PROCEEDINGS:
INTERNATIONAL WORKSHOP FOR THE CONSERVATION OF VANCOUVER ISLAND MARMOT

Robert W. Elner

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INTERNATIONAL WORKSHOP FOR THE CONSERVATION OF VANCOUVER ISLAND MARMOT

The Coast Bastion Inn, Nanaimo, British Columbia, Canada

June 16 - 19, 1999

**Compiled by: Robert W. Elner, Environment Canada,
Canadian Wildlife Service, Pacific Wildlife Research Centre,
5421 Robertson Road, Delta, British Columbia V4K 3N2**

**Workshop Organizing Committee: R.W. Elner, D. Janz, A.A. Bryant,
D. Nagorsen, N. Dawe**

Secretariat: S. Bucknell

Facilitator: A. Duffy

Workshop Sponsors: Environment Canada, Marmot Recovery Foundation, B.C. Ministry of Environment, Lands & Parks, Timber West, The Coast Bastion Inn.

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EXECUTIVE SUMMARY

Environment Canada's Canadian Wildlife Service (CWS), in partnership with the British Columbia Ministry of Environment, Lands and Parks (BC MELP) and the Vancouver Island Marmot Recovery (VIM) Team, held an International Workshop for the Conservation of Vancouver Island Marmot in Nanaimo, British Columbia, June 16 - 19, 1999. Approximately 50 experts from five countries (Australia, Austria, France, USA and Canada) collectively developed a research strategy to help recover the species.

Although Vancouver Island Marmot (*Marmota vancouverensis*) is probably the most endangered mammal in North America (less than 100 remain), attendees were afforded opportunity to see the animal during a field-trip to their sub-alpine habitat. The following day, attendees participated in four Working Groups focusing on key issues surrounding the species' sustainability, including: Nutrition, Disease, Genetics and Behaviour; Ecology of Reintroduction; Landscape Ecology for Marmot Sustainability; and, Monitoring and Modeling Small Populations.

The final plenary session received the reports of the four Working Groups and discussed research recommendations for species recovery.

The Proceedings summarizes Workshop discussions, provides a list of research priorities, and suggests a process to augment and coordinate this research. A compilation of the research recommendations of the four Working Groups and the plenary session appear in Appendix V.

RÉSUMÉ

Le Service canadien de la faune d'Environnement Canada, en collaboration avec le ministère de l'Environnement, des Terres et des Parcs de la Colombie-Britannique et l'équipe chargée du rétablissement de la marmotte de l'île de Vancouver, a organisé à Nanaimo (Colombie-Britannique), du 16 au 17 juin 1999, un atelier international pour la conservation de la marmotte de l'île de Vancouver. Près de 50 experts invités venant de cinq pays (Australie, Autriche, France, États-Unis et Canada) se sont rencontrés pour échanger des informations techniques et développer une stratégie de recherche axée sur le rétablissement de l'espèce. Bien que la marmotte de l'île de Vancouver (*Marmota vancouverensis*) soit probablement le mammifère le plus menacé de l'Amérique du Nord (il ne reste que 100 individus), les participants ont pu observer l'animal au cours d'une visite dans son habitat subalpin. Le lendemain, les participants ont pris part à quatre groupes de travail axés sur les questions clés concernant la préservation de l'espèce (Nutrition, maladie, génétique et comportement; Écologie de la réintroduction : Écologie du paysage pour la préservation des marmottes; Surveillance et modélisation des petites populations). La matinée finale était consacrée à une séance plénière avec présentation des rapports préparés par les quatre groupes de travail et discussion des recommandations concernant les axes de recherche pour le rétablissement de l'espèce.

Le compte rendu résume les discussions qui se sont tenues pendant l'atelier et comprend une liste des principaux besoins de recherche ainsi qu'une suggestion de procédure visant à intensifier et à coordonner les efforts dans le domaine.

A Message from the Marmots

*(As relayed by the Great Marmot-in-the-Sky to **Don Eastman** - a humble, human medium during the course of the Workshop)*

We are a furry mammal,
We're short and fat and brown.
In summer, we eat and loaf on rocks,
In winter, we're underground.

We are an ice age relict
Of that there is no doubt.
But why should that e'en matter
When our numbers are near nought?

For many years we prospered,
In wee high meadow spaces.
Until the logging came along
And gave us other places.

We really could not help it
For how were we to know,
That clearcuts were ephemeral
And not the spots to go?

My kin and many other folk
Would flock there with our mates.
We grew just fine and gained quite well,
But could not help our death rates.

And so our numbers dwindled
And things seemed such a shame.
And then a human came to study us,
Andrew Bryant was his name.

By him we were examined
In detail unsurpassed.
Our genitilia pushed and probed,
And things stuck up our ass.

We suffered all these many tests,
To learn why we were few.
We hoped and prayed that he would find,
Exactly what to do.

But, our numbers kept on falling,
Our survivorship stayed poor.
We could not seem to find a way
For our species to endure.

And so you folk had this event,
With scientists galore,
To seek the answer to the quest
Of how we could be more.

You talked of many things, we know,
Of food and sex and spaces;
And why we cannot find a way
Through all the hostile places.

You talked of genes and forest growth,
And predators and disease,
And captive rearing and transplants-
A tangled web to tease!

But now as you come to the end
Of meeting and discussion,
We only hope that you can find
The way to our salvation.

INTRODUCTION

THE WORKSHOP SCOPE

For a few sunny days in June 1999, the combined academic weight of the world's marmot specialists plus experts from supporting disciplines convened in Nanaimo, British Columbia, to observe Vancouver Island Marmots, *Marmota vancouverensis*, in their natural habitat and debate the understanding required to restore the species. The Vancouver Island Marmot (VIM) was declared Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1979 yet numbers have declined dramatically since the mid-1980's to the present total of less than 100 animals.

While the species falls under the jurisdiction of the Government of British Columbia, The Marmot Recovery Foundation approached Environment Canada for assistance. Accordingly, Environment Canada, in partnership with the British Columbia Ministry of Environment, Lands and Parks (BC MELP) organized an International Workshop for the Conservation of Vancouver Island Marmot to verify and expand on the Vancouver Island Marmot Recovery Plan (revised, 1998). The Proceedings summarize discussions held during the Workshop and feature agreed-upon priorities, supplementary research methodologies, and a suggested process to coordinate the research efforts. A valuable Workshop legacy was also the wealth of information exchanged and the professional networks developed.

In addition to the funding and support provided by Environment Canada and BC MELP, further assistance was provided by the private sector including Timber West, MacMillan Bloedel and The Coast Bastion Inn, for which the Workshop Organizing Committee was very grateful.

THE ROLE OF THE WORKSHOP ORGANIZING COMMITTEE

Workshop logistics, participant recruitment, agenda development (see Appendix I) and production of the Proceedings were carried out by the Workshop Organizing Committee. Members included: Bob Elner (Chair), Shelagh Bucknell (Secretariat) and Neil Dawe, Environment Canada; Doug Janz, BC MELP and Chair of the Recovery Team; Andrew Bryant, Chief Scientist for the Marmot Recovery Foundation; and, Dave Nagorsen, Royal British Columbia Museum. Ann Duffy, Cypress Communications & Environmental Management, advised on the planning stages, facilitated the Workshop and assisted with the Proceedings. Media relations support was provided by Margaret Phelan, Environment Canada. As final editor of the Proceedings, Bob Elner bore the challenging task of synthesizing the Group's input accurately yet succinctly; Ann Duffy provided expert editorial assistance. Shelagh Bucknell carried out the typing, formatting and editing. Environment Canada covered the costs of publication and distribution.

THE WORKSHOP PROCESS AND RESULTS

The initial four sections of these Proceedings reflect core discussions and research recommendations from four Working Groups (A - D). The Working Group subject areas corresponded with the research priorities identified in the Recovery Plan such as:

- "keeping wild and captive marmots healthy " (A),
- "introducing new colonies" (B),
- "saving the marmots remaining in the wild" (C), and
- "measuring and predicting marmot population size" (D).

Participants were nominated to a Working Group given their particular expertise (see Appendices II & III). Each Working Group was led by an appointed Chair and a rapporteur. The breakout process was enhanced by a roving Group of Resource Experts and the facilitator. Participants discussed information provided by the Committee (see Appendix IV) as well as self-generated issues to ultimately propose a prioritized list of research recommendations, associated testable hypotheses, and suggested research methods.

A. **Nutrition, disease, genetics and behaviour *(i.e. keeping wild and captive marmots healthy)*:** This Group focused on the requirements and methods of monitoring health in wild and captive marmots such as the relationships between habitat, parasites, disease, nutrition and health, incorporation of genetic issues in captive-breeding and reintroduction programs, and the role of marmot behavior in maximizing eventual success with recovery.

B. **Ecology of reintroduction *(i.e. introducing new colonies)*:** This Group identified the types of data required to select appropriate reintroduction habitats in areas where marmots no longer occur. Issues included methods necessary to test the likely influence of past and future logging, climate and vegetation change. The Group also focused on the value of habitat suitability models and the optimal temporal and spatial pattern for successful reintroduction.

C. **Landscape ecology for marmot sustainability *(i.e. saving the marmots remaining in the wild)*:** This Group focused on the probability of successfully maintaining marmots in the few areas where they presently occur. Specific issues included the ability to measure landscape effects (e.g., altered dispersal or "connectivity", effects of roads or other corridors, predator-prey relationships and predator control) and predicting how future landscape changes will likely influence the recovery project.

D. **Monitoring and Modeling Small Populations *(i.e. measuring and predicting marmot population size).*** This Group focused on overcoming the scientific difficulties posed by small population sizes and limited historical data such as validation of census monitoring techniques, and the likely value of tools such as mark-recapture modeling, population simulation modeling, sensitivity analysis, population viability analysis, spatial autocorrelation and epidemiology. Additional questions addressed "what is the role of scientific modeling in Vancouver Island Marmot recovery and is the intrusiveness of techniques a concern?"

Overall major research recommendations appear in Section E and reflect a Plenary Discussion with the entire Group. A compilation of all working and plenary Group research recommendations are provided in Appendix V. While the core purpose of these Proceedings is to serve the Recovery Team and augment the Recovery Plan, the issues covered and strategy employed may have a generic utility for other recovery efforts of endangered species. It is important to note the information contained herein is derived from a variety of sources, including the Workshop itself, existing scientific literature as well as unpublished work and anecdotal accounts. Care should be taken in both citing and interpreting the Proceedings as they do not substitute for peer-reviewed findings derived by the scientific method.

These Proceedings are presented to the Vancouver Island Marmot Recovery Team to assist in their efforts, and dedicated to *Marmota vancouverensis.*

Robert W. Elner
Delta, British Columbia
December 31, 1999

A. Nutrition, Disease, Genetics and Behaviour

Introduction

This Working Group session debated the requirements and methods of monitoring health in wild and captive marmots. Based on information previously provided (Appendix IV), the participants focused discussion on the relationships between habitat, parasites, disease, nutrition and health, incorporation of genetic issues in captive-breeding and reintroduction programs, and the role of marmot behaviour in maximizing the chances of success with reintroduction. Some of the questions and background notes of relevance to Nutrition, Disease, Genetics and Behaviour, respectively, covered the following:

Nutrition:

Can nutritional factors explain higher mortality in clearcuts?
Can habitat change and poor nutritional quality of forage explain the disappearance of this species from some of its historical range?
Marmota vancouverensis survival is lower in clearcuts, and most mortality in this habitat type apparently occurs during hibernation. We know that food-plant availability in clearcuts is different from that in natural habitats although comparative studies between the two habitats have not been conducted.

Yellow-bellied marmots (*Marmota flaviventris*) supplied with a diet deficient in essential fatty acids showed identical weight gains during summer, but exhibited higher spontaneous arousal rates, shortened bouts of deep hibernation and higher overall metabolic expenditures. That the latter could lead to increased winter mortality was noted from studies of other marmot species.

Disease:

Could disease be causing extinction?
Four transplanted VIM died during hibernation, apparently from a bacterial infection. The frequency of episodes of high mortality has increased in recent years and increased spatial autocorrelation of survival is consistent with a disease outbreak. Recent declines are mostly due to catastrophic losses over the span of one or two winters. Similarly, the literature suggests that disease threats to rare species may be underestimated.

Genetics:

Should transplants be designed to maximize genetic diversity?
Dependence upon captive-breeding requires the maintenance of existing genetic variation. DNA extraction techniques could be used on hair and blood samples but, to-date, only limited information exists on normal levels of genetic variation in VIM.

Electrophoresis of 44 blood samples from three colonies shows levels of variation are similar to other marmots. Specifically, results revealed levels of genetic variability comparable to *M. flaviventris* and *M. monax* (n=22 scorable loci, estimated polymorphic loci P=0.18, average expected heterozygosity *H*=0.073). Significant genetic differences were found between two colonies less than 20 kilometres apart, illustrating the importance of founder effects and infrequent dispersal. Effective population size (N_e) of the known population was close to 50 (based on a population estimate of ~250 animals, N_e = 34.6 to 64.4).

Behaviour:

What behavioural factors need to be understood in the design of an effective reintroduction program, in particular, with respect to numbers, social assemblages and geographic locations?
How critical to success is the age and sex structure of introduced marmots into a site?
What have the Russians and Europeans found on these questions?

Genetic diversity may also have to be considered. Beyond habitat suitability, the location of sites selected for reintroductions may have to consider factors such as the existing metapopulation structure.

Discussion Items

The Working Group developed a theme of "Marmot Production and Survival" and defined their scope as six major areas:

1. Reproduction	4. Behaviour
2. Disease	5. Nutrition
3. Genetics	6. Hibernation

1. Reproduction

The Working Group discussed the critical need for a standard husbandry protocol and the component factors to be considered, including:

- Understanding the estrous cycle - single estrous in this species.
- The importance of the light cycle in regulating males and females.
- Pairing, in terms of timing during annual cycle and determining the best age to pair (as juveniles or adults); the importance of physical contact, (especially with respect to intra-species aggression), and determining how to house separately while still maintaining monogamous pairing.
- Need for low disturbance, especially with isolation of females to prevent infanticide.
- Need for separation of paired animals prior to parturition.

Recommended Reproduction Research Protocols

- If necessary, have assisted reproduction techniques available, such as artificial insemination or manipulation and preservation of gametes with the use of the Hoary Marmot as a surrogate for the VIM.
- Support the study of female hormonal cycle.
- Develop protocol for hand-rearing neonates.
- Develop substitute formula for hand-rearing VIM using Hoary Marmots as surrogates.

Recommended Husbandry Research Protocols

- Keep marmots in pairs for breeding as per standard captive breeding programs.
- Optimal hibernation temperature is considered to be 5º-7º C.
- Use double fence system for standard housing (with live traps to capture escapees).
- Use a nestbox structure and latrine area.
- Separate female (before birth or as necessary).
- Use monogamous pairs as a strategy for captive breeding.
- Monitor mothering ability and weaning.

2. Disease

The Working Group discussed current research, knowledge and protocols, including:

- The identification of *Yersinia* organisms in animals that died during hibernation led to concerns of a more widespread role for this bacteria. A risk analysis was subsequently performed after a survey of *Yersinia* organisms at colony sites and in captive and wild animals. The conclusion was that these organisms do not appear be significant, at this time.
- The conditions of hairloss and presumptive chorioptic mange of Mount Washington VIM is persistently seen.
- Essential fatty acid levels in the diet have been critical in other marmot species, but have an unknown role in this species.
- Endoparasites identified in VIM include nematodes, *Strongyloides, Coccidia* and tapeworms. These are not expected to be present in hibernating animals.

Recommended Disease Research and Protocols

- Compare the role of parasite effects in marmots in natural habitat and clearcuts.
- Examine the relationship of immunosuppression and increased parasite loads.
- Continue to monitor levels of parasitism in wild marmots in various habitats.
- Examine anthelmintic treatment in the field for young that are not growing.
- Anthelmintic treatment during quarantine and reintroduction is advised.
- Quarantine into and out of captivity.
- As captive population will be naïve to disease organisms and parasites, a transition period before release (e.g. Mt. Washington facility use) is required. First hibernation after transfer from other breeding facilities could be employed
- Standard sampling protocols must be developed to assess VIM health including: general physical assessments, collection of blood, feces, morphometrics, oral and rectal swabs, fat biopsy, and ectoparasites.
- Trapping and handling protocols should employ two methods: sedation/ general anesthesia and physical handling alone with handling bags, as developed by Ken Armitage.
- Consider a study to compare disease impacts on Hoary Marmots and VIM and the issue of disease as a morbidity factor.
- The conditions of hairloss and presumptive chorioptic mange of Mount Washington VIM requires further investigation.

3. Genetics

The Working Group also discussed current research findings, questions and protocols, including:

- Determining whether captive animal breeding would select for “non-wild types” and negative behavior traits.
- The fact that there are only two markers for VIM, and poor polymorphism (2/16); although low heterozygosity in the wild population is not believed to be the cause for the species decline.

Recommended Genetics Research and Protocols:

- Begin the captive population with 20-30 founders, and build the population to a capacity of 100+.
- Individual marking of captive and wild marmots is critically important; wild animals with ear tags should have identification backed up by abdominal implants. Captive animals should have standard subcutaneous implants to back-up ear tags.
- DNA sampling and archiving strongly advised as part of standard sampling protocol.
- Compare heterozygosity of Hoary Marmots and VIM, potentially using other methods to compare variation.
- Further research on paternity and relatedness genotyping, although not a priority.

4. Behaviour

The Group discussed the following research needs:

- monitoring of hibernaculae (including behaviour during hibernation and association with temperatures).
- foraging behaviour.
- reproductive suppression and the possibility of infanticide.

Recommended Behaviour Research:

- Continue field work on the detailed social structure and behaviour of VIM and apply this understanding to captive breeding programs and genetic issues.
- Continue and expand radiotransmitter implantation marking of wild marmots and consider the use of temperature sensitive radio transmitters (i.e. small size, 3 year life, as developed by Dr. W. Arnold). Mark individuals visibly with backup ear tags and subcutaneous implants.

5. Nutrition

Nutrition Research Recommendations and Protocols:

- With the expertise of a plant ecologist, assess forage quality (especially total nitrogen and essential fatty acids) and quantity factors. Natural diet data, obtained from scat samples and field grids (note: there was no consensus about the efficacy of scat analysis to assist in establishing natural diet) as well as forage quality of clear-cuts and successional stages, should be used for captive breeding programs and determining the location of reintroduction sites.

- Develop a standard diet for captive animals.
- Consider the supplemental feeding of wild VIM, potentially using a self-feeder (e.g. Omelene 3000 as used in the USA) for 3 to 4 weeks, especially when there are severe environmental conditions (i.e. delayed melt and low snowpack). Refer to current USA research study for results of supplementary feeding trials.
- Consider corporate sponsorship for nutrition research.
- Exercise is important to captive animals.
- A captive diet currently being used elsewhere includes: "Purina Rodent Chow" (5001) with 4% fat (if higher fat levels, risk the development of fatty liver syndrome) supplemented with dandelions, broccoli, sunflower seeds, and carrots.
- Refer to nutritional trials in Russia and Toronto Zoo.

6. Hibernation

As VIM have a preference for southwest slopes for hibernation, the Group recommend the following hibernation protocols:

- Reintroduce animals in intact family groups as much as possible (i.e. 4-5 adults plus offspring).
- Perform reintroduction's as early as possible in the season and into empty but suitable sites to allow for weight gains.
- Hibernation should occur in captive populations, preferably as family groups. Animals should be forced, if necessary, by food removal, to hibernate from October 1 until late March.
- Advise a 5º-10º C temperature regime.
- Avoid increased temperature and food for captive animals. Arousal occurs with increased metabolic rate at higher temperature and with changes in airflow and pressure. Normal weight loss through hibernation is 30%.

Recommended Hibernation Research:

- Soil aspects, such as temperature profiles for various soil types (from dataloggers) should be used for the identification of potential reintroduction sites.
- Whether hibernation is a requirement for breeding or not, although hibernation is critical to synchronize animals for reintroductions.
- The best conditions for adapting captive animals for the wild including whether single females could be reintroduced back to family groups after weaning.
- The specifics of hibernation dynamics (i.e. family groups or singles, degree of synchrony of hibernation in each colony), and the recommended number of hibernacula per colony. Note that occasionally yearlings hibernate alone.

Prioritized Research Recommendations for Nutrition, Disease, Genetics and Behaviour

Recommendation # A1:
Reproduction
Research on the estrous cycle, and use of the Hoary Marmot as a model for reproductive studies on the VIM continue. Captive husbandry protocols should be standardized.

Recommendation # A2:
Disease
Monitoring for disease and developing the disease databases. Standard sampling protocols based on marked individuals should be established. Standard quarantine protocols need to be developed for animals coming into captivity and being re-introduced into the wild.

Recommendation # A3:
Genetics
Genotyping and DNA research on the species with particular reference to paternity and relatedness questions.

Recommendation # A4:
Behaviour
Work into details of the social behaviour of VIM to better manage captive groups and reintroductions. Additional behavioural research should address foraging, reproductive suppression, hibernation and infanticide.

Recommendation # A5:
Nutrition
Development of a standard diet for the captive population. A collaborative study with a plant ecologist to ascertain the quality and quantity of the field diet is critical. Field comparisons between the quality and quantity of forage for marmots in clear-cut and natural habitats are necessary to further understand the effects of clear-cut habitat on marmot survival. Information on natural diet should be used when choosing reintroduction sites.

Recommendation # A6:
Nutrition
A supplemental feeding trial for marmots in wild habitats as a potential strategy to increase survivorship.

Recommendation # A7:
Hibernation
As for Behaviour (# A4) and, also, work on how to condition captive animals for hibernation in the wild.

Plenary Recommendations to the Nutrition, Disease, Genetics and Behaviour Working Group

During the last day of the Workshop, the Plenary session, the attendees reviewed the Working Groups' research recommendations and made the following additional comments and recommendations.

1. The suggestion that the Hoary Marmot be used as a model for refining artificial insemination (AI) and other assisted reproduction techniques for VIM was discussed. A minimum of 20 unrelated adults are necessary for an effective captive breeding program, with a goal of 100 animals in the total captive population before considering the production of animals for reintroduction. Relatedness of the adults should be tested by genetics.

2. There was debate about the need for more genetic research on VIM, especially with respect to DNA analysis/genetic typing. While the research was a low priority for this Group, it was recognized that such information was important to other Groups and would be a useful tool for identifying new colonies by determining where new individuals come from.

   DNA technology could potentially offer a way to identify individual animals and their source colony. This may assist in determining where immigrants came from and emigrants go (assuming recaptures of marmots). Perhaps genetic research on Hoary Marmots should be conducted as a means to facilitate development of genetic techniques and tools that could be used on VIM. Given the relatively lost cost of genetic analyses (i.e. $50/sample, after primers have been developed) compared to other research approaches (e.g., radiotelemetry) all VIM should be genetically sampled when they are caught for the first time.

3. There was discussion on the wisdom of purging parasites from animals held in captivity given the propensity for them to become more vulnerable to re-infestation on reintroduction. However, it was argued that healthy animals can probably cope with parasites. A further observation with respect to successful reintroduction was that anti-predator behaviour may require training.

4. A suggestion was made that as many animals as possible in the wild population be implanted with abdominal transmitters.

B. Ecology of Reintroduction

Introduction

In this session, the Working Group discussed the requirements for selecting appropriate reintroduction habitats in areas where VIM no longer occur. Issues provided in the background material (Appendix IV) included methods necessary to test the influence of past and future logging, as well as the influence of climate and vegetation change. The utility of habitat suitability models and the optimal temporal and spatial pattern for successful reintroduction were also discussed.

Three of the key focus questions and background notes relevant to the Ecology of Reintroduction session were:

- How can the best potential reintroduction habitats be identified?
- Are historical habitats not occupied no longer suitable because of climatic or vegetation changes?
- What needs to be understood to design of effective release programs?

How can the best potential reintroduction habitats be identified?

The only *Marmota vancouverensis* reintroduction to-date failed, despite habitat assessment work and release of wild-captured animals into an area occupied by marmots in the recent past. Reintroductions with other species of marmot have been successful despite lack of understanding of the causes for population decline and small numbers of individuals. Nevertheless, with so few VIM available for transplants, it appears critical that habitat suitability be well understood.

Few empirical data exists with which to map potential marmot reintroduction habitats. Biophysical mapping has been done only for the Haley Lake and Mount McQuillan areas of Vancouver Island. Additional biophysical mapping may be needed for other areas. Critical habitat factors not picked up with biophysical mapping should also be identified.

Are historical habitats not occupied no longer suitable because of climatic or vegetation changes?

Certainly, *Marmota vancouverensis* distribution has became more restricted since the early post-glacial period as climate and vegetation changed. However, late Holocene records such as 1,000 year old bones from caves at Weymer Creek near Tahsis demonstrate that VIM were more widespread even in late prehistoric time. Some marmot habitats have suffered from tree-invasion and post-fire succession may limit current marmot habitat. However, empirical data on habitat change in areas occupied by marmots is weak.

Evidence from other marmot species suggests that *M. vancouverensis* has been placed between the proverbial “rock and hard place” for several thousands of years following glaciation (as forests invaded tundra parkland and open meadow habitats). The phenomenon of tree-invasion of sub-alpine meadows in the early postglacial and recent historical time has occurred throughout the mountains of western North America. One objective of the Recovery Plan is to establish a metapopulation of VIM in central Vancouver Island (i.e. Strathcona Park) through reintroductions. Possible reasons for the current disappearance in this area could be the habitat becoming unsuitable and changes in metapopulation processes. If this habitat is no longer suitable then reintroductions in this area may not be appropriate.

What needs to be understood to design effective release programs?
What behavioural factors need to be understood for an effective reintroduction program? Are there critical issues with respect to numbers, social assemblages and geographic locations? How critical to success is the age and sex of marmots introduced to a site?

Genetic diversity may also have to be considered. Beyond habitat suitability, the location of sites selected for reintroductions needs to consider factors such as the existing metapopulation structure in the area.

Discussion Items

1. Initial discussion centered on "how to rank topics" and the "what-where-how" of reintroductions. The questions considered were: a) likelihood of success; b) "comfort level" to the reintroduction strategy; c) value to the population; d) is the pay-off short-term or long-term? e) risk of type II error[1] (e.g. with respect to the effect of fertilizers, deer, wolves). Subsequent discussion examined "Habitat Issues" (items # 2 - # 8, below) and "Population Issues", including release techniques ("hard" versus "soft") (items # 9 - 11 #, below).

2. Thermal profiles of hibernacula were discussed including comparisons between the profiles under different snow regimes, in clear-cut and natural meadow sites, and in occupied and unoccupied sites. The implications of global climate change on the selection of release sites for marmots was also debated. For example, if there is a sustained warming trend then more northerly sites might be preferable. Subsequent discussion on hibernacula characteristics considered whether summer dens were similar or different to winter hibernacula.

3. Marmot survivorship in clear-cut situations was reviewed. Possible limiting factors were food (i.e. nutrients, species composition and abundance), cover against predators, hibernacula sites, snow patterns, variable temperature and predator presence. Extirpated sites compared with occupied sites were also debated.

4. Further to #3, the Group discussed habitat history, including past major disturbances and tree encroachment into natural meadows.

5. There was debate on whether corridors should be created between clear-cut and natural habitat so that dispersing marmots from clear-cuts can re-colonize natural sites. Concerns were expressed on the effect of predators and the possible need to create cover in such corridors.

6. The Group examined the utility of developing habitat suitability models, possibly using indicator sets of forage species.

7. Enhancement techniques that could be tested in natural and clear-cut habitats were debated, including artificial burrows and nest boxes, supplemental feeding, fertilizers, prescribed burning, disturbing soil to increase forb abundance, tree seedling removal, and installing rocks for loafing and hibernacula. There was ensuing talk on the bounds to enhancement,

[1] Falsely accepting a Null Hypothesis.

how much intervention was desirable and the feasibility of creating marmot habitat in areas that are presently forested.

8. Preferred habitat features of VIM colonies were listed:

Slope	35-60 degrees
Elevation	900-1400 m
Aspects	SW - W facing slopes
Subalpine meadows	created by avalanche/snow creep, and kept free of trees by avalanches, free of snow in early spring with forage
Loafing rocks	thermo-regulatory, lookouts and burrows
Hibernacula	physical scope
Vegetation	food plants available in May on steep areas, below snow retaining areas

9. Group B overlapped with discussions by Group A when it came to population and behavioural questions. Questions debated included: Are marmots social hibernators? How many marmots (especially adult females) should be introduced to a given site and what are the influences of social structure and relatedness on introductions? How can the physical fitness of marmots for introduction be maximized? What is the reproductive value of candidates for introduction? What are the merits of reintroducing at clusters of sites compared to repeated reintroductions at a single site? What are the impacts of predation and disease?

10. The Group discussed techniques for “soft-release” including: provision of temporary “cage/protection” at the release site to “encourage” the marmot to dig a burrow at the site, conditioning the site with faeces and starter burrows, and fencing colonies. There was talk of searching the literature base on release techniques (“hard” versus “soft” release) for other marmot species and actually testing field release techniques on other species.

11. Augmenting existing colonies compared to re-introducing marmots to extinct colony sites was also discussed. The Group advocated a risk analysis on the two strategies but suggested that augmentation may be riskier because resident females might drive off transplants (the latter appears true for Yellow-bellied Marmots but there is no information for VIM). The Group was advised to consider stochastic as compared to deterministic factors acting on colonies. Reintroduction in recently occupied habitats (i.e. colonies reduced to one adult) was felt to be a priority.

Research Recommendations

The Working Group discussions on reintroduction were broadly focused on:

- Values of Augmenting versus Reintroducing versus Introducing
- Efficacy of lessons from surrogate species and literature on other species
- Criteria for success
- Risk analysis of captive breeding versus present situation
- Release protocol development (including "hard" versus "soft" techniques)

Recommended Habitat-based Research

High Priority:

Recommendation # B1
Determine the climatic regimes in different marmot habitats. The studies would involve measuring effective temperatures and determining the effect of snow cover.

Recommendation # B2:
Determine the limiting factors to marmots inhabiting clear-cut situations.

Recommendation # B3:
Determine whether and how habitat at extirpated marmot colony sites differs from habitat at sites that are currently occupied.

Recommendation # B4:
Develop habitat suitability models for more effectively targeting optimal sites for VIM reintroductions.

Medium Priority

Recommendation # B5:
Determine if clear-cut habitats can be enhanced to better sustain marmots.

Recommendation # B6:
Predict how release sites might be impacted by global climate change.

Recommendation # B7:
Establish the long-term history (for example, vegetation, climate, and anthropogenic influences) of various habitats that are currently or were occupied by VIM.

Low Priority

Recommendation # B8:
Determine means of creating corridors linking clearcut and natural areas to promote natural dispersal.

Recommendation # B9:
Determine whether natural habitat occupied by VIM can be enhanced to increase survivorship and colony size.

Recommendation # B10:
Determine if and how new habitat for VIM might be created.

Recommended Population-based Research

High Priority

Recommendation # B11:
Research should focus on hibernation biology of VIM and if the system is similar to that for Alpine Marmots.

Recommendation # B12:
Determine the social structure of VIM colonies.

Recommendation # B13:
Determine the impact and nature of predation on marmots.

Recommendation # B14:
Ascertain whether VIM reintroductions should take place at multiple sites or repeatedly at one site.

Medium Priority

Recommendation # B15:
Determine how the fitness of marmots can be maximized prior to transplanting.

Recommendation # B16:
Determine the reproductive value of transplant candidates.

Low Priority

Recommendation # B17:
Document the impact of disease on VIM.

Plenary Recommendations to the Ecology of Reintroduction Working Group

The final Plenary gave rise to the following additional suggestions for enhancing research on the Ecology of Reintroduction.

1. There was a strong recommendation that studies be conducted to measure the effective (microclimate) temperature at the various VIM sites. Such monitoring could be usefully supplemented with body temperature data from hibernating marmots.

2. Different habitats should be typed according to their vegetation, including the fatty acid characteristics of the plants.

3. Options of “reintroduction” of marmots, as compared to “introduction” to sites were discussed. Some participants felt that marmots should not be released at sites where there were established marmots, as the residents might not accept immigration.

4. There is a need to link plant studies with the nutritional requirements of marmots. There was discussion of the efficacy of fecal studies for elucidating natural diets.

The notion of removing marmots from clear-cuts as a source of production for reintroduction (e.g. a marmot “pump”) and the need to be cautious on the potential genetic problems of such a scheme (as the offspring could originate from only two marmots) was also discussed.

C. Landscape Ecology for Marmot Sustainability

Introduction

The Working Group for this topic focused their discussion on the understanding required for successfully maintaining VIM in the few areas where they presently occur. Specific issues provided in the background material included measuring landscape effects (e.g. altered dispersal or "connectivity", effects of roads or other corridors, predator-prey relationships and predator control) and predicting how future landscape changes will likely influence VIM (Appendix IV).

Two key issues and background material relevant to the above that participants were asked to discuss were predation and connectivity effects.

Predation effects

Radio-telemetry has provided undeniable evidence that predators exert an important effect at some colonies of VIM. Also, spatial autocorrelation of survival is consistent with increased predation pressure at adjacent colonies. The "predator-pit" phenomenon suggests that predators might exert pressure on low-density prey populations sufficient to prevent their recovery. Given these facts, the Group debated whether predator control could be a tool for marmot recovery.

Connectivity effects

Landscape connectivity is a critical element to landscape structure and an understanding of connectivity and dispersal could be essential to plan the location of transplants. Habitat is not stable and connectivity is dynamic given changes with short-term vegetation succession (e.g. clear cuts) and long term global climate shifts. Forestry has produced changes in marmot density in the central portion of their existing range and circumstantial evidence suggests that dispersal movements are shortened by the availability of new clear cuts. Thus, the effects of succession in clear cuts on dispersal patterns must be understood. Could natural dispersal patterns be re-created through transplants?

Discussion items

1. The Group listed and attempted to rank landscape ecology factors that could be limiting to the persistence of existing VIM colonies. Two fundamental types of factor were apparent - habitat-based factors, and animal-based factors. The former tend to involve long-term processes and the latter shorter-term processes.

2. Walter Arnold presented an hypothesis for the declines in VIM abundance. The proposed mechanisms are based on his own research findings for the European Alpine Marmot, a highly social species, that VIM most likely resemble (see B11), with delayed dispersal and social hibernation. He argued that clear-cuts near natural marmot colonies may act as "perfect traps" (or "sinks") given marmot social and dispersal behaviour, in the following way:

   Initially, marmot offspring opt for a low risk strategy (Type I) with regard to dispersal. That is, they either remain in the natal colony, counting on the eventual death of a parent, or they relocate to a nearby natural meadow to establish a new colony. However, at a certain age, offspring may switch to a higher risk, but potentially higher gain strategy (Type II) involving longer-range dispersal to locate a suitable vacant site. The age of switching from a Type I to

Type II strategy depends on the chance of finding a vacant site. If there is only a small chance of founding a family in the vicinity of the natal site, marmots stay longer at home.

As a consequence, large groups can develop and large groups have improved overwintering survival due to the positive effects of social thermoregulation and warming of juveniles during hibernation. However, clear-cuts close to natural marmot colonies attract marmots and lead to premature dispersal thereby draining natural colonies. Potential dispersers may view clear-cuts as unoccupied but suitable habitat and may leave their natal groups earlier than the average in a natural situation. Marmots in clear-cuts suffer poor overwintering survival due to lack of snow cover and/or nutritional effects. Hence, supplemental feeding in clear-cut colonies is not a permanent solution to restore populations.

Moreover, because the hibernation success of juveniles depends on the presence of kin (i.e. parents and older siblings) in the hibernaculum, and clear-cuts alter group sizes in natural colonies by drawing offspring away too early, overwintering success decreases in the depauperate natural colonies.

If Walter Arnold's hypothesis is correct, the only long-term solution to population declines in VIM is to re-introduce family groups to natural meadows far from clear-cuts and/or force dispersing marmots away from clear-cuts.

3. In a general "brain-storming" session, the following habitat criteria tools and protocols were recommended for research on landscape ecology for marmot sustainability:

- Geo-spatial analysis of habitat
- Habitat connectivity and time processes
- Dispersal sink analysis, using empirical (as opposed to theoretical) geo-spatial modeling
- Silvicultural manipulation (with reference to private versus Crown lands and land management practices)
- GIS systems and their compatibility
- Ortho photos (aerial photographs geographically referenced into a digital image file)
- Costing out of marmot habitat needs
- Effects of climate-change (variability), including the El Nino phenomenon (ENSO) and the Pacific Decadal Oscillation (PDO)
- Cause of apparent clear-cut "sinks"
- Need to differentiate habitat quality (especially marginal habitat)
- Effect of climate change on reproduction, as distinct from mortality
- Relations to forest harvesting including short- and long-term issues
- Influence of vegetative succession and climate
- Habitat needs, linking connectivity to changes over time
- Dynamic spatial models
- Need for habitat manipulations to be planned well in advance

4. In the same “brain-storming” session, the following Animal Factors, criteria, issues and tools were identified with respect to marmot persistence:

   - Predator-prey relationships
   - Appraising whether the remaining VIM are a viable small population and can be retained (as opposed to be taken into captivity for breeding purposes)
   - Methods available to sustain the existing wild marmots
   - Use of predator control and supplemental feeding techniques to positively influence demographic parameters
   - Efficacy of taking peripheral colonies into captivity
   - Effect of dry summers and late springs in decreasing marmot survival
   - Need to test the assumptions of the current metapopulation and “source-sink” paradigms for VIM
   - Determining baseline demographic requirements for VIM replacement

5. The following combined animal and habitat factors emerged from the “brainstorming” with respect to marmot persistence:

   - Maximizing the value of existing data
   - Plotting a strategy to determine ecological processes, regardless of final outcome
   - Integration of analysis of limiting factors
   - Marmot sustainability cannot depend on natural processes but must link into technological manipulations
   - Wisdom of encouraging lateral-thinking, that is, not focusing exclusively on “doable” solutions; also, need to distinguish easy from hard solutions and separate long- from short-term initiatives
   - “Dispersal” questions link both habitat- and animal-based issues

6. Following the “brainstorming” session, the listed items were discussed, grouped into research recommendations and basic information gaps either as (I) Animal-based or (II) Habitat-related, and ranked. The ranking scheme involved three criteria:

   - Importance of the research: High (H); Medium (M); Low (L)
   - Difficulty of the work: High (H); Medium (M); Low (L)
   - Time-frame (urgency): Immediate (I), Medium (M), Long-term (L)

Also, consideration was given to the ideal partner to carry out the work: a) university/college (U); b) consultants/contractors (C); c) Federal Government (FG); Provincial Government (PG); Non-government organization (NGO); Resource-based Industry (I).

Landscape Ecology Research Recommendations

This Working Group developed a series of animal-based and habitat-based recommendations which are described below.

Animal-based Recommendations
In terms of scope, animal-based recommendations are designed to address three main questions:

- What are the most limiting factors to colony persistence?
- What is the age-specific effect of seasonality on survival and reproduction?
- What are the metapopulation dynamics of VIM?

Recommendation # C1
(H,L,I; PG,U):
Elucidate the most limiting factors to colony persistence. A major question associated with this is "Do VIM live longer when moved from clear-cut to natural environment"? The required study would have to include adequate controls and measure hibernacula characteristics. Depending on the results of the study, translocation techniques from clear-cuts could provide a tool to reverse marmot population declines.

Recommendation # C2
(H, L, I; U):
The quality and quantity of vegetation available to marmots as forage in clear-cut as compared to natural habitat remains a core unknown. The Group recommended that research on plants be carried out to measure the nutritional value of forage in both habitat types. Depending on the results of the study, supplemental feeding in clear-cut colonies could provide a tool to increase survivorship.

Recommendation # C3
(H, M, I; PG, C):
The impact of avian and terrestrial predators on the dwindling marmot population is a concern. Examine the option of selectively removing terrestrial predators, such as cougars and wolves, from the area as a means to reducing marmot mortality. Concomitantly, there should be monitoring studies to measure seasonal patterns in adult marmot survivorship to differentiate predation induced mortality from death during hibernation.

Recommendation # C4
(H, L, M; PG):
Determine the effects of augmenting existing colonies in natural habitats with marmots from captive breeding and clear-cut colonies. Again, as above, concomitant studies would be required to monitor survivorship of individuals in the augmented situations as compared to controls.

Recommendation # C5
(L, H, L; PG):
Further to Recommendation # C3 (above) on predator management, the Group suggested that the Recovery Team consider the effect of reducing alternative prey, such as elk, of marmot predators with the objective of decreasing predator abundance in the area.

Habitat-based Recommendations
In terms of scope, habitat-based recommendations are designed to address three main questions:

- What are the short-term and long-term needs of marmots in natural and clear-cut habitat?
- What are the (geo-spatial) distribution, abundance and connectivity of natural and clear-cut habitats?
- What temporal processes (including past, present and future climate) influence habitat quality for VIM?

Recommendation # C6
(H, L, I; U, PG, FG):
Research should be undertaken to quantify the fine-scale habitat needs of VIM. In particular, factors relating to forage, predator-cover, thermal patterns and spatial arrangements of habitat components appear of particular interest. The research would need to be stratified by season and carried out in a range of habitat types (e.g. successful as well as unsuccessful colony sites). Ideally, the work could be carried out as part of university postgraduate studies and be coordinated with plant sampling (Recommendation # C2). Understanding gained would serve to drive Recommendations # C7 and # C8.

Recommendation # C7
(H, M, M; I, PG, FG, U):
Mapping studies should be carried out to chart the distribution, abundance and connectivity of clear-cut and natural habitats over the core range of VIM. In particular, researchers need to map dispersal resistance. This could be important in order to evaluate potential translocation, donor and recipient sites.

Recommendation # C8
(M, M, L; I, PG, FG, U):
As per recommendation # C7 but over the historic range of VIM.

Recommendation # C9
(M,M,M; U, C):
Investigate and identify temporal processes influencing habitat quality for VIM. Potential methodology could include: calculating the metrics of each colony (e.g. distance to clear-cuts) for a connectivity model; running the connectivity model backwards in time to determine if there is a correlation between marmot persistence and land-use changes; and, running the connectivity model forwards under a variety of land management scenarios.

Recommendation # C10
(M, L, M; FG, U):
Elucidate climatic processes influencing marmots. These processes could be explored using simple correlation analyses (scattergrams) between short-term (annual) variables, such as snowpack, degree days and drought, as well as long-term (post- 1910) variables, such as the El Nino and PDO, against VIM abundance estimates. The analyses should be stratified by elevation and could be compared with climatic patterns already identified for other marmot species. The results would link back to habitat and connectivity classification recommendations, as well as be of use in identifying potential translocation sites.

Recommendation # C11
(M, M, M; PG, U):
The Group recommended that long-term vegetation monitoring stations be established to track changes in plant communities in and around marmot colonies. Given understanding of marmot habitat and foraging requirements, the database would be of use in assessing habitat quality and colony persistence.

Recommendation # C12
(L, L, L; PG):
The Group recommended that "benchmark" photographs be taken of all VIM sites to assist in documenting potential tree invasion problems.

Plenary Recommendations to the Landscape Ecology for Marmot Sustainability Working Group

The Workshop's concluding Plenary Session generated an additional recommendation for research methods associated with landscape ecology for existing VIM.

1. There was a suggestion that colonies be surrounded by electric fences ("hot-wired") to deter predators.

D. Monitoring and Modeling Small Populations

Introduction

Participants in this session addressed the scientific difficulties to understanding the dynamics of small populations, especially in the face of limited historical data. Specific consideration was given to an evaluation of census monitoring techniques, and the likely value of tools such as mark-recapture modeling, population simulation modeling, population viability analysis and sensitivity analysis (Appendix IV).

Some additional focus questions were:

What is the role of scientific modeling in VIM recovery, and is the intrusiveness of data collection techniques a concern?

How do we continue to learn and perform statistical tests and modeling when additional samples on VIM will likely not be forthcoming? Despite a sample of tagged marmots representing 10-15% of the entire population monitored for over a decade, some analyses (e.g., Cormack-Jolly-Seber survival analysis) had low statistical power. The situation is not likely to improve given a current population of fewer than 100 individuals.

What are the implications of considering "statistical significance" as compared to "biological significance" of findings by the Recovery Team?

In the absence of field testing, can modeling provide a useful means of challenging hypotheses?

Can models be used to predict at what population size VIM will escape the risk of extinction, given uncertainties in factors such as climate change, catastrophic events, and our ability to measure what's happening?

Discussion Items

1. The Modeling Group identified a lack of both gross and detailed information on dispersal as the most critical information gap. On a gross scale, there is still no clear understanding of the distances potentially traveled, or the routes taken, e.g., logging roads, when marmots disperse to new habitats. On a more detailed scale, we lack understanding of how and when a marmot chooses to disperse, and how a decision is made to choose a new habitat.

    - Implanted radio transmitters are an important tool for measuring dispersal, but an evaluation must be made of the risk to a marmot's health of implanting a transmitter.
    - Questions regarding gene flow can be addressed using radio transmitters to better understand the dispersal dynamics of a small population of marmots.

2. For the VIM recovery effort to be evaluated there must be some mechanism for adjudicating the success or failure of recovery efforts. The contemporary method of evaluating how well a population is doing is a modeling technique called Population Viability Analysis (PVA). Perhaps the most significant parameter that emerges from a PVA is an estimated time to

extinction, or alternatively, the probability of extinction after a certain time period, say 100 years. Although this seems a pessimistic criterion, it is an essential component of PVA and is a useful way to adjudicate how well a recovery program is doing.

Even perfectly healthy populations will generate a value for time to extinction. The idea is to make decisions on behalf of the VIM that move that time of extinction well into the future. The value of a PVA is that it provides an objective means to evaluate the consequences of recovery actions. A secondary outcome of a PVA is its value as a learning or conceptualization tool for those trying to better understand VIM population dynamics. It can also be valuable in identifying critical information gaps, i.e., sensitivity analyses. For example, how well do we need to understand dispersal in order to make useful decisions in the interest if the VIM?

3. Given the risk of working with a species that is currently under a serious threat of extinction, the Modeling Group advised that careful consideration be given to addressing some of the modeling questions raised in this Workshop by studying less endangered marmots.

   The work would include the need for studies that can compare and contrast VIM biology, ecology and population dynamics with closely related species living in geographically and climatologically similar regions. Judgments would have to be made concerning the potential transferability of knowledge gained from related species to a recovery effort for the VIM.

Research recommendations

Recommendation # D1:
Current population monitoring activities and techniques be continued.

Maintaining an accurate census is essential since the risk of extinction is so highly sensitive to population size when the number of individuals is small. We also need to have some measure of how well the VIM are doing in the face of recovery efforts.

Mark-recapture techniques should be pursued to try to refine our understanding of those unnatural sources of mortality that a small population cannot tolerate if it is to avoid extinction.

Recommendation # D2:
Given limited data, and therefore the potential for many competing explanations, all data should be made available to researchers to offer alternative hypotheses or analytical techniques.

Recommendation # D3:
Given limited data, it is unlikely that hypotheses can be proposed, tested and rejected as in a typical statistical approach to hypothesis testing. Decisions should be made in the interest of the VIM and should be evidence-driven. We cannot wait for definitive conclusions because they will probably come too late.

Recommendation # D4:
Analysis should be undertaken to determine the minimum population size below which depensatory mortality becomes a critical concern, i.e., the so-called Allee effect, when a population becomes so small that individuals have serious trouble finding a mate. Such an analysis has the potential to provide an estimate of the population size, or meta-population structure, below which a "rescue initiation - captive breeding" program becomes the essential or perhaps only viable means to sustain the VIM population.

Recommendation # D5:
Given that an important part of the recovery efforts will likely involve reintroductions, VIM individuals should be exploited for obtaining knowledge on dispersal to minimize the risk to health of "wild" marmots. These individuals would be focal points for habitat and nutrition studies, effects of climate on health and nutrition, disease, social behaviour and dispersal. An important aspect of "following" reintroduced individuals would be a comparison of behaviour of "wild" and introduced marmots, a so-called "retrospective validation" of the impacts of captive breeding. Population viability could be negatively associated with a behavioural modification that accompanies captive breeding before individuals are released into the wild.

Recommendation # D6:
Given the evidence, but not proof, that clear-cut logging might be creating a sink habitat for VIM, it is important that clearcuts continue to be a focus of concern and study in any PVA analysis for VIM. There remains the possibility that changes in forest management may be required to sustain the VIM. Modeling exercises should address the possibility that forestry management practices in alpine areas might play a major role in marmot sustainability, especially given the potential for rapid climate change in the next few years to decades, or a highly variable climate from year to year. The influence of roads and road-building for access to clearcuts should also be investigated. It might not just be that clearcuts are sinks, but that roads provide an easy access to those habitats for predators.

Recommendation # D7:
Given the large number of modeling "projects" identified, and the accompanying need for a diversity of expertise in various aspects of VIM population dynamics, biology and ecology, collaborative efforts should be arranged among marmot experts and experts in population modeling throughout the world. Some exercises would be suitable as university-based challenges, or for post-doctoral fellows in either university or government laboratories.

Plenary Session Recommendations to the Monitoring and Modeling Small Populations Working Group

1. Population trajectory and PVA modeling is important, but we have to address the difficulty of separating the effects of dispersal from natural mortality in current data sets and future experiments or monitoring.

2. There was an agreement on the need to ascertain the number of animals required for a stable population. PVA modeling and determining the minimum viable population (e.g., the critical size for an Allee affect) can be very useful for this.

3. Measuring dispersal is very important. However, it must be done wisely and in association with other critical questions. For example, multi-channel, temperature sensitive radio transmitters might be considered so that dispersal can be evaluated against prevailing environmental conditions.

4. It is important to study surface soil insulation properties on a per site basis to improve our understanding of habitats as potential sinks. Apparently there are some demographic data available for this.

5. There was a brief discussion on problems with interpreting scat analyses. Scat analyses can be an important means for assessing food habits and animal condition.

E. PLENARY DISCUSSIONS

(Saturday June 19)

Review of the Four Working Group Results

A final plenary discussion after the presentations from the four Working Group rapporteurs confirmed that the VIM Recovery Team were generally moving in the right direction by following recovery strategies based on current and available science. However, the research needs identified appear to outweigh currently available research resources and there is need for an enhanced research capacity. Given the original objective of the Workshop (i.e. to verify and expand on the VIM Recovery Plan), the interdisciplinary and broad base of expertise of the Group lead to the creation of several new ideas and enhancements on the Recovery Team's current approach.

During the first part of the final Plenary session, the Group collectively discussed research recommendations generated by each Working Group and provided additional suggestions. These appear at the end of each section of the four research themes in Sections A-D. A compilation of these recommendations appear in Appendix V.

General Plenary Discussion

The final plenary built on the joint review of the recommendations by the four Working Groups and subsequently led to three central concepts or principles.

1. Making more marmots, by:
    - Captive Breeding

2. Keeping the marmots, by:
    - Manipulation of habitat (in clear-cuts and by managing/creating avalanches)
    - Supplemental food
    - Control of predators

3. Increasing the wild population, by:
    - Reintroductions (but require increased understanding of social behaviour, and identification of release sites)

Given "what" needs to be done, the attendees outlined a desirable strategy on "how" to support these concepts and augment VIM populations and their habitat. Essential elements should be:

- Ongoing monitoring
- Capitalizing on existing data
- Generating new information
- Determining the management risk of actions (or inactions)
- Providing the best science information possible into the decision-making process, with appropriate sensitivity for the precautionary approach
- Ranking and implementing the research priorities.

The Workshop participants discussed potential linkages and commonalties between the research recommendations arising from the four Working Groups, including:

- Monitoring, and the multiple uses of samples, such as blood for nutrition and genetic studies.
- Collaboration on DNA paternity analysis
- Dispersal information
- Plant fatty acid, diet and habitat relationships
- Population Viability Analyses
- Utility of temperature sensitive radio locating transmitter
- DNA testing, including developing new primers

Overall major research recommendations

Recommendation # E1:
Support current population monitoring techniques
Census refinement, mark-recapture studies, radio-transmitter studies to understand dispersal and causes/rates of natural mortality, focusing efforts on a few selected colonies to support and augment current population monitoring efforts.

Recommendation # E2:
Collect information on dispersal
Attendees noted the lack of information on dispersal and effects of anthropogenic factors, such as roads, on natural patterns. They recommended additional research including use of DNA and telemetry techniques.

Recommendation # E3:
Make current data more available
The VIM databases should be made more available to interested investigators.

Recommendation # E4:
Identify minimum population size (Allee effect)
Develop a metapopulation model, to identify the minimum population size for VIM. The model could be used to identify the point at which all surviving marmots in the wild should be taken into captivity.

Recommendation # E5:
Carry out population viability and population sensitivity analyses
Population viability and sensitivity analyses, using data from past studies.

Recommendation # E6:
Establish reintroduction guidelines and protocols
Participants stressed the need to have standardized guidelines for both choosing habitat sites and release protocols from captive breeding.

The attendees identified five main problems that required solving:

- augmentations versus introduction
- efficacy of transferring knowledge from surrogate species, such as Olympic Marmot

- criteria for success of recovery efforts
- relative risk of a captive breeding program versus options such as non-intervention
- release protocols for marmots bred in captivity

Recommendation # E7:
There was consensus among participants that a Scientific Advisory Group be formed.
A technical team of competent biologists should be invited to form a formal Scientific Advisory Group to provide scientific direction for the Recovery Team. The Group should be comprised of research scientists; in addition sub-groups could be formed for each main technical aspect. Group members would be in regular e-mail contact.

The Scientific Advisory Group would operate as an interactive part of the Recovery Team in providing scientific direction rather than *ad hoc* advice. The core Group could consist of up to five research scientists.

The Recovery Team may choose to tender research problems determined by the Scientific Advisory Team Group for solution among the scientific community. While Group members would be eligible to compete for funding, there should be a separate formalized peer review process for funding applications in order to obtain independent scrutiny of Group projects.

The Scientific Advisory Group should be affiliated with at least one university or foundation so that a clear research program can be established. Such an affiliation would facilitate securing and directing graduate students and Postdoctoral Fellows.

Benefits of having the Scientific Advisory Group would be to:

- decrease or remove overhead costs for work done by universities
- foster collaborative research and peer review
- tap more major resources of university departments (e.g. GIS)
- provide sources for qualified personnel
- carry out data analyses and produce reports

APPENDIX I: AGENDA

VIM CONSERVATION WORKSHOP

Coast Bastion Inn, Nanaimo, British Columbia, Canada

Wednesday June 16 - Saturday June 19, 1999

Organizing Committee: *R.W. Elner, N. Dawe, D. Janz, D.W. Nagorsen, A.A. Bryant*

Sponsors: Environment Canada, Canadian Wildlife Service, Vancouver Island Marmot Recovery Team, BC MELP, Royal BC Museum

Objectives: To expand on the (Revised) Vancouver Island Marmot Recovery Plan by determining research strategies for Vancouver Island Marmot recovery. Recommendations will include a prioritized listing of testable hypotheses and suggested research methodology.

Wednesday June 16:

	Arrivals, Nanaimo, British Columbia	
13:00 - 18:00	Registration Desk (lobby area)	(S. Bucknell)
	(Malaspina Room)	
18:00 - 19:00	The VANCOUVER ISLAND MARMOT Story, Marmot etiquette etc.	(A. Bryant)
19:00 - 19:30	Why we're here and Introductions	(Facilitator)
19:30 - 21:00	Reception	
13:00 - 21:00:	VIM Booth, Library and Workroom (Room # 1411), Computer equipment and photocopier	(S. Bucknell)

Thursday June 17:

05:30 - 15:00:	Field Trip: VIM observations on Green Mountain (Timber West).	
16:00 - 17:30:	Planning Meeting (Facilitator, organizers, Chairs, Rapporteurs, Resource Experts) (Room # 315)	
All Day:	VIM Booth, Library and Workroom (Room # 1411)	(S. Bucknell)

Evening:	"Dine Around" (Details of local restaurants to be provided by hotel).	

Friday June 18:

	Malaspina Room	
	Media in attendance 09:30 to 10:45	
09:30	Opening Remarks (Malaspina Room)	Jim Walker
10:00 - 10:15	Introductions	(Facilitator)
10:15 - 10:45	VIM Recovery Plan	(D. Janz/Recovery Team)
10:45 - 11:15	Break (outside Malaspina Room)	
11:15	Breakouts: Goals and Strategies*	(Facilitator)
Noon	Buffet Lunch (VIM Videos) (Dunsmuir - Malahat Room)	
13:00	Breakout sessions:	

- Nutrition, Disease, Genetics and Behaviour (Boardroom)
- Ecology of Reintroduction (Douglas Room)
- Landscape Ecology for marmot sustainability (Malaspina Room)
- Monitoring and Modeling Small Populations (Room #315)

15:30	Break (outside Malaspina Room)	
15:50 - 17:30	Breakout Sessions (cont.)	
18:00 - 18:30	Planning Meeting (Facilitator, organizers, Chairs, Rapporteurs, Resource Experts) (Room #315)	
18:30	Reconvene for Banquet - Malaspina Room (Ken Armitage - guest speaker)	
All Day:	VIM Booth, Library and Workroom (Room #1411)	(S. Bucknell)

Saturday June 19:

09:00	Reports from Breakout Sessions (Malaspina Room)	

- Nutrition, Disease, Genetics and Behaviour
- Ecology of Reintroduction
- Landscape Ecology for VIM sustainability
- Monitoring and Modeling Small Populations

10:45	Break (outside Malaspina Room)	
11:00	Priority Research Recommendations	(Facilitator)
12:30	Workshop Close	
13:00 - 13:30:	Debrief: Facilitator, organizers, Chairs, Rapporteurs, Resource Experts) (Room # 315)	

(Attendees Depart Saturday June 19 - Sunday June 20)

* Participants in each of the four breakout sessions will discuss previously provided and self-generated issues and produce a prioritized list of testable hypotheses and suggested research methods. The four sessions are:

1. **Nutrition, disease, genetics and behaviour *(How to keep VIM healthy)*:** The session will focus on the requirements and methods of monitoring health in wild and captive marmots. Specific issues will include relationships between habitat, parasites, disease, nutrition and health, incorporation of genetic issues in captive-breeding and reintroduction programs, and the role of marmot behavior in maximizing the chances of eventual success.
2. **Ecology of reintroduction *(How to introduce new colonies)*:** The session will strive to identify the types of data required to select appropriate reintroduction habitats in the many areas where marmots no longer occur. Issues will include methods necessary to test the likely influence of past and future logging, climate and vegetation change. The session will also focus on the value of habitat suitability models and the optimal temporal and spatial pattern for successful reintroduction.
3. **Landscape ecology for marmot sustainability *(How to save what's there)*:** The session will focus on the probability of successfully maintaining marmots in the few areas where they presently occur. Specific issues will include the ability to measure landscape effects (e.g., altered dispersal or "connectivity", effects of roads or other corridors, predator-prey relationships and predator control) and predicting how future landscape changes will likely influence the project.
4. **Monitoring and Modeling Small Populations *(What are the limitations for measuring and predicting VIM population size?)*:** The session will focus on overcoming the scientific difficulties posed by small population sizes and limited historical data. Specific issues will include validation of census monitoring techniques, and the likely value of tools such as mark-recapture modeling, population simulation modeling, sensitivity analysis, population viability analysis, spatial autocorrelation and epidemiology. Additional questions are, what is the role of scientific modeling in VIM recovery and is the intrusiveness of techniques a concern?

Note: Although the Workshop will be specifically focused on problems concerning *Marmota vancouverensis*, these issues may have more generic utility for participants involved in other endangered species recovery efforts.

Appendix II: Participant List

VIM Conservation Workshop
Nanaimo, British Columbia. June 16-19, 1999

Dr. Kenneth B. Armitage
University of Kansas
Department of Ecology & Evolutionary Biology
Lawrence, Kansas 66045-2106
USA
Tel: 785 864 3236
Fax: 785 864 5321
Email: marmots@ukans.edu

Dr. Walter Arnold
Research Institute of Wildlife Ecology
Savoyenstrasse 1
A-1160 Vienna,
Austria
Tel: 43 1 4890915 20
Fax: 43 1 4890915 59
Email: Walter.Arnold@vu-wien.ac.at

Dr. Daniel Blumstein
Macquarie University
Departments of Biology, Psychology & The Marsupial CRC
Sydney NSW 2109
Australia
Tel: 61 2 9850 9440
Fax: 61 2 9850 9231 or 8062
Email: dan@galliform.bhs.mq.edu.au

Dr. Andrew Bryant
VANCOUVER ISLAND MARMOT Recovery Project
108 Fifth Street
Nanaimo, BC V9R 1N2
Canada
Tel: 250 754 1356
Fax: 250 754 1356
Email: abryant@home.com

Mrs. Shelagh Bucknell
Canadian Wildlife Service
5421 Robertson Road, RR #1
Delta, BC V4K 3N2
Canada
Tel: 604 940 4642
Fax: 604 946 7022
Email: shelagh.bucknell@ec.gc.ca

Dr. Marie-Pierre Callait
Le concorde
2, rue du Villard
73490 La Ravoire,
France
Tel: 0179 71 32 47
Fax: 01 79 75 25 92

Mr. John Carnio
Canadian Association of Zoos and Aquariums/Toronto Zoo
361A Old Finch Avenue
Scarborough, ON M1B 5K7
Canada
Tel: 416 392 5967
Fax: 416 392 4979
Email: carnio@sprint.ca

Dr. Colin Clark
University of British Columbia
9531 Finn Road
Richmond, BC V7A 2L3
Canada
Tel: 604 274 5379
Fax: 604 822 6074
Email: biec@interchange.ubc.ca

Dr. Mary Conner
Colorado State University
Department of Fishery & Wildlife Biology
Fort Collins, CO 80521
USA
Tel: 970 224 4714
Fax: 970 491 5091
Email: mconner@cnr.colostate.edu

Mr. Neil Dawe
Canadian Wildlife Service
3567 Island Highway West
Qualicum Beach, BC V9K 2B7
Canada
Tel: 250 752 9611
Fax: 250 752 9611
Email: ndawe@island.net

Mr. Don Doyle
Ministry of Environment, Lands & Parks
Environment and Lands Regional Office - Vancouver Island
2080-A Labieux Road
Nanaimo, BC V9T 6J9
Tel: 250 751 3219
Fax: 250 751 3103
Email: dddoyle@nanaimo.env.gov.bc.ca

Ms. Ann Duffy
Cypress Communications & Environmental Management
103-2445 Cornwall Avenue
Vancouver, BC V6K 1B9
Canada
Tel: 604 739 7966
Fax: 604 739 7906
Email: annduffy@direct.ca

Dr. Don Eastman
University of Victoria/Ministry of Environment
565 Beaver Lake Road
Victoria, BC V8X 3X1
Canada
Tel: 250 479 8382
Email: deastman@UVic.CA

Dr. Bob Elner
Canadian Wildlife Service
5421 Robertson Road, RR #1
Delta, BC V4K 3N2
Canada
Tel: 604 940 4674
Fax: 604 946 7022
Email: bob.elner@ec.gc.ca

Dr. Andrew Fall
Simon Fraser University
School of Computing Science
Burnaby, BC V5A 1S6
Canada
Tel: 604 291 5819
Fax: 604 291 3045
Email: fall@cs.sfu.ca

Dr. Etienne Farand
Universite Claude Bernard - Lyon 1
Laboratoire de Biologie des Populations d'Altitude, UMR 5553
Bat. 403, 1er étage, 43 Bvd. du 11 Novembre 1918
69622 Villeurbanne,
France
Tel: 04 72 43 14 04
Fax: 04 72 43 14 04
Email: farand@biomserv.univ-lyon1.fr

Dr. Gregory Florant
Colorado State University
Department of Biology
Ft. Collins, CO 80525
USA
Tel: 970 491 7627
Fax: 970 491 0649
Email: florant@lamar.colostate.edu

Mr. Dave Fraser
Ministry of Environment, Lands & Parks
PO Box 9374 STN PROV GOV
Victoria, BC V8W 9M4
Canada
Tel: 250 387 9756
Fax: 250 356 9145
Email: dffraser@fwydept.env.gov.bc.ca

Mr. Daniel Gavin
University of Washington
College of Forest Resources
104 Winkenwerder
Seattle, WA 98195
USA
Tel: 206 543 5777
Fax: 206 543 3254
Email: dgavin@u.washington.edu

Dr. Susan Glenn
University of British Columbia
Forest Sciences Dept., Faculty of Forestry
2424 Main Mall
Vancouver, BC V6T 1Z4
Canada
Tel: 604 822 4131
Fax: 604 822 9102
Email: sglenn@interchange.ubc.ca

Dr. Alton Harestad
Simon Fraser University
Department of Biological Sciences
8888 University Drive
Burnaby, BC V5A 1S6
Canada
Tel: 604 291 4809
Fax: 604 291 3496
Email: harestad@sfu.ca

Mr. Bill Harper
Osiris Wildlife Consulting - BC Wildlife Federation
3953 Juan De Fuca Terrace
Victoria, BC V8N 5W9
Canada
Tel: 250 721 0870
Fax: 250 721 0899
Email: bharper@tnet.net

Dr. Glen Jamieson
Mount Arrowsmith Biosphere Foundation/Department of Fisheries & Oceans
804 San Malo Crescent
Parksville, BC V9P 1S4
Canada
Tel: 250 756 7223
Fax: 250 756 7138
Email: jamiesong@pac.dfo-mpo.gc.ca / mabf@nanaimo.ark.com

Mr. Doug Janz
Ministry of Environment, Lands & Parks
Fish, Wildlife & Habitat Protection
2080 Labieux Road
Nanaimo, BC V9T 6E9
Canada
Tel: 250 751 3217
Fax: 250 751 3103
Email: DJANZ@nanaimo.env.gov.bc.ca

Dr. Luise Kruckenhauser
University of Vienna
Inst. Medical Biology, Dept. General Genetics
Wahringerstr. 10
A-1090 Wien,
Austria
Tel: 43 1 3191349 240
Fax: 43 1 3191349 238
Email: Luise.Kruckenhauser@univie.ac.at

Ms. Sally Leigh-Spencer
Ecologic Consulting/Marmot Recovery Team
5632 Menzies Road, RR #2
Duncan, BC V9L 1N9
Canada
Tel: 250 748 3047
Fax: 250 748 3047
Email: sallyls@cow-net.com

Mr. Jason Lewis
Vancouver Island Marmot Recovery Project/Univ. of Calgary Grad. Student
3456 Stephenson Point Road
108 Fifth Street
Nanaimo, BC V9T 1K2
Canada
Tel: 250 758 2005
Fax: 250 758 3457
Email: jclewis@ucalgary.ca

Mr. David J. Lindsay
TimberWest
1537 Chaplin Street
Crofton, BC V0R 1R0
Canada
Tel: 250 246 6879
Fax: 250 246 9644
Email: lindsayd@timberwest.com

Dr. Kathy Martin
Canadian Wildlife Service
5421 Robertson Road, RR #1
Delta, BC V4K 3N2
Canada
Tel: 604 940 4667
Fax: 604 946 7022
Email: kathy.martin@ec.gc.ca

Mr. Malcolm McAdie
Consultant
Ministry of Environment, Lands & Parks
Fish, Wildlife & Habitat Protection
2080 Labieux Road
Nanaimo, BC V9T 6E9
Canada
Tel: 250 751 3100
Fax: 250 751 3103
Email: mlmcadie@nanaimo.env.gov.bc.ca.

Mr. Rick McKelvey
Canadian Wildlife Service
5421 Robertson Road, RR #1
Delta, BC V4K 3N2
Canada
Tel: 604 940 4646
Fax: 604 946 7022
Email: rick.mckelvey@ec.gc.ca

Mr. Ronald McLaughlin
MacMillan Bloedel
65 Front Street
Nanaimo, BC V9R 5H9
Canada
Tel: 250 755 3404
Fax: 250 755 3550
Email: rt.mclaughlin@mbltd.com

Dr. Gray Merriam
GM Group - Ecological Land Management
Box 93
Arden, ON K0H 1B0
Canada
Tel: 613 335 3589
Fax: 613 335 3589
Email: gmerriam@ccs.carleton.ca

Mr. Bob Milko
Canadian Wildlife Service
3rd Floor, Place Vincent Massey
351 St. Joseph Blvd.
Hull, PQ K1A 0H3
Canada
Tel: 819 997 5781
Fax: 819 994 4445
Email: Bob.Milko@ec.gc.ca

Dr. Jan Murie
University of Alberta
Dept. of Biological Sciences
Edmonton, AB T5G 2E9
Canada
Tel: 780 492 3649
Fax: 780 492 9234
Email: jan.murie@ualberta.ca

Dr. Dave Nagorsen
Royal BC Museum
PO Box 9815 STN PROV GOV.
Victoria, BC V8W 9W2
Canada
Tel: 250 387 2933
Fax: 250 387 5364
Email: dnagorsen@royalbcmuseum.bc.ca

Dr. Rick Page
Page & Associates
3915 Scolton Road
Victoria, BC V8N 4E1
Canada
Tel: 250 882 4308
Fax: 250 721 7120
Email: Rick_Page@bc.sympatico.ca

Dr. David L. Peterson
USGS - Biological Resources Division
Forest & Rangeland Ecosystem Science Center
UW Field Station, Box 352100
Seattle, WA 98195
USA
Tel: 206 543 1587
Fax: 206 685 0790
Email: wild@u.washington.edu

Ms. Margaret Phelan
Environment Canada, Communications
700-1200 West 73 Avenue
Vancouver, BC V6P 6H9
Canada
Tel: 604 664 9162
Fax: 604 713 9517
Email: margaret.phelan@ec.gc.ca

M. Raymonde Ramousse
Universite Claude Bernard Lyon 1
JE 1942 Socioecologie et Conservation
Lyon,
France
Tel: 33 4 72 43 14 04
Email: ramousse@biomserv.univ-lyon1.fr

Dr. Helen Schwantje
Ministry of Environment, Lands & Parks
Wildlife Branch
PO Box 9374 STN PROV GOV
Victoria, BC V8W 9M4
Canada
Tel: 250 953 4285
Fax: 250 356 9145
Email: hschwant@fwhdept.env.gov.bc.ca

Dr. Orlando Schwartz
University of Northern Iowa
Department of Biology
Cedar Falls, IA 50614-0421
USA
Tel: 319 273 2106
Fax: 319 273 2893
Email: schwartzo@uni.edu

Mr. Rik Simmons
BC Parks
Strathcona District
Box 1479
Parksville, BC V9P 2H4
Canada
Tel: 250 954 4609
Fax: 250 248 8584
Email: rsimmons@prkparksvl.elp.gov.bc.ca

Dr. Barry Smith
Canadian Wildlife Service
Pacific Wildlife Research Centre
5421 Robertson Road, RR #1
Delta, BC V4K 3N2
Canada
Tel: 604 940 4677
Fax: 604 946 7022
Email: barry.smith@ec.gc.ca

Dr. Dan Smith
University of Victoria
Dept. of Geography
PO Box 3050
Victoria, BC V8W 3P5
Canada
Tel: 250 721 7328
Fax: 250 721 6216
Email: smith@uvvm.uvic.ca

Dr. Craig Stephen
Centre for Coastal Health
900 5th Street
Nanaimo, BC V9R 5S5
Canada
Tel: 250 741 2642
Fax: 250 755 8749
Email: cch@mala.bc.ca

Dr. Curtis Strobeck
University of Alberta
Department of Biological Sciences
Edmonton, AB T6G 2E9
Canada
Tel: 780 492 3515
Fax: 780 492 9234
Email: curtis.strobeck@ualberta.ca

Mr. Eric Taylor
Environment Canada, Climate Section
700 - 1200 73rd Avenue
Vancouver, BC V6P 6H9
Canada
Tel: 604 664 9123
Fax: 604 664 9195
Email: Eric.Taylor@ec.gc.ca

Dr. Dirk Van Vuren
University of California, Davis
Department of Wildlife, Fish & Conservation Biology
CA 95616
USA
Tel: 530 752 4181
Fax: 530 752 4154
Email: dhvanvuren@ucdavis.edu

Mr. Jim Walker
Ministry of Environment, Lands & Parks
PO Box 9339 STN PROV GOVT
Victoria, BC V8W 9M1
Canada
Tel: 250 356 0139
Fax: 250 387 5669

Mr. Rick Wenman
Calgary Zoo
Box 23 Site 9 RR 1
Dewinton, AB T0L 0X0
Canada
Tel: 403 256 9161
Fax: 403 256 7707
Email: zooranch@calgaryzoo.ab.ca

Mr. Brett Woods
University of Kansas
Department of Ecology & Evolutionary Biology
Lawrence, Kansas 66045-2106
USA
Tel: 785 864 3236
Fax: 785 864 5321
Email: bcwoods@falcon.cc.ukans.edu

Appendix III: Working Group List for Vancouver Island Marmot Workshop

ECOLOGY OF REINTRODUCTION (11)		
Dawe, Neil		Canadian Wildlife Service
Eastman, Don	**CHAIR**	University of Victoria/Ministry of Environment
Harestad, Alton		Simon Fraser University
Lewis, Jason		University of Calgary
Milko, Bob		Canadian Wildlife Service
Nagorsen, Dave	**RAPPORTEUR**	Royal BC Museum
Ramousse, Raymonde		Universite Claude Bernard Lyon 1
Simmons, Rik		BC Parks
Smith, Dan		University of Victoria
Taylor, Eric		Environment Canada, Climate Section
Van Vuren, Dirk		University of California, Davis

LANDSCAPE ECOLOGY (8)		
Elner, Bob		Canadian Wildlife Service
Fall, Andrew		Simon Fraser University
Gavin, Daniel		University of Washington
Harper, Bill	**RAPPORTEUR**	Osiris Wildlife Consulting - BC Wildlife Federation
Martin, Kathy	**CHAIR**	Canadian Wildlife Service
Merriam, Gray		Carleton University
Page, Rick		Page & Associates
Peterson, David L.		USGS - Biological Resources Division

MODELLING (7)		
Clark, Colin	**CHAIR**	University of British Columbia
Conner, Mary		Colorado State University
Farand, Etienne		Universite Claude Bernard - Lyon 1
Jamieson, Glen		Mount Arrowsmith Biosphere Foundation/Department of Fisheries & Oceans
Janz, Doug	**RAPPORTEUR**	Ministry of Environment, Lands & Parks
Murie, Jan		University of Alberta
Smith, Barry		Canadian Wildlife Service

NUTRITION, DISEASE, GENETICS & BEHAVIOUR (12)		
Arnold, Walter		Research Institute of Wildlife Ecology
Blumstein, Daniel		Macquarie University
Callait, Marie-Pierre		Le concorde
Carnio, John	**RAPPORTEUR**	Toronto Zoo
Florant, Gregory		Colorado State University
Kruckenhauser, Luis		University of Vienna
Schwantje, Helen	**CHAIR**	Ministry of Environment, Lands & Parks
Schwartz, Orlando		University of Northern Iowa
Stephen, Craig		Centre for Coastal Health
Strobeck, Curtis		University of Alberta

Wenman, Rick	Calgary Zoo
Woods, Brett	University of Kansas

RESOURCE EXPERTS (8)	
Armitage, Kenneth B.	University of Kansas
Bryant, Andrew	Vancouver Island Marmot Recovery Project
Doyle, Don	British Columbia Ministry of Environment, Lands & Parks
Fraser, Dave	British Columbia Ministry of Environment, Lands & Parks
Leigh-Spencer, Sally	Ecologic Consulting/Marmot Recovery Team
Lindsay, David J.	TimberWest
McCadie, Malcolm	Consultant
McKelvey, Rick	Canadian Wildlife Service

OPENING REMARKS	
Walker, Jim	Ministry of Environment, Lands & Parks

FACILITATOR	
Duffy, Ann	Cypress Communications & Environmental Management

COMMUNICATIONS/MEDIA RELATIONS	
Phelan, Margaret	Environment Canada, Communications

SECRETARIAT	
Bucknell, Shelagh	Canadian Wildlife Service

Appendix IV: Instructions and Background Material provided to participants in each of the Working Groups prior to the Workshop

A. Nutrition, Disease, Genetics and Behaviour

Nutrition, disease, genetics and behaviour *(How to keep VIM healthy)*: The session will focus on the requirements and methods of monitoring health in wild and captive marmots. Specific issues will include relationships between habitat, parasites, disease, nutrition and health, incorporation of genetic issues in captive-breeding and reintroduction programs, and the role of marmot behaviour in maximizing the chances of eventual success.

Nutrition, disease, genetics and behaviour (how can we learn the nuts and bolts of maintaining marmots in captivity and releasing successful groups to the wild?)

Nutrition

Empirical evidence:
Marmota vancouverensis survival is lower in clearcuts, and most mortality in this habitat type apparently occurs during hibernation (Bryant 1998). We know that food-plant availability in clearcuts is different from that in natural habitats (Martell and Milko 1986) although between-habitat food habits have not been formally tested.

The larger context:
Thorp *et al.* (1994) conducted a laboratory study with yellow-bellied marmots. Marmots supplied with a diet deficient in essential fatty acids showed identical weight gains during summer, but exhibited higher spontaneous arousal rates, shortened bouts of deep hibernation and higher overall metabolic expenditures. That this could lead to increased winter mortality is clear from studies of other marmots (Arnold 1993).

Relevance:
Nutrition could partially explain higher mortality in clearcuts. Habitat change and poor nutritional quality of forage might also explain the disappearance of this species from some of its historical range.

Essential literature:

Arnold, W. 1993. Energetics of social hibernation. Pages 65-80 *in* C. Carey, G. L. Florant, B. A. Wunder and B. Horwitz (Editors): *Life in the cold: ecological, physiological, and molecular mechanisms*. Westview Press (Boulder, CO). 214 pp.

Thorp, C.R., P.K. Ram and G.L. Florant. 1994. Diet alters metabolic rate in the Yellow-bellied marmot (*Marmota flaviventris*) during hibernation. *Physiological Zoology*. 67: 1213-1229.

Bryant, A.A. 1998. Metapopulation ecology of Vancouver Island Marmots (*Marmota vancouverensis*). Ph.D. dissertation, University of Victoria (Victoria, BC). 125 pp.

Martell, A.M. and R.J. Milko. 1986. Seasonal diets of Vancouver Island Marmots. *Canadian Field-Naturalist*. 100:241-245.

Disease

Empirical evidence:
Four transplanted marmots died during hibernation, apparently from a bacterial infection (Bryant *et al.* in press). The frequency of episodes of high mortality has increased in recent years and increased spatial autocorrelation of survival is consistent with a disease outbreak (Bryant 1998). Recent declines are mostly due to catastrophic losses over the span of one or two winters (Bryant in press).

The larger context:
A growing literature suggests that disease threats to rare species may be underestimated (Caughley and Gunn 1996).

Relevance:
Disease might cause extinction rapidly.

Essential literature:

Bryant, A.A., H.M. Schwantje and N.I. deWith. In press. Disease and unsuccessful reintroduction of Vancouver Island Marmots (*Marmota vancouverensis*). Proceedings, 3rd International Congress on Genus Marmota (Cheboksary, Russia, 25-30 August 1997).

Bryant, A.A. 1998. Metapopulation ecology of Vancouver Island Marmots (*Marmota vancouverensis*). Ph.D. dissertation, University of Victoria (Victoria, BC). 125 pp.

Caughley, G., and A. Gunn. 1996. *Conservation Biology in Theory and Practice*. Blackwell (Cambridge, MA). 459 pp.

Genetics

Empirical evidence:
Limited information exists concerning normal levels of genetic variation in VIM. Bryant (1990) used electrophoresis of 44 blood samples from three colonies to conclude that levels of variation were similar to other marmots. Specifically, results revealed levels of genetic variability comparable to *M. flaviventris* and *M. monax* (n=22 scorable loci, estimated polymorphic loci P=0.18, average expected heterozygosity H=0.073; see Schwartz and Armitage 1980, Wright *et al.* 1987). Significant genetic differences were found between two colonies less than 20 kilometres apart, illustrating the importance of founder effects and infrequent dispersal. Effective population size N_e of the known population was close to 50 (based on a population estimate of ~250 animals, N_e = 34.6 to 64.4).

The larger context:
Dependence upon captive-breeding dictates that efforts be undertaken to maintain existing genetic variation. DNA extraction techniques exist from hair and blood.

Relevance:
Transplants should be designed to maximize genetic diversity.

Relevant literature:

Bryant, A.A., H.M. Schwantje and N.I. deWith. In press. Disease and unsuccessful reintroduction of Vancouver Island Marmots (*Marmota vancouverensis*). Proceedings, 3rd International Congress on Genus Marmota (Cheboksary, Russia, 25-30 August 1997).

Bryant, A.A. 1990. *Genetic variability and minimum viable populations in The Vancouver Island Marmot Marmota vancouverensis*. M.E.Des. thesis, University of Calgary, Calgary, Alberta. 101 pp.

Schwartz, O.A. and K.B. Armitage. 1980. Genetic variation in social mammals: the marmot model. *Science*. 207: 665-667.

Wright, J., B.C. Tennant and B. May. 1987. Genetic variation between woodchuck populations with high and low prevalence rates of woodchuck hepatitis virus infection. *Journal of Wildlife Diseases*. 23: 186-191.

Behaviour

Design of release - numbers and social assemblages, and geographic locations

Empirical evidence:

Findings from the McQuillan experiment

The larger context:

What have the Russians and Europeans found on this?

Relevance:

It is critical to select the appropriate age and sex structure of marmots that will be introduced into a site to ensure the best chance of success. Genetic diversity may also have to be considered. Beyond habitat suitability the location of sites selected for reintroductions will have to account for existing metapopulation structure and potential rescue effect.

Essential literature:

Bryant, A.A., H.M. Schwantje and N.I. deWith. In press. Disease and unsuccessful reintroduction of Vancouver Island Marmots (*Marmota vancouverensis*). Proceedings, 3rd International Congress on Genus Marmota (Cheboksary, Russia, 25-30 August 1997).

B. Ecology of reintroduction

Ecology of reintroduction *(How to introduce new colonies)*: The session will strive to identify the types of data required to select appropriate reintroduction habitats in the many areas where marmots no longer occur. Issues will include methods necessary to test the likely influence of past and future logging, climate and vegetation change. The session will also focus on the value of habitat suitability models and the optimal temporal and spatial pattern for successful reintroduction.

The ecology of reintroduction (how can we restore marmots to places where they once occurred but are now absent?)

1. How to identify the best potential habitats for reintroduction?
2. Are historical habitats not occupied no longer suitable because of climatic or vegetation changes?
3. Design of release- numbers and social assemblages, and geographic locations

How to identify the best potential reintroduction habitats

Empirical evidence:
The only *Marmota vancouverensis* reintroduction to date failed (Bryant *et al.* in press) despite habitat assessment (biophysical mapping) work (Demarchi *et al*. 1996) and despite release of wild-captured animals in an area occupied by marmots in the recent (how recent?) past (indeed, transplanted marmots spent much of their time re-constructing existing burrows at habitats that were very close to the type locality for the species).

The larger context:
Other marmot reintroductions (e.g., Ramousse *et al*.1992) have been successful despite lack of understanding of causes of decline (e.g., in the Pyrenees; Herrero *et al.* 1992) and based on reintroductions of small numbers of individuals. Nevertheless with so few animals available for transplants, it is critical that habitat suitability is fully explored.

Relevance:
There exist few empirical data with which to map potential marmot reintroduction habitats. Biophysical mapping has been done for only the Haley Lake and Mount McQuillan areas; additional biophysical mapping may be needed for other areas. Any critical habitat factors not be picked up with biophysical mapping should also be identified.

Essential literature:
Bryant, A.A., H.M. Schwantje and N.I. deWith. In press. Disease and unsuccessful reintroduction of Vancouver Island marmots (*Marmota vancouverensis*). Proceedings, 3rd International Congress on Genus Marmota (Cheboksary, Russia, 25-30 August 1997).

Bryant, A.A. 1998. Metapopulation ecology of Vancouver Island marmots (*Marmota vancouverensis*). Ph.D. dissertation, University of Victoria (Victoria, BC). 125 pp.

Demarchi, D.A., L. Bonner, L. Lacelle, S. Moss and B. von Sacken. 1996. Biophysical analysis of Vancouver Island marmot habitat. Unpublished progress report, B.C. Ministry of Environment, Lands and Parks. 21 pp.
Herrero, J., R. Garc'a-Gonzalez, and A. Garc'a-Serrano. 1994. Altitudinal distribution of alpine marmot (*Marmota marmota*) in the Pyrenees, Spain/France. *Arctic and Alpine Research*. 26: 328-331.
Ramousse, R., J.P. Martinet and M. Le Berre. 1992. Twenty years of reintroduction policy of alpine marmots from the national park of La Vanoise (French Alps). Pages 171-177 *in* B. Bassano, P. Durio, U. Gallo Orsi and E. Macchi (Editors): *Proceedings, 1st International Symposium on Alpine Marmot and Genus Marmota*. Dipartimento di Produzioni Animali, Epidemiologia et Ecologia (Torino, Italy). 268 pp.

Are historical habitats not occupied no longer suitable because of climatic or vegetation changes?

Empirical evidence:
Marmota vancouverensis distribution has undoubtedly became more restricted since the early post-glacial period as climate and vegetation changed (Nagorsen *et al.* 1996). However, late Holocene records such as 1,000 year old bones from caves at Weymer Creek near Tahsis demonstrate that VI marmots were more widespread even in late prehistoric time. These areas no longer support potential habitat. Laroque (1998) suggested that some marmot habitats have suffered from tree-invasion, and Milko (1984) suggested that post-fire succession may limit marmot habitat. However, empirical data on habitat change in areas occupied by marmots are weak.

The larger context:
Evidence from other marmot species (e.g., Preleuthner *et al.* 1995) suggests that *M. vancouverensis* has been placed between the proverbial "rock and hard place" for several thousands of years following glaciation as forests invaded tundra parkland and open meadow habitats. The phenomenon of tree-invasion of sub-alpine meadows in the early postglacial and recent historical time has occurred throughout the mountains of western North America Rochefort *et al.* (1994).

Relevance:
One objective of the Recovery Plan is to establish a metapopulation in central Vancouver Island (Strathcona Park) through reintroductions. Possible reasons for the disappearance of *M. vancouverensis* from this area include: 1) the habitat has become unsuitable; or 2) metapopulation processes have been altered. If habitat is no longer suitable then reintroductions in this area may not be appropriate.

Essential literature:
Laroque, C.P. 1998. Tree invasion in subalpine Vancouver Island marmot meadows. Unpublished report to the B.C. Environmental research Scholarship Committee (Victoria, BC) 36 pp.
Milko, R.J. 1984. Vegetation and foraging ecology of the Vancouver Island marmot (*Marmota vancouverensis*). M.Sc. Thesis, University of Victoria (Victoria, BC). 127 pp.

Nagorsen, D.W, G. Keddie and T. Luszcz. 1996. Vancouver Island marmot bones from subalpine caves: archaeological and biological significance. Occasional Paper #4. B.C. Ministry of Environment, Lands and Parks (Victoria, BC). 58 pp.

Preleuthner, M., W. Pinsker, L. Kruckenhauser, W.J. Miller and H. Prosl. 1995. Alpine marmots in Austria: the present population structure as a result of the postglacial distribution history. *Acta Theriologica* (Supplement). 3: 87-100.

Schreiner, E.G., and J.E. Burger. 1994. Photographic comparisons: a qualitative appraisal of the influence of climate and disturbances on vegetation, 1915-1990. Pages 139-172 *in* D.B. Houston, E.G. Schreiner and B.B. Moorhead (Editors): *Mountain Goats in Olympic National Park: biology and management of an introduced species*. United States Department of the Interior Scientific Monograph NPS/NROLYM/NRSM-94/25.

Rochefort, R.M. R.M. Little, A. Woodward, D.L. Peterseon. 1994. Changes in sub-alpine tree distribution in western North America: a review of climatic and other causal factors. Holocene 4:89-100.

Design of release- numbers and social assemblages, and geographic locations

Empirical evidence:

Findings from the McQuillan experiment.

The larger context:

What have the Russians and Europeans found on this?

Relevance:

It is critical to select the appropriate age and sex structure of marmots that will be introduced into a site to ensure the best chance of success. Genetic diversity may also have to be considered. Beyond habitat suitability the location of sites selected for reintroductions will have to account for existing metapopulation structure and potential rescue effect.

Essential literature:

Bryant, A.A., H.M. Schwantje and N.I. deWith. In press. Disease and unsuccessful reintroduction of Vancouver Island marmots (*Marmota vancouverensis*). Proceedings, 3rd International Congress on Genus Marmota (Cheboksary, Russia, 25-30 August 1997).

C. Landscape Ecology for Marmot Sustainability

Landscape ecology for marmot sustainability *(How to save what's there)*: The session will focus on the probability of successfully maintaining marmots in the few areas where they presently occur. Specific issues will include the ability to measure landscape effects (e.g., altered dispersal or "connectivity", effects of roads or other corridors, predator-prey relationships and predator control) and predicting how future landscape changes will likely influence the project.

Landscape ecology (how can we maintain marmots in the places where they currently live?)

1. Predation
2. Connectivity
3. Habitat stability (succession, global climate change)

Predation

Empirical evidence:
Radio-telemetry provided undeniable evidence that predators exert an important effect at some colonies. Spatial autocorrelation of survival is consistent with increased predation pressure at adjacent colonies (Bryant 1998).

The larger context:
The "predator-pit" phenomenon suggests that predators might exert pressure on low-density prey populations sufficient to prevent their recovery (Haber 1977).

Relevance:
Predator control may provide a temporary respite for marmots

Essential literature:
Bryant, A.A. 1998. Metapopulation ecology of Vancouver Island marmots (*Marmota vancouverensis*). Ph.D. dissertation, University of Victoria (Victoria, BC). 125 pp.
Haber, G.C. 1977. Socio-ecological dynamics of wolves and prey in a subarctic ecosystem. Ph.D. Dissertation, University of British Columbia (Vancouver, BC). 786 pp.

Connectivity

Empirical evidence:
Forestry produced changes in marmot density in the central portion of the existing range. Circumstantial evidence suggests that dispersal movements are shortened by the availability of new clearcuts (Bryant 1998). Effects of succession in clear cuts??

The larger context:
Landscape connectivity is an important element of landscape structure (Dunning *et al*. 1992, Taylor *et al.* 1993).

Relevance:
Natural dispersal patterns might be re-created through transplants.

An understanding of connectivity and dispersal essential to plan location of transplants. Presumably connectivity is dynamic and will change with short term succession (e.g., clear cuts) and long term with global climatic changes. All of this complicates any attempts to maintain marmots where they now occur.

Essential literature:

Bryant, A.A. 1998. Metapopulation ecology of Vancouver Island marmots (*Marmota vancouverensis*). Ph.D. dissertation, University of Victoria (Victoria, BC). 125 pp.

Dunning, J.B., B.J. Danielson and H.R. Pulliam. 1992. Ecological processes that affect populations in complex landscapes. *Oikos*. 65: 169-175.

Taylor, P.D., L. Fahrig, K. Henein and G. Merriam. 1993. Connectivity is a vital element of landscape structure. *Oikos*. 68: 571-573.

D. Monitoring and Modeling Small Populations

Monitoring and Modeling Small Populations (*What are the requirements limitations for measuring and predicting VIM population size?*): The session will focus on addressing the scientific difficulties that accompany attempts to understand the dynamics of small population sizes, especially in the face of limited historical data. Specific issues will include an evaluation of census monitoring techniques, and the likely value of tools such as mark-recapture modeling, population simulation modeling, population viability analysis and sensitivity analysis. An additional question is: what is the role of scientific modeling in VIM recovery, and is the intrusiveness of techniques a concern?

Statistical inference and modeling (how do we continue to learn when additional samples will not be forthcoming?)

Empirical evidence:
Despite a sample of tagged marmots representing 10-15% of the entire population monitored for over a decade, some analyses (e.g., Cormack-Jolly-Seber survival analysis) had low statistical power (Bryant 1998). The situation is not likely to improve given a current population of fewer than 100 individuals.

The larger context:
There is sometimes a distinct difference between "statistical significance" and "biological significance" (Krebs 1989).

Relevance:
Modeling might provide a useful means of challenging hypotheses. For example, at what population size do we escape the risk of extinction in the near future, given uncertainties in factors such as climate change, catastrophic events, and our ability to measure what's happening?

Essential literature:
Bryant, A.A. 1998. Metapopulation ecology of Vancouver Island marmots (*Marmota vancouverensis*). Ph.D. dissertation, University of Victoria (Victoria, BC). 125 pp.
Krebs, C.J. 1989. *Ecological methodology*. Harper Collins (New York, NY). 654 pp.

Note: Data will be available to participants (CD ROM - Excel format) on:

Vancouver Island Marmot Population trends/raw data
Vancouver Island Marmot Mark recapture data
Vancouver Island Marmot Life tables/raw data
Vancouver Island Marmot Landscape change data (plus maps)
Weather trends
Vancouver Island Marmot Predator trends

Appendix V: Compilation of Working and Plenary Group Research Recommendations

The final plenary built from the joint review of the recommendations by the four Working Groups and subsequently led to three central concepts or research principles.

1. Making more marmots, by:
    - Captive Breeding

2. Keeping the marmots, by:
    - Manipulation of habitat (in clear-cuts and by managing/creating avalanches)
    - Supplemental food
    - Control of predators

3. Increasing the wild population, by:
    - Reintroductions (but require increased understanding of social behaviour, and identification of release sites)

Given "what" needs to be done, the attendees outlined a desirable strategy on "how" to support these concepts and augment VIM populations and their habitat. Essential elements should be:

- Ongoing monitoring
- Capitalizing on existing data
- Generating new information
- Determining the management risk of actions (or inactions)
- Providing the best science information possible into the decision-making process, with appropriate sensitivity for the precautionary approach
- Ranking and implementing the research priorities.

Potential linkages and commonalties between the research recommendations arising from the four Working Groups included:

- Monitoring, and the multiple uses of samples, such as blood for nutrition and genetic studies.
- Collaboration on DNA paternity analysis
- Dispersal information
- Plant fatty acid, diet and habitat relationships
- Population Viability Analyses
- Utility of temperature sensitive radio locating transmitter
- DNA testing, including developing new primers

A. NUTRITION, DISEASE, GENETICS AND BEHAVIOUR

Recommendation # A1:
Reproduction
Research on the estrous cycle, and use of the Hoary Marmot as a model for reproductive studies on the VIM continue. Captive husbandry protocols should be standardized.

Recommendation # A2:
Disease
Monitoring for disease and developing the disease databases. Standard sampling protocols based on marked individuals should be established. Standard quarantine protocols need to be developed for animals coming into captivity and being re-introduced into the wild.

Recommendation # A3:
Genetics
Genotyping and DNA research on the species with particular reference to paternity and relatedness questions.

Recommendation # A4:
Behaviour
Work into details of the social behaviour of Vancouver Island Marmots to better manage captive groups and reintroductions. Additional behavioural research should address foraging, reproductive suppression, hibernation and infanticide.

Recommendation # A5:
Nutrition
Development of a standard diet for the captive population. A collaborative study with a plant ecologist to ascertain the quality and quantity of the field diet is critical. Field comparisons between the quality and quantity of forage for marmots in clear-cut and natural habitats are necessary to further understand the effects of clear-cut habitat on marmot survival. Information on natural diet should be used when choosing reintroduction sites.

Recommendation # A6:
Nutrition
A supplemental feeding trial for marmots in wild habitats as a potential strategy to increase survivorship.

Recommendation # A7:
Hibernation
As for Behaviour (# A4), and, also, work on how to condition captive animals for hibernation in the wild.

B. ECOLOGY OF REINTRODUCTION

RECOMMENDED HABITAT-BASED RESEARCH

High Priority:

Recommendation # B1:
Determine the climatic regimes in different marmot habitats. The studies would involve measuring effective temperatures and determining the effect of snow cover.

Recommendation # B2:
Determine the limiting factors to marmots inhabiting clear-cut situations.

Recommendation # B3:
Determine whether and how habitat at extirpated marmot colony sites differ from habitat at sites that are currently occupied.

Recommendation # B4:
Develop habitat suitability models for more effectively targeting optimal sites for VIM reintroductions.

Medium Priority:

Recommendation # B5:
Determine if clear-cut habitats can be enhanced to better sustain marmots.

Recommendation # B6:
Predict how release sites might be impacted by global climate change.

Recommendation # B7:
Establish the long-term history (for example, vegetation, climate, and anthropogenic influences) of various habitats that are currently or were occupied by VIM.

Low Priority:

Recommendation # B8:
Determine means of creating corridors linking clearcut and natural areas to promote natural dispersal.

Recommendation # B9:
Determine whether natural habitat occupied by VIM can be enhanced to increase survivorship and colony size.

Recommendation # B10:
Determine if and how new habitat for VIM might be created.

RECOMMENDED POPULATION-BASED RESEARCH

High Priority:

Recommendation # B11:
Research should focus on hibernation biology of VIM and if the system is similar to that for Alpine Marmots.

Recommendation # B12:
Determine the social structure of VIM colonies.

Recommendation # B13:
Determine the impact and nature of predation on marmots.

Recommendation # B14:
Ascertain whether VIM reintroductions should take place at multiple sites or repeatedly at one site.

Medium Priority:

Recommendation # B15:
Determine how the fitness of marmots can be maximized prior to transplanting.

Recommendation # B16:
Determine the reproductive value of transplant candidates.

Low Priority:

Recommendation # B17:
Document the impact of disease on VIM.

C. LANDSCAPE ECOLOGY RESEARCH RECOMMENDATIONS

Research recommendations and research gaps :

(I) Animal-based	(II) Habitat-related.

The ranking scheme involved three criteria:

Importance of the research:	High (H); Medium (M); Low (L)
Difficulty of the work:	High (H); Medium (M); Low (L)
Time-frame (urgency):	Immediate (I), Medium (M), Long-term (L)

The ideal partner to carry out the work:

University/college (U)	Provincial Government (PG)
Consultants/contractors (C)	Non-government organization (NGO)
Federal Government (FG)	Resource-based Industry (I).

Recommendation # C1
(H,L,I; PG,U):
Elucidate the most limiting factors to colony persistence. A major question associated with this is “Do VIM live longer when moved from clear-cut to natural environment”? The required study would have to include adequate controls and measure hibernacula characteristics. Depending on the results of the study, translocation techniques from clear-cuts could provide a tool to reverse marmot population declines.

Recommendation # C2
(H, L, I; U):
The quality and quantity of vegetation available to marmots as forage in clear-cut as compared to natural habitat remains a core unknown. The Group recommended that research on plants be carried out to measure the nutritional value of forage in both habitat types. Depending on the results of the study, supplemental feeding in clear-cut colonies could provide a tool to increase survivorship.

Recommendation # C3
(H, M, I; PG, C):
The impact of avian and terrestrial predators on the dwindling marmot population is a concern. Examine the option of selectively removing terrestrial predators, such as cougars and wolves, from the area as a means to reducing marmot mortality. Concomitantly, there should be monitoring studies to measure seasonal patterns in adult marmot survivorship to differentiate predation induced mortality from death during hibernation.

Recommendation # C4
(H, L, M; PG):
Determine the effects of augmenting existing colonies in natural habitats with marmots from captive breeding and clear-cut colonies. Again, as above, concomitant studies would be required to monitor survivorship of individuals in the augmented situations as compared to controls.

Recommendation # C5
(L, H, L; PG):

Further to Recommendation C3 (above) on predator management, the Group suggested that the Recovery Team consider the effect of reducing alternative prey, such as elk, of marmot predators with the objective of decreasing predator abundance in the area.

Recommendation # C6
(H, L, I; U, PG, FG):
Research should be undertaken to quantify the fine-scale habitat needs of VIM. In particular, factors relating to forage, predator-cover, thermal patterns and spatial arrangements of habitat components appear of particular interest. The research would need to be stratified by season and carried out in a range of habitat types (e.g. successful as well as unsuccessful colony sites). Ideally, the work could be carried out as part of university postgraduate studies and be coordinated with plant sampling (Recommendation # C2). Understanding gained would serve to drive Recommendations # C7 and C8.

Recommendation # C7
(H, M, M; I, PG, FG, U):
Mapping studies should be carried out to chart the distribution, abundance and connectivity of clear-cut and natural habitats over the core range of VIM. In particular, researchers need to map dispersal resistance. This could be important in order to evaluate potential translocation, donor and recipient sites.

Recommendation # C8
(M, M, L; I, PG, FG, U):
As per recommendation # C7 but over the historic range of VIM.

Recommendation # C9
(M,M,M; U, C):
Investigate and identify temporal processes influencing habitat quality for VIM. Potential methodology could include: calculating the metrics of each colony (e.g. distance to clear-cuts) for a connectivity model; running the connectivity model backwards in time to determine if there is a correlation between marmot persistence and land-use changes; and, running the connectivity model forwards under a variety of land management scenarios.

Recommendation # C10
(M, L, M; FG, U):
Elucidate climatic processes influencing marmots be elucidated. These processes could be explored using simple correlation analyses (scattergrams) between short-term (annual) variables, such as snowpack, degree days and drought, as well as long-term (post- 1910) variables, such as the El Nino and PDO, against VIM abundance estimates. The analyses should be stratified by elevation and could be compared with climatic patterns already identified for other marmot species. The results would link back to habitat and connectivity classification recommendations, as well as be of use in identifying potential translocation sites.

Recommendation # C11
(M, M, M; PG, U):
The Group recommended that long-term vegetation monitoring stations be established to track changes in plant communities in and around marmot colonies. Given understanding of marmot habitat and foraging requirements, the database would be of use in assessing habitat quality and colony persistence.

Recommendation # C12
(L, L, L; PG):
The Group recommended that “benchmark” photographs be taken of all VIM sites to assist in documenting potential tree invasion problems.

D. RECOMMENDATIONS FOR MONITORING & MODELING SMALL POPULATIONS

Recommendation # D1:
Current population monitoring activities and techniques be continued.

Maintaining an accurate census is essential since the risk of extinction is so highly sensitive to population size when the number of individuals is small. We also need to have some measure of how well the VIM are doing in the face of recovery efforts.

Mark-recapture techniques should be pursued to try to refine our understanding of those unnatural sources of mortality that a small population cannot tolerate if it is to avoid extinction.

Recommendation # D2:
Given limited data, and therefore the potential for many competing explanations, all data should be made available to researchers to offer alternative hypotheses or analytical techniques.

Recommendation # D3:
Given limited data, it is unlikely that hypotheses can be proposed, tested and rejected as in a typical statistical approach to hypothesis testing. Decisions should be made in the interest of the VIM be evidence-driven. Still, we cannot wait for definitive conclusions because they will probably come too late.

Recommendation # D4:
Analysis should be undertaken to determine the minimum population size below which depensatory mortality becomes a critical concern, i.e., the so-called Allee effect, when a population becomes so small that individuals have serious trouble finding a mate. Such an analysis has the potential to provide an estimate of the population size, or meta-population structure, below which a "rescue initiation - captive breeding" program becomes the essential or perhaps only viable means to sustain the VIM population.

Recommendation # D5:
Given that an important part of the recovery efforts will likely involve reintroductions, VIM individuals should be exploited for obtaining knowledge on dispersal to minimize the risk to health of "wild" marmots. These individuals would be focal points for habitat and nutrition studies, effects of climate on health and nutrition, disease, social behaviour and dispersal. An important aspect of "following" reintroduced individuals would be a comparison of behaviour of "wild" and introduced marmots, a so-called "retrospective validation" of the impacts of captive breeding. Population viability could be negatively associated with a behavioural modification that accompanies captive breeding before individuals are released into the wild.

Recommendation # D6:
Given the evidence, but not proof, that clear-cut logging might be creating a sink habitat for VIM, it is important that clearcuts continue to be a focus of concern and study in any PVA analysis for VIM. There remains the possibility that changes in forest management may be required to sustain the VIM. Modeling exercises should address the possibility that forestry management practices in alpine areas might play a major role in marmot sustainability, especially given the potential for rapid climate change in the next few years to decades, or a highly variable climate from year to year.

The influence of roads and road-building for access to clearcuts should also be investigated. It might not just be that clearcuts are sinks, but that roads provide an easy access to those habitats for predators.

Recommendation # D7:
Given the large number of modeling "projects" identified, and the accompanying need for a diversity of expertise in various aspects of VIM population dynamics, biology and ecology, the collaborative efforts should be arranged among marmot experts and experts in population modeling throughout the world. Some exercises would be suitable as university-based challenges, or for post-doctoral fellows in either university or government laboratories.

OVERALL MAJOR RESEARCH RECOMMENDATIONS

Recommendation # E1:
Support current population monitoring techniques
Census refinement, mark-recapture studies, radio-transmitter studies to understand dispersal and causes/rates of natural mortality, focusing efforts on a few selected colonies to support and augment current population monitoring efforts.

Recommendation # E2:
Collect information on dispersal
Attendees noted the lack of information on dispersal and effects of anthropogenic factors, such as roads, on natural patterns. They recommended additional research including use of DNA and telemetry techniques.

Recommendation # E3:
Make current data more available
The VIM databases should be made more available to interested investigators.

Recommendation # E4:
Identify minimum population size (Allee effect)
Develop a metapopulation model, to identify the minimum population size for VIM. The model could be used to identify the point at which all surviving marmots in the wild should be taken into captivity.

Recommendation # E5:
Carry out population viability and population sensitivity analyses
Population viability and sensitivity analyses, using data from past studies.

Recommendation # E6:
Establish reintroduction guidelines and protocols
Participants stressed the need to have standardized guidelines for both choosing habitat sites and release protocols from captive breeding.

The attendees identified five main problems that required solving:

- augmentations versus introduction
- efficacy of transferring knowledge from surrogate species, such as Olympic Marmot
- criteria for success of recovery efforts
- relative risk of a captive breeding program versus options such as non-intervention
- release protocols for marmots bred in captivity

Recommendation # E7:
There was consensus among participants that a Scientific Advisory Group be formed.
A technical team of competent biologists should be invited to form a formal Scientific Advisory Group to provide scientific direction for the Recovery Team. The Group should be comprised of research scientists; in addition sub-groups could be formed for each main technical aspect. Group members would be in regular e-mail contact.

The Scientific Advisory Group would operate as an interactive part of the Recovery Team in providing scientific direction rather than *ad hoc* advice. The core Group could consist of up to five research scientists.

The Recovery Team may choose to tender research problems determined by the Scientific Advisory Team Group for solution among the scientific community. While Group members would be eligible to compete for funding, there should be a separate formalized peer review process for funding applications in order to obtain independent scrutiny of Group projects.

The Scientific Advisory Group should be affiliated with at least one university or foundation so that a clear research program can be established. Such an affiliation would facilitate securing and directing graduate students and Postdoctoral Fellows.

Benefits of having the Scientific Advisory Group would be to:

- decrease or remove overhead costs for work done by universities
- foster collaborative research and peer review
- tap more major resources of university departments (e.g. GIS)
- provide sources for qualified personnel
- carry out data analyses and produce reports