POPULATION AND HABITAT VIABILITY ASSESSMENT (PHVA) FOR PEARY CARIBOU AND ARCTIC-ISLAND CARIBOU (*Rangifer tarandus*)

Yellowknife, Northwest Territories, Canada

27 February – 1 March, 1998

REPORT

Sponsored By:
Department of Resources, Wildlife and Economic Development (RWED)
of the Government of Northwest Territories, Canada

Northwest Territories
Caribou Project
Resources, Wildlife and Economic Development
Yellowknife

With Participating Organizations:
Nunavut Wildlife Management Board, Inuvialuit Game Council, Wildlife Management Advisory Council, Qikiqtaaluk Wildlife Board, the regional Hunters' and Trappers' associations, Alberta Environmental Protection Natural Resources Service, University of Alberta, Devonian Wildlife Conservation Center, Yukon Renewable Resources.

In collaboration with:
The Conservation Breeding Specialist Group (SSC/IUCN)

A contribution of the IUCN/SSC Conservation Breeding Specialist Group, in collaboration with the Department of Resources, Wildlife and Economic Development of the Government of Northwest Territories, Canada and workshop participants.

Cover photo courtesy of Anne Gunn.

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Section 1

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

Peary caribou on the Queen Elizabeth Islands and arctic-island caribou on Banks Island were classified as 'Endangered' by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1990. The arctic-island caribou on Prince of Wales, Somerset, Victoria and King William islands and Boothia Peninsula were classified as 'Threatened'.

Peary caribou on the western High Arctic have declined to the lowest recorded abundance since surveys began in 1961. Numbers declined from an estimated 24,000 in 1961 to about 1,100 in 1997. Periodic die-offs, which occur during exceptionally severe winters, drive the declines. In 1961, Peary caribou numbers were low on the eastern High Arctic but their subsequent abundance is unknown.

Since the 1970s, and based upon the most recent surveys, two arctic-island caribou populations have virtually disappeared, one declined and may have recovered and the other two populations are possibly stable.

To address these and other problems, a PHVA Workshop for the Peary caribou and Arctic-island caribou was held from 27 February – 1 March 1998 in Yellowknife, Northwest Territories, Canada. The workshop was a collaborative endeavor of the Department of Resources, Wildlife and Economic Development (RWED) of the Government of Northwest Territories, Canada and the Conservation Breeding Specialist Group (CBSG) of the IUCN-World Conservation Union's Species Survival Commission. The meeting was hosted by RWED in Yellowknife. The meeting was sponsored by the RWED and CBSG. The 34 participants included people from co-management boards (Nunavut Wildlife Management BoardWildlife Management Advisory Council); Inuvialuit Game Council, regional hunter's organizations (Qikiqtaaluk Wildlife Board, Kitikmeot Hunters' and Trappers' Association); representatives from the hunters' and trappers' organizations for the seven communities within the range; Government of the Northwest Territories (Department of Resources, Wildlife and Economic Development); the national Recovery Team and the Devonian Wildlife Conservation Center.

The meeting was opened with an Inuit prayer and welcoming comments by Douglas Stewart, Director of RWED. He commented on the diversity of climate, vegetation, and the caribou themselves across the arctic islands and he indicated that there were two purposes for organizing this workshop. The first was to provide a forum for open discussion and to share information. The second was to assess information and identify recommendations for recovery options to become part of a draft co-management plan for the Peary caribou and Arctic-Islands caribou. He emphasized that they wish to consider long-term management options to assist the caribou in their recovery and the long-term maintenance of populations. The report from the PHVA Workshop will be taken back to the communities to deliberate and offer comments. This commentary and draft would then go to the management boards for their review and consideration in their decision making process.

The first day's agenda began with an opening presentation by CBSG (Seal) on the workshop process, the use of thinking tools, the use of small working groups to do the analyses and prepare the report, and basic facilitation guidelines for conduct of the group sessions. This was followed by four technical presentations summarizing caribou status in the High Arctic and the mid-arctic islands. An overview of the molecular genetic studies of the populations indicated that they are closely related and that the arctic-island animals do not appear to be intergrades between the Peary and barren-ground caribou.

We began a group discussion of factors influencing the decline of the caribou using flip charts. This was a topic of keen interest and provided the opportunity to demonstrate some of the principles of group participation. All of the people present participated offering ideas. This session was followed in the afternoon with the full group with a similar discussion but opened to consider to full range of problems of importance for caribou management and utilization. These ideas were grouped into themes by 5 of the participants for formation of the working groups. The working group sessions began at about 4 PM. They were given the option of continuing to work after dinner at each of the groups' discretion. All chose to do so and in fact did so both Friday and Saturday nights. The working groups themes were the topics of Co-management and Decision Making, Factors Influencing Caribou Populations, Information Needs, and Population Biology and Modeling. The various stakeholders were distributed in all of the topic groups. These groups were maintained throughout the workshop.

The first plenary took the entire morning on Saturday as each group presented the results of their further problem analysis and offered each other suggestions. They started with problem analysis and then were to proceed to a needs analysis followed by suggested actions. Working group participants facilitated the groups. Each group encountered some difficulties in structuring their process in a systematic sequence but the facilitators resolved these problems as they arose.

The Factors Affecting Peary Caribou and Arctic-Island Caribou Working Group classified the problems identified into human induced factors and natural factors. The human induced factors included harvesting, contaminants, vegetation-habitat, migration, biologists, low recruitment, disturbances, global climate, and shipping traffic. The natural factors included disease, vegetation-habitat, migration, predation, competition, birth and survival, and weather-climate. The impact of these factors in each of the management areas was evaluated. Harvesting was considered a major negative factor in the Banks Island, NW Victoria, and Dolphin & Union populations and is of concern in the Boothia population. Predation by wolves is an important negative factor in the Banks Island, Boothia, and Bathurst populations. Competition was identified as important for the Banks Island and Boothia populations. The group then moved to an analysis of four management options that might be used for short-term recovery options. Opinions varied so the group decided to simply list the pros and cons of each option as they explored it and shared information about it. The options discussed were wolf management, emergency feeding, translocation and captive breeding. All participants agreed on the need for information sharing and especially improved access for the communities to technical information on the options. Recommendations were to provide the communities information on the benefits and potential negative consequences of supplemental feeding, of translocation of caribou, of captive breeding, and of wolf management. It was noted that more information is needed on some of the problems associated with each of these options.

The Information Needs Working Group undertook the analysis of the two major problem areas of surveys and climate/habitat/caribou relationships. On the survey topic, they identified the need for an Eastern Queen Elizabeth's Island Peary Caribou population survey, to establish management boundaries for each survey, to establish a schedule for future surveys, for harvest data collection and analysis, for health monitoring and for careful survey design. On the climate and habitat topic they noted the need to establish the relationships between weather, range condition, and caribou population effects. They suggested studies of association between specific weather events and caribou and to establish the impact of weather fluctuations on the range of variation of caribou population dynamics. Other suggestions were to determine the impact of environmental contaminants, to do a retrospective assessment of the impacts of human activities, and to initiate a program to utilize traditional knowledge in caribou management.

The high priority recommendations from this group were:

- The Eastern Q. E. Peary Caribou Population survey,
- Define management boundaries
- Establish and implement immediately a necropsy protocol for animals in die-offs.
- Establish and implement within one year a sampling protocol for contaminants, pathogens, and other abnormalities.
- Obtain and incorporate traditional and local knowledge into caribou management, and form a working group to develop mutually acceptable methods.

The Co-management Working Group chose two major problems areas for further analysis, Communication and Implications of Inaction, from a list of 13 problems generated in the plenary session. In the area of communication they recommended active participation and involvement in the development of management options by the communities (with provision of funding support) as well as RWO and RWED. The involvement of Renew and recovery team needs to be clarified. Several examples of the improvement of communication were provided.

Consequences of inaction could be the result of either a deliberate decision or a failure to make a decision. Nine sub-problems, as possible consequences of inaction, were identified and three were chosen for further analysis: Conservation of Species, Loss to Co-management Credibility, and Community Effects. Multiple needs and possible actions were identified for each of these sub-problems. The preferred actions for each need were ranked as a suggested order of priority. An overall ranking of actions was not done and many would be developed in parallel as actions are taken. The major theme in all of the recommended actions is for active community involvement from the earliest stages of planning and decision making.

The Population Biology and Modeling Working Group developed general and location specific values for the input parameters of a baseline simulation model for these caribou populations. This model served as a baseline for adding the effects of severe weather events, harvesting, and variations in population size on the risk of extinction and fluctuations in population size in 100-year projections. Criteria need to be selected as indicators of the urgency of the threat to each of the populations. One criterion might be the time projected for a population to reach given level of risk of extinction. For example with a probability of extinction [P(E)] of 10% or greater is chosen, the worst-case scenario for the Western Queen Elizabeth Island population would reach a 15% P(E) in 40 years. Severe weather events with the frequencies and severities that have been experienced in the past 10 years may be sufficient to increase the risk of extinction to 50-60% over 100 years and to account for the population declines that have been experienced. Harvest scenarios indicate that removal of a fixed number of males from the population can also lead to increased risk of extinction in small populations. High priority recommendations were for specific information of calf mortality, adult female mortality, and age of first reproduction in years when a population is growing and when it is near estimated carrying capacity, and information on immigration and emigration rates between populations. We emphasize that the VORTEX modeling tool has specific limitations, as used in this workshop, not allowing inclusion some of the factors that might influence the outcomes. For example, levels of harvesting were constant and not sensitive to abundance, variations in immigration and emigration were annual not episodic, and others. Due attention should be paid to these limitations in interpreting the results of the simulations. Additional work by interested caribou biologists with newer versions of the software can adjust for these factors, if desired.

The recommendations of the working groups were reviewed in the final plenary session. There was not time to rank and assign priorities to the collective recommendations of all of the groups. Also, because of a lack of analysis of impacts and consensus on use of specific recovery options, there is a need to undertake further analysis and deliberations on recovery options. One of the guidelines for the workshop from the beginning was that objections or alternatives to the recommendations of the workshop needed to be presented during the workshop. The option was provided that any individual wishing to express an alternative opinion could do so in writing and it would be made a part of the workshop proceedings. Thus these accepted recommendations represent general agreement of the workshop participants.

It was agreed that the draft would be given six weeks for review and comment in the communities. The draft will be assembled from the workshop reports and distributed by the CBSG office. If this review results in a written commentary or opinion, this material will made a part of the workshop report in a separate section. All comments are to be submitted to the CBSG office for revision of the draft and preparation of the final report.

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Section 2

LIST OF WORKSHOP PARTICIPANTS AND GLOSSARY

PEARY CARIBOU AND ARCTIC-ISLAND CARIBOU WORKSHOP

List of Participants

Jan Adamczewski
Yukon Renewable Resources
Box 194
Watson Lake, YT Y0A 1C0

Seeglook Akeeagok
Resources, Wildlife and Economic Development
Government of the N.W.T.
Box 65
Grise Fiord, NT X0A 0J0
Tel: (867) 980-4164
Fax: (867) 980-4250
email:seeglook_akeeagok@gov.nt.ca

Joanasie Akumalik
Qikiqtaaluk Wildlife Board, Building #924
Box 478
Iqaluit, NT X0A 0H0
Tel: (867) 979-1560, 1561, 1563
Fax: (867) 979-1491
email: akumalik@nunanet.com

Stephen Atkinson
Resources, Wildlife and Economic Development
Government of the N.W.T.
Box 1870
Iqaluit, NT X0A 0H0
Tel: (867) 979-5072
Fax: (867) 979-6026
email: stephen_atkinson@gov.nt.ca

Sandy Buchan
Resources, Wildlife and Economic Development
Government of the N.W.T.
Kugluktuk, NT X0E 0E0
Tel: (867) 982-7245
Fax: (867) 982-3701

Andy Carpenter
Wildlife Management Advisory Council (NWT)
Joint Secretariat
Box 2120
Inuvik, NT X0E 0T0

Ray Case
Resources, Wildlife and Economic Development
Government of the N.W.T.
600, 5102 - 50 Avenue
Yellowknife, NT X1A 3S8
Tel: (867) 920-8067
Fax: (867) 920-0293
email: ray_case@gov.nt.ca

Bob Cooper
Devonian Wildlife Conservation Centre
Calgary Zoo
Box 3036, Station B
Calgary, AB T2M 4R8
Tel: (403) 232-9390
Fax: (403) 237-8318
email: 102646.2627@compuserve.com

Mike Ferguson
Resources, Wildlife and Economic Development
Government of the N.W.T.
Pond Inlet, NT X0A 0S0
Tel: (867) 899-8876
Fax: (867) 899-8711

Harry Flaherty
Nunavut Wildlife Management Board Box 116
Iqaluit, NT X0A 0H0
Tel: (867) 979-6720
Fax: (867) 979-4451
email: flaherty@nunanet.com

George Francis
Dept. of Environment and Resource Studies
University of Waterloo
Waterloo, Ontario N2L 3G1
Tel: (519) 885-1211 ext 3061
Fax: (519) 746-0292
E-mail: francis@sciborg.uwaterloo.ca

Anne Gunn
Resources, Wildlife and Economic Development
Government of the N.W.T.
600, 5102 - 50 Avenue
Yellowknife, NT X1A 3S8
Tel: (867) 873-7763
Fax: (867) 873-0293
email: anne_gunn@gov.nt.ca

Jimmy Haniliak
Ekaluktutiak Hunters' and
Trappers'Organization
Box 78
Cambridge Bay, NT X0E 0C0
Tel: (867) 983-2426
Fax: (867) 983-2427

Roger Hitkolok
Kitikmeot Hunters' and Trappers'Association
General Delivery
Kugluktuk, NT X0E 0E0

Brian Johnston
Wildlife Management Advisory Council (NWT)
Joint Secretariat
Box 2120
Inuvik, NT X0E 0T0
Tel: (867) 777-2828
Fax: (867) 777-2610
email: wmacnwt@jointsec.nt.ca

Phillip Kadlun
Hunters' and Trappers' Organization General
Delivery
Kugluktuk, NT X0E 0E0

David Kalluk
Hunters' and Trappers' Organization
Box 15
Grise Fiord, NT X0A 0J0
Tel: (867) 980-9080
Fax: (867) 980-4311

Isaac Kalluk
Hunters' and Trappers' Organization
Box 133
Resolute Bay, NT X0A 0V0
Tel: (867) 252-3871
Fax: (867) 252-3800

John Keevik
Hunters' and Trappers' Committee
General Delivery
Sachs Harbour, NT X0E 0Z0

Frank L. Miller
Canadian Wildlife Service
Room #200
4999 - 98th Avenue
Edmonton, AB T6B 2X3
Tel: (403) 951-8672 (office)
(403) 455-5149 (home)
Fax: (403) 495-2615 (office)
email: frank.miller@ec.gc.ca (office)

Phil Miller
Conservation Breeding Specialist Group
12101 Johnny Cake Ridge Road
Apple Valley, MN 55124 – 8151 USA
Tel: (612) 431-9325
Fax: (612) 432-2757
email: pmiller@cbsg.org

Ron Morrison
Resources, Wildlife and Economic Development
Government of the N.W.T.
Bag Service #1
Inuvik, NT X0E 0T0
Tel: (867) 777-7286
Fax: (867) 777-7321

John Nagy
Resources, Wildlife and Economic Development
Government of the N.W.T.
Bag Service #1
Inuvik, NT X0E 0T0
Tel: (867) 777-7305
Fax: (867) 777-2418
email: john_nagy@gov.nt.ca

John Nishi
Resources, Wildlife and Economic Development
Government of the N.W.T.
Box 390
Fort Smith, NT X0E 0P0
Tel: (867) 872-6446
Fax: (867) 872-4250
email: nishi@gov.nt.ca

Colin Okheena
Box 65
Holman, NT X0E 0S0
Tel: (867) 396-4241
Fax: (867) 396-3256

David Shackleton
Faculty of Agricultural Sciences
University of British Columbia
Vancouver, BC V6T 1Z4

Chris Shank
Alberta Environmental Protection
Natural Resources Service
Box 1420
Cochrane, AB T0L 0W0
Tel: (403) 932-4923
Fax: (403) 932-5128
email: shank@telusplanet.net

Ulysses S Seal
Conservation Breeding Specialist Group
12101 Johnny Cake Road
Apple Valley, MN 55124 - 8151 USA
Tel: (612) 431-9325
Fax: (612) 432-2757
email: office@cbsg.org

Duane Smith
Inuvialuit Game Council
Box 2120
Inuvik, NT X0E 0T0
Tel: (867) 777-2828

Doug Stewart
Resources, Wildlife and Economic Development
Government of the N.W.T.
600, 5102 - 50 Avenue
Yellowknife, NT X1A 3S8
Tel: (867) 873-8064
Fax: (867) 873-0293
email: doug_stewart@gov.nt.ca

Curtis Strobeck
Department of Biological Sciences
University of Alberta
Edmonton, AB T6G 2E9
Tel: (403) 492-3515
Fax: (403) 492-9234
email: curtis.strobeck@ualberta.ca

Joe Tigullaraq
Resources, Wildlife and Economic Development
Government of the N.W.T.
Box 1870
Iqaluit, NT X0A 0H0
Tel: (867) 979-5120
Fax: (867) 979-4602/6026
email: joe_tigullaraq@gov.nt.ca

David Tucktoo
Hunters' and Trappers' Organization
Taloyoak, NT X0E 1B0
Tel: (867) 561-5060

Peter J. Usher
Wildlife Management Advisory Council (NWT)
Box 4815, Station E
Ottawa, ON K1S 5H9
Tel: (613) 730-2375
Fax: (613) 730-0382
email: pjusher@istar.ca

Alden Williams
Resources, Wildlife and Economic Development
Government of the N.W.T.
P.O. Box 1870
Iqaluit, NT X0A 0H0
Tel: (867) 979-5004
Fax: (867) 979-6791
email: alden_williams@gov.nt.ca

Glossary

RWED	Department of Resources, Wildlife and Economic Development (Government of the Northwest Territories)
WMAC	Wildlife Management Advisory Council (NWT)
QEI	Queen Elizabeth Islands (High Arctic)
RENEW	Recovery of Nationally Endangered Wildlife
NWMB	Nunavut Wildlife Management Board
RRO	Renewable Resource Offices
RWO	Regional Wildlife Organizations
HTO	Hunters' and Trappers' Organization

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Section 3

FACTORS INFLUENCING CARIBOU POPULATIONS

FACTORS AFFECTING ARCTIC-ISLAND & PEARY CARIBOU POPULATIONS

Working Group Participants:
Chris Shank – Co-Facilitator
David Shackleton – Co-Facilitator
Andy Carpenter
Anne Gunn
Jimmy Haniliak
Roger Hitkolok
Philip Kadlun
David Kalluk
Isaac Kalluk
Frank Miller
Colin Okheena
David Tucktoo

APPROACH

The Group decided that a useful approach to deal with the complexity of factors, would be to divide them into those that were Natural and those that were Human Induced. Members also recognised that factors are often inter-related, but for initial discussion purposes, had to deal with them separately. Emphasis was placed on factors that worked at the population level. Factors that could be changed through human intervention were also identified.

HUMAN INDUCED FACTORS

Contaminants
Some control is possible but generally not at our level of influence (e.g. air pollution, greenhouse gasses, etc.). However, communities need to know about contaminant level in meat, etc.

Vegetation-Habitat
Factors such as displacement from a range, habitat damage, and fragmentation of habitat, that are human caused, may be significant at a local level, but probably not at the population level. Many can be controlled/managed.

Migration
Seismic activity may have both negative and positive effects, but probably is not a population-level factor, though it could be controlled (through timing of operations, etc.). There was also evidence that some negative reactions by caribou had occurred early on, but they seemed to have shown habituation to many human activities since.

Biologists
Can create disturbances and present viewpoints. They can be “controlled”.

Birth rate and Early Survival *("low recruitment")*
The group considered a human effect through selective harvesting of pregnant females and/or

young animals; males being avoided because of poor condition, taste, etc.. This was an area where controls were possible.

Disturbances
There are obviously various factors, but an important one is aircraft disturbance on the calving rounds. This can be controlled.
Weather-Climate
Global climate change, air pollution, greenhouse gases can be influenced only through international political pressure.

Harvesting
This can be controlled through community decisions/co-management.

Shipping Traffic
Timing of shipping can probably be controlled (through timing of ship traffic). This is most significant for Dolphin and Union herds.

NATURAL FACTORS

Disease
Disease seems to be rare in caribou, though the future is uncertain. It probably will be difficult, if not impossible, to control.

Vegetation/Habitat
Factors are 1) Over-grazing by caribou (as opposed to over-grazing due to other species); 2) climate effects on vegetation and habitat. It may be possible to affect overgrazing, but not weather.

Migration
It is not possible to influence migration beneficially.

Predation
Predation, primarily by wolves, is especially a problem on the calving rounds. It is possible to implement wolf control when wolves are demonstrated to be the cause.

Competition
Multi-species competition can lead to habitat/vegetation loss/damage. Competitors include muskox, geese, lemmings. It should be possible to reduce multi-species competition where necessary.

Birth & Survival
Birth rate, early calf survival, age at first breeding, etc. - these factors can not be controlled/affected by management. It is necessary to know about these population parameters.
Weather-Climate
Natural fluctuations in climate, global climate change - nothing can be done.

Accidents
Accidents can be both human and naturally caused, but by their nature could not be prevented

Next, the Group discussed and decided what were the most important factors for each population across the Arctic. This resulted in a descriptive matrix (Table 1). The factors are not in order of priority - but those listed are considered to be the most important ones that impacted populations. The matrix also indicates those factors that were considered open to change or manipulation through human intervention and actions through co-management decisions; it was based on previous the discussion session.

<u>FACTORS & ACTIONS</u>

The next step to meet on the workshop objectives was for the Group to identify problems, then develop needs, actions and goals to address the identified problems.

! = Problem
◊= Need
>= Action

- **HARVESTING** (It was noted that "harvest quota" was perceived as numbers of animals <u>set by Government</u>. Determining numbers of animals to harvest is now a community decision, hence the term "harvest level" is better)

  ◊ Determine caribou numbers to ensure that harvesting is sustainable.
  - > Aerial Surveys
  - > Ground Surveys
  - > Sighting Record System (for incidental observations by hunters; important between aerial surveys and to index trends)
  - > Local knowledge should be used to help determine when and where to do surveys.
  - > Radio-tracking to identify herds

  ◊ Link population numbers with desired harvest levels
  - > DRWED needs to develop better population models; perhaps in form that they can be presented to the communities.

  ◊ Decide on appropriate harvest levels
  - > Biologists work with Hunters' and Trappers' to develop conservative harvest levels.
  - > Timely feedback on survey information is needed.

  ◊ Determine the number needed and wanted by the community
  - > Hunters' and Trappers' Organisations, Committees, and Associations need to establish needs.
  - > Regional wildlife organisations may have some role.

- **PREDATION** (Only wolves are significant)
  - ◊ Deal with public response/perceptions
    - > Ensure that program is science-backed.
    - > Invest in public relations and education.

  - ◊ Ensure that wolves do not go extinct
    - > Consider wolf protection in some areas and caribou protection in others.

<u>REFOCUS</u>
At this stage one of the members suggested that because of time constraints, and the need to address the problem of low caribou numbers in some areas, the Group should concentrate on the main management options for dealing with these problem herds. Dr. Seal suggested a change in direction. The group was presented with the suggestion and agreed to focus their discussion on management options that would be discussed at the community/co-management level.

It was agreed that the new objectives were: 1) to identify by region/herd, those factors the group had considered were probably responsible for low caribou numbers **and** that were possible to change through the co-management process; and 2) to identify other management options that could address the problem of low numbers. The discussion resulted in a second matrix (Table 2).

Using the information in Table 2, the Group then focused its attention on 4 possible mitigation actions; supplemental feeding, translocation, captive breeding, and wolf management. It was decided that no recommendations could me made on whether to undertake these actions since they would necessarily be community-based decisions. However, none of these actions were rejected out-of-hand—it was agreed that there might be circumstances when any might be appropriate. The group concentrated its attentions on identifying the benefits and negative consequences of these four actions. The results are summarised in Tables 3 –6. It was decided that action items would consist of those information items which should be presented to the communities as a priority—these are indicated with the symbol (() in Table 3-6. Available information about these items is needed by the communities to help them in their decision-making process. Consequently, translation, at the least of summary information, will be needed.

The most significant factor we failed to deal with was multi-species competition.

Table 1. Major factors, in approximate order of importance, considered to have negatively affected populations of caribou in each of the areas.

					Western High Arctic		Eastern High Arctic
Banks Is.	NW Victoria	Dolphin & Union	Somerset	Boothia[1]	Melville	Bathurst	
Harvest[2]	**Harvest**	**Harvest**	**Wolves**	Harvest	**Wolves**	**Habitat**	Habitat
Wolves	Habitat	**Disturbances**	Migration	**Wolves**	Climate	**Wolves**	Climate
Competition	Migration	Habitat	Competition	**Competition**		Climate	
Climate	Climate	Climate	Climate	Climate			
		Early Survival		Disease			
		Contaminants		Accidents			
		Accidents					

1. Boothia has no problem with caribou, but the community is concerned about the factors listed.
2. Factors in bold are believed to have been major causes of declines/low numbers.
Contaminants and disturbance were also raised as future concerns for all areas/populations

Table 2. The factors and management options that could be considered for each area/populations where numbers of caribou have declined.

Factor/Action	Population			
	Pr. of Wales - Somerset	NW Victoria (Banks?)	Melville	Bathurst
Factors from Table 1				
Wolf Control	✓ [1]	✓	✓	✓
Multi-species Competition	✓	-	-	-
Habitat/Vegetation	-	✓	-	
Harvest	-	✓	-	✓
Short term actions				
Winter Feeding	?[2]	?	?	?
Move animals to augment a herd[3]	?	?	?	?
Captive Breeding[4]	(?)	(?)	(?)	(?)
Do Nothing				

1. A "✓" indicates that this factor was identified for this area and considered to be possible to change.
2. A "?" indicates that this management option was discussed and though not supported as an action for the present, it may be a later option.
3. If a nearby population/herd has enough caribou of the same type, some animals could be moved to herds or areas with low or no caribou, to augment (increase) or re-establish a herd.
4. Before being considered further, the group's wish was that this option must be discussed by the communities. Further details are given in the following section.

Table 3. Supplemental Feeding

BENEFITS	POTENTIAL NEGATIVE CONSEQUENCES
■ Can save caribou from dying of starvation. ■ Done only as needed for single winters. Not a long-term, multi-year program.	■ Animals may become tame and vulnerable to wolf predation. ■ Could change the caribou's foraging behaviour and movement patterns. ■ Very expensive. ☞ ■ Hay could blow away and pellets/hay could get drifted over and become unavailable to the caribou. ■ Novel, high quality food can cause death. ☞ ■ Livestock diseases might be introduced in the feed. ☞ ■ New plants might be introduced in the seeds. ☞
Appropriate actions at this stage consist of providing the communities with information on certain items so that more informed decision-making can take place. Items for which information is especially needed are marked with the symbol (☞).	

Table 4. Translocate Caribou

POTENTIAL BENEFITS	**POTENTIAL NEGATIVE CONSEQUENCES**
■ Re-establish lost populations. ■ Augment depleted populations. ■ Save the subspecies. ■ Insurance: the risk of extinction can be reduced with more local populations, particularly in a species whose local populations commonly disappear. ■ Community relations and understanding might be enhanced through the necessary co-operation and joint decision-making.	■ Caribou may return home or disperse away from the reintroduction site. ■ Expensive and may include cost of airstrips. ☞ ■ Source populations must exist which are of the same caribou type and large enough to sustain the loss. ■ Causes of population decline or loss must be understood and eliminated before caribou are reintroduced. ☞ ■ Diseases might be introduced from another area. ☞ ■ The capture and release process may be stressful to the animals. ☞
Appropriate actions at this stage consist of providing the communities with information on certain items so that more informed decision-making can take place. Items for which information is especially needed are marked with the symbol (☞).	

Table 5. Captive Breeding

<table>
<tr><th>POTENTIAL BENEFITS</th><th>POTENTIAL NEGATIVE CONSEQUENCES</th></tr>
<tr><td>■ Insurance against extinction.
■ Relatively low cost if done at Calgary Zoo. Detailed information is included in the workshop’s briefing book.
■ A few jobs will be created if done in the North.
■ Captive population can increase dialogue about caribou and promote greater understanding.</td><td>■ Disrespectful to caribou to keep them in captivity.
■ Traditional migration routes may be lost. ☟
■ Caribou may become tame and vulnerable to wolves upon reintroduction. ☟
■ Caribou may become adapted to southern conditions and be unable to readapt to the Arctic. ☟
■ Stress during capture, captivity, and reintroduction. ☟
■ Caribou may introduce southern diseases upon reintroduction. ☟
■ Very expensive if captive breeding done in the North. ☟
■ Disrespectful to the knowledge of the elders who say that caribou will return in the future.</td></tr>
<tr><td colspan="2">Appropriate actions at this stage consist of providing the communities with information on certain items so that more informed decision-making can take place. Items for which information is especially needed are marked with the symbol (☟).</td></tr>
</table>

Table 6. Wolf Management

POTENTIAL BENEFITS	POTENTIAL NEGATIVE CONSEQUENCES
■ Can reduce rate of decline or enhance rate of recovery. ☞ ■ Local hunters could benefit from a wolf management program.	■ Concern that management might affect the very important ecosystem role that wolves play; e.g., “cleansing” the herd. ■ Reaction from animal rights organisations and individuals. ☞ ■ Arctic wolves are being considered for listing by COSEWIC as “threatened”. How do we weigh the needs of two endangered species? ☞ ■ There are few data on wolf numbers so it is unclear how many should be removed.
NB Poison and aerial hunting were not considered appropriate methods. Appropriate actions at this stage consist of providing the communities with information on certain items so that more informed decision-making can take place. Items for which information is especially needed are marked with the symbol (☞).	

POPULATION AND HABITAT VIABILITY ASSESSMENT (PHVA) FOR PEARY CARIBOU AND ARCTIC-ISLAND CARIBOU (*Rangifer tarandus*)

Yellowknife, Northwest Territories, Canada

27 February – 1 March, 1998

REPORT

Section 4

INFORMATION NEEDS

INFORMATION NEEDS

Working Group Participants:
Curtis Strobeck (facilitator)
Seeglook Akeeagok
Bob Cooper
Brian Johnston
John Keevik
Joe Tigullaraq
Peter Usher
Alden Williams

1. Surveys

What needs to be done:

I Eastern Q. E. I. Peary Caribou Population Survey

1. Proceed with the Eastern QEI Survey as recommended by the workshop Oct 7 at Grise Fiord.
* Start fiscal year 1998 / 99.

2. Define management boundaries for each survey. Consideration was given to movements, genetics, visual characteristics (morphology), fidelity to a specific calving grounds and co-management.
Methodology:
- Traditional and local knowledge
- Radio collaring
- Genetics
* Start now and have studies completed before subsequent surveys.

3. Establish schedule for future surveys.
* By the year 2000.

II Harvest Data Survey

Harvest data should be collected and analysed to assess the impact of harvesting on Peary and Arctic Island Caribou populations, and to achieve ongoing management goals.

What needs to be done:

West Harvest study
Have 12 years of data by sex, age class, location of harvest, community by month.
East Harvest study
Access to 2 years of data by sex, location of harvest, community by month. There are 3 years remaining in this 5 year program.

Recommendations
1. Maintain harvest surveys indefinitely for at least Peary's caribou, arctic island caribou, muskox, wolves, snow geese, ptarmigan and rabbits.
2. Collect retrospective harvest data from local knowledge and file data for Peary, arctic island caribou, muskox, wolves, snow geese, ptarmigan and rabbits.
3. Improve data collection from non-beneficiary harvesters for Peary caribou, arctic island caribou, muskox, wolves, snow geese, ptarmigan and rabbits.

III Health Monitoring

1. Immediately establish and implement a necropsy protocol for use in the event of a significant die off (disease, starvation, contaminants, etc).
2. Establish and implement within a year an opportunistic sampling protocol for health status including; contaminants, pathogens and visible abnormalities to establish a data base.

IV Survey Design

Concerns:
- Utilize co-management in all aspects of survey design.
- Incorporate traditional and local knowledge in all surveys.
- Have ground proofing of survey techniques (aerial surveys, utilize community input)

2. Climate / Habitat

What needs to be done:
Establish relationships among weather, range and caribou

1. Studies to be Initiated:

a) Confirm or establish association of specific weather events on caribou including:
Heavy, wet snowfall or freezing rain.
Wet - windy weather for calving.
Altered wind conditions modifying preferred feeding areas.
Warm springs may bring early green up.

b) Establish if weather fluctuations are within normal ranges of variations.
Method
- Meteorological data.
- Specific studies that have documented weather, snow conditions and their effects on caribou.
- Traditional knowledge to determine the correlation between weather data and adverse effect on caribou and to fill in and extend weather history.

2. Monitoring Range Condition

Establish the relationship between weather, the availability of forage, and condition of the caribou using qualitative data from a community-based program. The resulting information should be linked to the ongoing meteorological and snow course data.
- Train community members to monitor environmental conditions - i.e. snow conditions
- Data - traditional or scientific - should be collected in a consistent way each year

- Focus on winter ranges - ranges that have the ability to restrict the growth of the caribou population
- Cook for cratering sites and assess the quality of those sites

3. OTHER STUDIES

What needs to be done:

a) Document the presence and effect of long range contaminates.
Action

Ensure Northern Contaminates Program addresses specific concerns respecting Peary and Arctic island caribou.

b) Initiate a retrospective impact assessment of human activity on caribou such as:
-Mining -Exploration (oil, gas, minerals) -Shipping
-Settlements (research, military, hamlet) -Aircraft (research, tourism)
-Ground transportation

c) Traditional Knowledge

1. Establish an organized and funded program to systematically obtain and incorporate traditional and local knowledge into Peary and Arctic island caribou management.
2. Form a working group to develop mutually acceptable methods and standards for gathering and utilizing local and traditional knowledge.

Program	Priority
Eastern Q. E. I. Peary Caribou Population Survey	**HIGH**
Define Management Boundaries	**HIGH**
Establish Schedule	**MEDIUM**
Harvest:	
a) Main Harvest Surveys	**MEDIUM**
b) Retrospective Data	**MEDIUM**
c) Improve collection - non-beneficiaries	**MEDIUM**
Health Monitoring:	
a) Necropsy	**HIGH**
b) Sampling Protocol	**HIGH**
Studies of weather effects	
a) Confirm or establish association of specific weather events on caribou	**MEDIUM**

b) Establish if weather fluctuations are within normal ranges of variations **MEDIUM**
c) Monitoring range condition **MEDIUM**

Other Studies:

a) Document the presence and effect of long-range contaminants **LOW**
b) Initiate a retrospective impact of human activity on caribou **MEDIUM**
c) Traditional knowledge **HIGH**

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Section 5

CO-MANAGEMENT

Co-Management Group

Working Group Participants:
Ron Morrison, Facilitator
Jan Adamczewski
Joanasie Akumalik
Alex Buchan
Ray Case
Harry Flaherty
George Francis
Duane Smith

Discussion on co-management definition.

- Effective participation of the users of the resource in that resource's management
- Encompasses a large range of things within the realm of wildlife management
- HTO are pooled expertise to do work with
- partnership between technical and local knowledge for the wise use and conservation of the resource
- Shared responsibility for making decisions
- Having the effective parties working as a group for Wildlife Management

Discussion on what we need to do as a group. Who is involved - Inuvialuit, RWED, Nunavut - main players. What's going to happen after this meeting? What is this group responsible for?

Try to work toward a process.

Decided to go through each suggested topic or area of concern.

1. International scope of caribou - Peary caribou - Greenland. Should Greenland people be involved? We should develop a model which can then be presented to them - they have no co-management in place. Not in the short-term - but down the road, w.r.to transfers.
What are Peary caribou? Need a strong definition. Should not get hung up on it.

2. Division of governments - how will division affect conservation of Peary/arctic is. caribou? Main players will stay the same. Communities will remain involved. Main players - RWED, Inuvialuit, Nunavut. Will there be a problem with info exchange, matters of funding? Is it a major problem? Probably not a major problem. Focus may change with new Nunavut govt - but division of government is not a major concern.

3. Rank populations - on basis of numbers? Priorities among populations - we need management plans for each population. Moved to modelling group.

4. Review "working group's mandate. Given wide range of interests - make sure all info brought forward and made available to communities, co-management boards. Reviewed what recovery team is supposed to do - recommend options. RWED has on-going studies. RWED working group - work with co-management boards. Some overlap in functions. Where should

the process go next?

5. When to do re-introductions - either from one island to the next - group questions whether this is appropriate for this group - also question as to minimum numbers for captive effort. May need to re-visit this later on. Repatriation of animals -

6. Levels of management or conservation plan - at what level -population, type - we need further discussion, possibly with larger group. Recovery plan would be umbrella plan - the individual management plans then fit in under the umbrella plan. There is management planning at two levels - population plans (lots of community involvement) and the overall recovery plan.

Three areas related to criteria for management actions were evaluated as not appropriate for co-management part of the discussion.

Discussion of where RENEW process fits with co-management in the north. Currently RENEW plans do not include the co-management process adequately. Note that recovery plan must be approved in Ottawa.

7. Federal govt. - legislation - Endangered Species Act and RENEW process - extended discussion on how these fit with co-management discussions.

8. Value of other island ecosystem components - wolves, muskoxen and caribou are all important. How do you benefit one without affecting others? Discussion but no solution. Viewed as an important problem.

9. How southern views will affect management options - overlaps with 8. Note of public awareness in south of wolf kill in the NT. Group recognized that this is a serious issue and must be dealt with.

10. Are there too many players involved? Too much discussion and not much happening. All the elements are needed - consultation has to occur. Some review of the process by which the capture in 1997 was stopped - i.e. the need for more consultation at that time.

11. Alternate meat sources - some programs are already in place. Funding these programs may be a problem to address. Examples of programs where one community provides meat to another. There should be greater inter-community trade opportunities.

12. Bureaucracy - difficulty of getting information from headquarters. Desire to know a little more about what is happening at HQ. Comment that people from communities attend workshops but do not get needed information in regions.

13. Need to get survey information back to communities - related to previous point.

SELECTED PROBLEMS

(1) Problem: Communication

Overall - comments about how the planned capture for captive breeding in 1997 did not include enough communication and consultation. Seems clear that much of the mistrust and perceived lack of communication revolves around this operation. A lot of the discussion centred on **lack** of communication as a main problem.

Component Problems:

1. Capture option - 1996, 1997 - not enough consultation
2. Draft renew plan - lack of knowledge
3. Management options at time of capture effort - limited number
4. Lack of consensus (within RWED and among other groups)
    (a) lack of consensus on capture effort
    (b) questions about survey design
    (c) questions about research needs
    (d) Is there a problem? - issue raised repeatedly
5. What are we trying to save? - related to 4(d)
6. Need for an agreed-on management plan
7. Urgency - the need to act vs. the need to take time and consult fully

Needs:

1. Active participation in development of management options
2. Agreement on the technical issues, agreement on development of choices and criteria
3. Agreement on interpretation of information, choices and criteria
4. Agreement on how decisions are made, and who makes them
5. (a) Understanding of technical matters (by all parties)
    (b) Who will make decisions to implement (need understanding)
6. Recognition of cultural values and approaches, which may differ.

Actions:

(1) Identify funding for active participation by communities and other participants
(2) Involve - Communities (HTO), RWO, Regional Dept (RWED) Staff
(3) Renew, Recovery Team - involvement needs to be clarified
(4) Develop management options in consultation with all players

Examples of where communication is working

<u>(1) Current RWED consultation with communities on Peary and arctic island caribou</u>

- for more detail, refer to Doug Stewart, Mike Ferguson, Alex Buchan, John Nagy, Anne Gunn
HQ Technical staff - Dept is developing draft options at metapopulation and population level, in consultation with RWED staff and communities in regions - survey results presented, idea is to offer some options and ask for further ideas and options, and incorporate local needs. Within last year.

Some highlights to date:

Meetings in Grise Fjord, Resolute Bay - for Eastern Queen Elizabeth Islands - need surveys; for Western Queen Elizabeth Islands - definite concern over declines;
Meetings in Sachs Harbour, Holman - perception that for Banks Island, studies and management have situation in hand; for NW Victoria - decline is a major concern
Meetings in Cambridge Bay, Holman - for Dolphin-Union herd, concern over harvest, disturbances such as shipping
Meetings in Taloyoak - re Prince of Wales, Somerset - what happened?
Boothia - concerns over a range of factors - wolves, harvest, disturbance
Note that this is an on-going effort

<u>(2) Cooperation between people working with muskoxen in Saskatoon and Cambridge Bay</u>
(muskox calf capture in 1993)

- 5 muskox calves captured in May 1993 for research herd at Univ. Saskatchewan
- cooperative - Univ. Saskatchewan, RWED (Yellowknife, Kugluktuk), Cambridge Bay HTA; - orphan calf sent to Saskatoon in 1996 as follow-up
- possible because trust had been built between the partners over a period of years;
- key component was bringing local and regional HTA presidents to Saskatoon to see firsthand how animals were kept, also communication later on how the animals were doing, study results

(2) PROBLEM: IMPLICATIONS OF INACTION

Definitions - Consequences of selecting the no-action option.

Consequences of failure to make a decision on action to take.

Sub-Problem components with identified needs:

P1. Political implications (N4, N5)
P2. Conservation - species (N5, N6, N7, N11)
P3. Community effects (N1, N5, 6, 7, 8, 9, 10)
P4. Wasted effort (N10, N11)
P5. Losing of options (N1, N4, N11)
P6. Loss of credibility (N1,2,3,4,5,8,12)
P7. Loss of credibility to co-management (N8,9,12)
P8. Economic losses (N8, N13)
P9. Communication on action to take, with community (N5, N11)

Needs

N1. Management of Peary and arctic island caribou populations
N2. Criteria for not taking action
N3. Clear decisions
N4. Demonstrate decisiveness - be decisive
N5. Provide reasons, rationale for actions
N6. Protect resource for future generations
N7. Protect intrinsic value of Peary caribou as an ecosystem component
N8. Protect economic basis of community
N9. Protect cultural values - hunting, education, crafts, traditions
N10. Accountability to public
N11. Timely decisions
N12. Maintain trust of constituency
N13. Protect resource based economy

Linked Needs and Actions

Tried paired-ranking approach for assessing sub-problem priorities:
(Each individual in the working group uses this process to systematically compare each option with all of the other options in terms of the relative priority. The cumulative scores over all participants then determine the ranking.) The scores give a sense of the magnitude of the preference. Thus scores of 44 and 40 are close and both items are considered of high priority.

1st – P2 Conservation of species (score 44)
2nd - P7 Loss to co-management credibility (40)
3rd - P3 Community effects (34)
4th - Economic losses (31)
5th - Loss of credibility (30)
6th and 7th - Losing of options (25), Political consequences (25)
8th - Communication on action to take with community
9th - Wasted effort (time, money) (5)

SUB-PROBLEM NEEDS AND ACTIONS ANALYSIS –

After generation of the needs and actions for each of the sub-problems, the group went through a paired-ranking exercise (each option is compared with every other option and the prefered option tallied; every partitpant does this separately and the results are tallied to caluculate the preference rank. This process tends to overcome strong individually held preferences for particular items without losing any information. It is usually seen as a fair way to establish priorities and preferences by the participants.) with each P-N combination - i.e. within each of the 3 sub-problems paired with a need - ranked each action. The group did not progress beyond this with respect to prioritising among the various actions, or with respect to condensing them and removing redundancies. There was recognition that this needed to be done, but no further time or energy to do it. Also, there was no further elaboration of the needs and actions to take on Communication, although there was also recognition that this needed to be done. Other notes -

initially Ron Morrison was facilitator, later Ulie, and on the last day, Joanasie. Joanasie did a fine job. Doug Stewart was not originally part of the group but joined it later. General observation was that everyone did take part and there was sometimes frustration but no personal animosity.

Conservation of Species (Subproblem P2)

Note that all rankings were done only within the P-N combination.

P2-N1

A1. Management plans developed at community level - 32
A2. Collect all available information on status of populations - 13
A3. Get written reports on on-going or completed reports (if not yet available) - 12
A4. Establish deadlines for reports - 0
A5. Establish objectives for each management plan - 31

N5

A1. RWED, NWMB, WMAC - to issue joint statement explaining activities and approach to management of Peary and arctic island caribou - 6
A2. generation of conservation education material to be a priority- 2

P2-N6-A1

A1. More education effort and materials - 0
A2. Protect use of resource - 23
A3. Provide for communities to participate in short and long-term protection - 27
A4. Establish community-level ecological monitoring program - 21
A5. Secure funding for ecological monitoring programs - 9

P2 N7

A1. Provide educational materials on different values of caribou - 24
A2. Develop caribou life history & ecological materials as basis for education programs - 36
A3. Label management plans as caribou conservation plans - 8
A4. Peary caribou web page - 8
A5. Expedite caribou calving areas protection (n5, N6, N1) - 24
A6. Establish partnerships with national and international organizations (Duane Smith disagrees) - 20

P2 N11

A1. Establish and adhere to deadlines for management - 28
A2. All levels of co-management be kept fully informed about decisions - 37
A3. Criteria for management options be set by April in time for field season -27
A4. Contingency plan prepared - 29

A5. Improve collaborative process between all participants - 37
A6. Annual reports to allow measurement of results - 19
A7. Recognize & respond to information needs with change in governments - 11
A8. Establish coordinator position for all parts - 34
A9. Who is to implement?

Community Effects (Sub-problem P3)

P3 N1 (see P2 A1-A6)
A1. (N1, N5, N6, N7)

P3 N10
A2. Ensure and provide information binders to RRO's for community use - 7
A3. Provide annual reports to communities - 7
A4. Clarify & define the roles/responsibilities at the community level - 10

P3 N8
A1. Determine economic values of Peary/arctic island caribou - 7
A2. Maximize community involvement in research projects (implementation of management options - jobs) -15
A3. Provide information on activities of NGO's (non-governmental organizations) - 2

P3 N9
A1. Investigate alternative hunting opportunities - 12
A2. Ensure youth/elders involved in opportunities to hunt caribou - 17
A3. Identify TK on caribou and get direction(s) from RWO's on priorities - 19
A4. Provide info. to non-user groups on importance of caribou to Inuit culture - 9

Loss of Credibility to Co-management (Subproblem P7)

P7 N12
A1. Ensure agreements are followed through with involved parties. - 7
A2. Ensure on-going consultations between all stake-holders - 1

General Recommendations

1. Recommend that we need to get better information on Greenland caribou - genetics especially.

2. Regardless of division of governments, management plans should be developed and remain in place after division.

3. There should be an assessment by the whole group after the workshops to see whether the working group is on track.

4. Several items related to criteria for management recommendations were not appropriate for co-management discussion. These should be dealt with at the technical level, but within this workshop.

5. Recommend that the Canadian Endangered Species Act and the new RENEW process be moved along as quickly as possible. This legislation has an important influence on agency's ability to act.

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REPORT

Section 6

POPULATION BIOLOGY AND MODELING

Population Biology and Modeling of Canadian Arctic Island Caribou

Working Group Participants:
Phil Miller, Facilitator
Stephen Atkinson
Mike Ferguson
Frank Miller
John Nagy
John Nishi

Introduction

The need for and effects of alternative management strategies can be modeled to suggest which practices may be the most effective in conserving Peary caribou across the Canadian Arctic. VORTEX, a simulation modeling package written by Robert Lacy and Kim Hughes, was used as a tool to study the interaction of multiple demographic and environmental variables that change randomly over time.

The VORTEX package is a Monte Carlo simulation of the effects of deterministic forces as well as demographic, environmental, and genetic stochastic events on wild populations. VORTEX simulates population dynamics as discrete, sequential events (e.g., births, deaths, sex ratios, catastrophes, etc.) that occur according to defined probability distributions. The probabilities of events are modeled as constants or as random variables that follow specified distributions. The package simulates a population by stepping through the series of events that describe the typical life cycle of sexually reproducing, diploid organisms.

VORTEX is not intended to give absolute answers, since it is projecting stochastically the interactions of the many parameters that enter into the model and because of the random processes involved in nature. Interpretation of the output depends upon our knowledge of the biology of Peary caribou, the conditions affecting the population, and possible changes in the future. More specifically, we utilized data from various populations of Peary and other arctic-island caribou where available. For each tentatively recognized metapopulation, we developed a series of values for the demographic input parameters, based on either specific metapopulation-level information, generalized information available from other caribou populations or educated guesses if necessary

Methods

Our approach to using the VORTEX package to model the dynamics of Peary and arctic-island caribou was to first apply the demographic parameters in the absence of extreme stochastic environmental effects (i.e., catastrophes) or the influence of human harvest and/or predation. To minimize complexity, we did not consider genetic effects.

After inputting demographic parameters, we checked observed rates of increase to check whether the model represented the true reproductive potential of caribou. This was accomplished by considering an historical population on Bathurst Island from the 1980s that had previously declined to low numbers after a severe winter and then tripled in size in about six years.

An important observation from preliminary modeling was that in the absence of density dependent effects, simulated caribou population tended to fluctuate narrowly around a predefined static carrying capacity. As this was thought to somewhat unrealistic for caribou, we acknowledged the ecological principle of density-dependence as a fundamental part of the model and recognize different views of caribou on the arctic islands. For example, one view is that caribou on Bathurst Island have not increased in number (based on aerial survey data) to a level where density-dependant processes may have affected either the rate of births or deaths. Another view is that density-dependant processes have played a role in the observed dynamics of Peary caribou on Bathurst Island.

Input Parameters for Simulations

Table 1 summarizes the environmental and demographic information required for the models described in this section. We have identified five metapopulation units that serve as the basis for the simulation effort (Figure 1):

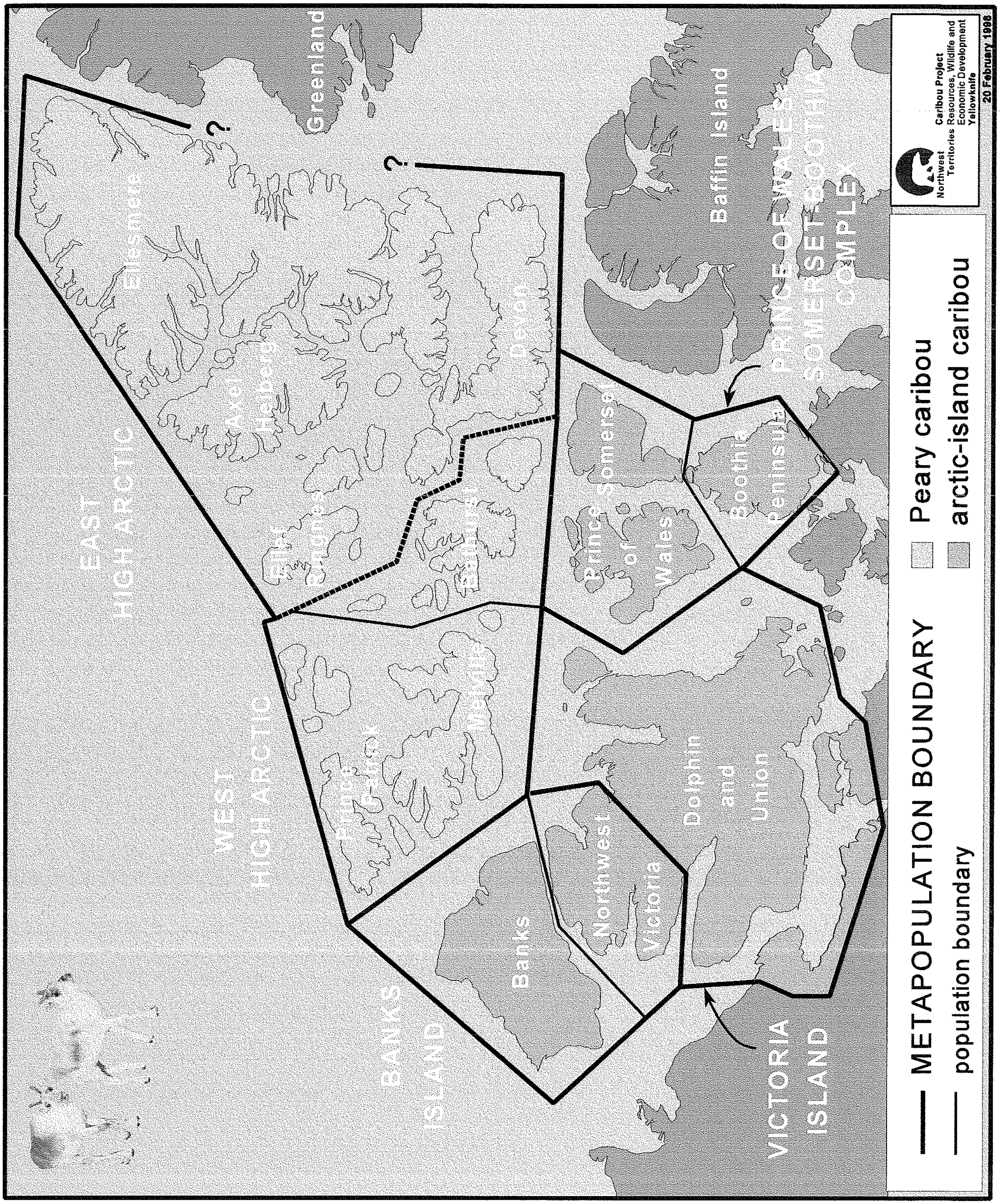
- Western Queen Elizabeth Islands Complex, composed of the Bathurst and Melville / Prince Patrick populations;
- Eastern Queen Elizabeth Islands Complex;
- Prince of Wales / Somerset / Boothia Complex;
- Banks Island Complex, composed of Banks Island and Northwest Victoria Island;
- The Dolphin and Union herd, Victoria Island.

While it is listed here, note that the Dolphin and Union herd was not considered in this set of analyses on account of its large size, making modeling difficult with the VORTEX system.

Population Spatial Structure: Each metapopulation is considered a distinct unit, with their component populations able to exchange individuals from year to year through normal dispersal/migration. The minimum allowable age for this movement was set at 1 year old and animals were assumed to be able to move among populations in this manner throughout their lives. All metapopulation models included a symmetric annual migration rate of 1%; stated another way, the probability of a given individual moving from one population to another from one year to the next was set at 1%. We assumed that the survivorship of a given dispersing/migrating animal was reduced by 25% due to increased exposure to predators and environmental conditions, and we set the minimum density required for movement out of a population (emigration) at 10% of the carrying capacity. We appreciate the need to be able to more realistically simulate episodes of density-dependent emigration/immigration in this species but were unable to achieve this level of sophistication in the current modeling effort.

Mating System: Polygynous.

Figure 1. Map of metapopulation units comprising the Peary and Arctic-island caribou populations considered in this report.



Average Age of First Reproduction: VORTEX defines breeding as the time when young are born, not the age of sexual maturity. Age of sexual maturity of females (i.e., first breeding) was accepted as 16 months which represents the potential for caribou occupying good habitat. Age of sexual maturity of males (i.e., first breeding) was accepted as 40 months. These were entered as 2 and 4 years, respectively, for the age at first reproduction. We attempted to assess uncertainty in the estimation of these parameters by developing alternative models in which the age of first calving was set at three years for both males and females.

Table 1. Summary of VORTEX Input Parameters for Peary and High Arctic Caribou

PARAMETER	META-POPULATION (COMPONENT POPULATIONS)									
	Western QEI (Bathurst / Melville-Prince Patrick)		Eastern QEI		Prince of Wales - Somerset / Boothia		Banks / Northwest Victoria		Dolphin & Union	
Initial population size	76 / 886		1,000		100 / 7000		725 / 100		28000	
Carrying capacity	1450 / 3550		2,000		7000 / 10000		15000 / 10000		100000	
Harvest?	N		15		N		36* & 0		Y	
Inbreeding depression?	N		N		N		N		N	
Density dependence?	Y		Y		Y		Y		Y	
Probability of catastrophe	0.05		0.025		0.025		0.04		0.02	
Severity (Reproduction)	0		0		0		0		0	
Severity (Survival)	0.25		0.5		0.5		0.5		0.5	
	Reproductive parameters									
	Male	Fem	Male	Fem	Male	Fem	Male	Fem	Male	Fem
Breeding age (yr)	4	2								
% Mortality (±s.d) 0 - 1	50 (20)	50 (20)								
1 - 2	15 (5)	15 (4)								
2 - 3	10 (3)	10 (3)								
3 - 4	10 (3)	10 (3)								
Adult, 4+	15 (1.5)	10 (1.5)								
Maximum age (yr)	15									
Adult females producing calves (%) ±s.d.	80 (12)									
Sex ratio at birth	50:50									
All males breeders?	Y									
% males in breeding pool	40									
Concordance between reprod. & survival	Y									

* All male harvest

Maximum Age of Breeding: VORTEX assumes that animals can breed (at the normal rate) throughout their adult life. Data from caribou indicate that both males and females are reproductively capable until 13 years of age. This may be conservative because it was based on the maximum ages of caribou samples after the 1973-74 declines on the Parry and Peel islands.

Calf Production: Calf production was estimated from an average observed pregnancy rate (88%) of caribou collected on Prince of Wales and Somerset islands during 1975-77. Assuming that not all pregnant females produce viable calves, we reduced this pregnancy rate to a more realistic calving rate of 80%. Additional models were developed with a reduced calving rate of 70% in order to assess the sensitivity of a simulated caribou population to measurement uncertainty in this parameter.

Environmental variation in this reproductive parameter is modeled in VORTEX by entering a standard deviation (SD) for the proportion of adult females producing calves. We used a standard deviation of 12%, based on observed variation in pregnancy rates on Prince of Wales / Somerset Island from 1975-77.

Male Breeding Pool: The proportion of adult males breeding each year was initially set at 40% (a guess). This guess was based on general considerations on large ungulates with some degree of social structure. It is possible that the male breeding pool is considerably larger than this; consequently, additional models were developed in which 80% of the adult males are considered to be available for breeding.

Sex Ratio at Birth: As little data exist indicating other than a 50:50 sex ratio at birth for caribou, we used an equal sex ratio for all simulations.

Mortality: Predation, weather, and forage quality and quantity are the primary determinants of calf survival among caribou populations. As a result, we assumed that calf mortality would be higher and more variable among years compared to subadults and adults. Additionally, field data suggest that adult females have lower mortality that adult males, probably due to the greater physiological demands placed on males during the rutting season. These and additional discussions during the workshop led to the following baseline mortality schedule, expressed as mean (standard deviation):

Age Class	Female	Male
0-1	50 (20)	50 (20)
1-2	15 (5)	15 (5)
2-3		10 (3)
3-4		10 (3)
Adult	10 (1.5)	15 (1.5)

Since some degree of uncertainty exists in our estimates of these mortalities, additional models were developed in which calf mortality (both sexes) was reduced to 45%. In the same fashion, adult mortality was changed to 7.5% (female) and 10% (male) to investigate uncertainty in these age classes as well.

Density-Dependent Reproduction: Many species exhibit a reduction in breeding success when population densities are very high and space, food resources, etc. are limited. Similarly, when population density becomes very low, behavioral cues to initiate breeding may be absent or it may even be possible for individuals to have difficulty finding one another to mate (collectively know as an Allee effect). Density dependence in reproduction (proportion of females producing calves in a given year) is modeled in VORTEX according to the following equation:

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

in which *P*(*N*) is the percent of females that breed when the population size is *N*, *P*(0) is the percent of females breeding when the population is close to 0 (in the absence of any Allee effect), and *P*(*K*) is the percent that breed when the population is at carrying capacity (*K*, to be entered later). The exponent *B* determines the shape of the curve relating percent breeding to population size, as population size gets large. If *B* is 1, the percent breeding changes linearly with population size. If *B* is 2, *P*(*N*) is a quadratic function of *N*. The term *A* in the density-dependence equation defines the Allee effect. One can think of *A* as the population size at which the percent of females breeding falls to half of its value in the absence of an Allee effect (Akçakaya and Ferson 1990, p. 18).

No Allee effect is expected in Peary caribou populations at very low densities. However, we expect that successful breeding among adult females may drop dramatically when population density is high. We suggested that, while 80% of adult females successfully reproduce at optimal densities, only 10% do so when populations are at high densities (essentially at carrying capacity). The equation above was adjusted to account for this expectation: P(0) = 80%, P(K) = 10%, A = 0, and B = 4. The functional form of this relationship is shown in Figure 2.

Inbreeding Depression: Inbreeding depression is currently not included in this set of models.

Initial Population Size: Demographic sensitivity analysis models were developed with a population size beginning at 1000 animals. This value was selected based on the estimated population of caribou on Bathurst Island during the late 1980s in order to compare growth dynamics of a simulated population with observed historic dynamics on this island. Subsequent metapopulation models used population-specific values as shown in Table 1. These estimates are based on the most recent census information where available.

Carrying Capacity: The carrying capacity (K) defines an upper limit for the population size, above which additional mortality is imposed equally across age and sex classes in order to return the population to this value. The initial set of sensitivity analysis models used a value of 5000 caribou based on Bathurst Island information. It is important to note, however, that because of the density dependent breeding effects included in the model it is unlikely that a population will reach this upper size limit. Subsequent metapopulation models were developed with population-specific carrying capacities as shown in Table 1.

Catastrophes: Catastrophes are singular events outside the bounds of normal environmental variation affecting reproduction and survival. These types of events are modeled by assigning an annual probability of occurrence and a pair of severity factors that affect either reproduction (% cows calving) or mortality across all age-sex classes. A factor of 0.0 indicates a total catastrophe, i.e., no reproduction in a given catastrophe year, while a factor of 1.0 indicates no effect.

The most common significant event affecting caribou populations in the arctic islands is severe winters, characterized by deep snow and/or icing conditions. Based on infrequent field observations, we estimated that such an event occurred on average every 20-40 years depending on the specific population under consideration. No calves are produced in the year of such an event (100% decrease in the proportion of adult females calving), and survival across all age-sex classes is reduced by 50-75%. This impact is thought to be unrealistically extreme in that during severe winter events we know that younger age classes, adult males, and old females are the most vulnerable to mortality.

Harvesting: While the group understands that harvesting of caribou may not currently be practiced in each of the populations studied in this report, it is instructive to develop simulation models to assess the possible impacts of such harvesting on all populations should it begin at some time in the future. We simulated harvesting of caribou by local communities as an annual removal of a fixed number of animals. Two types of harvests were considered:

1. Male-only, with 20% of the harvested animals greater than 3 years of age, 60% between the ages of 2-3, and 20% consisting of yearlings.
2. Both males and females in rough accord with the sex ratio of adults in the field. This simulates a more indiscriminate harvest with respect to the sex of animals taken. The rough adult sex ratio was obtained from baseline model output.

Rates of harvesting were specific to an individual area (see Table 1). If no such estimates were available, or if harvesting is not currently being practiced in a given area, simple models were developed in which the number taken is equal to 5% of the initial population size. This figure is loosely based on past observations of 36 animals harvested from the Banks Island population of about 720 and is merely a starting point from which we may assess the impacts of harvesting in more detail in subsequent modeling efforts.

Iterations and Years of Projection: All scenarios were initially simulated 500 times, with population projections extending for 100 years. Output results were summarized at 10-year intervals for use in some of the tables and figures that follow. All simulations were conducted using VORTEX version 8.02 (December 1997).

Results from Simulation Modeling

The Baseline Peary Caribou Model

General Population Dynamics
The input parameters discussed above were combined to develop a baseline model for a given historic population of Peary caribou inhabiting the Bathurst Island Complex. We initially simulated this population in the absence of a catastrophic climatic event so as to investigate simple growth dynamics according to the life table we constructed (Table 1). If random fluctuations in demographic rates are ignored (in other words, if the model is deterministic), we would expect this baseline simulated population to grow at a rate of 3.3% per year (r = 0.033). However, such a deterministic model is optimistic and overestimates the growth potential of a population. If random environmental variation is incorporated into the model, the simulated population is expected to grow at an average rate of only 1.2% per year (r = 0.012). The year-to-year variation in this growth rate, however, is quite large as expressed by the standard deviation of this rate (SD(r) = 0.107). During particularly favorable periods, the population could grow as much as 15-20% per year due to random increases in rates of birth and/or survival in the population caused by environmental fluctuations. By the same reasoning, an equivalent rate of decline may show up for a period of time if a streak of bad environmental conditions happens to occur. This amount of simulated variation in population size seems to reasonably accurately reflect the observed rates of change among Peary and other caribou populations, thereby providing some level of satisfaction with the general behavior of the modeling process.

Demographic Sensitivity Analysis
During the development of the baseline model, the group recognized that agreement on many of the input demographic parameters required educated guesswork. It is often important to evaluate the impact of our uncertainty in these parameters that is due to measurement error (or, perhaps, lack of measurement altogether). We can do this by running a series of models with a range of input parameters and comparing the average growth characteristics across models with a given common input value. Knowledge gained from this exercise can be helpful in guiding and/or prioritizing research needs or management options.

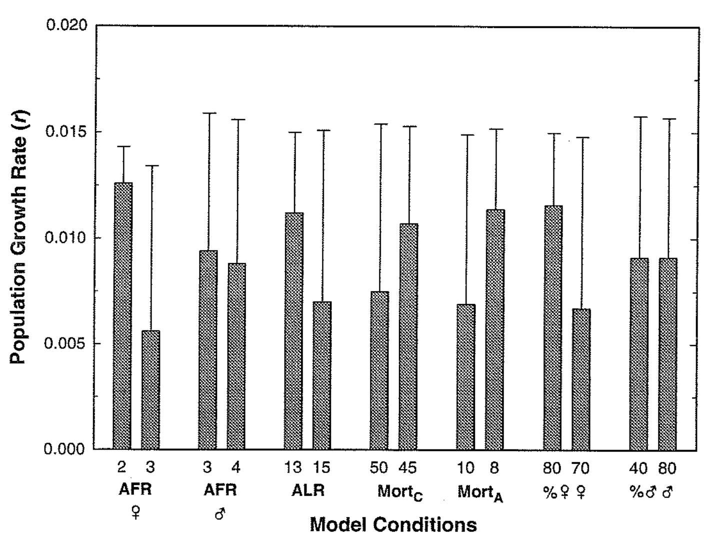
This technique was applied here and the results of such an analysis are shown in Figure 3. The following parameters were evaluated: age of first calving in females and males; maximum age of breeding; mortality of both calves and adults; the proportion of adult females successfully calving in a given year; and the annual proportion of adult males available for breeding. A total of 128 different models were constructed that included all possible combinations of alternative calving in a given year; and the annual proportion of adult males available for breeding. A total of 128 different models were constructed that included all possible combinations of alternative input parameters to give us information on population dynamics across a wide range of demographic possibilities. It is important to remember that the primary value of this analysis is in the *comparisons* among different groups of models and not the absolute value of any one model outcome.

The figure shows, for example, that if the age of first calving among females is 3 years instead of 2, the population growth potential is reduced dramatically. This is simply because an increase in the mean female age of first calving shortens an individual female's reproductive life span and, consequently, reduces the number of breeding-age females in the population. On the other hand, if the age of first calving among males is increased by a year, there is very little if any impact on the growth potential of the population. Because of the polygynous breeding system in caribou, the number of calves produced annually is not a function of the number of bulls (except, perhaps, in extreme cases of very low population density) but it is of course strongly influenced by the number of cows. Using similar logic, an increase in the maximum age of breeding from 13 to 15 years also increases the growth potential of a simulated caribou population by increasing a female's reproductive lifespan. However, because fewer females survive to this age, a change in this parameter has relatively less impact compared to changes made to the breeding age of a larger crop of younger animals.

This type of reasoning also helps to explain why a given change in calf mortality has a greater impact on population growth than the same change in adult mortality. Figure 3 shows that if calf mortality is reduced by 10% of its original value--from 50% to 45%--the mean growth rate is reduced from 0.011 to 0.007. However a change in the adult mortality rate of the same magnitude is expected to reduce the growth rate by less than half as much.

Once again, the polygynous breeding system in caribou means that the proportion of bulls available for breeding is relatively unimportant demographically while the proportion of cows successfully calving greatly impacts caribou population growth.

Figure 3. Peary caribou demographic sensitivity analysis. Mean and standard deviation of population growth rate averaged across a series of models representing all combinations of the listed parameters. AFR and ALR, age of first and last reproduction, respectively; $Mort_C$ and $Mort_A$, calf and adult mortality, respectively; %♀♀, percentage of adult females successfully calving in a give year; %♂♂, percentage of adult males available for breeding in a given year.



mortality (although the importance of good estimates for adult mortality cannot be discounted). As a result, all of the risk assessment models discussed below will include alternative estimates of the age of first calving among females, the proportion of those females that successively calve in a given year, and the annual mortality of calves. This will allow us to incorporate levels of "measurement uncertainty" into our risk assessments to provide a more comprehensive picture of Peary caribou population viability.

Table 2. Western QEI metapopulation catastrophe analysis. Average population growth rate (r), Probability of extinction (P(E)), and mean population size at the end of the 100-year simulation (N_{100}) are shown for each of the component populations and for the total metapopulation. AFR, age of first calving among females; %EE, mean percentage of adult females successively calving each year; $Mort_C$, annual calf mortality. See text for additional discussion of model input.

Model Conditions			Model Results (Bathurst / Melville - Prince Patrick / Total)		
AFR	%EE	$Mort_C$	Mean r	P(E)	N_{100}
Weather catastrophe absent					
2	80	50	0.026 / 0.009 / 0.012	0.000 / 0.000 / 0.000	1002 / 2150 / 3152
3			0.020 / 0.001 / 0.005	0.000 / 0.000 / 0.000	647 / 1153 / 1800
2		45	0.027 / 0.009 / 0.012	0.000 / 0.000 / 0.000	1097 / 2191 / 3288
3			0.025 / 0.008 / 0.011	0.000 / 0.000 / 0.000	951 / 1957 / 2908
2	70	50	0.020 / 0.001 / 0.005	0.000 / 0.000 / 0.000	665 / 1189 / 1854
3			0.001 / -0.016 / -0.012	0.036 / 0.000 / 0.000	141 / 250 / 385
2		45	0.024 / 0.002 / 0.007	0.000 / 0.000 / 0.000	882 / 1226 / 2108
3			0.015 / -0.004 / 0.000	0.002 / 0.000 / 0.000	434 / 699 / 1132
Weather catastrophe present					
2	80	50	-0.025 / -0.046 / -0.045	0.648 / 0.534 / 0.504	226 / 368 / 506
3			-0.044 / -0.064 / -0.064	0.836 / 0.744 / 0.724	103 / 145 / 196
2		45	-0.019 / -0.046 / -0.042	0.584 / 0.506 / 0.468	312 / 369 / 587
3			-0.034 / -0.055 / -0.054	0.742 / 0.630 / 0.606	183 / 257 / 361
2	70	50	-0.048 / -0.066 / -0.066	0.858 / 0.730 / 0.714	92 / 118 / 157
3			-0.061 / -0.086 / -0.086	0.952 / 0.896 / 0.878	52 / 68 / 79
2		45	-0.034 / -0.064 / -0.059	0.726 / 0.688 / 0.644	134 / 139 / 225
3			-0.051 / -0.072 / -0.071	0.896 / 0.784 / 0.774	82 / 105 / 139

Metapopulation Risk Assessment

Catastrophe Analysis

Tables 2 through 5 present results of those models run first in the absence of and then including severe winter weather catastrophes for each of the four metapopulation units under study. In the absence of the catastrophe, three of the four metapopulations can grow at an average annual rate

Metapopulation Risk Assessment

Catastrophe Analysis

Tables 2 through 5 present results of those models run first in the absence of and then including severe winter weather catastrophes for each of the four metapopulation units under study. In the absence of the catastrophe, three of the four metapopulations can grow at an average annual rate of about 3 – 4% under baseline demographic conditions (Tables 2, 4 and 5, top row). The exception to this observation is the Eastern Queen Elizabeth Islands, with an average annual rate of growth of 0.3% (Table 3, top row). The Eastern QEI metapopulation was restricted from growing at a higher rate because the density-dependent nature of the breeding characteristics restricted the production of calves once the metapopulation grew beyond about 1200-1300 individuals. Since the initial population size was 1000, little growth was possible.

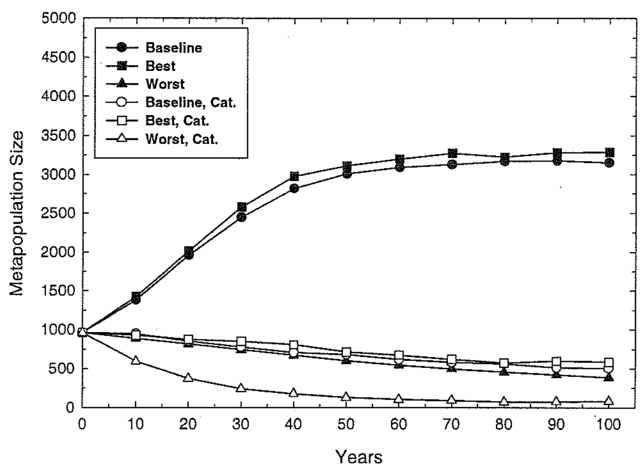


Figure 4. Population trajectories for the Western Queen Elizabeth Islands Peary caribou metapopulation without (black symbols) and with (white symbols) a severe winter weather catastrophe. The baseline model incorporates the best estimates of caribou demographics, while "best" and "worst" refer to optimistic and pessimistic demographic scenarios, respectively, given our level of uncertainty in these estimates.

As also shown in the tables, under the most "optimistic" set of demographic conditions—age of first calving at 2 years, 80% of females calving each year, and 45% calf mortality—growth rates can be larger, but only slightly. This is again due to the fact that little opportunity for additional growth is possible over the baseline projections due to the density-dependent growth we've imposed. On the other hand, the most "pessimistic" demographic scenario results in dramatic reductions in population growth potential (see also Figure 4 using the Western QEI as an example). Because of the uncertainty in our estimates of these (and other) demographic parameters for caribou populations, we conclude that the most likely future projection for any population will fall within these extremes and probably near our baseline simulation projection.

The addition of a severe winter weather catastrophe can drastically reduce the average long-term growth rate of caribou populations and can even lead to a risk of metapopulation extinction (Tables 2 – 5, bottom; Figures 4 and 5). This is especially true for the Western Queen Elizabeth Islands metapopulation simulations, where this type of event was assumed to occur more often and lead to a more severe effect on individual survivorship. Table 1 shows that the Bathurst Island population, due in part to its small size at present, could be particularly vulnerable to extinction from this type of event. The Banks Island complex shows a similar situation: the NW Victoria population could be at considerably greater risk compared to the Banks Island population precisely because of its smaller size and greater vulnerability to random chance playing a detrimental role in determining future population persistence.

2	80	50	0.003	0.000	1352
3			-0.005	0.000	727
2		45	0.004	0.000	1459
3			0.000	0.000	1073
2	70	50	-0.001	0.000	1014
3			-0.020	0.004	205
2		45	0.002	0.000	1267
3			-0.008	0.000	543
Weather catastrophe present					
2	80	50	-0.004	0.008	886
3			-0.023	0.072	248
2		45	0.000	0.000	1110
3			-0.014	0.024	485
2	70	50	-0.015	0.040	444
3			-0.041	0.260	74
2		45	-0.007	0.004	727
3			-0.028	0.106	184

An inspection of the individual model output files reveals that recolonization of populations that became extinct was a relatively rare event. This is probably because we restricted movement out of a given population to occur only when that population was at least 10% of carrying capacity. Since the severe winter weather event was set up to affect both subsets of a metapopulation, it appears unlikely that there were sufficient numbers of animals from one population to recolonize another that had become locally extinct. Future modeling efforts should perhaps take this observation into account provide for a greater opportunity to exchange of individuals between populations.

Table 4. Prince of Wales metapopulation catastrophe analysis. See Table 2 for column header definitions.

Model Conditions			Model Results (Prince of Wales - Somerset / Boothia / Total)		
AFR	% ♀♀	$Mort_C$	Mean r	P(E)	N_{100}
Weather catastrophe absent					
2	80	50	0.038 / -0.001 / 0.004	0.000 / 0.000 / 0.000	4724 / 6401 / 11125
3			0.033 / -0.006 / 0.000	0.000 / 0.000 / 0.000	3072 / 4133 / 7205
2		45	0.039 / -0.001 / 0.005	0.000 / 0.000 / 0.000	5008 / 6342 / 11350
3			0.038 / -0.002 / 0.003	0.000 / 0.000 / 0.000	4367 / 5808 / 10174
2	70	50	0.034 / -0.006 / 0.000	0.000 / 0.000 / 0.000	3203 / 4179 / 7382
3			0.018 / -0.020 / -0.015	0.000 / 0.000 / 0.000	812 / 1143 / 1955
2		45	0.037 / -0.005 / 0.002	0.000 / 0.000 / 0.000	4152 / 4402 / 8554
3			0.029 / -0.01 / -0.005	0.000 / 0.000 / 0.000	2141 / 2872 / 5013
Weather catastrophe present					
2	80	50	0.031 / -0.009 / -0.003	0.002 / 0.000 / 0.000	2940 / 3964 / 6898
3			0.015 / -0.023 / -0.017	0.026 / 0.002 / 0.002	1023 / 1411 / 2410
2		45	0.035 / -0.007 / -0.001	0.000 / 0.000 / 0.000	3865 / 4333 / 8198
3			0.027 / -0.013 / -0.007	0.002 / 0.000 / 0.000	2178 / 2857 / 5030
2	70	50	0.016 / -0.022 / -0.017	0.034 / 0.012 / 0.004	1153 / 1570 / 2675
3			-0.005 / -0.040 / -0.035	0.128 / 0.048 / 0.036	225 / 349 / 548
2		45	0.024 / -0.020 / -0.012	0.006 / 0.004 / 0.002	1851 / 1728 / 3568
3			0.008 / -0.029 / -0.024	0.046 / 0.006 / 0.002	609 / 880 / 1458

Figure 5. Population size trajectories for (A) the High Arctic Islands and (B) the Prince of Wales and the Banks Island metapopulations under the baseline demographic conditions described in the text. Lines with black symbols indicate models without catastrophes, while lines with white symbols indicate models that include the severe winter event.

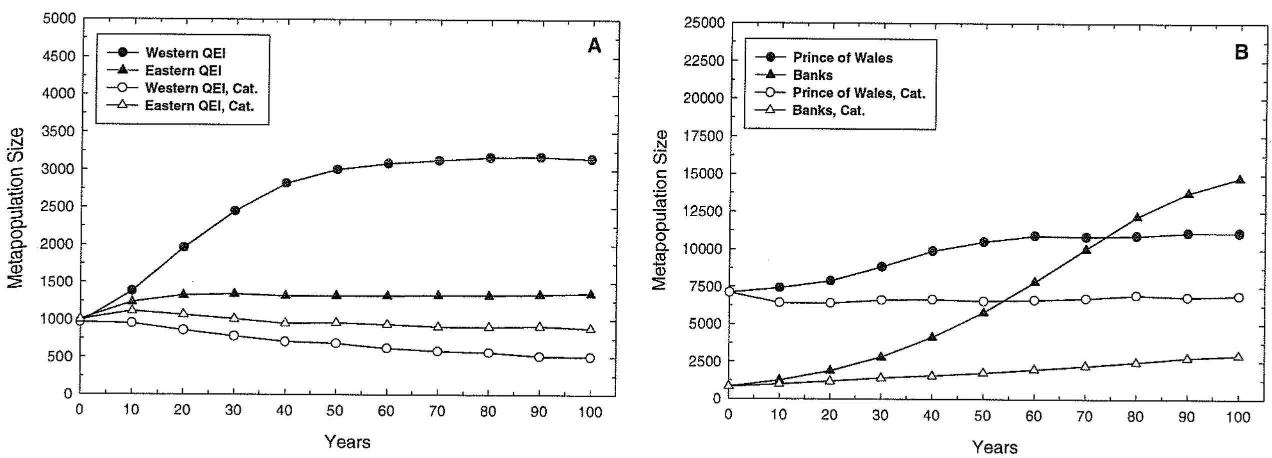


Table 5. Banks metapopulation catastrophe analysis. See Table 2 for column header definitions.

Model Conditions			Model Results (Northwest Victoria / Banks / Total)		
AFR	%EE	$Mort_C$	Mean r	P(E)	N_{100}
Weather catastrophe absent					
2	80	50	0.041 / 0.024 / 0.028	0.000 / 0.000 / 0.000	6056 / 8691 / 14749
3			0.018 / 0.008 / 0.010	0.006 / 0.000 / 0.000	1101 / 2003 / 3098
2		45	0.042 / 0.025 / 0.029	0.000 / 0.000 / 0.000	7119 / 8840 / 15959
3			0.034 / 0.018 / 0.023	0.000 / 0.000 / 0.000	3606 / 5279 / 8885
2	70	50	0.019 / 0.008 / 0.011	0.010 / 0.000 / 0.000	1185 / 2154 / 3327
3			-0.016 / -0.013 / -0.012	0.238 / 0.000 / 0.000	64 / 317 / 366
2		45	0.031 / 0.010 / 0.017	0.000 / 0.000 / 0.000	2928 / 2707 / 5636
3			0.004 / 0.001 / 0.003	0.036 / 0.000 / 0.000	336 / 1031 / 1355
Weather catastrophe present					
2	80	50	0.006 / -0.003 / -0.001	0.174 / 0.044 / 0.032	1286 / 1848 / 2923
3			-0.026 / -0.026 / -0.025	0.520 / 0.158 / 0.144	168 / 269 / 358
2		45	0.017 / -0.001 / 0.005	0.110 / 0.044 / 0.036	2186 / 2218 / 4218
3			-0.011 / -0.014 / -0.013	0.356 / 0.064 / 0.056	521 / 752 / 1101
2	70	50	-0.026 / -0.028 / -0.027	0.522 / 0.216 / 0.194	213 / 327 / 444
3			-0.048 / -0.047 / -0.047	0.856 / 0.472 / 0.46	28 / 71 / 77
2		45	-0.010 / -0.025 / -0.021	0.318 / 0.174 / 0.134	375 / 370 / 648
3			-0.033 / -0.032 / -0.032	0.628 / 0.228 / 0.214	74 / 183 / 215

Population Harvesting Analysis

Tables 6 through 12 and Figures 6 and 7 give the results of models in which an attempt was made to evaluate the impact of harvesting of caribou among each of the metapopulation units. Preliminary inspection of these models suggests that the impact of harvesting a fixed number of males each year could be strongly tied to a population size "threshold" effect, particularly in the absence of severe winter events (catastrophes). If we take the Melville - Prince Patrick Islands population as an example (Tables 6 and 7), this population may be able to increase in size in the presence of the fixed-number harvest as long as random environmental and demographic fluctuations do not drive the population below about 400-500 animals from an initial population of 900. Under these conditions, the fixed number of 44 animals being removed from the population annually (equivalent to 5% of the initial population size) becomes a much larger proportion of the total population, particularly among males. Consequently, the population may not able to support such a removal, especially if only a subset of the total pool of adult males is available for breeding in any given year.

Each of the tables also clearly indicates that removal of a mixed-sex group of animals, in rough accord with the adult sex ratio, may have a much more severe effect on the population than removal of only males, as would be expected. In addition, the results indicate that larger populations may be able to support a given level of harvest more easily than smaller populations and could essentially be immune from this "threshold" effect since the deleterious consequences of random fluctuations in birth and death rates are less in larger populations.

Table 6. Western QEI metapopulation harvesting analysis, no catastrophes. See Table 2 for column header definitions.

Model Conditions			Model Results (Bathurst / Melville - Prince Patrick / Total)		
AFR	**%EE**	**$Mort_C$**	**Mean r**	**P(E)**	**N_{100}**
All - Male Harvest					
2	80	50	0.026 / 0.008 / 0.011	0.000 / 0.052 / 0.000	1013 / 2209 / 3108
3			0.017 / -0.009 / -0.003	0.002 / 0.516 / 0.002	536 / 1329 / 1186
2		45	0.027 / 0.007 / 0.011	0.000 / 0.074 / 0.000	1083 / 2215 / 3153
3			0.025 / 0.005 / 0.009	0.000 / 0.128 / 0.000	918 / 1982 / 2648
2	70	50	0.017 / -0.008 / -0.003	0.004 / 0.502 / 0.004	564 / 1420 / 1278
3			-0.005 / -0.050 / -0.031	0.092 / 0.982 / 0.092	94 / 521 / 106
2		45	0.023 / -0.008 / 0.002	0.000 / 0.488 / 0.000	806 / 1388 / 1524
3			0.012 / -0.018 / -0.011	0.004 / 0.696 / 0.004	357 / 997 / 665
Mixed Harvest					
2	80	50	0.023 / -0.092 / -0.002	0.000 / 0.980 / 0.000	818 / 952 / 838
3			0.009 / -0.152 / -0.017	0.008 / 1.000 / 0.008	248 / 0 / 248
2		45	0.026 / -0.095 / 0.000	0.000 / 0.988 / 0.000	993 / 1749 / 1014
3			0.018 / -0.127 / -0.007	0.002 / 1.000 / 0.002	552 / 0 / 552
2	70	50	0.008 / -0.152 / -0.017	0.006 / 1.000 / 0.006	258 / 0 / 258
3			-0.012 / -0.188 / -0.039	0.178 / 1.000 / 0.178	54 / 0 / 54
2		45	0.020 / -0.149 / -0.006	0.006 / 1.000 / 0.006	636 / 0 / 636
3			0.002 / -0.167 / -0.023	0.016 / 1.000 / 0.016	137 / 0 / 137

If catastrophic winter events are included in the harvesting models, each of the metapopulations may be unable to support a harvest during and immediately after those years in which winters are particularly severe and the population could rapidly decline to extinction. These preliminary models suggest that the combined effects of unusually harsh environmental conditions and removal of individuals by local communities could drive a local population to extinction. Recovery of such a population may then depend on dispersal/migration of individuals from nearby island populations. Unfortunately, the characteristics of harvest we have set up in these VORTEX models do not completely and accurately reflect how real caribou populations are harvested. The VORTEX harvest is continuous and is in effect until a population becomes extinct. Additionally, in a metapopulation simulation, a locally extinct population that is recolonized will immediately be subject to that same level of harvest and will rapidly become extinct once again. More sophisticated models should be developed in which harvesting begins only when a population grows above a given size and stops when a population drops below a given threshold. As the models discussed here do not incorporate this dependence on population size or density, they tend to overestimate the long-term effects of such a practice. An improvement to the VORTEX modeling effort as outlined above will likely be possible in the near future.

Table 7. Western QEI metapopulation harvesting analysis, catastrophes present. See Table 2 for column header definitions.

Model Conditions			Model Results (Bathurst / Melville - Prince Patrick / Total)		
AFR	**%EE**	**$Mort_C$**	**Mean r**	**P(E)**	**N_{100}**
All - Male Harvest					
2	80	50	0.026 / 0.008 / 0.011	0.000 / 0.052 / 0.000	1013 / 2209 / 3108
3			0.017 / -0.009 / -0.003	0.002 / 0.516 / 0.002	536 / 1329 / 1186
2		45	0.027 / 0.007 / 0.011	0.000 / 0.074 / 0.000	1083 / 2215 / 3153
3			0.025 / 0.005 / 0.009	0.000 / 0.128 / 0.000	918 / 1982 / 2648
2	70	50	0.017 / -0.008 / -0.003	0.004 / 0.502 / 0.004	564 / 1420 / 1278
3			-0.005 / -0.050 / -0.031	0.092 / 0.982 / 0.092	94 / 521 / 106
2		45	0.023 / -0.008 / 0.002	0.000 / 0.488 / 0.000	806 / 1388 / 1524
3			0.012 / -0.018 / -0.011	0.004 / 0.696 / 0.004	357 / 997 / 665
Mixed Harvest					
2	80	50	0.023 / -0.092 / -0.002	0.000 / 0.980 / 0.000	818 / 952 / 838
3			0.009 / -0.152 / -0.017	0.008 / 1.000 / 0.008	248 / 0 / 248
2		45	0.026 / -0.095 / 0.000	0.000 / 0.988 / 0.000	993 / 1749 / 1014
3			0.018 / -0.127 / -0.007	0.002 / 1.000 / 0.002	552 / 0 / 552
2	70	50	0.008 / -0.152 / -0.017	0.006 / 1.000 / 0.006	258 / 0 / 258
3			-0.012 / -0.188 / -0.039	0.178 / 1.000 / 0.178	54 / 0 / 54
2		45	0.020 / -0.149 / -0.006	0.006 / 1.000 / 0.006	636 / 0 / 636
3			0.002 / -0.167 / -0.023	0.016 / 1.000 / 0.016	137 / 0 / 137

A close look at many of the harvest models shows some seemingly odd results. For example, in the Prince of Wales metapopulation, the larger Boothia Peninsula population shows a strong rate of decline and a substantial risk of extinction under all conditions simulated, while the much smaller Prince of Wales - Somerset population grows rapidly throughout the 100 years of the simulation (Tables 10 and 11). This result stems from the fact that harvesting was not implemented on very small populations such as Prince of Wales - Somerset and Bathurst Island but was included for larger populations. Moreover, this harvest was set to occur each year for the full 100 years of the simulation. Therefore, these simulated small populations were immune from any deleterious effects of the harvest while larger populations, particularly in the presence of severe winter events, were rapidly reduced in size and ultimately driven to extinction under the conditions modeled. Once again, additional modeling should be undertaken with a more sophisticated harvesting schedule that takes into account not only initial population size but the rate of change in population size over time.

Table 8. Eastern QEI metapopulation harvesting analysis, no catastrophes. See Table 2 for column header definitions.

Model Conditions			Model Results (Total)		
AFR	**%EE**	**$Mort_C$**	**Mean r**	**P(E)**	**N_{100}**
All-Male Harvest					
2	80	50	0.003	0.000	1336
3			-0.006	0.060	710
2		45	0.004	0.000	1449
3			0.000	0.002	1087
2	70	50	-0.001	0.018	1019
3			-0.026	0.596	330
2		45	0.002	0.000	1245
3			-0.011	0.138	540
Mixed Harvest					
2	80	50	-0.006	0.126	1059
3			-0.068	0.934	354
2		45	0.003	0.002	1342
3			-0.037	0.642	577
2	70	50	-0.041	0.676	528
3			-0.103	1.000	0
2		45	-0.012	0.220	872
3			-0.083	0.994	163

Note also that, when the Boothia population is harvested, the growth rate of the Prince of Wales – Somerset population is reduced (compare Tables 4 and 10). This results from the fact that there is little or no opportunity for migration in to Prince of Wales – Somerset from the rapidly declining Boothia population subjected to harvesting. Since there is continued migration out of Prince of Wales – Somerset, the net effect of harvesting the larger population is that it becomes a "sink" that accepts individuals from the smaller population but allows return migration with much lower frequency.

Figure 6. Population size trajectories for (A) the Western and (B) the Eastern Queen Elizabeth Islands metapopulations under alternative harvesting strategies described in the text. All models shown were run under baseline demographic conditions. Lines with black symbols indicate models without catastrophes, while lines with white symbols indicate models that include the severe winter event. Legend entries with asterisks indicate catastrophe scenarios.

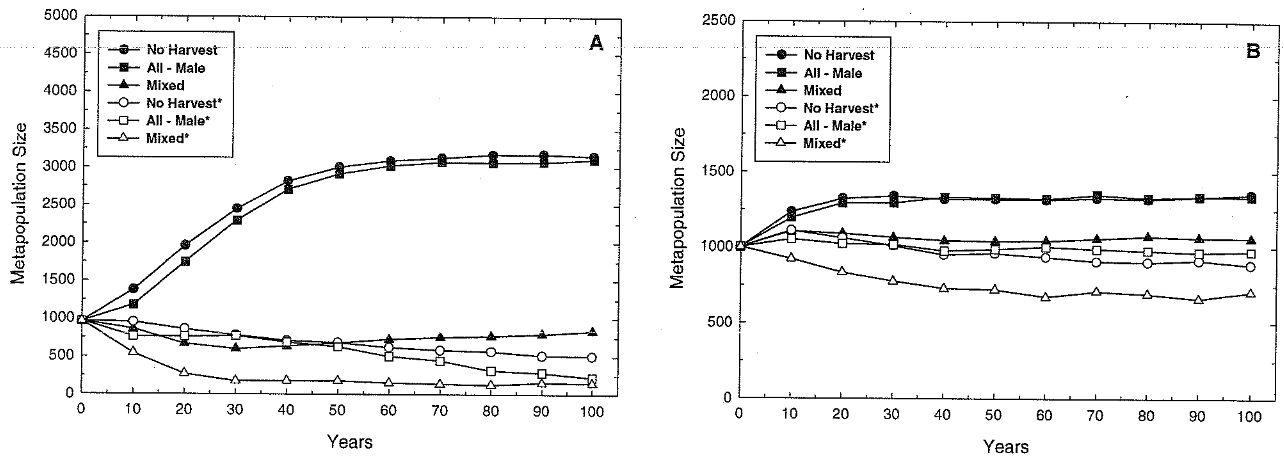


Table 9. Eastern QEI metapopulation harvesting analysis, catastrophes present. See Table 2 for column header definitions.

Model Conditions			Model Results (Total)		
AFR	% ♀♀	$Mort_C$	Mean r	P(E)	N_{100}
All-Male Harvest					
2	80	50	-0.007	0.158	974
3			-0.033	0.694	464
2		45	-0.002	0.082	1156
3			-0.019	0.422	661
2	70	50	-0.020	0.450	640
3			-0.052	0.928	201
2		45	-0.010	0.230	850
3			-0.036	0.762	369
Mixed Harvest					
2	80	50	-0.048	0.726	707
3			-0.102	1.000	0
2		45	-0.026	0.448	887
3			-0.076	0.930	388
2	70	50	-0.085	0.958	517
3			-0.131	1.000	0
2		45	-0.055	0.780	643
3			-0.108	0.998	651

Despite some of their limitations, these harvest models do point out the sensitivity of small populations to removals of animals in the presence of serious events that occur randomly over time. Harvesting a given number of animals following a severe winter may be much more damaging to the population compared to a removal of the same number of animals in a year with "normal" environmental conditions. In addition, these models suggest that the removal of a fixed number of individuals from year to year may have a greater impact on future population persistence than a program in which a given proportion, say 3-5%, of animals is removed annually. This latter practice, then, removes fewer animals from smaller populations, but it also requires a relatively more complete knowledge of the status of the population, and in particular whether that population is increasing, stable, or declining in size. Information like this is often difficult to obtain; moreover, the ability to detect a population trend with any confidence requires careful census measurement over many years.

Table 10. Prince of Wales metapopulation harvesting analysis, no catastrophes. See Table 2 for column header definitions.

Model Conditions			**Model Results (Prince of Wales - Somerset / Boothia / Total)**		
AFR	**%EE**	**$Mort_C$**	**Mean r**	**P(E)**	**N_{100}**
All-Male Harvest					
2	80	50	0.038 / -0.005 / 0.002	0.000 / 0.254 / 0.000	4659 / 6550 / 9578
3			0.028 / -0.028 / -0.013	0.000 / 0.840 / 0.000	2186 / 4670 / 2981
2		45	0.039 / -0.006 / 0.003	0.000 / 0.272 / 0.000	5079 / 6349 / 9736
3			0.036 / -0.011 / -0.002	0.000 / 0.470 / 0.000	3952 / 5737 / 7044
2	70	50	0.029 / -0.026 / -0.012	0.000 / 0.812 / 0.000	2364 / 4736 / 3302
3			0.009 / -0.065 / -0.034	0.002 / 1.000 / 0.002	365 / 0 / 359
2		45	0.035 / -0.027 / -0.006	0.000 / 0.832 / 0.000	3632 / 4844 / 4520
3			0.022 / -0.040 / -0.020	0.000 / 0.958 / 0.000	1234 / 4788 / 1465
Mixed Harvest					
2	80	50	0.036 / -0.137 / -0.007	0.000 / 1.000 / 0.000	3773 / 0 / 3773
3			0.022 / -0.175 / 0.000	0.000 / 1.000 / 0.000	1100 / 0 / 1100
2		45	0.038 / -0.138 / -0.004	0.000 / 1.000 / 0.000	4765 / 0 / 4765
3			0.031 / -0.157 / -0.012	0.000 / 1.000 / 0.000	2580 / 0 / 2580
2	70	50	0.022 / -0.179 / -0.021	0.000 / 1.000 / 0.000	1139 / 0 / 1139
3			0.004 / -0.205 / -0.039	0.008 / 1.000 / 0.008	229 / 0 / 229
2		45	0.032 / -0.177 / -0.010	0.000 / 1.000 / 0.000	2903 / 0 / 2903
3			0.015 / -0.194 / -0.027	0.000 / 1.000 / 0.000	590 / 0 / 590

Table 11. Prince of Wales metapopulation harvesting analysis, catastrophes present. See Table 2 for column header definitions.

Model Conditions			Model Results (Prince of Wales - Somerset / Boothia / Total)		
AFR	**%EE**	**$Mort_C$**	**Mean r**	**P(E)**	**N_{100}**
All-Male Harvest					
2	80	50	0.026 / -0.034 / -0.015	0.002 / 0.890 / 0.002	2185 / 5465 / 2843
3			0.007 / -0.058 / -0.036	0.038 / 0.992 / 0.038	593 / 2306 / 625
2		45	0.032 / -0.034 / -0.010	0.000 / 0.880 / 0.000	3111 / 5282 / 3816
3			0.020 / -0.038 / -0.021	0.014 / 0.892 / 0.014	1534 / 5065 / 2120
2	70	50	0.008 / -0.059 / -0.035	0.052 / 0.994 / 0.052	665 / 4867 / 710
3			-0.014 / -0.088 / -0.059	0.236 / 1.000 / 0.236	115 / 0 / 115
2		45	0.020 / -0.053 / -0.023	0.012 / 0.980 / 0.012	1426 / 3632 / 1529
3			0.001 / -0.071 / -0.043	0.086 / 1.000 / 0.086	334 / 0 / 340
Mixed Harvest					
2	80	50	0.022 / -0.164 / -0.021	0.010 / 1.000 / 0.010	1652 / 0 / 1652
3			0.002 / -0.200 / -0.042	0.076 / 1.000 / 0.076	349 / 0 / 349
2		45	0.030 / -0.167 / -0.013	0.006 / 1.000 / 0.006	2862 / 0 / 2862
3			0.013 / -0.184 / -0.030	0.034 / 1.000 / 0.034	799 / 0 / 799
2	70	50	0.002 / -0.203 / -0.042	0.084 / 1.000 / 0.084	358 / 0 / 358
3			-0.021 / -0.231 / -0.068	0.358 / 1.000 / 0.358	66 / 0 / 66
2		45	0.013 / -0.203 / -0.030	0.054 / 1.000 / 0.054	922 / 0 / 922
3			-0.005 / -0.209 / -0.049	0.106 / 1.000 / 0.106	163 / 0 / 163

Table 12. Banks Island metapopulation harvesting analysis, no catastrophes. See Table 2 for column header definitions.

Model Conditions			Model Results (Northwest Victoria / Banks / Total)		
AFR	% ♀♀	$Mort_C$	Mean r	P(E)	N_{100}
All-Male Harvest					
2	80	50	0.040 / 0.024 / 0.028	0.000 / 0.030 / 0.000	5965 / 8715 / 14420
3			0.018 / 0.004 / 0.006	0.008 / 0.244 / 0.006	1090 / 2363 / 2885
2		45	0.042 / 0.025 / 0.029	0.000 / 0.006 / 0.000	7061 / 8798 / 15806
3			0.033 / 0.017 / 0.020	0.000 / 0.060 / 0.000	3308 / 5202 / 8198
2	70	50	0.018 / 0.003 / 0.005	0.006 / 0.302 / 0.006	1204 / 2587 / 3022
3			-0.015 / -0.032 / -0.034	0.202 / 0.906 / 0.196	70 / 753 / 159
2		45	0.029 / 0.006 / 0.013	0.002 / 0.256 / 0.002	411 / 2544 / 2778
3			0.005 / -0.008 / -0.008	0.028 / 0.524 / 0.026	378 / 1398 / 1062
Mixed Harvest					
2	80	50	0.032 / -0.040 / 0.012	0.000 / 0.516 / 0.000	3272 / 1489 / 3995
3			0.007 / -0.139 / -0.014	0.020 / 1.000 / 0.020	367 / 0 / 367
2		45	0.041 / -0.001 / 0.021	0.000 / 0.074 / 0.000	6112 / 1496 / 7497
3			0.022 / -0.110 / 0.001	0.000 / 0.948 / 0.000	1257 / 400 / 1280
2	70	50	0.010 / -0.136 / -0.012	0.018 / 0.994 / 0.018	485 / 34 / 485
3			-0.015 / -0.175 / -0.038	0.232 / 1.000 / 0.232	66 / 0 / 66
2		45	0.024 / -0.123 / 0.003	0.002 / 0.894 / 0.002	1549 / 70 / 1558
3			0.000 / -0.155 / -0.021	0.032 / 1.000 / 0.032	192 / 0 / 192

Figure 7. Population size trajectories for (A) the Western and (B) the Eastern Queen Elizabeth Islands metapopulations under alternative harvesting strategies described in the text. All models shown were run under baseline demographic conditions. Lines with black symbols indicate models without catastrophes, while lines with white symbols indicate models that include the severe winter event. Legend entries with asterisks indicate catastrophe scenarios.

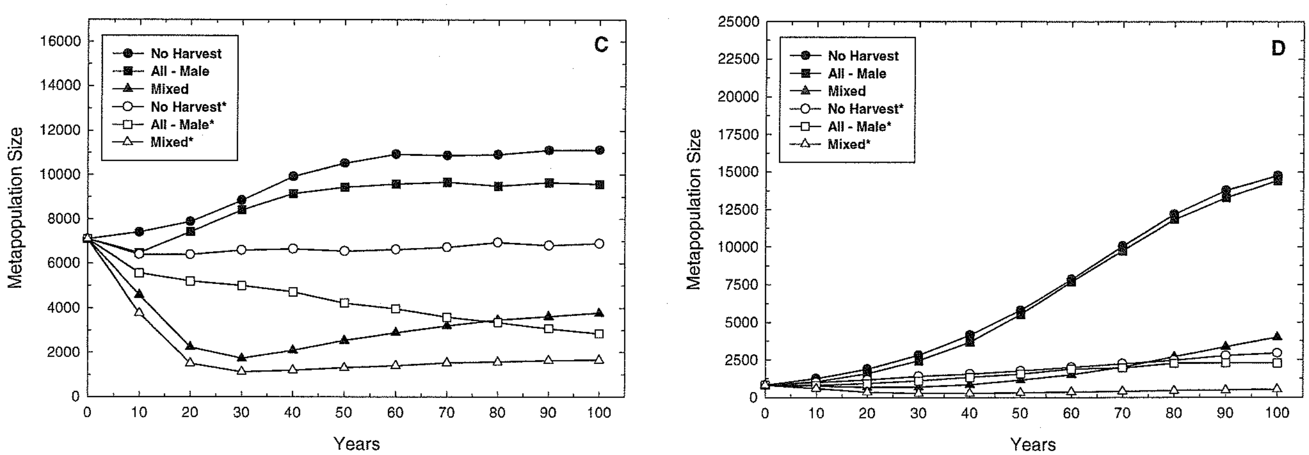


Table 13. Banks Island metapopulation harvesting analysis, catastrophes present. See Table 2 for column header definitions.

Model Conditions			Model Results (Northwest Victoria / Banks / Total)		
AFR	%EE	$Mort_C$	Mean r	P(E)	N_{100}
All-Male Harvest					
2	80	50	0.001 / -0.014 / -0.017	0.212 / 0.654 / 0.208	954 / 3017 / 2269
3			-0.027 / -0.043 / -0.050	0.538 / 0.918 / 0.534	143 / 1055 / 329
2		45	0.016 / -0.009 / -0.003	0.094 / 0.592 / 0.094	2007 / 3522 / 3597
3			-0.009 / -0.023 / -0.029	0.302 / 0.774 / 0.300	505 / 2232 / 1226
2	70	50	-0.026 / -0.046 / -0.050	0.550 / 0.952 / 0.550	133 / 1242 / 268
3			-0.049 / -0.075 / -0.080	0.838 / 0.994 / 0.834	31 / 1122 / 73
2		45	-0.010 / -0.044 / -0.033	0.308 / 0.916 / 0.308	382 / 1436 / 558
3			-0.037 / -0.058 / -0.064	0.684 / 0.976 / 0.682	52 / 607 / 99
Mixed Harvest					
2	80	50	-0.005 / -0.132 / -0.028	0.258 / 0.982 / 0.258	504 / 1166 / 532
3			-0.029 / -0.182 / -0.056	0.572 / 1.000 / 0.572	81 / 0 / 81
2		45	0.013 / -0.105 / -0.009	0.098 / 0.850 / 0.098	1375 / 456 / 1451
3			-0.011 / -0.161 / -0.035	0.286 / 0.992 / 0.286	232 / 801 / 241
2	70	50	-0.027 / -0.178 / -0.054	0.544 / 1.000 / 0.544	108 / 0 / 108
3			-0.050 / -0.214 / -0.084	0.846 / 1.000 / 0.846	24 / 0 / 24
2		45	-0.011 / -0.178 / -0.034	0.294 / 0.998 / 0.294	258 / 5 / 258
3			-0.034 / -0.189 / -0.062	0.652 / 1.000 / 0.652	69 / 0 / 69

Figure 8 presents a summary of the extinction risks each simulated metapopulation complex face under the various types of conditions discussed and modeled in this section. In each case, the baseline model with no winter catastrophe and population harvesting absent shows no risk of metapopulation extinction. When a severe winter event is added to the models, the risk of metapopulation extinction can rise dramatically as in the case of the Western Queen Elizabeth islands complex (Fig. 8A).

It is important to remember that this Figure shows only metapopulation extinction risk and not that for each of the component populations making up the total. There may be considerable extinction risk for one part of a metapopulation, but the other component may be large enough to avoid any real risk. An example of this phenomenon is found in selected models of the Prince of Wales Complex, where the extinction risk for the small Prince of Wales – Somerset component may be quite high under certain conditions but the much larger Boothia population shows no risk of extinction. As a result, the aggregate metapopulation is considered safe from extinction under the specific conditions modeled. Additionally, note that the metapopulation extinction risks for the Banks Island Complex (Fig. 8D) are smaller than may be expected, especially given the smaller sizes of each of the component populations. This again is an artifact of the model conditions: since harvesting was not imposed on the very small NW Victoria population, the overall metapopulation extinction risk becomes relatively low as this component population is itself less vulnerable to extinction resulting from overharvesting.

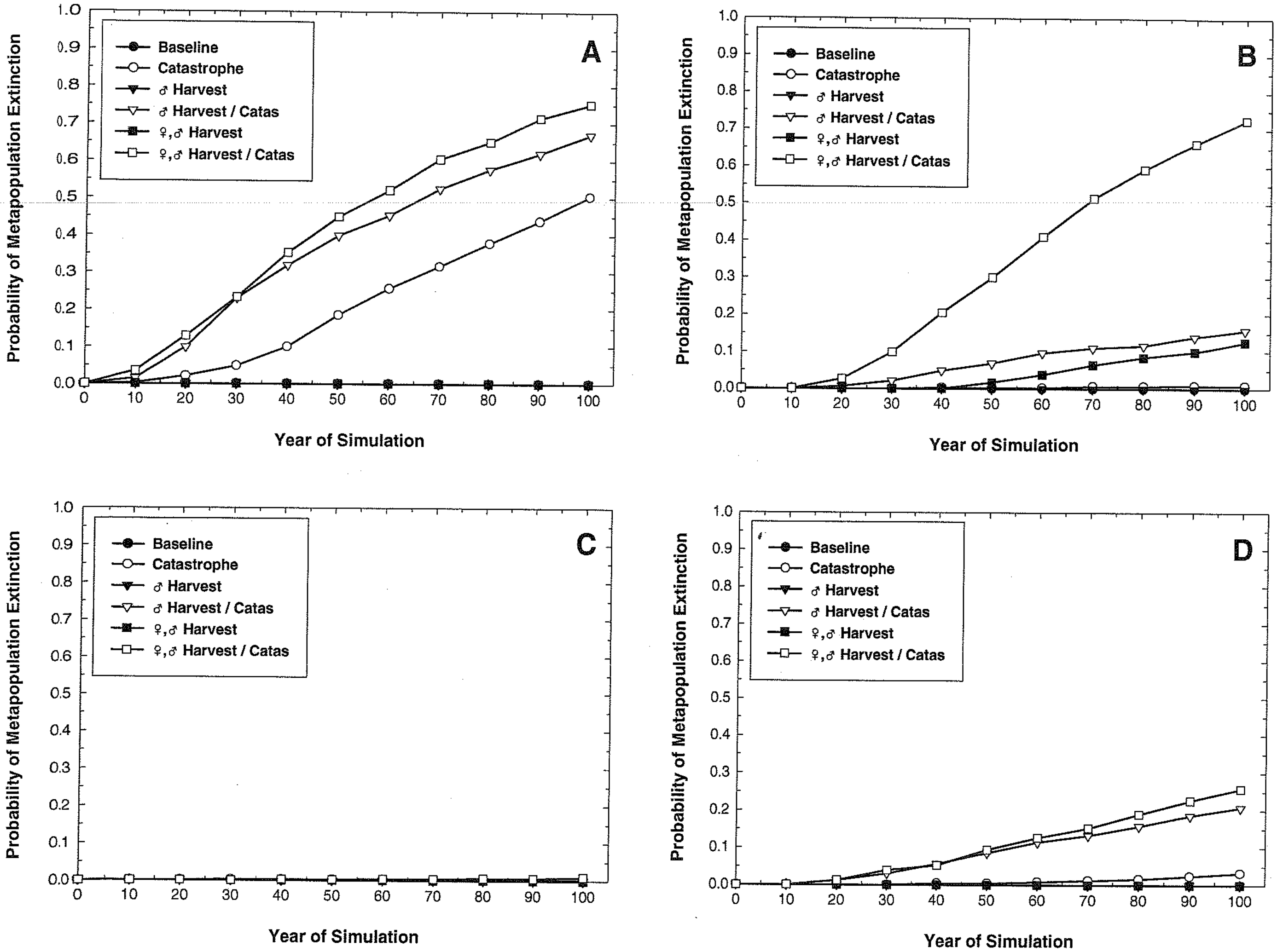


Figure 8. Time series of total metapopulation extinction probabilities under alternative simulated harvesting strategies for the Western Queen Elizabeth Islands (A), Eastern Queen Elizabeth Islands (B), Prince of Wales (C), and Banks Island (D) metapopulation complexes. Projections labeled "Baseline" and "Catastrophe" do not include harvesting.

Discussion

Using the best demographic and environmental information available for Peary caribou and Arctic-island caribou, we developed a simple baseline simulation model for caribou population dynamics inhabiting selected islands of the Northwest Territories. Because of many uncertainties creeping into our model parameter estimates, a demographic sensitivity analysis was undertaken to better understand the impact of this uncertainty on our predictions of caribou population growth dynamics. This analysis indicated that female breeding characteristics play a primary role in governing these dynamics, while many of those same characteristics among adult males play a relatively smaller role. Future study of the demographics of caribou herds should focus on collecting and synthesizing such data as adult female mortality rates and more precise estimates of adult female interbirth intervals.

An analysis of the impacts of the sole catastrophic event considered in this study, a severe winter involving significant rain, snow and ice buildup, suggests that caribou populations may indeed be vulnerable to local extinction following such an event, particularly when those populations have already been reduced by other forces such as severe winters in previous years or some type of human-mediated event.

Finally, a number of models were developed that attempted to look at the impacts of caribou harvesting practices by local human populations. These simplified models point out the vulnerability of smaller caribou populations to removals of animals in the presence of infrequent but severe environmental events that occur randomly over time. If harvesting is accomplished either immediately before or after such an event, it becomes possible that the population may not be able to recover to a level considered viable over the long term.

We recognize that these models are an oversimplification of, among other things, the complexities of density-dependent migration and harvesting of caribou in this region. Additionally, the group concluded that the model is unrealistic in its mode of reflecting changes in female reproductive parameters following a severe winter event. By the same token, it should be recognized that models are valuable tools for making our assumptions explicit concerning any number of biological processes, for testing many plausible ideas and scenarios (most of which can never be accomplished experimentally), and for making testable predictions about real processes. It is in this spirit that these models are developed and discussed.

It is clear from discussions in our group, as well as in the larger set of workshop participants, that considerably more work is possible concerning the use of simulation models to assess the viability of Peary and high Arctic caribou populations in the Northwest Territories. The VORTEX model could perhaps be used in a more sophisticated fashion based on discussions at this workshop; alternatively, new modeling techniques could be employed that perhaps simulate the specifics of caribou population ecology and dynamics more accurately. It is our hope that this initial modeling exercise will stimulate this expanded effort.

Appendix IA: Sample VORTEX Input File

```
CARIB333.OUT     ***Output Filename***
Y     ***Graphing Files?***
N     ***Each Iteration?***
500     ***Simulations***
100     ***Years***
10     ***Reporting Interval***
0     ***Definition of Extinction***
2     ***Populations***
1     ***Lower Age For Migration***
13     ***Upper Age For Migration***
B     ***MigratingSex: F, M, or Both***
75.000000 **Migration Survival**
0.100000 **Density for Emigration**
         0.010000    ***Migration From Population 1***
0.010000             ***Migration From Population 2***
N     ***Inbreeding Depression?***
Y     ***EV concordance between repro and surv?***
0.500000     ***Correlation of EV among populations***
1     ***Types Of Catastrophes***
P     ***Monogamous, Polygynous, or Hermaphroditic***
2     ***Female Breeding Age***
4     ***Male Breeding Age***
13     ***Maximum Age***
0.500000     ***Sex Ratio***
1     ***Maximum Litter Size (0 = normal distribution) *****
Y     ***Density Dependent Breeding?***
80.000000     ***Density dependence term P(0)***
10.000000     ***Density dependence term P(K)***
4.000000     ***Density dependence term B***
0.000000     ***Density dependence term A***
12.00  **EV-breeding
50.000000  *FMort age 0
20.000000  ***EV
15.000000  *FMort age 1
5.000000  ***EV
10.000000  *Adult FMort
1.500000  ***EV
50.000000  *MMort age 0
20.000000  ***EV
15.000000  *MMort age 1
5.000000  ***EV
10.000000  *MMort age 2
3.000000  ***EV
10.000000  *MMort age 3
3.000000  ***EV
15.000000  *Adult MMort
1.500000  ***EV
G     ****Local or Global catastrophe?****
5.000000     ***Probability Of Catastrophe 1***
0.000000     ***Severity--Reproduction***
0.250000     ***Severity--Survival***
N     ***All Males Breeders?***
Y     ***Answer--A--Known?***
40.000000     ***Percent Males In Breeding Pool***
Y     ***Start At Stable Age Distribution?***
76     ***Initial Population Size***
1450     ***K***
0.000000     ***EV--K***
N     ***Trend In K?***
N      ***Harvest?***
N     ***Supplement?***
80.000000     ***Density dependence term P(0)***
10.000000     ***Density dependence term P(K)***
4.000000     ***Density dependence term B***
```

Sample VORTEX Input File (contd.)

```
0.000000     ***Density dependence term A***
12.00  **EV-breeding
50.000000  *FMort age 0
20.000000  ***EV
15.000000  *FMort age 1
5.000000  ***EV
10.000000  *Adult FMort
1.500000  ***EV
50.000000  *MMort age 0
20.000000  ***EV
15.000000  *MMort age 1
5.000000  ***EV
10.000000  *MMort age 2
3.000000  ***EV
10.000000  *MMort age 3
3.000000  ***EV
15.000000  *Adult MMort
1.500000  ***EV
G     ****Local or Global catastrophe?****
5.000000     ***Probability Of Catastrophe 1***
0.000000     ***Severity--Reproduction***
0.250000     ***Severity--Survival***
N     ***All Males Breeders?***
Y     ***Answer--A--Known?***
40.000000     ***Percent Males In Breeding Pool***
Y     ***Start At Stable Age Distribution?***
886     ***Initial Population Size***
3550     ***K***
0.000000     ***EV--K***
N     ***Trend In K?***
Y      ***Harvest?***
1     ***First Year Harvest***
100     ***Last Year Harvest***
1     ***Harvest Interval***
0     ***Females Age 1 Harvested***
0     ***Adult Females Harvested***
9     ***Males Age 1 Harvested***
13     ***Males Age 2 Harvested***
13     ***Males Age 3 Harvested***
9     ***Adult Males Harvested***
N     ***Supplement?***
Y     ***AnotherSimulation?***
```

Appendix IB: Sample VORTEX Output File

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

CARIB333.OUT
Thu Mar 12 09:04:04 1998


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

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

  No inbreeding depression

  Minimum age at migration is 1.
  Maximum age at migration is 13.
  Both females and males migrate.
  Percent survival during migration = 75.000000
  Threshold density (N/K) for emigration = 0.100000

  Migration matrix:
           1       2
   1   0.99000 0.01000
   2   0.01000 0.99000

  First age of reproduction for females: 2   for males: 4
  Age of senescence (death): 13
  Sex ratio at birth (proportion males): 0.50000

Population 1:

  Polygynous mating;
 40.00 percent of adult males in the breeding pool.

  Reproduction is assumed to be density dependent, according to:
  % breeding = ((80.00*[1-((N/K)^4.00)])+(10.00*[(N/K)^4.00]))*(N/(0.00+N))
   EV in % adult females breeding = 12.00 SD

   Of those females producing litters, ...
   100.00 percent of females produce litters of size 1

   50.00 percent mortality of females between ages 0 and 1
    EV in % mortality = 20.000000 SD
   15.00 percent mortality of females between ages 1 and 2
    EV in % mortality = 5.000000 SD
   10.00 percent mortality of adult females (2<=age<=3)
    EV in % mortality = 1.500000 SD
   50.00 percent mortality of males between ages 0 and 1
    EV in % mortality = 20.000000 SD
   15.00 percent mortality of males between ages 1 and 2
    EV in % mortality = 5.000000 SD
   10.00 percent mortality of males between ages 2 and 3
    EV in % mortality = 3.000000 SD
   10.00 percent mortality of males between ages 3 and 4
    EV in % mortality = 3.000000 SD
   15.00 percent mortality of adult males (4<=age<=5)
    EV in % mortality = 1.500000 SD

EVs may be adjusted to closest values possible for binomial distribution.
    EV in reproduction and mortality will be concordant.
    Correlation of EV among populations = 0.500000

  Type 1 catastrophes are global.
  Frequency of type 1 catastrophes: 5.000 percent
    with 0.000 multiplicative effect on reproduction
     and 0.250 multiplicative effect on survival
```

Sample VORTEX Output File (contd.)

```
  Initial size of Population 1:       76
    (set to reflect stable age distribution)
 Age 1   2   3   4   5   6   7   8   9  10  11  12  13    Total
     6   5   5   4   3   3   2   2   2   1   1   1   1    36  Males
     6   5   5   4   4   3   2   3   2   2   1   2   1    40  Females

  Carrying capacity = 1450
    EV in Carrying capacity = 0.00 SD

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

     r =  -0.014     lambda = 0.986     R0 =     0.919
   Generation time for:  females = 5.94    males = 7.00

Stable age distribution:  Age class    females    males
                              0        0.126      0.126
                              1        0.062      0.062
                              2        0.051      0.051
                              3        0.045      0.045
                              4        0.039      0.039
                              5        0.035      0.033
                              6        0.030      0.027
                              7        0.027      0.023
                              8        0.024      0.019
                              9        0.021      0.016
                             10        0.018      0.013
                             11        0.016      0.011
                             12        0.014      0.009
                             13        0.012      0.007

Ratio of adult (>= 4) males to adult (>= 2) females: 0.590

Population 2:

  Polygynous mating;
 40.00 percent of adult males in the breeding pool.

  Reproduction is assumed to be density dependent, according to:
  % breeding = ((80.00*[1-((N/K)^4.00)])+(10.00*[(N/K)^4.00]))*(N/(0.00+N))
   EV in % adult females breeding = 12.00 SD

   Of those females producing litters, ...
   100.00 percent of females produce litters of size 1

50.00 percent mortality of females between ages 0 and 1
    EV in % mortality = 20.000000 SD
   15.00 percent mortality of females between ages 1 and 2
    EV in % mortality = 5.000000 SD
   10.00 percent mortality of adult females (2<=age<=3)
    EV in % mortality = 1.500000 SD
   50.00 percent mortality of males between ages 0 and 1
    EV in % mortality = 20.000000 SD
   15.00 percent mortality of males between ages 1 and 2
    EV in % mortality = 5.000000 SD
   10.00 percent mortality of males between ages 2 and 3
    EV in % mortality = 3.000000 SD
   10.00 percent mortality of males between ages 3 and 4
    EV in % mortality = 3.000000 SD
   15.00 percent mortality of adult males (4<=age<=5)
    EV in % mortality = 1.500000 SD
```

Sample VORTEX Output File (contd.)

```
    EVs may be adjusted to closest values possible for binomial distribution.
    EV in reproduction and mortality will be concordant.
    Correlation of EV among populations = 0.500000

  Type 1 catastrophes are global.
  Frequency of type 1 catastrophes: 5.000 percent
    with 0.000 multiplicative effect on reproduction
     and 0.250 multiplicative effect on survival

  Initial size of Population 2:      886
    (set to reflect stable age distribution)
 Age 1   2   3   4   5   6   7   8   9  10  11  12  13    Total
    73  61  53  47  38  33  26  23  18  15  13  11   8    419  Males
    73  61  53  47  41  36  32  28  24  22  18  17  15    467  Females

  Carrying capacity = 3550
    EV in Carrying capacity = 0.00 SD

  Animals harvested from population 2, year 1 to year 100 at 1 year intervals:
    9 males 1 years old
    13 males 2 years old
    13 males 3 years old
    9 male adults (4 <= age <= 13)

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

     r =  -0.014     lambda = 0.986     R0 =     0.919
   Generation time for:  females = 5.94    males = 7.00

Stable age distribution:  Age class    females    males
                              0        0.126      0.126
                              1        0.062      0.062
                              2        0.051      0.051
                              3        0.045      0.045
                              4        0.039      0.039
                              5        0.035      0.033
                              6        0.030      0.027
                              7        0.027      0.023
                              8        0.024      0.019
                              9        0.021      0.016
                             10        0.018      0.013
                             11        0.016      0.011
                             12        0.014      0.009
                             13        0.012      0.007

Ratio of adult (>= 4) males to adult (>= 2) females: 0.590
```

Sample VORTEX Output File (contd.)

```
********  Meta-population Summary  ********


Year 10
     N[Extinct] =       7, P[E] = 0.014
     N[Surviving] =   493, P[S] = 0.986
     Population size =          761.50 (  25.91 SE,  575.30 SD)
     Expected heterozygosity =   0.992 (  0.001 SE,   0.020 SD)
     Observed heterozygosity =   0.998 (  0.000 SE,   0.010 SD)
     Number of extant alleles =  513.93 (  13.45 SE,  298.72 SD)

Year 20
     N[Extinct] =      49, P[E] = 0.098
     N[Surviving] =   451, P[S] = 0.902
     Population size =          760.23 (  42.58 SE,  904.27 SD)
     Expected heterozygosity =   0.956 (  0.003 SE,   0.074 SD)
     Observed heterozygosity =   0.981 (  0.002 SE,   0.045 SD)
     Number of extant alleles =  256.43 (  10.49 SE,  222.78 SD)

Year 30
     N[Extinct] =     115, P[E] = 0.230
     N[Surviving] =   385, P[S] = 0.770
     Population size =          768.68 (  55.39 SE, 1086.90 SD)
     Expected heterozygosity =   0.930 (  0.005 SE,   0.105 SD)
     Observed heterozygosity =   0.961 (  0.004 SE,   0.078 SD)
     Number of extant alleles =  168.41 (   8.97 SE,  175.97 SD)

Year 40
     N[Extinct] =     159, P[E] = 0.318
     N[Surviving] =   341, P[S] = 0.682
     Population size =          686.78 (  58.15 SE, 1073.78 SD)
     Expected heterozygosity =   0.905 (  0.007 SE,   0.128 SD)
     Observed heterozygosity =   0.936 (  0.006 SE,   0.117 SD)
     Number of extant alleles =  119.93 (   7.70 SE,  142.10 SD)

Year 50
     N[Extinct] =     199, P[E] = 0.398
     N[Surviving] =   301, P[S] = 0.602
     Population size =          627.36 (  61.27 SE, 1063.02 SD)
     Expected heterozygosity =   0.887 (  0.008 SE,   0.140 SD)
     Observed heterozygosity =   0.917 (  0.008 SE,   0.137 SD)
     Number of extant alleles =   90.18 (   6.60 SE,  114.47 SD)

Year 60
     N[Extinct] =     226, P[E] = 0.452
     N[Surviving] =   274, P[S] = 0.548
     Population size =          501.87 (  57.17 SE,  946.28 SD)
     Expected heterozygosity =   0.870 (  0.009 SE,   0.147 SD)
     Observed heterozygosity =   0.907 (  0.009 SE,   0.141 SD)
     Number of extant alleles =   68.95 (   5.67 SE,   93.93 SD)

Year 70
     N[Extinct] =     262, P[E] = 0.524
     N[Surviving] =   238, P[S] = 0.476
     Population size =          445.98 (  57.42 SE,  885.82 SD)
     Expected heterozygosity =   0.863 (  0.010 SE,   0.147 SD)
     Observed heterozygosity =   0.889 (  0.010 SE,   0.154 SD)
     Number of extant alleles =   54.56 (   4.98 SE,   76.83 SD)
```

Sample VORTEX Output File (contd.)

```
Year 80
     N[Extinct] =     288, P[E] = 0.576
     N[Surviving] =   212, P[S] = 0.424
     Population size =          315.58 (  43.59 SE,  634.65 SD)
     Expected heterozygosity =    0.844 (  0.011 SE,   0.156 SD)
Observed heterozygosity =    0.879 (  0.010 SE,   0.147 SD)
     Number of extant alleles =   40.91 (   4.01 SE,   58.43 SD)

Year 90
     N[Extinct] =     310, P[E] = 0.620
     N[Surviving] =   190, P[S] = 0.380
     Population size =          287.49 (  45.07 SE,  621.19 SD)
     Expected heterozygosity =    0.831 (  0.011 SE,   0.158 SD)
     Observed heterozygosity =    0.868 (  0.012 SE,   0.159 SD)
     Number of extant alleles =   33.01 (   3.44 SE,   47.48 SD)


Year 100
     N[Extinct] =     335, P[E] = 0.670
     N[Surviving] =   165, P[S] = 0.330
     Population size =          224.84 (  33.14 SE,  425.70 SD)
     Expected heterozygosity =    0.807 (  0.013 SE,   0.170 SD)
     Observed heterozygosity =    0.857 (  0.013 SE,   0.161 SD)
     Number of extant alleles =   25.61 (   2.81 SE,   36.07 SD)


In 500 simulations of Meta-population for 100 years:
  335 went extinct and 165 survived.

This gives a probability of extinction of 0.6700 (0.0210 SE),
  or a probability of success of          0.3300 (0.0210 SE).

335 simulations went extinct at least once.
Median time to first extinction was 66 years.

Of those going extinct,
    mean time to first extinction was 47.54 years (1.38 SE, 25.33 SD).

Mean final population for successful cases was 224.84 (33.14 SE, 425.70 SD)

   Age 1       2       3   Adults    Total
   20.72   12.39   11.30   54.68     99.10  Males
   21.25                  104.56    125.82  Females

During years of harvest and/or supplementation
  mean growth rate (r) was -0.0678 (0.0020 SE, 0.3605 SD)

Across all years, prior to carrying capacity truncation,
  mean growth rate (r) was -0.0678 (0.0020 SE, 0.3605 SD)

Final expected heterozygosity was      0.8071 ( 0.0132 SE,  0.1699 SD)
Final observed heterozygosity was      0.8568 ( 0.0125 SE,  0.1612 SD)
Final number of alleles was             25.61 (   2.81 SE,   36.07 SD)
************************************************************************
```

Appendix II:
Simulation Modeling and Population Viability Analysis

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

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

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

A number of properties of the problem of assessing vulnerability of a population to extinction make it difficult to rely on mental or intuitive models. Numerous processes impact population dynamics, and many of the factors interact in complex ways. For example, increased fragmentation of habitat can make it more difficult to locate mates, can lead to greater mortality as individuals disperse greater distances across unsuitable habitat, and can lead to increased inbreeding which in turn can further reduce ability to attract mates and to survive. In addition, many of the processes impacting population dynamics are intrinsically probabilistic, with a random component. Sex determination, disease, predation, mate acquisition -- indeed, almost all events in the life of an individual -- are stochastic events, occurring with certain probabilities rather than with absolute certainty at any given time. The consequences of factors influencing population dynamics are often delayed for years or even generations. With a long-lived species, a population might persist for 20 to 40 years beyond the emergence of factors that ultimately cause extinction. Humans can synthesize mentally only a few factors at a time, most people have difficulty assessing probabilities intuitively, and it is difficult to consider delayed effects. Moreover, the data needed for models of population dynamics are often very uncertain. Optimal decision-making when data are uncertain is difficult, as it involves correct assessment of probabilities that the true values fall within certain ranges, adding yet another probabilistic or chance component to the evaluation of the situation.

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

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

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

The VORTEX Population Viability Analysis Model

For the analyses presented here, the VORTEX computer software (Lacy 1993a) for population viability analysis was used. VORTEX models demographic stochasticity (the randomness of reproduction and deaths among individuals in a population), environmental variation in the annual birth and death rates, the impacts of sporadic catastrophes, and the effects of inbreeding in small populations. VORTEX also allows analysis of the effects of losses or gains in habitat, harvest or supplementation of populations, and movement of individuals among local populations.

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

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

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

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

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

Dealing with Uncertainty

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

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

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

Results

Results reported for each scenario include:

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

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

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

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

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

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

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

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POPULATION AND HABITAT VIABILITY ASSESSMENT (PHVA) FOR PEARY CARIBOU AND ARCTIC-ISLAND CARIBOU (*Rangifer tarandus*)

Yellowknife, Northwest Territories, Canada

27 February – 1 March, 1998

REPORT

Section 7

ADDITIONAL LITERATURE

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NISC DISC REPORT

WILDLIFE WORLDWIDE   November 1997
SEARCH STRATEGY

BASIC SEARCH   : RANGIFER TARANDUS PEARYI

Total Matches: 75
Total Records Tagged For Output: 75
Date: Thu Mar 5 1998

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POPULATION AND HABITAT VIABILITY ASSESSMENT (PHVA) FOR PEARY CARIBOU AND ARCTIC-ISLAND CARIBOU (*Rangifer tarandus*)

Yellowknife, Northwest Territories, Canada

27 February – 1 March, 1998

REPORT

Section 8

IUCN POLICIES AND GUIDELINES

IUCN/SSC Guidelines For Re-Introductions

Prepared by the SSC Re-introduction Specialist Group*
Approved by the 41st Meeting of the IUCN Council, Gland Switzerland, May 1995

INTRODUCTION

These policy guidelines have been drafted by the Re-introduction Specialist Group of the IUCN's Species Survival Commission (1), in response to the increasing occurrence of re-introduction projects worldwide, and consequently, to the growing need for specific policy guidelines to help ensure that the re-introductions achieve their intended conservation benefit, and do not cause adverse side-effects of greater impact. Although IUCN developed a Position Statement on the Translocation of Living Organisms in 1987, more detailed guidelines were felt to be essential in providing more comprehensive coverage of the various factors involved in re-introduction exercises.

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

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

This document has been written to encompass the full range of plant and animal taxa and is therefore general. It will be regularly revised. Handbooks for re-introducing individual groups of animals and plants will be developed in future.

CONTEXT

The increasing number of re-introductions and translocations led to the establishment of the IUCN/SSC Species Survival Commission's Re-introduction Specialist Group. A priority of the Group has been to update IUCN's 1987 Position Statement on the Translocation of Living Organisms, in consultation with IUCN's other commissions.

It is important that the Guidelines are implemented in the context of IUCN's broader policies pertaining to biodiversity conservation and sustainable management of natural resources. The philosophy for environmental conservation and management of IUCN and other conservation bodies is stated in key documents such as "Caring for the Earth" and "Global Biodiversity Strategy" which cover the broad themes of the need for approaches with community involvement and participation in sustainable natural resource conservation, an overall enhanced quality of human life and the need to conserve and, where necessary, restore ecosystems. With regards to the latter, the re-introduction of a species is one specific instance of restoration where, in general, only this species is missing. Full restoration of an array of plant and animal species has rarely been tried to date.

Restoration of single species of plants and animals is becoming more frequent around the world. Some succeed, many fail. As this form of ecological management is increasingly common, it is a priority for the Species Survival Commission's Re-introduction Specialist Group to develop guidelines so that re-introductions are both justifiable and likely to succeed, and that the conservation world can learn from each initiative, whether successful or not. It is hoped that these Guidelines, based on extensive review of case - histories and wide consultation across a range of disciplines will introduce more rigour into the concepts, design, feasibility and implementation of re-introductions despite the wide diversity of species and conditions involved.

Thus the priority has been to develop guidelines that are of direct, practical assistance to those planning, approving or carrying out re-introductions. The primary audience of these guidelines is, therefore, the practitioners (usually managers or scientists), rather than decision makers in governments. Guidelines directed towards the latter group would inevitably have to go into greater depth on legal and policy issues.

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1. DEFINITION OF TERMS

"Re-introduction": an attempt to establish a species(2) in an area which was once part of its historical range, but from which it has been extirpated or become extinct (3) ("Re-establishment" is a synonym, but implies that the re-introduction has been successful).

"Translocation": deliberate and mediated movement of wild individuals or populations from one part of their range to another.

"Re-inforcement/Supplementation": addition of individuals to an existing population of conspecifics.

"Conservation/Benign Introductions": an attempt to establish a species, for the purpose of conservation, outside its recorded distribution but within an appropriate habitat and eco-geographical area. This is a feasible conservation tool only when there is no remaining area left within a species' historic range.

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2. AIMS AND OBJECTIVES OF RE-INTRODUCTION

a. Aims:
The principle aim of any re-introduction should be to establish a viable, free-ranging population in the wild, of a species, subspecies or race, which has become globally or locally extinct, or extirpated, in the wild. It should be re-introduced within the species' former natural habitat and range and should require minimal long-term management.

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

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3. MULTIDISCIPLINARY APPROACH

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

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4. PRE-PROJECT ACTIVITIES

4a. BIOLOGICAL

(i) Feasibility study and background research

- An assessment should be made of the taxonomic status of individuals to be re-introduced. They should preferably be of the same subspecies or race as those which were extirpated, unless adequate numbers are not available. An investigation of historical information about the loss and fate of individuals from the re-introduction area, as well as molecular genetic studies, should be undertaken in case of doubt as to individuals' taxonomic status. A study of genetic variation within and between populations of this and related taxa can also be helpful. Special care is needed when the population has long been extinct.
- Detailed studies should be made of the status and biology of wild populations(if they exist) to determine the species' critical needs. For animals, this would include descriptions of habitat preferences, intraspecific variation and adaptations to local ecological conditions, social behaviour, group composition, home range size, shelter and food requirements, foraging and feeding behaviour, predators and diseases. For migratory species, studies should include the potential migratory areas. For plants, it would include biotic and abiotic habitat requirements, dispersal mechanisms, reproductive biology, symbiotic relationships (e.g. with mycorrhizae, pollinators), insect pests and diseases. Overall, a firm knowledge of the natural history of the species in question is crucial to the entire re-introduction scheme.
- The species, if any, that has filled the void created by the loss of the species concerned, should be determined; an understanding of the effect the re-introduced species will have on the ecosystem is important for ascertaining the success of the re-introduced population.
- The build-up of the released population should be modelled under various sets of conditions, in order to specify the optimal number and composition of individuals to be released per year and the numbers of years necessary to promote establishment of a viable population.
- A Population and Habitat Viability Analysis will aid in identifying significant environmental and population variables and assessing their potential interactions, which would guide long-term population management.

(ii) Previous Re-introductions

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

(iii) Choice of release site and type

- Site should be within the historic range of the species. For an initial re-inforcement there should be few remnant wild individuals. For a re-introduction, there should be no remnant population to prevent disease spread, social disruption and introduction of alien genes. In some circumstances, a re-introduction or re-inforcement may have to be made into an area which is fenced or otherwise delimited, but it should be within the species' former natural habitat and range.
- A conservation/ benign introduction should be undertaken only as a last resort when no opportunities for re-introduction into the original site or range exist and only when a significant contribution to the conservation of the species will result.
- The re-introduction area should have assured, long-term protection (whether formal or

otherwise).

(iv) Evaluation of re-introduction site

- Availability of suitable habitat: re-introductions should only take place where the habitat and landscape requirements of the species are satisfied, and likely to be sustained for the for-seeable future. The possibility of natural habitat change since extirpation must be considered. Likewise, a change in the legal/ political or cultural environment since species extirpation needs to be ascertained and evaluated as a possible constraint. The area should have sufficient carrying capacity to sustain growth of the re-introduced population and support a viable (self-sustaining) population in the long run.
- Identification and elimination, or reduction to a sufficient level, of previous causes of decline: could include disease; over-hunting; over-collection; pollution; poisoning; competition with or predation by introduced species; habitat loss; adverse effects of earlier research or management programmes; competition with domestic livestock, which may be seasonal. Where the release site has undergone substantial degradation caused by human activity, a habitat restoration programme should be initiated before the re-introduction is carried out.

(v) Availability of suitable release stock

- It is desirable that source animals come from wild populations. If there is a choice of wild populations to supply founder stock for translocation, the source population should ideally be closely related genetically to the original native stock and show similar ecological characteristics (morphology, physiology, behaviour, habitat preference) to the original sub-population.
- Removal of individuals for re-introduction must not endanger the captive stock population or the wild source population. Stock must be guaranteed available on a regular and predictable basis, meeting specifications of the project protocol.
- Individuals should only be removed from a wild population after the effects of translocation on the donor population have been assessed, and after it is guaranteed that these effects will not be negative.
- If captive or artificially propagated stock is to be used, it must be from a population which has been soundly managed both demographically and genetically, according to the principles of contemporary conservation biology.
- Re-introductions should not be carried out merely because captive stocks exist, nor solely as a means of disposing of surplus stock.
- Prospective release stock, including stock that is a gift between governments, must be subjected to a thorough veterinary screening process before shipment from original source. Any animals found to be infected or which test positive for non-endemic or contagious pathogens with a potential impact on population levels, must be removed from the consignment, and the uninfected, negative remainder must be placed in strict quarantine for a suitable period before retest. If clear after retesting, the animals may be placed for shipment.
- Since infection with serious disease can be acquired during shipment, especially if this is intercontinental, great care must be taken to minimize this risk.
- Stock must meet all health regulations prescribed by the veterinary authorities of the recipient country and adequate provisions must be made for quarantine if necessary.

(vi) Release of captive stock

- Most species of mammal and birds rely heavily on individual experience and learning as juveniles for their survival; they should be given the opportunity to acquire the necessary information to enable survival in the wild, through training in their captive environment; a captive bred individual's probability of survival should approximate that of a wild counterpart.
- Care should be taken to ensure that potentially dangerous captive bred animals (such as large carnivores or primates) are not so confident in the presence of humans that they might be a danger to local inhabitants and/or their livestock.

4b. SOCIO-ECONOMIC AND LEGAL REQUIREMENTS

- Re-introductions are generally long-term projects that require the commitment of long-term financial and political support.
- Socio-economic studies should be made to assess impacts, costs and benefits of the re-introduction programme to local human populations.
- A thorough assessment of attitudes of local people to the proposed project is necessary to ensure long term protection of the re-introduced population, especially if the cause of species' decline was due to human factors (e.g. over-hunting, over-collection, loss or alteration of habitat). The programme should be fully understood, accepted and supported by local communities.
- Where the security of the re-introduced population is at risk from human activities, measures should be taken to minimise these in the re-introduction area. If these measures are inadequate, the re-introduction should be abandoned or alternative release areas sought.
- The policy of the country to re-introductions and to the species concerned should be assessed. This might include checking existing provincial, national and international legislation and regulations, and provision of new measures and required permits as necessary.
- Re-introduction must take place with the full permission and involvement of all relevant government agencies of the recipient or host country. This is particularly important in re-introductions in border areas, or involving more than one state or when a re-introduced population can expand into other states, provinces or territories.
- If the species poses potential risk to life or property, these risks should be minimised and adequate provision made for compensation where necessary; where all other solutions fail, removal or destruction of the released individual should be considered. In the case of migratory/mobile species, provisions should be made for crossing of international/state boundaries.

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5. PLANNING, PREPARATION AND RELEASE STAGES

- Approval of relevant government agencies and land owners, and coordination with national and international conservation organizations.
- Construction of a multidisciplinary team with access to expert technical advice for all phases of the programme.
- Identification of short- and long-term success indicators and prediction of programme duration, in context of agreed aims and objectives.
- Securing adequate funding for all programme phases.
- Design of pre- and post- release monitoring programme so that each re-introduction is a carefully

designed experiment, with the capability to test methodology with scientifically collected data. Monitoring the health of individuals, as well as the survival, is important; intervention may be necessary if the situation proves unforseeably favourable.

- Appropriate health and genetic screening of release stock, including stock that is a gift between governments. Health screening of closely related species in the re-introduction area.
- If release stock is wild-caught, care must be taken to ensure that: a) the stock is free from infectious or contagious pathogens and parasites before shipment and b) the stock will not be exposed to vectors of disease agents which may be present at the release site (and absent at the source site) and to which it may have no acquired immunity.
- If vaccination prior to release, against local endemic or epidemic diseases of wild stock or domestic livestock at the release site, is deemed appropriate, this must be carried out during the "Preparation Stage" so as to allow sufficient time for the development of the required immunity.
- Appropriate veterinary or horticultural measures as required to ensure health of released stock throughout the programme. This is to include adequate quarantine arrangements, especially where founder stock travels far or crosses international boundaries to the release site.
- Development of transport plans for delivery of stock to the country and site of re-introduction, with special emphasis on ways to minimize stress on the individuals during transport.
- Determination of release strategy (acclimatization of release stock to release area; behavioural training - including hunting and feeding; group composition, number, release patterns and techniques; timing).
- Establishment of policies on interventions (see below).
- Development of conservation education for long-term support; professional training of individuals involved in the long-term programme; public relations through the mass media and in local community; involvement where possible of local people in the programme.
- The welfare of animals for release is of paramount concern through all these stages.

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6. POST-RELEASE ACTIVITIES

- Post release monitoring is required of all (or sample of) individuals. This most vital aspect may be by direct (e.g. tagging, telemetry) or indirect (e.g. spoor, informants) methods as suitable.
- Demographic, ecological and behavioural studies of released stock must be undertaken.
- Study of processes of long-term adaptation by individuals and the population.
- Collection and investigation of mortalities.
- Interventions (e.g. supplemental feeding; veterinary aid; horticultural aid) when necessary.
- Decisions for revision, rescheduling, or discontinuation of programme where necessary.
- Habitat protection or restoration to continue where necessary.
- Continuing public relations activities, including education and mass media coverage.
- Evaluation of cost-effectiveness and success of re- introduction techniques.
- Regular publications in scientific and popular literature.

Footnotes:

1. Guidelines for determining procedures for disposal of species confiscated in trade are being developed separately by IUCN.
2. The taxonomic unit referred to throughout the document is species; it may be a lower taxonomic unit (e.g. subspecies or race) as long as it can be unambiguously defined.
3. A taxon is extinct when there is no reasonable doubt that the last individual has died.

The IUCN/SSC Re-introduction Specialist Group

The IUCN/SSC Re-introduction Specialist Group (RSG) is a disciplinary group (as opposed to most SSC Specialist Groups which deal with single taxonomic groups), covering a wide range of plant and animal species. The RSG has an extensive international network, a re-introduction projects database and re-introduction library. The RSG publishes a bi-annual newsletter RE-INTRODUCTION NEWS.

If you are a re-introduction practitioner or interested in re-introductions please contact:

IUCN/SSC Re-introduction Specialist Group (RSG),
c/o African Wildlife Foundation (AWF),
P.O. Box 48177,
Nairobi, Kenya.
Tel:(+254-02) -710367, Fax: (+254-02) - 710372 or
E-Mail: awf.nrb@tt.gn.apc.org

IUCN Policy Statement on Captive Breeding

Prepared by the SSC Captive Breeding Specialist Group*
Approved by the 22nd Meeting of the IUCN Council, Gland Switzerland, 4 September 1987

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

PROBLEM STATEMENT

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

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

FEASIBILITY

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

RECOMMENDATION

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

SUGGESTED PROTOCOL

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

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

HOW: Captive populations need to be founded and managed according to sound scientific principles for the primary purpose of securing the survival of species through stable, self-sustaining captive populations. Stable captive populations preserve the options of reintroduction and/or supplementation of wild populations. A framework of international cooperation and coordination between captive breeding institutions holding species at risk must be based upon agreement to cooperatively manage such species for demographic security and genetic diversity. The IUCN/SSC Captive Breeding Specialist Group* is an appropriate advisory body concerning captive breeding science and resources.

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

Notes:
Currently the *Conservation Breeding Specialist Group and the
** World Conservation Monitoring Centre
