3 and 4
5.00 (EV = 3.00 SD) percent mortality of females between ages 4 and 5
5.00 (EV = 3.00 SD) percent annual mortality of adult females (5<=age<=30)
70.00 (EV = 16.20 SD) percent mortality of males between ages 0 and 1
10.00 (EV = 3.00 SD) percent mortality of males between ages 1 and 2
5.00 (EV = 3.00 SD) percent mortality of males between ages 2 and 3
5.00 (EV = 3.00 SD) percent mortality of males between ages 3 and 4
5.00 (EV = 3.00 SD) percent mortality of males between ages 4 and 5
5.00 (EV = 3.00 SD) percent annual mortality of adult males (5<=age<=30)
EVs may have been adjusted to closest values possible for binomial distribution.
EV in mortality will be correlated among age-sex classes but independent from EV in reproduction.

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

Age	Males	Females
1	12	12
2	11	11
3	9	9
4	10	10
5	8	8
6	8	8
7	8	8
8	7	7
9	6	6
10	7	7
11	5	5
12	6	6
13	5	5
14	4	4
15	5	5
16	4	4
17	3	3
18	4	4
19	3	3
20	3	3
21	3	3
22	3	3
23	3	3
24	2	2
25	2	2
26	2	2
27	2	2
28	2	2
29	1	1
30	2	2
Total	150	150

Carrying capacity = 5000 (EV = 0.00 SD)

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

r = 0.017 lambda = 1.017 R0 = 1.279
Generation time for: females = 14.26 males = 14.26

Stable age distribution:

Age class	females	males
0	0.107	0.107
1	0.031	0.031
2	0.028	0.028
3	0.026	0.026

4	0.024	0.024
5	0.023	0.023
6	0.021	0.021
7	0.020	0.020
8	0.018	0.018
9	0.017	0.017
10	0.016	0.016
11	0.015	0.015
12	0.014	0.014
13	0.013	0.013
14	0.012	0.012
15	0.011	0.011
16	0.011	0.011
17	0.010	0.010
18	0.009	0.009
19	0.009	0.009
20	0.008	0.008
21	0.008	0.008
22	0.007	0.007
23	0.007	0.007
24	0.006	0.006
25	0.006	0.006
26	0.005	0.005
27	0.005	0.005
28	0.005	0.005
29	0.004	0.004
30	0.004	0.004

```
Ratio of adult (>= 5) males to adult (>= 5) females: 1.000


Population1

Year 10
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     10, P[S] = 1.000
     Population size =           309.90 (  17.82 SE,   56.36 SD)
     Expected heterozygosity =    0.997 (  0.000 SE,   0.000 SD)
     Observed heterozygosity =    1.000 (  0.000 SE,   0.000 SD)
     Number of extant alleles =  369.90 (  11.88 SE,   37.55 SD)

Year 20
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     10, P[S] = 1.000
     Population size =           326.10 (  27.75 SE,   87.75 SD)
     Expected heterozygosity =    0.995 (  0.000 SE,   0.001 SD)
     Observed heterozygosity =    0.999 (  0.001 SE,   0.002 SD)
     Number of extant alleles =  272.70 (  13.15 SE,   41.58 SD)

Year 30
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     10, P[S] = 1.000
     Population size =           314.60 (  25.49 SE,   80.60 SD)
     Expected heterozygosity =    0.993 (  0.000 SE,   0.001 SD)
     Observed heterozygosity =    0.998 (  0.001 SE,   0.003 SD)
     Number of extant alleles =  212.80 (  11.92 SE,   37.71 SD)

Year 40
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     10, P[S] = 1.000
     Population size =           345.30 (  36.99 SE,  116.98 SD)
     Expected heterozygosity =    0.991 (  0.001 SE,   0.002 SD)
     Observed heterozygosity =    0.996 (  0.001 SE,   0.003 SD)
     Number of extant alleles =  178.00 (  11.87 SE,   37.54 SD)

Year 50
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     10, P[S] = 1.000
     Population size =           378.70 (  51.16 SE,  161.78 SD)
```

```
    Expected heterozygosity =    0.989 (  0.001 SE,    0.003 SD)
    Observed heterozygosity =    0.993 (  0.001 SE,    0.004 SD)
    Number of extant alleles =  155.30 (  11.23 SE,    35.51 SD)

Year 60
    N[Extinct] =        0, P[E] = 0.000
    N[Surviving] =     10, P[S] = 1.000
    Population size =          378.60 (  54.68 SE,   172.90 SD)
    Expected heterozygosity =    0.987 (  0.002 SE,    0.005 SD)
    Observed heterozygosity =    0.994 (  0.001 SE,    0.005 SD)
    Number of extant alleles =  136.40 (  10.59 SE,    33.48 SD)

Year 70
    N[Extinct] =        0, P[E] = 0.000
    N[Surviving] =     10, P[S] = 1.000
    Population size =          404.90 (  60.51 SE,   191.34 SD)
    Expected heterozygosity =    0.984 (  0.002 SE,    0.008 SD)
    Observed heterozygosity =    0.989 (  0.002 SE,    0.008 SD)
    Number of extant alleles =  123.00 (  10.67 SE,    33.75 SD)

Year 80
    N[Extinct] =        0, P[E] = 0.000
    N[Surviving] =     10, P[S] = 1.000
    Population size =          403.10 (  61.48 SE,   194.41 SD)
    Expected heterozygosity =    0.982 (  0.003 SE,    0.009 SD)
    Observed heterozygosity =    0.990 (  0.002 SE,    0.007 SD)
    Number of extant alleles =  110.40 (  10.34 SE,    32.68 SD)

Year 90
    N[Extinct] =        0, P[E] = 0.000
    N[Surviving] =     10, P[S] = 1.000
    Population size =          423.50 (  68.72 SE,   217.32 SD)
    Expected heterozygosity =    0.980 (  0.003 SE,    0.010 SD)
    Observed heterozygosity =    0.984 (  0.002 SE,    0.008 SD)
    Number of extant alleles =  101.20 (  10.02 SE,    31.70 SD)

Year 100
    N[Extinct] =        0, P[E] = 0.000
    N[Surviving] =     10, P[S] = 1.000
    Population size =          441.30 (  76.77 SE,   242.76 SD)
    Expected heterozygosity =    0.978 (  0.003 SE,    0.009 SD)
    Observed heterozygosity =    0.979 (  0.004 SE,    0.014 SD)
    Number of extant alleles =   94.60 (   9.81 SE,    31.03 SD)


In 10 simulations of 100 years of Population1:
  0 went extinct and 10 survived.

This gives a probability of extinction of 0.0000 (0.0000 SE),
  or a probability of success of          1.0000 (0.0000 SE).

Mean final population for successful cases was 441.30 (76.77 SE, 242.76 SD)

   Age 1       2       3       4    Adults    Total
   14.80   14.30   14.70   12.10   162.70    218.60  Males
   17.60   13.30   15.20   11.10   165.50    222.70  Females

Without harvest/supplementation, prior to carrying capacity truncation,
  mean growth rate (r) was 0.0020 (0.0020 SE, 0.0648 SD)

Final expected heterozygosity was      0.9785 ( 0.0029 SE,  0.0092 SD)
Final observed heterozygosity was      0.9794 ( 0.0044 SE,  0.0139 SD)
Final number of alleles was             94.60 (   9.81 SE,   31.03
```

master

POPULATION VIABILITY ANALYSIS DATA FORM - BIRDS

Species: Eudyptes pachyrhynchus

Species distribution: South & South west of the South Island of NZ and west Stewart Is

Study taxon (subspecies): Eudyptes pachyrhynchus pachyrhynchus

Study population location: Open Bay Islands (Taumaka Is)

Metapopulation - are there other separate populations? Are maps available?:
(Separation by distance, geographic barriers?)

Specialized requirements (Trophic, ecological): Bush or caves to nest in, small twigs to make nest.

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

a)Earliest: ?

b)Mean: ?

Clutch size (N, mean, SD, range): normally = 2 [on rare occaisions 3 are laid see Warham 1974]

Number fertile: 1 - 2

Number hatched: 1 - 2

Number fledged: 1

Laying Season: late July to early August approx. July 27 to August 10th.

Laying frequency (interclutch interval): yearly.

Are multiple clutches possible? no

Duration of incubation: 31-36 days. after laying of second egg.
Second egg laid about 4 days after the first egg

Hatchling sex ratio:

Egg weights:

	n	weight (g) ± S.D.	
1st egg	66	99.9 ± 7.8	Warham (1974)
2nd egg	52	120.3 ± 8.6	

→ **Hatchling weights (male and female):**

weight (g)	n	mean	SD	range	
chick A (from 1st eggs)	20	68.55	6.78	57 - 84	Cassady St Clair (1990)
Chick B (from 2nd eggs)	20	87.05	12.10	72 - 117	

→ **Age(s) at fledging:**
≈ 100 days. since hatching.

Adult sex ratio: ?

Adult body weight of males and females:

mean weights in grams

	♂	♀		♂	♀		♂	♀
middle of July prior to laying	4500	4026	end of Sept prior to chicks joining creche.	2716	2612	February	4646	4137

Warham 1974

Reproductive life-span (Male & Female, Range):
Warham (1974) notes that some birds bred for 5 seasons on the same nest but the reproductive life span could be longer than this.

Life time reproduction (Mean, Male & Female): ?

Social structure in terms of breeding (random, pair-bonded, polygyny, polyandry, etc; breeding male and female turnover each year?):
Pair bonded for at least 2 seasons

Proportion of adult males and females breeding each year: ?

Dispersal distance (mean, sexes): Immatures frequently seen in South Australia & Tasmania (1 found in Falkland Islands). Two out of three birds taken from Jackson head & released at Christchurch were subsequently seen at point of capture. Warham 1974

Migrations (months, destinations):
At sea from late November to beginning of February [then moult].
" " " " February - - - July [then breeding]

Territoriality (home range, season):
Nest site becomes territory from middle of July to end of November.

Age of dispersal:
at fledging ≈ 100 days.

Maximum longevity: ?

→ Population census - most recent. Date of last census. Reliability estimate.:
Census being carried out in Fiordland → 1991 - Breaksea & Dusky Sounds
Results suggest fewer than 1000 nests for the species annually. Russ et. al. 1992.

Projected population (5, 10, 50 years).: ?

Past population census (5, 10, 20 years - dates, reliability estimates):

? Population sex and age structure (young, juvenile, & adults) - time of year.:

Fecundity rates (by sex and age class):

Mortality rates and distribution (by sex and age) (neonatal, juvenile, adult);

→ Population density estimate. Area of population. Attach marked map.:
South Westland including Open Bay Islands, Fiordland, South coast of NZ as far as Green Islets and as far South as Solander Is, the west coast of Stewart Island and a number of small islands in this area.

Sources of mortality-% (natural, poaching, harvest, accidental, seasonal?).:

Predators - Dogs & stoats & wekas

natural

?

Check Richard Henry 1903.

* Habitat capacity estimate (Has capacity changed in past 20, 50 years?).: Richard Henry (1903 p 34) noted that he had seen "thousands" of Fiordland crested penguins, and that "the bush is just full of them near shore". So it appears that this species was numerous in Dusky Sound, & has declined dramatically this century. The 1991 survey of Dusky Sound only found 9 nests and 24 birds (includes birds on nest)

Present habitat protection status.:

Projected habitat protection status (5, 10, 50 years).:

Environmental variance affecting reproduction and mortality (rainfall, prey, predators, disease, snow cover ?).:

Predators - wekas, domestic dog

Is pedigree information available?:

Attach Life Table if available.

Date form completed: 8/08/92.

Correspondent/Investigator:

Name: Belinda Studholme.

Address: Zoology Department, University of Canterbury, Private Bag Christchurch.

Telephone: 667-001 ext 6061

Fax:

Henry, R. 1903. The habits of flightless birds in New Zealand. With notes on other birds. Wellington: John McKay Government Printer.

References:

Cassidy St Clair, Colleen 1990, Mechanisms of brood reduction in Fiordland Crested Pe[nguin] master Thesis.

Phillipson, S.M. 1991, Aspects of the brood reduction process of the FCP. MS[c]

Russ, R.B, McLean, I.G., Studholme, BJS, 1992 The Fiordland Crested Penguin Survey stage II Notornis Vol 39 part II pg 113.

Warham, J. The Fiordland Crested Penguin 1974 IBIS vol 116 no.1.

Comments:

Problems with captive breeding of Fiordland crested penguin:

1. Only raise one chick.
2. Female can only lay 2-3 eggs at the most.

So eggs production cannot be significantly increased by continually removing eggs from laying females. Given that only one chick per nest will be raised. it is probable that more eggs would be laid than could be raised anyway

TAXON: EUDYPTES ROBUSTUS Snares Island crested penguin

Status: **CITES Appendix** - not listed
Red Data Book - not listed
Mace-Lande - Vulnerable?

Breeding Distribution: Snares Island

Estimated wild population: 23,000 breeding pairs (Miskelly et al., 1987)

Current/Ongoing field studies: There has been no work carried out since 1987 (Miskelly et al., 1987; 1988).

Captive population: none listed in ISIS

Concerns/Comments: Available data suggests that the population is stable or possibly has increased since 1968. If exploitation of oil and other minerals in the Antarctic ever becomes a reality, oil pollution is potentially a threat. Other potential threats would be a fishing boat accident that could spill oil, and changes in fisheries practices relating to competition for food resources. Currently, there is a major fishery for quid around the Snares. At present there are no introduced predators on the Snares; the potential for such remains a constant threat.

Recommendations:
PHVA: Yes
More intensive wild management: No
Captive program: Pending PHVA
Research: Survey, Taxonomy, Other
Survey the population during incubation and breeding phases, with that being the primary reason for an expedition to Snares. (Prior censuses have been carried out during chick-rearing stage). Taxonomic question - may be two subpopulations; the population on the western chain has a breeding season about six weeks later than the rest of the population. Diet and breeding performance work is needed.

VORTEX -- simulation of genetic and demographic stochasticity

SNARE8
Thu Aug 20 12:30:07 1992

1 population(s) simulated for 100 years, 10 runs

No inbreeding depression

First age of reproduction for females: 5 for males: 5
Age of senescence (death): 30
Sex ratio at birth (proportion males): 0.5000

Population 1:
Monogamous mating; 90.00 percent of adult males in the breeding pool.

Reproduction is assumed to be density independent.

20.00 (EV = 12.65 SD) percent of adult females produce litters of size 0

80.00 percent of adult females produce litters of size 1

```
 60.00 (EV = 16.33 SD) percent mortality of females between ages 0 and 1
  7.50 (EV = 3.00 SD) percent mortality of females between ages 1 and 2
  7.50 (EV = 3.00 SD) percent mortality of females between ages 2 and 3
  7.50 (EV = 3.00 SD) percent mortality of females between ages 3 and 4
  7.50 (EV = 3.00 SD) percent mortality of females between ages 4 and 5
  7.50 (EV = 3.00 SD) percent annual mortality of adult females
(5<=age<=30)
 60.00 (EV = 16.33 SD) percent mortality of males between ages 0 and 1
  7.50 (EV = 3.00 SD) percent mortality of males between ages 1 and 2
  7.50 (EV = 3.00 SD) percent mortality of males between ages 2 and 3
  7.50 (EV = 3.00 SD) percent mortality of males between ages 3 and 4
  7.50 (EV = 3.00 SD) percent mortality of males between ages 4 and 5
  7.50 (EV = 3.00 SD) percent annual mortality of adult males
(5<=age<=30)
```

EVs may have been adjusted to closest values possible for binomial distribution.
EV in mortality will be correlated among age-sex classes but independent from EV in reproduction.

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

```
 Age 1      2      3      4      5      6      7      8      9     10     11     12
13     14     15     16     17     18     19     20     21     22     23     24     25
 26     27     28     29     30     Total
    50     45     42     37     34     30     28     25     22     21     18     17
14     14     12     11     10      9      8      8      6      6      6      5      4
  4      4      3      3      3     499  Males
    51     45     42     37     34     30     28     25     22     21     18     17
14     14     12     11     10      9      8      8      6      6      6      5      4
  4      4      3      3      3     500  Females
```

Carrying capacity = 5000 (EV = 0.00 SD)

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

r = 0.024 lambda = 1.024 R0 = 1.356
Generation time for: females = 12.86 males = 12.86

Stable age distribution:

Age class	females	males
0	0.103	0.103
1	0.040	0.040
2	0.036	0.036
3	0.033	0.033

4	0.030	0.030
5	0.027	0.027
6	0.024	0.024
7	0.022	0.022
8	0.020	0.020
9	0.018	0.018
10	0.016	0.016
11	0.015	0.015
12	0.013	0.013
13	0.012	0.012
14	0.011	0.011
15	0.010	0.010
16	0.009	0.009
17	0.008	0.008
18	0.007	0.007
19	0.006	0.006
20	0.006	0.006
21	0.005	0.005
22	0.005	0.005
23	0.004	0.004
24	0.004	0.004
25	0.004	0.004
26	0.003	0.003
27	0.003	0.003
28	0.003	0.003
29	0.002	0.002
30	0.002	0.002

```
Ratio of adult (>= 5) males to adult (>= 5) females: 1.000

Population1

Year 10
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     10, P[S] = 1.000
     Population size =         1346.80 (  87.83 SE,  277.75 SD)
     Expected heterozygosity =   0.999 (  0.000 SE,   0.000 SD)
     Observed heterozygosity =   1.000 (  0.000 SE,   0.000 SD)
     Number of extant alleles = 1252.60 (  39.07 SE,  123.54 SD)

Year 20
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     10, P[S] = 1.000
     Population size =         1580.40 ( 145.16 SE,  459.03 SD)
     Expected heterozygosity =   0.999 (  0.000 SE,   0.000 SD)
     Observed heterozygosity =   0.999 (  0.000 SE,   0.001 SD)
     Number of extant alleles =  990.00 (  47.33 SE,  149.66 SD)

Year 30
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     10, P[S] = 1.000
     Population size =         1921.60 ( 194.30 SE,  614.44 SD)
     Expected heterozygosity =   0.998 (  0.000 SE,   0.000 SD)
     Observed heterozygosity =   0.999 (  0.000 SE,   0.001 SD)
     Number of extant alleles =  844.80 (  49.45 SE,  156.39 SD)

Year 40
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     10, P[S] = 1.000
     Population size =         2364.00 ( 326.80 SE, 1033.42 SD)
     Expected heterozygosity =   0.998 (  0.000 SE,   0.001 SD)
     Observed heterozygosity =   0.999 (  0.000 SE,   0.001 SD)
     Number of extant alleles =  745.60 (  50.11 SE,  158.45 SD)

Year 50
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     10, P[S] = 1.000
     Population size =         2468.50 ( 330.11 SE, 1043.89 SD)
     Expected heterozygosity =   0.997 (  0.000 SE,   0.001 SD)
```

```
     Observed heterozygosity =    0.999 (  0.000 SE,    0.001 SD)
     Number of extant alleles =  668.80 (  49.54 SE,   156.67 SD)

Year 60
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     10, P[S] = 1.000
     Population size =          2935.70 ( 424.28 SE, 1341.69 SD)
     Expected heterozygosity =    0.997 (  0.000 SE,    0.001 SD)
     Observed heterozygosity =    0.998 (  0.000 SE,    0.001 SD)
     Number of extant alleles =  623.50 (  48.95 SE,   154.79 SD)

Year 70
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     10, P[S] = 1.000
     Population size =          3232.20 ( 422.35 SE, 1335.59 SD)
     Expected heterozygosity =    0.997 (  0.000 SE,    0.001 SD)
     Observed heterozygosity =    0.998 (  0.000 SE,    0.001 SD)
     Number of extant alleles =  582.30 (  47.65 SE,   150.67 SD)

Year 80
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     10, P[S] = 1.000
     Population size =          3636.80 ( 409.83 SE, 1295.98 SD)
     Expected heterozygosity =    0.997 (  0.000 SE,    0.001 SD)
     Observed heterozygosity =    0.997 (  0.000 SE,    0.001 SD)
     Number of extant alleles =  556.40 (  45.54 SE,   144.01 SD)

Year 90
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     10, P[S] = 1.000
     Population size =          3936.80 ( 347.80 SE, 1099.85 SD)
     Expected heterozygosity =    0.996 (  0.000 SE,    0.001 SD)
     Observed heterozygosity =    0.996 (  0.001 SE,    0.002 SD)
     Number of extant alleles =  533.40 (  42.82 SE,   135.39 SD)

Year 100
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     10, P[S] = 1.000
     Population size =          3776.50 ( 385.97 SE, 1220.56 SD)
     Expected heterozygosity =    0.996 (  0.000 SE,    0.001 SD)
     Observed heterozygosity =    0.997 (  0.000 SE,    0.001 SD)
     Number of extant alleles =  510.20 (  41.15 SE,   130.14 SD)


In 10 simulations of 100 years of Population1:
  0 went extinct and 10 survived.

This gives a probability of extinction of 0.0000 (0.0000 SE),
  or a probability of success of          1.0000 (0.0000 SE).

Mean final population for successful cases was 3776.50 (385.97 SE, 1220.56
SD)

   Age 1       2       3       4  Adults    Total
  150.30  141.70  154.10  124.90 1313.00   1884.00  Males
  153.50  143.80  155.70  125.90 1313.60   1892.50  Females

Without harvest/supplementation, prior to carrying capacity truncation,
  mean growth rate (r) was 0.0155 (0.0020 SE, 0.0645 SD)

Final expected heterozygosity was      0.9962 ( 0.0004 SE,  0.0012 SD)
Final observed heterozygosity was      0.9971 ( 0.0003 SE,  0.0009 SD)
Final number of alleles was            510.20 (  41.15 SE,  130.14 SD)
```

TAXON: EUDYPTES SCLATERI - Erect-crested penguin

Status: **CITES Appendix** - not listed
Red Data Book - not listed
Mace-Lande - Vulnerable?

Breeding Distribution: Breeding only on the Antipodes and Bounty Islands

Estimated wild population:
Auckland - possibly one pair
Bounty - 115,000 pairs on 8 islands
Antipodes - $\leq$ 300,000 pairs; 76 colonies

Current/Ongoing field studies: Monitoring and rehabilitation of moulters in Otago, New Zealand. A few birds come ashore at Otago during the moult. Currently, there are no studies at the breeding grounds.

Captive population: None listed in ISIS

Concerns/Comments: Richdale reported one pair breeding on the Otago Peninsula in the 1940's. G. Taylor and D. Cunningham suggest that because rockhoppers have declined from these islands, then the population of *E. sclateri* should not be assumed stable. Mice are potential vectors for disease threat at the Antipodes Islands (G. Taylor).

Antipodes - Exact figures are not available due to nesting colonies includeing rockhopper penguins. R.H. Taylor estimated that rockhoppers comprised 15% of the penguin population in 1989. If this proportion was the same in 1972/73, then numbers of erect-crested penguins would have been in the order of approximately 300,000. Evidence of great decline since the 1950's.
Bounty Island - Baseline estimate made in 1978. Needs re-censusing to determine status.
Auckland Islands - A breeding pair was seen on Disappointment Island in 1972/73 and in December 1976. No other records since. Note that there is evidence of a temporary resurgence of rockhopper penguin numbers on Campbell Island after a cold period during the 1960's. Erect-crested penguins on Auckland Island may also have benefitted.

Recommendations:

PHVA: Yes

More intensive wild management: No

Captive program: Pending PHVA
Research: Survey, Other
Basic life history work is needed. A dedicated survey group for one month to the Antipodes Islands is needed, followed by aerial photography of Bounty and Antipodes.

Antipodes - Expedition needed specifically to census erect-crested penguins and establish photo-points for ongoing monitoring. Also need to opportunistically collect food samples to determine prey type.
Bounties - Allocate funds for two hours of flying time of the RNZAF Lockheed Orion and photographic costs to take oblique photographs of all islands in the group every ten years. Start 1992/1993 season. Funds also needed for contract worker to use oblique photographs to count numbers of erect-crested penguins, Salvin's mollymawks, fur seals, and possibly, Bounty Island shags. Next visit to those islands should also opportunistically collect food samples.

Auckland Islands - Ground checks needed to determine presence and breeding status of erect-crested penguins at rockhopper penguin breeding colonies.

Campbell Island - Monitor non-breeding numbers of breeding attempts and moulters at accessible colonies at Penguin Bay.

VORTEX -- simulation of genetic and demographic stochasticity

ERECT9
Fri Aug 21 11:38:29 1992

1 population(s) simulated for 100 years, 20 runs

No inbreeding depression

First age of reproduction for females: 7 for males: 8
Age of senescence (death): 30
Sex ratio at birth (proportion males): 0.5000

Population 1:
Monogamous mating; 90.00 percent of adult males in the breeding pool.

Reproduction is assumed to be density independent.

48.00 (EV = 5.00 SD) percent of adult females produce litters of size 0
52.00 percent of adult females produce litters of size 1

33.00 (EV = 10.02 SD) percent mortality of females between ages 0 and 1
15.00 (EV = 3.00 SD) percent mortality of females between ages 1 and 2
7.00 (EV = 3.00 SD) percent mortality of females between ages 2 and 3
7.00 (EV = 3.00 SD) percent mortality of females between ages 3 and 4
7.00 (EV = 3.00 SD) percent mortality of females between ages 4 and 5
7.00 (EV = 3.00 SD) percent mortality of females between ages 5 and 6
7.00 (EV = 3.00 SD) percent mortality of females between ages 6 and 7
7.00 (EV = 3.00 SD) percent annual mortality of adult females (7<=age<=30)
33.00 (EV = 10.02 SD) percent mortality of males between ages 0 and 1
15.00 (EV = 3.00 SD) percent mortality of males between ages 1 and 2
7.00 (EV = 3.00 SD) percent mortality of males between ages 2 and 3
7.00 (EV = 3.00 SD) percent mortality of males between ages 3 and 4
7.00 (EV = 3.00 SD) percent mortality of males between ages 4 and 5
7.00 (EV = 3.00 SD) percent mortality of males between ages 5 and 6
7.00 (EV = 3.00 SD) percent mortality of males between ages 6 and 7
7.00 (EV = 3.00 SD) percent mortality of males between ages 7 and 8
7.00 (EV = 3.00 SD) percent annual mortality of adult males (8<=age<=30)
EVs may have been adjusted to closest values
possible for binomial distribution.
EV in mortality will be correlated among age-sex classes
but independent from EV in reproduction.

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

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total	
	48	41	37	34	31	29	26	24	23	20	19	17	16	14	13	13	11	10	10	8	8	7	7	6	6	5	5	4	4	4	500	Males
	48	41	37	34	31	29	26	24	23	20	19	17	16	14	13	13	11	10	10	8	8	7	7	6	6	5	5	4	4	4	500	Females

Carrying capacity = 5000 (EV = 0.00 SD)

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

r = 0.013 lambda = 1.013 R0 = 1.214
Generation time for: females = 14.92 males = 15.70

Stable age distribution: Age class females males

0	0.064	0.064
1	0.042	0.042
2	0.035	0.035
3	0.032	0.032
4	0.030	0.030
5	0.027	0.027
6	0.025	0.025
7	0.023	0.023
8	0.021	0.021
9	0.019	0.019
10	0.018	0.018
11	0.016	0.016
12	0.015	0.015
13	0.014	0.014
14	0.013	0.013
15	0.012	0.012
16	0.011	0.011
17	0.010	0.010
18	0.009	0.009
19	0.008	0.008
20	0.008	0.008
21	0.007	0.007
22	0.006	0.006
23	0.006	0.006
24	0.005	0.005
25	0.005	0.005
26	0.005	0.005
27	0.004	0.004
28	0.004	0.004
29	0.004	0.004
30	0.003	0.003

Ratio of adult (>= 8) males to adult (>= 7) females: 0.906

Population1

```
Year 10
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     20, P[S] = 1.000
     Population size =          1029.70 (  29.85 SE,  133.49 SD)
     Expected heterozygosity =    0.999 (  0.000 SE,    0.000 SD)
     Observed heterozygosity =    1.000 (  0.000 SE,    0.000 SD)
     Number of extant alleles = 1133.90 (  23.00 SE,  102.86 SD)

Year 20
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     20, P[S] = 1.000
     Population size =          1050.00 (  41.72 SE,  186.57 SD)
     Expected heterozygosity =    0.998 (  0.000 SE,    0.000 SD)
     Observed heterozygosity =    1.000 (  0.000 SE,    0.000 SD)
     Number of extant alleles =  839.00 (  21.24 SE,   95.00 SD)

Year 30
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     20, P[S] = 1.000
     Population size =          1063.10 (  49.74 SE,  222.46 SD)
     Expected heterozygosity =    0.998 (  0.000 SE,    0.000 SD)
     Observed heterozygosity =    0.999 (  0.000 SE,    0.001 SD)
     Number of extant alleles =  666.45 (  19.76 SE,   88.36 SD)

Year 40
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     20, P[S] = 1.000
     Population size =          1081.30 (  49.96 SE,  223.45 SD)
     Expected heterozygosity =    0.997 (  0.000 SE,    0.000 SD)
     Observed heterozygosity =    0.998 (  0.000 SE,    0.001 SD)
     Number of extant alleles =  559.75 (  17.76 SE,   79.44 SD)
```

```
Year 50
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     20, P[S] = 1.000
     Population size =          1059.60 (  60.44 SE,  270.28 SD)
     Expected heterozygosity =    0.997 (  0.000 SE,    0.001 SD)
     Observed heterozygosity =    0.998 (  0.000 SE,    0.001 SD)
     Number of extant alleles =  481.30 (  17.79 SE,   79.55 SD)

Year 60
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     20, P[S] = 1.000
     Population size =          1063.65 (  65.47 SE,  292.79 SD)
     Expected heterozygosity =    0.996 (  0.000 SE,    0.001 SD)
     Observed heterozygosity =    0.997 (  0.000 SE,    0.002 SD)
     Number of extant alleles =  419.95 (  16.62 SE,   74.30 SD)

Year 70
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     20, P[S] = 1.000
     Population size =          1046.95 (  75.60 SE,  338.10 SD)
     Expected heterozygosity =    0.995 (  0.000 SE,    0.001 SD)
     Observed heterozygosity =    0.997 (  0.000 SE,    0.001 SD)
     Number of extant alleles =  373.10 (  15.93 SE,   71.25 SD)

Year 80
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     20, P[S] = 1.000
     Population size =           984.50 (  70.13 SE,  313.64 SD)
     Expected heterozygosity =    0.995 (  0.000 SE,    0.001 SD)
     Observed heterozygosity =    0.996 (  0.000 SE,    0.002 SD)
     Number of extant alleles =  332.00 (  14.93 SE,   66.76 SD)

Year 90
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     20, P[S] = 1.000
     Population size =           957.80 (  77.46 SE,  346.43 SD)
     Expected heterozygosity =    0.994 (  0.000 SE,    0.001 SD)
     Observed heterozygosity =    0.996 (  0.001 SE,    0.002 SD)
     Number of extant alleles =  297.80 (  14.28 SE,   63.86 SD)

Year 100
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =     20, P[S] = 1.000
     Population size =           999.55 (  93.94 SE,  420.13 SD)
     Expected heterozygosity =    0.993 (  0.000 SE,    0.002 SD)
     Observed heterozygosity =    0.995 (  0.001 SE,    0.003 SD)
     Number of extant alleles =  269.75 (  13.31 SE,   59.52 SD)


In 20 simulations of 100 years of Population1:
  0 went extinct and 20 survived.

This gives a probability of extinction of 0.0000 (0.0000 SE),
  or a probability of success of         1.0000 (0.0000 SE).

Mean final population for successful cases was 999.55 (93.94 SE, 420.13 SD)

   Age 1       2       3       4       5       6       7   Adults    Total
   42.95   38.55   32.15   31.20   29.55   26.90   24.20   270.85   496.35
Males
   46.55   40.80   34.35   30.70   30.60   26.80           293.40   503.20
Females

Without harvest/supplementation, prior to carrying capacity truncation,
  mean growth rate (r) was -0.0008 (0.0009 SE, 0.0414 SD)

Final expected heterozygosity was      0.9933 ( 0.0004 SE,   0.0017 SD)
Final observed heterozygosity was      0.9952 ( 0.0007 SE,   0.0030 SD)
Final number of alleles was            269.75 (  13.31 SE,   59.52 SD)
```

NEW ZEALAND PENGUINS

POPULATION AND HABITAT VIABILITY ANALYSIS

INITIAL WORKSHOP REPORT

FIRST DISCUSSION DRAFT

19-21 August 1992

Christchurch

SECTION 5

LITTLE BLUE PENGUIN

PHVA REPORT FOR LITTLE PENGUINS IN NEW ZEALAND

The following original input data was used as the starting point, they are best estimates based information from the white flippered penguin;

age at first breeding 3 years for both sexes
maximum age of breeding 15 " " "
sex ratio at birth 1:1 (assumed)
maximum young per female per year 2

% females fledging	0 young per year	34
	1 " " "	33
	2 " " "	33

mortality both sexes	0-1 years	36%
	1-2 "	26%
	2-3 "	20%
	>=3 "	18%

% adult males in the breeding pool 95

Initial population size is 1000.

Following runs on Vortex the following impressions can be gained.

1) The original estimates gave the following : r was -0.0185, final population size was 296.6, SD 314.81.

2) With mortality set as follows and the balance of factors constant:
35% year 0 and 1
25% year 1 and 2
19% year 2 and 3
18% >= 3

r was -0.0085, final population size was 517.3, SD 280.23.

3) With mortality set as follows:
34% year 0 and 1
24% year 1 and 2
18% year 2 and 3
18% >=3

r was -0.0016, final population size was 903.90, SD 436.44.

4) With mortality set as follows:
33% year 0 and 1
23% year 1 and 2

18% year 2 and 3
18% >= 3

r was reported at 0.0020, final population size was 1231.2, SD 651.16.

5) With mortality set as follows:
33% year 0 and 1
23% year 1 and 2
18% year 2 and 3
18% >= 3

A catastrophe was introduced at 4% frequency with no chicks fledging and an increase in mortality of all age classes >=1 of 1.5 normal mortality rates. r was -0.0145, final population size was 428.1, SD 441.78.

6) With mortality set as follows:
33% year 0 and 1
23% year 1 and 2
18% year 2 and 3
18% >= 3

A catastrophe was introduced at 1% frequency and with the same increase of mortality as for 5 above. r was 0.0005, final population size was 979.0, SD 556.11.

SUMMARY

The original data placed the population at substantial risk of extinction within 100 years.

The effect disappeared with a 2% reduction in the mortality of the first 3 age classes (ie 0-3 years).

Catastrophes with no chicks fledgling and a 50% in crease in mortality with a frequency of 4% would push the population towards extinction, whereas a frequency of 1% had little affect.
It is only with productivity rates set at this level that the population avoids extinction over this time frame.

```
BLU17.OUT     ***OutputFilename***
Y      ***PlotterFiles?***
N      ***EachRun?***
10      ***Simulations***
100      ***Years***
10      ***ReportingInterval***
1      ***Populations***
N      ***InbreedingDepression?***
Y      ***EVcorrelation?***
1      ***TypesOfCatastrophes***
M      ***MonogamousOrPolygynous***
3      ***FemaleBreedingAge***
3      ***MaleBreedingAge***
15      ***MaximumAge***
0.500000      ***SexRatio***
2      ***MaximumLitterSize***
N      ***DensityDependentBreeding?***
34.000000      ***Population1:PercentLitterSize0***
33.000000      ***Population1:PercentLitterSize1***
33.000000      ***Population1:PercentLitterSize2***
8.000000      ***EV--Reproduction***
33.000000      ***FemaleMortalityAtAge0***
12.140840      ***EV--FemaleMortality***
23.000000      ***FemaleMortalityAtAge1***
4.000000      ***EV--FemaleMortality***
18.000000      ***FemaleMortalityAtAge2***
3.000000      ***EV--FemaleMortality***
18.000000      ***AdultFemaleMortality***
3.000000      ***EV--AdultFemaleMortality***
33.000000      ***MaleMortalityAtAge0***
12.140840      ***EV--MaleMortality***
23.000000      ***MaleMortalityAtAge1***
4.000000      ***EV--MaleMortality***
18.000000      ***MaleMortalityAtAge2***
3.000000      ***EV--MaleMortality***
18.000000      ***AdultMaleMortality***
3.000000      ***EV--AdultMaleMortality***
1.000000      ***ProbabilityOfCatastrophe1***
0.000000      ***Severity--Reproduction***
0.89100000      ***Severity--Survival***
N      ***AllMalesBreeders?***
95.000000      ***PercentMalesInBreedingPool***
Y      ***StartAtStableAgeDistribution?***
1000      ***InitialPopulationSize***
2000      ***K***
0.000000      ***EV--K***
N      ***TrendInK?***
N      ***Harvest?***
N      ***Supplement?***
N      ***AnotherSimulation?***
```

VORTEX -- simulation of genetic and demographic stochasticity

BLU17.OUT
Fri Aug 21 10:34:13 1992

1 population(s) simulated for 100 years, 10 runs

No inbreeding depression

First age of reproduction for females: 3   for males: 3
Age of senescence (death): 15
Sex ratio at birth (proportion males): 0.5000

Population 1:
Monogamous mating; 95.00 percent of adult males in the breeding pool.

Reproduction is assumed to be density independent.

34.00 (EV = 8.00 SD) percent of adult females produce litters of size 0
33.00 percent of adult females produce litters of size 1
33.00 percent of adult females produce litters of size 2

33.00 (EV = 12.14 SD) percent mortality of females between ages 0 and 1
23.00 (EV = 4.00 SD) percent mortality of females between ages 1 and 2
18.00 (EV = 3.00 SD) percent mortality of females between ages 2 and 3
18.00 (EV = 3.00 SD) percent annual mortality of adult females (3<=age<=15)
33.00 (EV = 12.14 SD) percent mortality of males between ages 0 and 1
23.00 (EV = 4.00 SD) percent mortality of males between ages 1 and 2
18.00 (EV = 3.00 SD) percent mortality of males between ages 2 and 3
18.00 (EV = 3.00 SD) percent annual mortality of adult males (3<=age<=15)
EVs may have been adjusted to closest values
possible for binomial distribution.
EV in reproduction and mortality will be correlated.

Frequency of type 1 catastrophes: 1.000 percent
with 0.000 multiplicative effect on reproduction
and 0.891 multiplicative effect on survival

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

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total	
	103	79	64	52	42	35	27	23	18	15	12	10	8	7	5	500	Males
	103	79	64	52	42	35	27	23	18	15	12	10	8	7	5	500	Females

Carrying capacity = 2000 (EV = 0.00 SD)

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

r = 0.009   lambda = 1.009   R0 = 1.057
Generation time for: females = 6.43   males = 6.43

Stable age distribution:

Age class	females	males
0	0.119	0.119
1	0.079	0.079
2	0.060	0.060
3	0.049	0.049
4	0.040	0.040
5	0.032	0.032
6	0.026	0.026
7	0.021	0.021
8	0.017	0.017
9	0.014	0.014

```
                     10        0.011        0.011
                     11        0.009        0.009
                     12        0.007        0.007
                     13        0.006        0.006
                     14        0.005        0.005
                     15        0.004        0.004

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

Population1

Year 10
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =             975.30 ( 115.73 SE,   365.98 SD)
     Expected heterozygosity =       0.998 (   0.000 SE,   0.000 SD)
     Observed heterozygosity =       1.000 (   0.000 SE,   0.000 SD)
     Number of extant alleles =    686.40 (  47.82 SE,   151.23 SD)

Year 20
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =             940.80 ( 121.53 SE,   384.31 SD)
     Expected heterozygosity =       0.996 (   0.000 SE,   0.001 SD)
     Observed heterozygosity =       0.998 (   0.000 SE,   0.001 SD)
     Number of extant alleles =    418.60 (  38.37 SE,   121.32 SD)

Year 30
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =             965.10 ( 165.52 SE,   523.44 SD)
     Expected heterozygosity =       0.994 (   0.001 SE,   0.002 SD)
     Observed heterozygosity =       0.996 (   0.000 SE,   0.001 SD)
     Number of extant alleles =    308.20 (  32.25 SE,   101.98 SD)

Year 40
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =             821.70 ( 138.63 SE,   438.38 SD)
     Expected heterozygosity =       0.991 (   0.001 SE,   0.003 SD)
     Observed heterozygosity =       0.994 (   0.002 SE,   0.005 SD)
     Number of extant alleles =    231.40 (  27.13 SE,    85.80 SD)

Year 50
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =             880.90 ( 166.59 SE,   526.80 SD)
     Expected heterozygosity =       0.989 (   0.001 SE,   0.005 SD)
     Observed heterozygosity =       0.990 (   0.002 SE,   0.007 SD)
     Number of extant alleles =    189.00 (  24.60 SE,    77.79 SD)

Year 60
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =            1011.20 ( 214.14 SE,   677.18 SD)
     Expected heterozygosity =       0.986 (   0.002 SE,   0.007 SD)
     Observed heterozygosity =       0.989 (   0.004 SE,   0.012 SD)
     Number of extant alleles =    160.10 (  24.05 SE,    76.06 SD)

Year 70
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =             948.40 ( 170.83 SE,   540.22 SD)
     Expected heterozygosity =       0.984 (   0.003 SE,   0.009 SD)
     Observed heterozygosity =       0.985 (   0.004 SE,   0.012 SD)
     Number of extant alleles =    140.70 (  21.68 SE,    68.57 SD)
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Year 80
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =              1024.90 ( 181.63 SE,   574.35 SD)
     Expected heterozygosity =        0.981 (  0.004 SE,    0.011 SD)
     Observed heterozygosity =        0.981 (  0.004 SE,    0.014 SD)
     Number of extant alleles =     126.60 (  19.81 SE,    62.63 SD)

Year 90
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =               906.40 ( 173.04 SE,   547.20 SD)
     Expected heterozygosity =        0.977 (  0.005 SE,    0.014 SD)
     Observed heterozygosity =        0.984 (  0.003 SE,    0.009 SD)
     Number of extant alleles =     112.80 (  17.37 SE,    54.94 SD)

Year 100
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =               979.00 ( 175.86 SE,   556.11 SD)
     Expected heterozygosity =        0.975 (  0.005 SE,    0.017 SD)
     Observed heterozygosity =        0.976 (  0.006 SE,    0.019 SD)
     Number of extant alleles =     102.70 (  15.71 SE,    49.69 SD)


In 10 simulations of 100 years of Population1:
  0 went extinct and 10 survived.

This gives a probability of extinction of 0.0000 (0.0000 SE),
  or a probability of success of         1.0000 (0.0000 SE).

Mean final population for successful cases was 979.00 (175.86 SE, 556.11 SD)

   Age 1        2    Adults     Total
  100.10    82.30    310.30    492.70   Males
  100.70    77.70    307.90    486.30   Females

Without harvest/supplementation, prior to carrying capacity truncation,
  mean growth rate (r) was 0.0005 (0.0031 SE, 0.0965 SD)

Final expected heterozygosity was        0.9749 ( 0.0054 SE,   0.0170 SD)
Final observed heterozygosity was      0.9764 ( 0.0059 SE,   0.0188 SD)
Final number of alleles was          102.70 (  15.71 SE,   49.69 SD)
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EUDYPTULA MINOR (Blue penguin)

GENERAL NOTE FOR TAXON:

The following notes set out the generic concerns that face the forms of this species. The following pages recognize the taxonomy set out by Falla and Kinsky. Most observers recognize that resolution of the issue of taxonomy is of high priority.

POLLUTION
Oil pollution has been responsible for some deaths; plastic pollution also.

FISHING AND FISHERIES
Birds are used for crayfish bait (Bowker, 1980), caught in fishing nets (Robertson & Bell, 1984), particularly set nets.In New Zealand a policy change at the national level is required to ban on set-netting off all penguin nesting areas.

PREDATION AND VANDALISM
Birds are taken illegally, disturbed by residential activities and other human disturbance. Introduced predators such as foxes (*Vulpes vulpes*)Australia; dogs (*Canis familiaris*) stoats and cats (*Felix catus*),in both Australia and New Zealand take adults and young. Cattle have been reported to trample burrows (Reilly, 1977)..Threats include human disturbance and high levels of predation by introduced species such as stoats and dogs which take adults as well as chicks. Dogs were responsible for the deaths of 30 birds in the breeding area between the main wharf and Oamaru Creek during 1991 (David Houston, pers. comm. to P. Dann); dogs killed at least 34% of this part of the colony in 1991/92 (Dann, in prep). On the west coast of the South Island (NZ) predation is probably caused by dogs, stoats, and feral cats; at Stewart Island predation is primarily by cats; for east coast South Island, dogs, mustelids, and cats are a major problem and as well as vandalism by humans. Populations are declining on the mainland but seem to be stable on islands. ,

RESEARCH
As well as continuing research on predation and finding a sustainable solution to such, possibly including exclusion of predators. Priorities for research are the resolution of the taxonomy of this group of taxa; dietary work.

TAXON: EUDYPTULA MINOR NOVAEHOLLANDIAE Blue penguin

Status: **CITES Appendix** - not listed
Red Data Book - not listed
Mace-Lande - Safe?

Breeding Distribution: Tasmania, southern Australian islands and southern Australian mainland

Estimated wild population: < 1,000,000

Tasmania -
- Bass Straits Islands - > 5,000
- E. coast, S. southeast coast - 15,000 pairs
- South coast (southeast coast - Pt. Davey) - 8,000 pairs
- N. coast and King Island - 2,500

Southern Australia -
- Victoria border - Encounter Bay - little recent precise data

Western Australia -
- Recherche Archipelago, Albany though the north of Leeuwin - little data
- Esperance - Albany - < 1,500 pairs

New South Wales -
- N. coast, se. Newcastle - >2,000 pairs
- Central coast, Newcastle - Wollongong - 1,500
- S. coast, Wollongong - Victoria border - 10,000 -20,000 pairs

Victoria - apx. 40,000 breeding birds, 60,000 immatures
- E. Gippsland - 5,000 - 10,000 pairs
- Wilson's Promontory - 5,000 - 10,000 pairs
- Western Port - Port Phillip bay - > 6,000 pairs
- Western district - 2,000 pairs

Current/Ongoing field studies: Coordinate research program "Penguin Protection Plan" in place at Phillip Island, Victoria. Dann, Cullen, Jessop, and Montague continue to monitor the population at Phillip Island and other locations

Captive population: 53 listed in ISIS; 67 in Australian zoos (Adelaide 13; Melbourne 18; Perth 11; Taronga Park 25), also some in Jurong Bird Park. 61 in private zoos in Australia.

Concerns/Comments: Populations have declined and fragmented over the past 50 years, especially those colonies on the Australian mainland, being affected by habitat modificaion and factors associated with human settlement. Population dynamics at most sites is little known. Extrapolations from the number of penguins crossing Summerland Beach indicate that population at Phillip Island continues to decrease (Dann, 1992). Survival of birds banded as chicks and adults in the Phillip Island study area has declined from 38% to 28% for immatures and from 78% to 66% for adults between 1968 and 1985 (Dann & Cullen, 1990). The onset of breeding has become progressively later in the year since 1968 (Dann, 1992), a corresponding reduction in the opportunity to raise two broods successfully and hence increase potential recruitment, but numbers of chicks produced per breeding attempt have varied seasonally without a consistent trend. For first and second year birds, almost all mortality occurs at sea, largely because they are rarely ashore (Reilly & Cullen, 1982; Dann *et al.*, 1992). The combined effects of internal parasites and starvation appear to be important mortality factors for these age groups (Harrigan, 1992). Major cause of adult mortality at sea appears to be starvation (Harrigan, 1992). In addition to these, oil pollution has been responsible for some deaths; plastic pollution also (Dann, 1990). Birds are used for crayfish bait (Bowker, 1980), caught in set nets (Stahel & Gales, 1987), taken illegally, disturbed by residential activities and other human disturbance. Predation at sea by New Zealand fur seals (*Arctocephalus pusillus*), and possibly by sharks, are also causes of mortality. Introduced predators such as foxes (*Vulpes vulpes*), dogs (*Canis familiaris*), and in Tasmania, cats (*Felis catus*), take adults and young. Cattle have been reported to trample burrows (Reilly, 1977). Habitat available for breeding does not appear to be limiting at present and is unlikely to account for increases in the mortality of adults and immatures (Dann, 1992). There seems to be no evidence of decreasing numbers in colonies on offshore islands, with the exception of some which have been intensely settled (Bruny Island, Tasmania, Hodgson, 1975; Phillip Island, Victoria, Dann, 1992). Reduction in numbers has occurred for some colonies on the mainlands of Australia, Tasmania, and New Zealand. A new colony has started at St. Kilda, victoria during the past 35 years and appears to be maintaining itself (M. Cullen, unpublished data, cited in Dann, 1992). Introduced ferrets may be a potential threat. Fluctuations in food have caused major die-offs in certain years (1984/85) (Harrigan, 1992).

Recommendations:
PHVA: Yes
More intensive wild management: Yes, pending PHVA
Captive program: Nuc II
Research: Taxonomy, Survey, Other
Taxonomic issues need to be re-addressed. Effects of actual or potential pollutants including chemical and plastic. Changes in prey populations in conjunction with long-term oceanographic changes. Dietary research is needed, as well as continuing research on predation and finding a sustainable solution to such, possibly including exclusion of predators.

TAXON: EUDYPTULA MINOR MINOR Blue penguin

Status: CITES Appendix - not listed
Red Data Book - not listed
Mace-Lande - Safe? on the mainland, Safe on islands

Breeding Distribution: Coasts of Otago and Southland from Oamaru south to Foveaux Straight, Stewart Island, and outlying islands, west coast of South Island of New Zealand north to Karamea

Estimated wild population:

New Zealand - 11,000 (Otago), including immatures. 1991/92 survey (Dann) reports at least 1996 breeding pairs between the Waitaki River and Nugget Point.

Otago Peninsula - c. 300 breeding pairs
Taieri Island - 1,338 burrows (Dann, in prep)
Oamaru - 218 pairs (Dann, in prep)
Green Island - 223 breeding pairs

Stewart Island - no data available
Northland, Auckland, South Auckland, Bay of Plenty, Gisborne, Wellington, Wanganui - no estimates available
Codfish Is - 2,000 pairs

Current/Ongoing field studies: Besides Dann's 1991/92 survey of the Otago populations, small scale surveys and monitoring at Punakaiki on the West Coast of New Zealand is underway. Oamaru, Otago is now being monitored by the New Zealand Department of Conservation and Forest and Bird.

Captive population: none listed in ISIS

Concerns/Comments: No accurate information exists on population size and trends on the west coast. Threats include human disturbance and high levels of predation by introduced species such as stoats and dogs which take adults as well as chicks. Dogs were responsible for the deaths of 30 birds in the breeding area between the main wharf and Oamaru Creek during 1991 (David Huston, pers. comm. to P. Dann); dogs killed at least 34% of this part of the colony in 1991/92 (Dann, in prep). Population numbers have decreased overall on the Otago Peninsula also, despite an increase being recorded at Pilot's Beach at Taiaroa Head (Dann, in prep); 78% of the breeding population occurs on two islands free of introduced mammalian predators. The current phase of predation began approximately between 1955 and 1970. Richdale (1940) estimated that there were well over 1,000 on the "whole coast," although it is unclear as to how many penguins were on the Otago Peninsula itself. Richdale's comments imply that numbers were greater than the 300 birds estimated to breed there at present (Dann, in prep). According to Dann (in prep), the population at Oamaru appears to have increased in the past six years. According to Lalas (1984) and Dann, the population at Green Island has declined appreciably in from an estimated 1500 pairs in 1983/84 to an estimated 223 pairs in 1991/92. At Taieri Island, obvious degradation of the island is occurring through erosion, probably caused by introduced rabbits. In some areas extensive amounts of topsoil are being lost and some loss of flax is obvious (Dann, in prep). Rabbit eradication would seem an important step in ensuring the continuing of Taieri Island as the most important site for Blue penguins in Otago. Predation is on both chicks and adults throughout their range. On the west coast of the South Island predation is probably caused by dogs, stoats, and feral cats; at Stewart Island predation is primarily by cats; for east coast south islands, dogs, mustelids, and cats are a major problem and as well as vandalism by humans. Populations are declining on the mainland but seem to be stable on islands. A policy change is required at a national level to implement a ban on set-netting off all penguin nesting areas.

Recommendations:
PHVA: Yes
More intensive wild management: Yes, pending PHVA
Captive program: None
Research: Taxonomy, Survey, Other
Taxonomic issues need to be re-addressed. Priority is survey work and monitoring, with a first step to locate breeding locations. Dietary research is needed.

TAXON: EUDYPTULA MINOR CHATHAMENSIS

Status: **CITES Appendix** - not listed
Red Data Book - not listed
Mace-Lande - Vulnerable on the main island, Safe on other islands

Breeding Distribution: Chatham Islands (Chatham, Pitt, South East, Mangere, and Star Keys)

Estimated wild population:
Chatham - estimated < 10,000

Current/Ongoing field studies: Unaware of specific efforts

Captive population: none listed in ISIS

Concerns/Comments: No information available; assumptions based on best-guess estimates. Population is declining on the main islands; decreasing on the main islands. Birds are being drowned in set nets used in fisheries. Settlements are near suitable penguin nesting areas. Predation by cats and dogs are a threat, as well as marine perturbations, habitat loss, and pollution.

Recommendations:
PHVA: Yes
More intensive wild management: Yes, pending PHVA
Captive program: None
Research: Taxonomy, Survey, Other
Taxonomic issues need to be re-addressed. Role of introduced mammalian predators in determining distribution and abundance. Population estimates and monitoring. Dietary research is needed,

TAXON: EUDYPTULA MINOR IREDALEI

Status: **CITES Appendix** - not listed
Red Data Book - not listed
Mace-Lande - Unknown (insufficient data to assess)

Breeding Distribution: Northern half of the North Island of New Zealand: coasts and islands of the northern part of the North Island from East Cape through Bay of Plenty, Hauraki Gulf, and Northland to North Cape and South on the west coast to about Kawhia Harbor and possibly further south. Not recorded on Three Kings Islands.

Estimated wild population: 10,000 total population

Current/Ongoing field studies: Unaware of specific recent efforts. Jones (1979) M.Sc. thesis, Auckland University.

Captive population: none listed in ISIS

Concerns/Comments: Cats, dogs, mustelids presumed predators.

Recommendations:
PHVA: Yes
More intensive wild management: Yes, pending PHVA
Captive program: None
Research: Taxonomy, Survey, Other
Taxonomic issues need to be re-addressed. Survey and monitoring.

TAXON: EUDYPTULA MINOR VARIABILIS

Status: **CITES Appendix** - not listed
Red Data Book - not listed
Mace-Lande - Unknown (insufficient data to assess)

Breeding Distribution: Coasts and islands of the southern part of the North Island from Cape Kidnappers south to Palliser Bay through Cook Straight and north to Cape Egmont; coasts and islands of the northern part of the South Island from Karamea on the west coast to Kaikoura on the east coast.

Estimated wild population: unknown

Current/Ongoing field studies: Unaware of specific recent efforts. Kinsky (1960) studied this taxa in the Wellington Harbor area.

Captive population: none listed in ISIS

Concerns/Comments: Cats, dogs, mustelids presumed predators.

Recommendations:
PHVA: Yes
More intensive wild management: Yes, pending PHVA
Captive program: None
Research: Taxonomy, Survey, Other
Taxonomic issues need to be re-addressed. Survey and monitoring.

TAXON: EUDYPTULA MINOR ALBOSIGNATA White-flippered penguin

Status: **CITES Appendix** - not listed
Red Data Book - not listed
Mace-Lande - Vulnerable/Safe (Vulnerable but bordering on Safe)

Breeding Distribution: Banks Peninsula and Motunau Island, New Zealand

Estimated wild population: $\geq$500 breeding pairs; > 1,850 Banks Peninsula
1,350 breeding pairs; 5,000 total birds on Motunau Island

Current/Ongoing field studies:
Banks Peninsula: (Challies)
12-year study of population biology 1975-1987; trial of chick transfer technique is in the fifth year of a 10-year ongoing program; Survey and nature and impact of predation on breeding colonies ongoing.
Monunau Island: (Challies)
Demographic study based on long-term chick banding nearing completion;
Long-term monitoring of population size and composition ongoing;
Movement study based on recoveries of banded birds is ongoing.

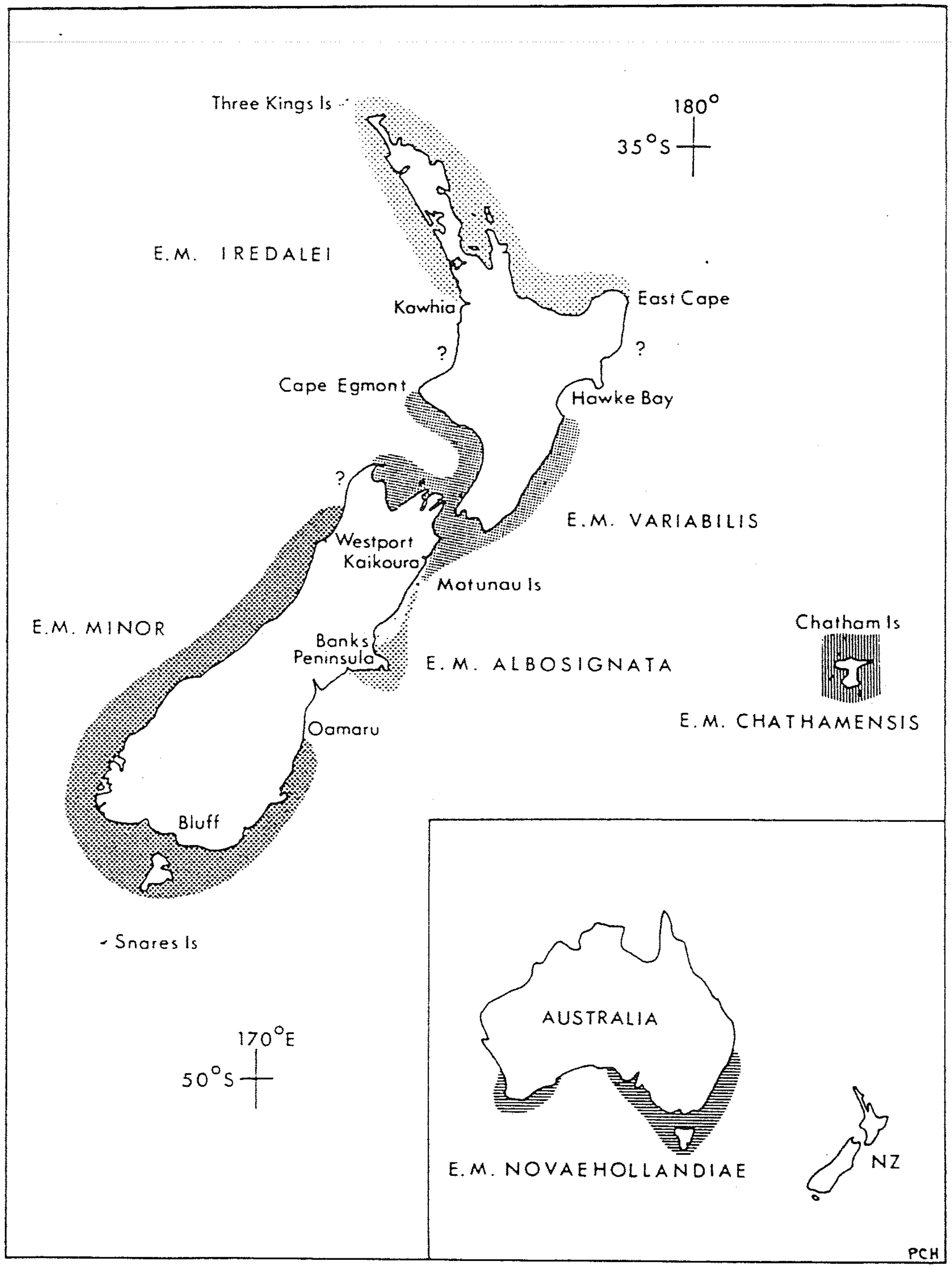
Captive population: None

Concerns/Comments:
Banks Peninsula:
Numbers declining because of predation on breeding colonies. Since 1980 there has been an overall loss from known colonies of 50% of breeding pairs. The current phase of predation started in 1981. Ferrets (*Mustela furo*) are mainly responsible for the decline. Numbers and status of breeding colonies in inaccessible places is not known.

Motunau Island:
Island is a Nature Reserve with limited public access and no predators. Population appears stable. The only known threat is inshore net-setting by amateur fishermen; several multiple catches of penguins have been reported in recent years.

To reduce the risk of penguin entanglement, a ban onall inshore net setting is needed around Motanau Island and a night ban on netting is needed around Banks Peninsula.

Recommendations:
PHVA: Yes
More intensive wild management: Yes, pending PHVA
Captive program: None
Research: Taxonomy, Survey, Other
Taxonomic issues need to be re-addressed. Completion of current research program and reporting of key results. Formal recognition of present monitoring on Motunau Island and provision for its continuance. Survey of breeding colonies on Banks Peninsula to determine numbers, distribution, and recruitment patterns as it effects the survival of residual populations. Dietary research is needed, as part of a comparative study throughout the range of *E. minor*. Current research on predation should be expanded to include finding a sustainable solution to the predation problem.


Three Kings Is
180°
35°S
E.M. IREDALEI
Kawhia
East Cape
?
?
Cape Egmont
Hawke Bay
?
E.M. VARIABILIS
Westport
Kaikoura
Motunau Is
E.M. MINOR
Chatham Is
Banks
Peninsula
E.M. ALBOSIGNATA
E.M. CHATHAMENSIS
Oamaru
Bluff
Snares Is
170°E
50°S
AUSTRALIA
E.M. NOVAEHOLLANDIAE
NZ
PCH

NEW ZEALAND PENGUINS

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Christchurch

SECTION 6

ROCKHOPPER PENGUIN

TAXON: EUDYPTES CHRYSOCOME FILHOLI Southern rockhopper penguin

Status: **CITES Appendix** - not listed
Red Data Book - not listed
Mace-Lande - Vulnerable

Breeding Distribution: Kerguelen Island, Heard Island, Prince Edward, Crozet and islands south of New Zealand; Macquarie, Campbell, Antipodes, Auckland Islands

Estimated wild population:
- Kerguelen - 85,000 pairs
- Heard - < 10,000 pairs; 12 colonies
- Macquarie - 300,000 pairs; 23 colonies
- Bishop and Clerk - 20 pairs; 2 colonies
- Campbell - 51,500 pairs; 11 colonies
- Antipodes - < 50,000 pairs; 76 colonies
- Auckland - 2700-3600 pairs; 11 colonies
- Prince Edward - 1,730,000 pairs
- Crozets - 153,000 pairs

Current/Ongoing field studies:
Planned analysis and write up of diet and productivity on Campbell Island (Cunningham and Moors); Ongoing monitoring of colony sizes by photographs taken from cliff-top photo-points on Campbell Island (Cunningham); Diet and diving behavior at Heard Island.

Captive population: none listed in ISIS; none in New Zealand

Concerns/Comments:
There has been a decline historically on Campbell, Auckland, and Antipodes, but the trends are likely stable or increasing at other sites.

Campbell Island - 94% decline since the 1940's. Almost certainly a result of sea-surface warming with consequential effects on diet. Bulk of prey items are post-larval fish compared with other rockhopper populations which feed principally on euphausids. Effects of occasional rat predation on chicks and disease (*Pasteurella multocida*) may be contributing factors in some years. Currently there is a major fishery for southern blue whiting (a common prey species) in the New Zealand subantarctic. Expect continued decline.

Antipodes Islands - Decline from 86 colonies in 1972/73 to approximately 76 in 1989/90, numbers in later count unknown. Numbers in earlier count are a very rough estimate based on moulting birds seen in March 1973. R.H. Taylor estimated that rockhopper penguins comprised about 15% of the total numbers of penguins in 1989. It is difficult to determine actual numbers of this species as they nest with erect-crested penguins. R.H. Taylor estimates that there may have been a decline of both species from the 1950's equal to that at Campbell (94%).

Macquarie Island - Population unchanged (Rounsevell & Brothers, 1984). Status needs continued review but possibly stable.

Auckland Island - Decline from estimated 5,000-10,000 pairs in 1972/73 to current population of 2,700-3,600.

Heard Island and the Mcdonald Islands - are protected under Australian law and are the largest subantarctic island group free of introduced plant and animal species. Boats visiting the Territory are not legally required to undergo quarantine inspection, which presents a potential threat for introductions.

Threats are pollution, including plastics, in the marine environment; potential threats if predators introduced to Heard and McDonald Islands. Potential threats include disease, climatic change, predation by rats and cats of Campbell and Macquarie Islands, also wekas on Macquarie. It is important to eradicate rats on Campbell, pigs on Auckland, and feral mammals on the Prince Edward and Kerguelen Islands. Also may be important to regulate/prohibit domestic poultry being allowed on penguin islands.

Recommendations:
PHVA: Yes
More intensive wild management: Yes
Captive program: Pending PHVA
Research: Survey, Other
Research recommendations: According to the SCAR Bird Biology Subcommittee (Woehler, in prep.), surveys are needed for the following areas: Heard Island, the Auckland Islands, Antipodes Islands, and Macquarie Island. Continued monitoring is needed.

Campbell Island - continued monitoring with periodic re-measurement of colonies, periodic food sampling to monitor prey type, regular surveillance of colonies for predation and disease, and continued measurement of sea temperatures.

Antipodes Islands - baseline survey to determine population numbers. Food samples to monitor prey type.

Auckland Island - Census based on ground surveys to establish baseline for future monitoring. Food samples to monitor prey type.

Recommend survey and monitoring of populations. Opportunistically study diets on the Antipodes, Campbell, and Auckland Islands in the context of interactions with the fishing industry, monitoring of food available, by catch. Recommend that for all the crested penguins telemetric studies be carried out to elucidate what is happening during the winter, as well as foraging range during the breeding season. Also, comparison of genetics in populations of different islands need to be carried out.

VORTEX -- simulation of genetic and demographic stochasticity

ROCK14
Thu Aug 20 12:30:07 1992

1 population(s) simulated for 100 years, 10 runs

No inbreeding depression

First age of reproduction for females: 5   for males: 5
Age of senescence (death): 25
Sex ratio at birth (proportion males): 0.5000

Population 1:
Monogamous mating; 90.00 percent of adult males in the breeding pool.

Reproduction is assumed to be density independent.

20.00 (EV = 12.65 SD) percent of adult females produce litters of size 0

80.00 percent of adult females produce litters of size 1

60.00 (EV = 14.77 SD) percent mortality of females between ages 0 and 1
10.00 (EV = 3.00 SD) percent mortality of females between ages 1 and 2
8.00 (EV = 3.00 SD) percent mortality of females between ages 2 and 3
8.00 (EV = 3.00 SD) percent mortality of females between ages 3 and 4
8.00 (EV = 3.00 SD) percent mortality of females between ages 4 and 5
8.00 (EV = 3.00 SD) percent annual mortality of adult females (5<=age<=25)
60.00 (EV = 14.77 SD) percent mortality of males between ages 0 and 1
10.00 (EV = 3.00 SD) percent mortality of males between ages 1 and 2
8.00 (EV = 3.00 SD) percent mortality of males between ages 2 and 3
8.00 (EV = 3.00 SD) percent mortality of males between ages 3 and 4
8.00 (EV = 3.00 SD) percent mortality of males between ages 4 and 5
8.00 (EV = 3.00 SD) percent annual mortality of adult males (5<=age<=25)
EVs may have been adjusted to closest values
possible for binomial distribution.
EV in mortality will be correlated among age-sex classes
but independent from EV in reproduction.

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

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total	
	50	46	41	38	34	31	28	26	23	21	19	18	16	14	13	12	11	10	9	8	7	7	6	5	6	499	Males
	51	46	41	38	34	31	28	26	23	21	19	18	16	14	13	12	11	10	9	8	7	7	6	5	6	500	Females

Carrying capacity = 9999 (EV = 0.00 SD)

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

r = 0.012   lambda = 1.012   R0 = 1.158
Generation time for: females = 11.90   males = 11.90

Stable age distribution:

Age class	females	males
0	0.103	0.103
1	0.041	0.041
2	0.036	0.036
3	0.033	0.033

4	0.030	0.030
5	0.027	0.027
6	0.025	0.025
7	0.022	0.022
8	0.020	0.020
9	0.019	0.019
10	0.017	0.017
11	0.015	0.015
12	0.014	0.014
13	0.013	0.013
14	0.011	0.011
15	0.010	0.010
16	0.009	0.009
17	0.009	0.009
18	0.008	0.008
19	0.007	0.007
20	0.006	0.006
21	0.006	0.006
22	0.005	0.005
23	0.005	0.005
24	0.004	0.004
25	0.004	0.004

Ratio of adult (>= 5) males to adult (>= 5) females: 1.000

```
Population1

Year 10
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =           1075.70 (  72.99 SE,   230.80 SD)
     Expected heterozygosity =     0.999 (  0.000 SE,    0.000 SD)
     Observed heterozygosity =     1.000 (  0.000 SE,    0.000 SD)
     Number of extant alleles =  1069.10 (  52.01 SE,   164.46 SD)

Year 20
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =           1132.30 ( 127.80 SE,   404.15 SD)
     Expected heterozygosity =     0.998 (  0.000 SE,    0.000 SD)
     Observed heterozygosity =     0.999 (  0.000 SE,    0.001 SD)
     Number of extant alleles =   767.80 (  46.72 SE,   147.76 SD)

Year 30
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =           1168.00 ( 172.40 SE,   545.16 SD)
     Expected heterozygosity =     0.997 (  0.000 SE,    0.001 SD)
     Observed heterozygosity =     0.999 (  0.000 SE,    0.001 SD)
     Number of extant alleles =   600.10 (  43.91 SE,   138.87 SD)

Year 40
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =           1212.50 ( 206.91 SE,   654.32 SD)
     Expected heterozygosity =     0.997 (  0.000 SE,    0.001 SD)
     Observed heterozygosity =     0.998 (  0.000 SE,    0.001 SD)
     Number of extant alleles =   494.20 (  46.58 SE,   147.31 SD)

Year 50
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =           1176.40 ( 204.74 SE,   647.45 SD)
     Expected heterozygosity =     0.996 (  0.000 SE,    0.001 SD)
     Observed heterozygosity =     0.997 (  0.001 SE,    0.002 SD)
     Number of extant alleles =   417.20 (  45.92 SE,   145.22 SD)
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Year 60
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =          1353.30 ( 259.42 SE,   820.35 SD)
     Expected heterozygosity =    0.995 (  0.001 SE,    0.002 SD)
     Observed heterozygosity =    0.997 (  0.001 SE,    0.002 SD)
     Number of extant alleles =  370.30 (  44.32 SE,   140.14 SD)

Year 70
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =          1313.60 ( 271.99 SE,   860.12 SD)
     Expected heterozygosity =    0.994 (  0.001 SE,    0.002 SD)
     Observed heterozygosity =    0.997 (  0.001 SE,    0.002 SD)
     Number of extant alleles =  329.80 (  42.62 SE,   134.77 SD)

Year 80
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =          1482.10 ( 313.83 SE,   992.41 SD)
     Expected heterozygosity =    0.993 (  0.001 SE,    0.003 SD)
     Observed heterozygosity =    0.995 (  0.001 SE,    0.002 SD)
     Number of extant alleles =  305.50 (  42.16 SE,   133.31 SD)

Year 90
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =          1608.90 ( 354.49 SE,  1120.99 SD)
     Expected heterozygosity =    0.992 (  0.001 SE,    0.004 SD)
     Observed heterozygosity =    0.993 (  0.002 SE,    0.005 SD)
     Number of extant alleles =  281.20 (  40.54 SE,   128.19 SD)

Year 100
     N[Extinct] =          0, P[E] = 0.000
     N[Surviving] =       10, P[S] = 1.000
     Population size =          1748.60 ( 405.45 SE,  1282.15 SD)
     Expected heterozygosity =    0.991 (  0.002 SE,    0.005 SD)
     Observed heterozygosity =    0.993 (  0.001 SE,    0.005 SD)
     Number of extant alleles =  264.30 (  39.43 SE,   124.69 SD)
```

In 10 simulations of 100 years of Population1:
0 went extinct and 10 survived.

This gives a probability of extinction of 0.0000 (0.0000 SE),
or a probability of success of 1.0000 (0.0000 SE).

Mean final population for successful cases was 1748.60 (405.45 SE, 1282.15 SD)

Age 1	2	3	4	Adults	Total	
85.70	82.00	59.30	69.90	580.80	877.70	Males
84.40	83.50	63.30	64.10	575.60	870.90	Females

Without harvest/supplementation, prior to carrying capacity truncation,
mean growth rate (r) was 0.0029 (0.0020 SE, 0.0637 SD)

```
Final expected heterozygosity was      0.9914 ( 0.0016 SE,  0.0051 SD)
Final observed heterozygosity was      0.9933 ( 0.0015 SE,  0.0047 SD)
Final number of alleles was            264.30 (  39.43 SE,  124.69 SD)
```

NEW ZEALAND PENGUINS

POPULATION AND HABITAT VIABILITY ANALYSIS

INITIAL WORKSHOP REPORT

FIRST DISCUSSION DRAFT

19-21 August 1992

Christchurch

SECTION 7

REFERENCE MATERIALS

Penguin Discussion Review Draft

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Preparation and Documentation Needs

Information to be included in briefing book:

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

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

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

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

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

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

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

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

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

10. SSP and similar masterplans any captive populations.

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

Plans for the Meeting:

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

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

3. Preparation of briefing document.

4. Funding - primarily for travel and per diem during the meeting. Also preparation of briefing document and the PVA report. CBSG costs are for preparation of the documents, completion of the modelling and report after the meeting, travel of 3-4 people, and their per diem. This totals about $15,000 plus travel and per diem.

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

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