VANCOUVER ISLAND MARMOT

Population and Habitat Viability Assessment Workshop Final Report

calgaryzoo — Discover Life on Earth
Marmot Recovery Foundation
IUCN SSC Species Survival Commission
CONSERVATION BREEDING SPECIALIST GROUP — Planning a Future for Wildlife
RSG

Calgary, Canada
3-6 March 2015

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Section 1
Executive Summary

Executive Summary

The Vancouver Island marmot (*Marmota vancouverensis*) is one of the top priority species of conservation concern in Canada. It is included in the Legal List of Species at Risk under the Species at Risk Act (SARA, 2002) and is the only endemic mammal species in Canada designated as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2008).

A Recovery Plan for the Vancouver Island marmot (VIM) was first published in 1994, with an update in 2000 and a Recovery Strategy in 2008. Questions about the projections for the population of wild marmots and the future of the captive population resulted in a Population and Habitat Viability Assessment (PHVA) workshop conducted at the Calgary Zoo on 3-6 March 2015. This workshop was organized by the Calgary Zoo's Centre for Conservation Research in collaboration with the Marmot Recovery Foundation (MRF) and IUCN's Reintroduction Specialist Group (RSG) and Conservation Breeding Specialist Group (CBSG). CBSG provided facilitation, process design and PVA modeling tools and skills, and financial support was provided by the Calgary Zoo and Marmot Recovery Foundation. This multi-stakeholder workshop included over 40 participants representing a diversity of expertise and perspectives, from field researchers, wildlife modelers, zoological breeding facilities, conservation NGOs, and government representatives to representatives of local timber companies. The workshop reviewed existing recovery plan goals and progress towards reaching recovery plan goals. It identified further management actions needed and explored intensive population management strategies necessary over the short and intermediate term.

Presentations at the beginning of the workshop provided brief status overviews of various issues and topics relevant to the subsequent discussions of Vancouver Island marmot management. Presentations covered the following topics:

- 1994, 2000 and 2008 recovery plans, goals, management approaches, successes and failures (Doyle)
- Nanaimo Lakes VIM population, current status, population trends (C. Jackson)
- VIM populations in the Forbidden Plateau and Western Strathcona regions, current status, population trends (C. Jackson)
- Captive VIM population, current status, trends (McAdie)

Workshop participants identified issues associated with Vancouver Island marmot recovery that, when grouped, fell into three categories: population status and management, environment and ecology, and financial and human resources. Working groups were formed around each of these categories and each working group identified specific problems, goals, objectives and actions necessary to address these problems. After the goals of each working group were presented in plenary, the group as a whole agreed that to secure a future for the Vancouver Island Marmot the following overarching goals must be realized:

- Maximize existing biological information as a foundation that can guide science-based wildlife management and financial investment;
- Accurately determine the size, trend, and drivers of Vancouver Island marmot populations in the wild;
- Understand the relationship among landscape changes, human presence, and predator/prey relationships;
- Ensure that the captive population is of a sufficient size and genetic diversity to support the growth of wild marmot populations and to act as a safe-guard for wild populations in the long term; and
- Achieve financial stability, without which all recovery actions are threatened and the sustainability of the species may be compromised.

Within the above goals two were deemed critical at this point in time:

- Existing and future data must be recorded in a consistent manner so that it is easily accessible and useable for population management.
- In order to meet this and other goals the project must achieve financial stability now and into the future.

Population simulation modeling completed after the workshop yielded the following recommendations:

- Maximize population size, reproduction and survival as feasible.
- Support at least two large VIM populations, either in the wild and/or captivity.
- Improve data collection and management to better inform management decisions.

A discussion at the end of the workshop about the definition of the term "sustainable" resulted in the following suggested revisions to recovery plan goals (for consideration by the Recovery Team):

- Moving away from the term "sustainable" and the use of exact numbers and replacing these with established, defensible and measurable criteria as described by COSEWIC;
- Setting specific goals based on a stage-based process (i.e. to downlist to one threat level and then to the next) with the ultimate goal of using the COSEWIC criteria to move the species from the SARA status of "endangered" to that of "special concern"; and
- Recognizing that a population of this size will always require some level of monitoring, and building this into future plans for the species.

This workshop successfully integrated a wide diversity of stakeholders to evaluate and recommend both *ex situ* and *in situ* conservation management techniques as part of an integrated conservation plan to support the recovery of the Vancouver Island marmot. This PHVA report and the recommendations within it are considered advisory to the Vancouver Island Marmot Recovery Team to help guide actions thought to be beneficial to the long-term survival of the Vancouver Island marmot in Canada. Recommendations from the workshop will be forwarded to the Recovery Team for consideration at their next assessment of the status of the species.

Communication of the results of the workshop was discussed, and it was determined that moving forward a Communication Committee would include representatives from all stakeholders. Calgary will work with MRF and the Recovery Team to determine when communications are appropriate.

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Section 2
History and Status Review

History and Status Review

The Vancouver Island marmot (*Marmota vancouverensis*) is the rarest of the six species of marmot found in North America and is limited to the more mountainous regions of Vancouver Island, British Columbia, Canada. Its closest relatives are the Olympic marmot (*M. olympus*) of the Olympic Peninsula, United States, and the more widespread hoary marmot (*M. caligata*) (Barash 1989). This species inhabits steep slopes (35-90% incline) in subalpine areas between 1000-1400m in elevation and prefers southeastern to western facing slopes with pockets of deep soil for burrowing (Bryant 1993). Vancouver Island marmots live in small colonies of two to twenty individuals, consisting of one or more family groups and non-related dispersers from other colonies. Each family might include an adult male, one or more adult females, and their offspring from different years. They are obligate herbivores and burrow dwellers, hibernating from late September/early October until late April/early May of the following year. Young are born in the burrows in early June, with pups emerging from the burrows for the first time in early July. Adults lose approximately one-third of their body weight during hibernation. In 2002 Bryant *et al.* estimated that more than half of the population of Vancouver Island marmots lived in forest habitat that had recently been harvested, referred to in this document as “cutblocks”. However in Nanaimo Lakes there are no colonies currently occurring in logged habitat. Colonies interact frequently with one another and all of the colonies within a region are referred to as a meta-population.

There are limited data on the historical distribution and abundance of Vancouver Island marmots, but a population estimate in the late 1970s set the number as low as 50-100 animals. Substantial population growth over the next decade probably reflected increased and improved inventory efforts in part. A 1985 survey (Munro *et al*.) suggested a population of 200-300 individuals. Surveys were inconsistent between 1984 and 1987, and no surveys were completed between 1987 and 1992. During the decade between 1985 and 1995, the population declined substantially, and surveys between 1994 and 1998 suggested a population of 71–103 individuals. In 2001 the population was estimated to be approximately 75 individuals dropping to as low as ~30 marmots in 2003. A captive breeding program was initiated in 1997 and following the release of captive-bred marmots, the population began to grow in the mid-2000s to ~100 individuals by 2008 and over 300 marmots by 2012 (see Figure 1 in the Population Modeling Report for more information).

Based on observations between 2002 and 2005, Brashares *et al.* (2010) noted substantial differences between the ecology and behavior of marmots observed during their study compared with historic data from the mid-1970s. They noted that contemporary Vancouver Island marmots had home ranges that were anywhere from 10 to 60 times larger than historical ranges. It should be noted that the Brashares study was conducted primarily at Mount Washington when the colony was at low numbers and the sex ratio biased towards males. The large home ranges primarily reflected movements of males among females and may not be characteristic of marmot colonies today. Marmots in the contemporary colonies interacted with conspecifics at a rate 10% less than the historical rate. Contemporary marmots spent 10 times more time in anti-predator activities and showed an 86% decline in feeding rates when compared with the historic population, and entered hibernation on average 20 days later.

The Vancouver Island marmot was listed as Endangered by COSEWIC in 1978 and legally designated as Endangered by the Province of British Columbia in 1980. The first recovery team was established in 1988 and identified the goals of preventing inbreeding, maintaining genetic variability over the long term, and reducing the risk of extinction through random environmental events. To accomplish these goals, the 1994 Recovery Plan recommended a total population of 400-600 marmots dispersed in three meta-populations on Vancouver Island and that downlisting from Endangered to Threatened not occur until there was a total population of 300-400 animals in two meta-populations. Recovery Plans published in 1994 (Janz *et al*.), 2000 (Janz *et al*.), and the 2008 Recovery Strategy (Vancouver Island Marmot

Recovery Team) continued to recommend a total population of 400-600 marmots dispersed in three meta-populations. The 2000 Recovery Plan recognized captive breeding combined with reintroduction as the best hope of increasing the wild population within a reasonable time period.

The following presentations at the beginning of the workshop provided information on the history of the Vancouver Island marmot population and management, its current status in the wild, and the management and status of the captive population.

A Review of the 1994, 2000 and 2008 Recovery Plans, Goals, Management Approaches, Successes and Challenges

Presented by Don Doyle

The first National Recovery Plan was developed in 1994 with the goal of removing the Vancouver Island marmot from the endangered species list. Three objectives supported this goal:

- Objective 1: Maintain the existing Nanaimo Lakes – Lake Cowichan meta-population at not fewer than 200 animals within the current known distribution of the species. Species status remains "Endangered".
- Objective 2: When a second stable or increasing meta-population is discovered or established through translocation, downlist from "Endangered" to "Threatened". Total population 300-400.
- Objective 3: When a third stable or increasing meta-population is discovered or established through translocation, downlist from "Threatened" to "Vulnerable". Total population 400-600.

Strategies for achieving the objectives included:

- Monitoring of known populations.
- Determining habitat requirements and mapping habitats.
- Completing an inventory for undiscovered colonies and habitats.
- Protecting and managing important subalpine and logged habitats.
- Conducting intensive population management if warranted.
- Developing public support through education, participation and fund raising activities.

<u>Successes and Challenges</u>:

- The lack of consistent funding to support the identified objectives led MacMillan Bloedel Ltd, now Timberlands, (forest company - private landowner) to challenge the government of British Columbia to commit to matched funding of $1 million over 5 years. This in turn led to the formation of the Marmot Recovery Foundation.
- Inventories of all existing colonies were completed and surveys in the historic range also were conducted. No new colonies were found and the population was confirmed to be low and declining from the high recorded population numbers of the mid-1980s.
- The first translocation of six marmots was attempted in 1996 from colonies living in cutblock to vacant historic habitats. One individual was predated prior to hibernation, the status of another untelemetered individual was never determined, and four died during a communal hibernation.

In 2000, the result of the efforts based on the 1994 recovery plan objectives were evaluated, and an updated National Recovery Plan was developed (Janz *et al.* 2000). The results of the efforts from the mid-1990s were that no new colonies were found in any areas and the overall population was highly endangered and declining. The failure of the initial translocation and the rapidly declining population in both natural and man-made habitats precluded further translocation trials. It was felt that captive breeding combined with reintroductions was the best hope of increasing the populations within a reasonable period of time. This led to the development of several additional objectives in the 2000 Recovery Plan:

- Objective 1: Establish a captive breeding program utilizing colonies as a surrogate for genetic diversity of the founder population.
- Objective 2: Build a dedicated breeding/release facility on Vancouver Island to assist with captive breeding and facilitate the re-introduction program.
- Objective 3: Begin experimenting with re-introductions when genetically surplus animals become available.

Between 1997 and 2004 a total of 55 marmots were removed from the wild to establish the captive program at the Toronto Zoo, Calgary Zoo, and the Mountain View Conservation and Breeding Centre. An additional facility was built on Mount Washington – the site of the most northerly wild colony and at an appropriate elevation for wild Vancouver Island marmot colonies. In 2003 four marmots were released back to the wild to Green Mountain.

A third update, the Recovery Strategy for the Vancouver Island Marmot, occurred in 2008 (Vancouver Island Marmot Recovery Team, 2008). In all the years between 1994 and 2008 and to the present day, the goal has remained the same: to remove the Vancouver Island marmot from the endangered species list. The third recovery plan identified specific objectives for the captive population, while maintaining the wild target population sizes first established in the 1994 plan.

Objectives for the captive population included:

- Maintain a captive population of at least 125–150 marmots, with positive demographic rates, by 2020.
- Maintain at least 95% of the existing genetic variability within the global population, until 2020.
- Maximize wild breeding potential by providing solitary wild females with captive-bred potential mates when necessary.
- Restore the wild population to a minimum of 400-600 individuals dispersed in three meta-populations by 2020.

<u>Successes and Challenges</u>:
The captive population target was met by 2005. Unfortunately, because of declining funding levels, the captive program has been cut back and the size of the captive population has declined each year since 2008. There are now just two facilities that are used for breeding. Until the present, the captive genetic targets of maintaining at least 95% of the existing genetic variability have been met.

Since the inception of the captive program, over 400 captive-bred marmots have been released back to the wild. Survival and reproduction of captive-born individuals helped to re-establish a free-ranging southern meta-population consisting of over 90% wild-born individuals. Due to excellent reproduction at the wild colony on Mount Washington, wild marmot translocations were tested as well as alternate release techniques for captive-born marmots.

The 2017 recovery planning process will review the results up to 2016 with a focus on answering two questions:

1) Is the recovery in the southern meta-population (Nanaimo Lakes region) sustainable without additional releases?
2) Is there evidence that the releases in the northern meta-populations are showing enough survival to justify continuing with releases and translocations?

Recent History of (and Recovery Efforts for) the Wild Population in the Regions of Nanaimo Lakes, Forbidden Plateau, and Western Strathcona

Presented by Cheyney Jackson

Nanaimo Lakes Population

The Nanaimo Lakes region sits west of Nanaimo, north of Lake Cowichan, east of Alberni Inlet and Qualicum Beach.

In 2003, there were 21 marmots distributed on just four mountains: Heather Mountain, Marmot Mountain, P Mountain and Mount Moriarty. Between 2003 and 2011, 157 captive-bred marmots were released to 16 mountains using the standard release methods described by Jackson (2012). Release groups varied in size from 1-9 marmots, with supplemented colonies receiving between 2-17 captive-bred marmots in total.

Captive-bred marmots showed poor survival in their first wild hibernation (Jackson 2012), and lower annual survival than wild-born marmots (Aaltonen et al. 2009; Jackson 2012). Only a single, breeding-aged female successfully weaned pups in the spring after her first wild hibernation. We suspected that poor initial reproduction was a consequence of the physical demands of wild hibernation. Marmots that survived their first wild hibernation were found to survive as well as wild-born marmots for subsequent hibernations (Jackson 2012), and appeared to reproduce at similar levels to wild-born marmots. By 2011 the population had increased in size to ~150 marmots, and there was strong reproduction by wild-born marmots and captive-bred marmots that had become established in the wild.

In 2008, 2009, and 2011-2013, the population produced a greater number of pups than the number of documented mortalities in those years, yielding a positive growth rate. After 2011, there was no further supplementation of captive-bred marmots to the region, and by 2014, wild-born marmots comprised ~98% of the Nanaimo Lakes population.

The main causes of mortality where transmitters were recovered or pinned to a burrow included predation (53%), hibernation (17%, mostly newly released captive-bred marmots), and suspected predation (5%, based on timing of the mortality). An additional 25% of mortalities were not recovered with enough sign to infer the cause, but it is believed that the vast majority of those mortalities were also caused by predation.

Despite very positive results in 2011-2013, the field season of 2014 recorded much smaller counts of untagged yearlings and adults than was expected based on previous years. There was also very low reproduction (16 pups compared to >60 pups in 2012 and 2013), possibly as a consequence of mortality in the previous year that removed breeding-aged adults. There was much greater uncertainty in these estimates compared to those in previous years, largely because of unusual drought conditions that may have changed marmot behavior and/or habitat use, and an overall project focus on work conducted outside this region.

Regional population counts from 2007-2014 used a combination of radiotelemetry detections and visual observation. In 2014, the “low” count included telemetered marmots that were detected alive that year and not detected on mortality signal, as well as untagged marmots that were observed and/or heard over the course of the field season. The “high” count also included telemetered marmots aged ≤10 years not detected in 2014 but detected alive in 2012-2013, and untagged marmots that were believed to be additional individuals, but could theoretically have been included in the low count.

At the end of 2014, the Nanaimo Lakes population low-high counts included 100-130 marmots.

Forbidden Plateau and Western Strathcona Populations

The Forbidden Plateau population is located almost entirely within Strathcona Provincial Park, and sits on the east side of Buttle Lake, south of Campbell River, north of Great Central Lake, and west of (and including) Mount Washington ski hill. There has been some degree of marmot activity on Mt. Washington since the 1940s, but the last sighting in the region at a site other than Mt. Washington was in 1981. In 2003, the Mt. Washington colony included ~10 marmots.

The Western Strathcona population is located on the west side and south end of Buttle Lake, south of Gold River and north of Great Central Lake. In 2003, there were ~10 marmots living at a single colony (Mt. Washington ski hill) in the Forbidden Plateau region. The last known wild marmot sighting in the Western Strathcona region occurred in 1995, near the Myra Falls mine at the south end of Buttle Lake.

Between 2003 and 2011, 41 captive-bred marmots were released to five mountains in Forbidden Plateau, and from 2007-2011, 106 captive-bred marmots were released to six mountains in Western Strathcona. These releases were conducted using standard methods described by Jackson (2012). Marmots in both regions recorded poor overwinter survival in their first wild hibernation, and no breeding-aged females successfully weaned pups in their first spring in the wild. As with the captive-bred marmots released in the Nanaimo Lakes region, we suspected this was a consequence of the physical toll of that first wild hibernation. However, reproduction remained poor in these regions, even when pairs or small groups were known to have survived to spring. We attributed this to predation, which reduced pairs and groups to solitary marmots or eliminated fledgling colonies entirely.

In the winter of 2010-11, there were extremely heavy snow loads on Vancouver Island, and very limited spring food sources available to marmots. On Mt. Washington, several marmots emerged from hibernation and descended to areas at lower elevations with less snow. These marmots were seen close to the Strathcona Parkway, the main road connecting Mt. Washington Alpine Resort to the highway, which put them at risk of injury or mortality from vehicle traffic. In an attempt to attract marmots back to appropriate habitat, we installed spring feeders filled with Mazuri® leaf-eater biscuits at several hibernacula. That summer, there was very strong reproduction on Mt. Washington, although it was not clear whether or not this was related to food supplementation. There was less snow in the springs of 2012-2014, but we expanded the supplemental feeding program beyond Mt. Washington to include select sites in Forbidden Plateau and Western Strathcona. The hope was that supplemental feeding would improve maternal condition to increase the likelihood of successfully weaning a litter, although management activities and other confounding factors precluded the statistical analysis of these data.

In 2012, we initiated translocation trials to determine whether captive-bred marmots with no wild experience (“direct-released” or “facility”), some wild experience (“pre-conditioned”), or wild-born marmots with all wild experience (“wild-born”) best survived and reproduced in Strathcona Provincial Park. “Direct-released” marmots (2012) spent one hibernation at the Mount Washington facility prior to their release, whereas “facility” marmots (2013 and 2014) were moved to the Mt. Washington facility just two months before their release. All pre-conditioned marmots (2012-14) were released to the Mt. Washington colony a year before their translocation to another colony, and all wild-born marmots (2012-14) were born at Mt. Washington and translocated at ≥1 year of age. The prediction, based on survival data from previous releases, was that resources would be used more effectively by moving marmots into Strathcona only after they had survived a hibernation in the wild.

Between 2012 and 2014, four “facility”, four “pre-conditioned” and eight wild-born marmots were released to two mountains in Forbidden Plateau region. An additional 38 captive-bred marmots were released to Mt. Washington but not translocated into Strathcona Provincial Park, either because they died within the first year or because they could not be re-trapped. Eleven “facility”, 17 “direct-released”, 20 “pre-conditioned”, and 25” wild-born” marmots were released to seven mountains in the Western Strathcona region. The translocation trials are ongoing, and data are still being collected for analysis.

In 2014, there was reproduction on Mt. Washington, as expected, but also at three colonies in Western Strathcona and two colonies in Forbidden Plateau. At four of these sites, these litters were the first ever recorded. At the end of 2014, the Forbidden Plateau and Western Strathcona low-high counts included 60-70 and 50-60 marmots in each region, respectively. It is important to note that >70% of the marmots in the Forbidden Plateau region were located on Mt. Washington.

An Overview of the Vancouver Island Marmot Captive Population

Presented by Malcolm McAdie

History and Background

Between 1984 and 2003 it is estimated that the abundance of marmots in the wild dropped from approximately 300 to 350 to a low of fewer than 30. In 1996, six wild Vancouver Island marmots were translocated to Mount McQuillan in an effort to begin re-establishing marmots at historical sites. Four of the six translocated marmots remained at the release site, where they occupied old burrows and excavated new ones. They hibernated communally but died at some point during their first hibernation.

The 2000 update of the National Recovery Plan for the VIM noted that the population was continuing to decline and reiterated population goals established in the 1994 plan, with a population target of 400-600 animals dispersed in three discrete areas of Vancouver Island. It also identified that there was sufficient natural habitat remaining on Vancouver Island to support these population goals. However, it concluded that the number of wild marmots was so low that few animals existed for translocation, reintroduction, or other management activities and that it was unlikely that wild populations had the capacity to rebound on their own. Thus the 2000 Plan recommended captive breeding and reintroduction as presenting the only chance of increasing populations within a reasonable period of time and minimizing the risk of extinction.

Two Canadian zoos, the Toronto Zoo and the Calgary Zoo, began establishing captive colonies of Vancouver Island marmots in 1997 and 1998 respectively. It was felt that these zoo-based programs could provide security against the risk of a catastrophic event in the wild, provide a long-term reservoir of genetic material, allow for the development of appropriate husbandry techniques, support directed research, and provide animals for reintroduction. An additional captive colony was established at the Mountain View Conservation and Breeding Centre, Langley, British Columbia in May 2000. In 2001 a dedicated Vancouver Island facility was opened at Mount Washington to further support captive breeding efforts, to provide pre-release exposure to natural conditions (elevation, food, weather, etc.), to simplify the logistics of reintroduction (timing, quarantine, etc.) and to provide additional marmots for release. Appendix I details the population sizes at each facility over time.

Principles of Captive Management

Captive management of marmots requires consideration of many factors including: health and disease, hibernation, reproduction, genetics, diet, nest box design, substrate, group composition, enrichment and enclosure design.

Health management. With respect to health management, the approach taken is that of disease prevention. The health management strategy is to limit access to the captive colonies, with no public display, effectively putting the animals in a permanent quarantine situation. Strict adherence to quarantine procedures is enforced, with disinfectant footbaths, dedicated clothing and masks and gloves worn by caretakers. Insofar as possible, exposure to other species is limited. Distributing marmots over multiple facilities minimizes the risk of a catastrophic disease outbreak. Marmots moving between facilities or between wild and captive are placed in an additional quarantine situation. Regular health monitoring and evaluation and post mortem examination of all mortalities is standard.

Hibernation. Providing appropriate conditions for hibernation requires strict control of ambient temperatures within a range of 5–7^{o}C. Hibernating animals are treated as immunocompromised and strict adherence to sanitation is required. Animals are weighed periodically throughout hibernation, and additional monitoring is done with closed circuit television cameras, temperature loggers and other remote devices to limit disturbance. Between 1997 and 2014 (17 winters) there were a total of 1551 individual marmot hibernations in captivity with a success rate of 98.4%.

Management of breeding. Each year the studbook keeper recommends pairings, using mean kinship values to maximize genetic diversity, and inbreeding coefficients to avoid inbreeding. New breeding pairs are established prior to or during hibernation.

Preparation for release. Candidates for release are identified a year prior to their actual release. Prior to their release they are transferred to the facility at Mount Washington where they undergo a quarantine period of 30 days or more, receive a health evaluation, and are implanted with abdominal transmitters and marked with metal ear tags.

Research. Semen collection from the captive males is being collected for cryopreservation studies. The effect of hormone treatment (eCG/LH alone) is being studied, and studies on safe and effective contraception methods for the captive population are ongoing.

Captive/Release Numbers (see Appendix I)

Between 1997 and 2004, 55 wild marmots were brought into captivity, consisting of 30 males, 24 females, and 1 unknown. Adults, two year olds, yearlings and pups were included among these animals, which came from both logged and natural sites. Of the wild captures, one animal is still alive today. Thirty-six of the 55 animals (65.5%) bred at least once in captivity. Six animals did not breed even after a prolonged period in captivity (up to 12 years) and of the remaining 13 animals that did not breed, seven died of iatrogenic/management causes, two were released before they had an opportunity to breed, one was euthanized due to a congenital heart problem, and three died prematurely due to infections.

During the period from 2000 to 2014, 551 marmots were weaned in captivity, with the highest birth rates between 2005 and 2011. Between 2003 and 2014, 453 captive marmots were released back into the wild. (August 2015 update: 556 marmots weaned in captivity, 477 captive marmots released to the wild. 469 captive-born and 8 wild-born marmots held in captivity).

At the time of the March 2015 meeting, the captive population stood at 55 (28 females and 27 males) in two facilities. Toronto Zoo had 15 marmots, with six breeding pairs. Four or five marmots from Toronto Zoo were scheduled for release in 2015. Calgary Zoo had 40 marmots with 7 breeding pairs. Twenty-two marmots from Calgary Zoo were scheduled for release in 2015. The Mountain View Wildlife Conservation facility was phased out of the breeding program in 2014. (*August 2015 update: The current population stands at 46 (16 males, 15 females and 15 currently unsexed pups*). At the end of this active season 32 marmots will be at the Calgary Zoo and 14 marmots at the Toronto Zoo. Thirteen marmots (all from the Calgary Zoo, all born in 2015) are scheduled for release in 2016.

Summary

In summary, 2015 is the 18th year of the captive program, and the 13th year of captive releases. 2014 was the 15th consecutive year of successful breeding (2000-2014). At the time of the March meeting the program had produced a total of 162 weaned litters and 551 weaned pups, an average of 10 pups for every one of the original wild captures. For every original wild capture, 8.24 captive marmots have been released. Of the 606 marmots maintained historically at some point in captivity (55 wild captures + 551 captive born), 453 (75%) have been released to the wild. Eight of the animals released were the original wild captures, and 445 were captive born.

From 1997 to 2014 the average litter size was 3.4. Annual breeding success of pairs has ranged from 23-50%, with an overall average of 41%. Since 1997, 100 captive animals have died. Male lifespan is approximately 9 years, while female lifespan is approximately 11-12 years.

Due to diminishing resources the captive population has been intentionally downsized since 2008. The current captive population of 46 individuals is insufficient to maintain the genetic diversity originally captured from the wild, and in 2016 20% of the breeding animals will be at or exceed average life expectancy. Maintaining marmots at only two facilities reduces the flexibility in the event of a catastrophic outbreak. Plans for the future include a release in 2015, a smaller release in 2016, and 2017, with limited breeding in 2016.

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Section 3
Plenary Discussion: Issue Identification

Plenary Discussion: Issue Identification

Issues

A thorough understanding of factors that impact the viability of Vancouver Island marmot meta-populations is critical in identifying and evaluating management strategies to address threats and promote viability. Recovery plans in 1994 and 2000 (Janz *et al*., 1994; Janz *et al*., 2000) had postulated a number of threats, including environmental stochasticity, population fragmentation and resulting small isolated populations, and predation. The 2008 Recovery Strategy for the Vancouver Island marmot (Vancouver Island Marmot Recovery Team, 2008) cited predation, post-logging succession in cutblocks, and vegetation changes related to climate change as additional major threats. Disease was identified as a potential threat in the 2008 strategy, but its role was unclear at that time.

A group exercise was conducted at this stakeholder-diverse workshop to bring all of these threats and issues to the attention of all participants, to provide the participants with the opportunity to highlight additional threats, and to take advantage of their diverse expertise to identify potential causal relationships that may have implications for mitigation or management.

Workshop participants were asked to brainstorm challenges to Vancouver Island marmot conservation by writing each issue on a card and placing it on the wall. Next the participants grouped related issues together, resulting in three primary focus areas:

1. **Population Status and Management** (including: better/robust vital rate estimates; custom built model(s) to reflect marmot life history population dynamics; we still don’t really understand population growth rate in the South in the absence of reintroductions; Allee effects; are all colonies created equal, is there a source/sink effect; probability of detection estimate; disease transfer by people and other animals; changes in epidemiology with increasing population, increasing contact, climate change; how to monitor cheaply and over the long-term; have the reasons for the initial decline been identified and rectified?).
2. **Environment and Ecology** (including: changes in forage, species, older seral stages; habitat suitability/adaptability; climate change, increasing/decreasing snowpack; food availability - impacts of drought, increased precipitation; changes in carrying capacity with climate change associated with increased awake time, increased food use; elevation and colonies related to snow levels; ingrowth of alpine forests).
3. **Financial and Human Resources** (including government support; resources required to monitor and sustain wild populations; long term support; realistic ideas of recovery; inability for plan to respond quickly; who makes final decisions, where does the buck stop; too many priorities, too few crew; stakeholder involvement; increasing numbers leading to decreasing dollars and public interest).

These served as a basis for the formation of working groups for further discussion. Each working group received all of the issues that fell under its primary topic. Over the course of the next several days, working group participants were asked to develop specific problem statements for each identified issue, and to articulate specific goals, objectives, and actions that would address each problem statement. Reports from the working groups follow.

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Vancouver Island Marmot
Population and Habitat Viability Assessment Workshop
Final Report

Calgary, Canada
3-6 March 2015

Section 4
Working Group Report: Population Status

Working Group Report: Population Status

Members: Sandie Black, Dan Blumstein, John Carnio, Elizabeth Gillis, Sue Griffin, Cheyney Jackson, Tim Karels, Natasha Lloyd, Erica McClaren, Madan Oli, Tara Stephens. Malcolm McAdie joined the group for the discussion of the health risks for the population.

Background: Role of Population Management Strategies

Small populations are particularly vulnerable to stochastic processes and genetic impacts that threaten the species' long-term persistence. Specifically, small populations are at risk of severe decline or even extinction due to random fluctuations in demographic rates (demographic stochasticity) and environmental conditions (environmental variation). 'Catastrophic' events, either natural or human-related, have especially negative impacts on populations that are small. Small populations also lose genetic variation faster and at a rate that cannot be replaced through mutation – meaning that the population loses its potential to adapt to new conditions and becomes increasingly vulnerable over time to inbreeding effects. These processes can lead to reduced survival, reduced reproduction, and/or a decline in population size, making the population even more vulnerable and likely to decline further – a feedback loop known as the "extinction vortex" (Gilpin and Soulé 1986). Once underway, this process becomes more challenging to halt and reverse and can lead to population extinction.

For species such as the Vancouver Island marmot that have declined to small populations, conservation strategies should not only address the primary threats that led to this decline but also provide short-term strategies, in conjunction with longer-term strategies, to prevent extinction and promote demographic and genetic viability while these larger threats are reduced. Increasingly, various population management strategies such as translocation and *ex situ* management are being used to counteract the impacts of stochastic processes that affect population size, demography, and genetics. These techniques can maintain short-term viability and prevent imminent extinction until all threats are reduced and the population can be expanded to a more secure size. Two recently revised IUCN guidelines – one for reintroduction and conservation translocation (IUCN 2013) and the second for *ex situ* management for species conservation (IUCN 2014) – provide a decision making process for considering such options. The Vancouver Island marmot recovery program already incorporates such methods into its conservation and recovery activities.

Working Group Overview

The Population Status Working Group focused on threats to the population size of the Vancouver Island marmot as well as threats resulting from an incomplete understanding of population dynamics. A plenary session in which all the workshop attendees participated was the forum from which the threats to population viability were identified, discussed, and grouped together under the "Population Status" theme. The Population Status Working Group organized the threats associated with population viability identified during the plenary session into the following categories: 1) the failure to fully utilize and analyze the field data already available for Vancouver Island marmots; 2) an inability to detect changes in population size and vital rates in the wild population and an incomplete understanding as to what drives changes in population size (both past and present); 3) the potential for health issues to impact population size; 4) the potential for future loss of genetic diversity within the wild and captive populations to contribute to population declines; and 5) the potential for an Allee effect to greatly accelerate population declines at low population sizes.

For each of the categories listed above, the working group first discussed the threat and developed a problem statement. The group then identified factors that might contribute to the threat and assessed the potential impacts of the threat to Vancouver Island marmot populations. Each relationship between an identified threat and a contributing factor or potential impact was also evaluated to see whether it was supported by data, or if the relationship was assumed.

Next, for each threat, the working group identified goals to reduce the threat (and address the problem statement) and specific objectives for each goal. For each threat, the working group identified the actions required to meet each objective. Time limitations precluded the working group from identifying the detailed actions required for all objectives for all threats.

Issue: Fully Utilizing and Analyzing the Field Data Collected

The group acknowledged that there has been a large amount of field data collected on Vancouver Island marmots. Over the past few decades, however, data collection methods have varied, different personnel and projects have been involved, and there have been different data entry templates used. As a result, the data have not always been easily accessible to be used in data analysis. This has precluded a more advanced analysis of much of the data that has been collected, for example rigorous population estimates with confidence intervals, and spatially explicit population modeling (Fig. 1). The group felt that some of the data needed to answer questions surrounding population dynamics of marmots already may have been collected – it simply needs to be made more accessible for those with the appropriate expertise to analyze rigorously. Failing to utilize the data fully may lead to the VIM Recovery Team making decisions without all the available information.

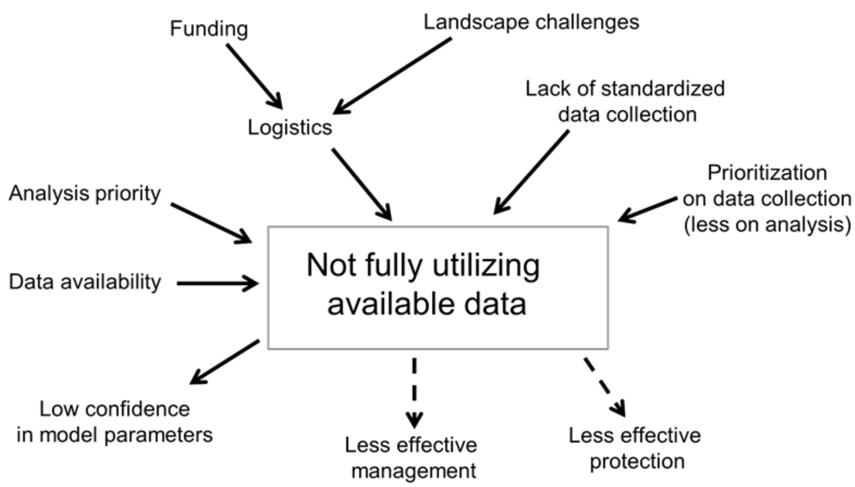

Figure 1. Potential factors that have led to not fully utilizing the data already available for Vancouver Island marmots and the impacts this may have for Vancouver Island marmot management decisions. Solid arrows represent relationships for which there are data to support a relationship. Dashed arrows represent relationships that are assumed to exist.

PROBLEM STATEMENT

The data collected on Vancouver Island marmots have not been fully utilized because they are in different formats (some still in field books), the data entry formats have not been consistent, and not all data are easily accessible from one location. As a result, the analyses used when making management decisions and parameterizing models could be more rigorous than what is currently used. In addition, it is currently difficult to identify data gaps and future data priorities because the full potential of current data has not yet been realized.

GOAL: Ensure all data are available in an accessible and usable form.

> ***Objective 1*: *Create and fill a database manager position***. *At minimum, this will be a 4-month full-time position, although it is strongly suspected that a longer term may become necessary. Also, it should be expected that some ongoing part-time maintenance will be required in order to keep the database functional and current.*

Action: Hire someone based on the objectives and actions outlined below. This individual should be experienced with database development, and ideally, would also possess a working knowledge of PMx, population ecology, population modeling.

Responsibility: Marmot Recovery Foundation (MRF), BC Ministry of Forests, Lands, and Natural Resource Operations (FLNRO). During its development, we recommend consultation with Tara Stephens at the Calgary Zoo, zoo registrars, and others who will use the database.
Timeline: September 1, 2015
Resources Required: At a minimum 4-6 months ($20,000 - $40,000). There is some potential that this individual could continue on to conduct some of the analyses recommended by this working group later in the document. However, it is most important that the database manager has extensive experience in database development, ideally for a similar species or research project.
Measure of Success: The position is filled.

Objective 2: Consolidate all past and current raw data.

Action: Identify which data are not currently stored by the Marmot Recovery Team and survey all past researchers and advisors to see if the missing data are available.

Responsibility: Cheyney Jackson, with advice from Don Doyle to identify past projects of which Cheyney may not be aware.
Timeline: April 30, 2015
Measure of Success: All data have been located, past researchers have been contacted, and any missing data have been submitted to the Recovery Team.

Objective 3: Create and populate the database.

Action: Develop initial relational database structure in consultation with end users, and develop required tables and relationships. Enter in all data available in electronic form or hard copy (may need to prioritize data entry based on data analysis priorities).

Responsibility: Database manager with input from Cheyney Jackson. During its development, we recommend consultation with Tara Stephens at the Calgary Zoo, zoo registrars, and others who will use the database.
Timeline: November 1, 2015

Objective 4: Debug database.

Action: Run queries, enter data in forms, revise structure, and validate data.

Responsibility: Database manager with input from Cheyney Jackson and Kathy Traylor-Holzer (CBSG).
Timeline: December 1, 2015

Objective 5: Develop a manual for use of database and system to archive data.

Action: Develop metadata and database procedures manual.

Responsibility: Database manager with input from Cheyney Jackson.
Timeline: December 31, 2015

Action: Create and document archiving procedures.

Responsibility: Database manager with input from Cheyney Jackson.
Timeline: December 31, 2015

Objective 6: Ensure that data from all future projects are incorporated into the database.

Action: Develop policy that ensures ALL data collected on VI marmots is stored in the database.

Responsibility: Liz Gillis is willing to create a draft in consultation with MRF and BC FLNRO, Dan Blumstein is willing to consult

Timeline: May 1, 2016

Objective 7: Ensure that data are accessible to other researchers and can also be tracked.

Action: Develop a data use policy.

Responsibility: Liz Gillis is willing to draft in consultation with MRF and BC FLNRO, Dan Blumstein is willing to consult

Timeline: May 1, 2016

Relative impact of success on goal of population viability: HIGH, by providing managers with the ability to access all data and gain a more comprehensive picture of past, present, and future demographic trends.

Issue: Detecting Changes in Population Size and Vital Rates and Understanding What Drives Changes in Population Size (Past and Currently)

Participants at the workshop identified two main problems related to population status that needed to be addressed: 1) an inability to quickly detect changes in population size and vital rates; and 2) a general lack of understanding of the processes that drive changes in population size. Initially, the working group mapped and evaluated these problems separately (see Figs. 2 and 3). However, when the group began to develop actions to address these issues, it became clear that the potential consequences for each problem were similar (the potential for misdirected resources and a slow or ineffective management response) and the recommendations would also be similar (namely, to hire someone with the dedicated time and statistical experience to tackle more complex analyses and better inform the management processes). Therefore, it was decided to amalgamate the two issues into a single problem statement and a set of actions and measures of success that were applicable to both. The group also agreed that if the individual hired to conduct the statistical analyses possessed the necessary set of skills, he or she could first be hired as the database manager to prepare the data for analysis.

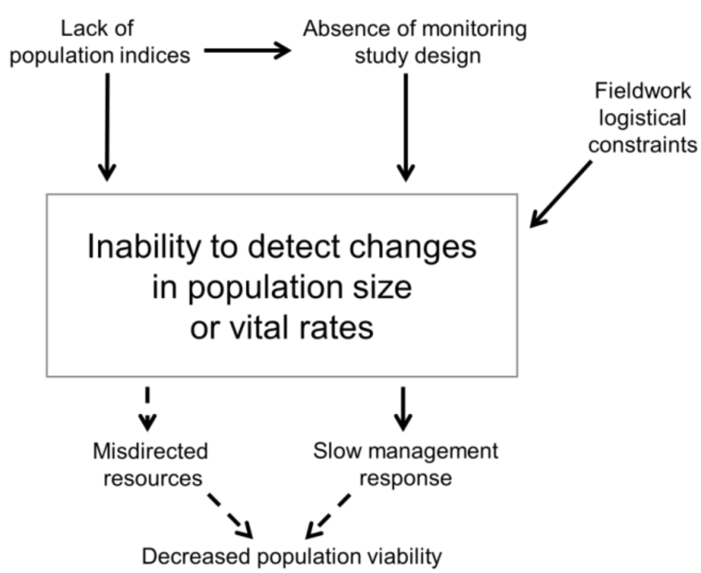

Figure 2. Factors that may have contributed to an inability to detect changes in the population size and vital rates for Vancouver Island marmots, and the impact this may have for species management. Solid arrows represent relationships for which there are data to support a relationship. Dashed arrows represent relationships that are assumed to exist.

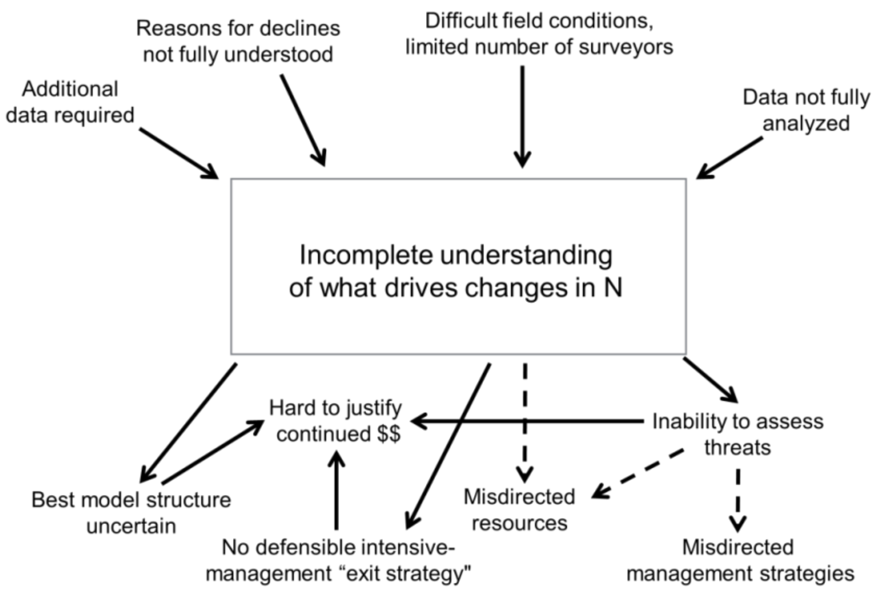

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Figure 3. Factors that may have contributed to an incomplete understanding of what drives changes in the population size and vital rates for Vancouver Island marmots, and the impact this may have for management of the species. Solid arrows represent relationships for which there are data to support a relationship. Dashed arrows represent relationships that are assumed to exist.

When managing an endangered species in the wild, especially one with a small population size like the Vancouver Island marmot, it is important to be able to detect and respond to fine-scale changes in population size or vital rates. The present inability to detect these changes was seen as a function of several factors, including monitoring that may have been designed for too coarse a scale, a lack of population indices in general, and the many logistical constraints introduced through trying to study an endangered species under intensive management in remote, subalpine locations. The group expressed concern that late detection of any downward trends would delay critical management responses or could contribute to a general misdirection of resources that could decrease, or even just fail to improve, population viability for the Vancouver Island marmot.

The IUCN SSC guidelines for *ex situ* management and for reintroductions recommend that all reintroduction projects analyze and ideally address the causes of primary threats before reintroducing any animals to the wild. Field data provided strong evidence that predation was the proximate cause of marmot decline; however, landscape-level predator-prey dynamics were not fully understood. Reintroductions were initiated as soon as marmots that were surplus to the captive program became available for release. Although the recovery project continues to emphasize data collection and monitoring, there are obvious logistical constraints on data collection as a consequence of challenging field conditions and a limited number of field crew. Moreover, many datasets have not yet been thoroughly analyzed.

The working group felt that it would be extremely valuable for managers to have a more comprehensive understanding of the processes that drive changes in population size. This includes an understanding of the processes that were influential in earlier stages of the recovery effort and, if different, those that are driving current demographic changes. With only an incomplete understanding of these relationships, managers risk inefficient allocation of resources and may struggle to accurately assess threats. A better understanding of these drivers would enable managers to create a science-based, model-informed exit strategy for intensive management of the species. Such a strategy, if available, would also provide a stronger justification to funding bodies for continuing financial contributions

PROBLEM STATEMENT

It is not always possible to detect change in population size and vital rates, especially small changes or those that occur over a short period of time, and the underlying factors that affect population size (current and past) are not fully understood. This lack of understanding impedes the ability of managers to apply the most effective management options for species' recovery. In addition, the inability to quickly detect negative demographic changes could jeopardize the wild population because of a time lag between the start of a downturn, its detection, and initiation of a management response.

***GOAL*: *To be able to better detect changes in N (long-term) and vital rates and respond accordingly*.**

O*bjective 1: Create and fill a population ecologist position.* The VI marmot Population Ecologist would be hired to accomplish a prioritized set of tasks, including:

1. Analyze existing data to estimate population size and evaluate vital rates as a function of intrinsic and extrinsic factors such as climate, forestry, predators, and food supply. (2 years, if data are accessible and usable).
2. Develop and test hypotheses for potential drivers of N. Use information from hypothesis testing to refine long-term monitoring protocols and management actions. (additional 4-5 years).
3. Develop indices for estimating population size and vital rates during long-term monitoring. Conduct field research to test potential indices for population size and vital rate. (4-5 years, simultaneously with task #2).
4. Identify data gaps and future research questions that need addressing. (throughout the process).

<u>Action:</u> Acquire funding.

Resources needed: The anticipated cost for the position itself is a minimum of $55K/year, with additional costs for data collection and field support. It is anticipated that this position would need to be filled for at least 6-7 years in order to accomplish all described tasks. There were some suggestions that this could be a post-doctoral position, in which case the affiliated university would be the source of additional costs.

Responsibility: Marmot Recovery Foundation.

Measure of Success: There is funding available for this position.

<u>Action:</u> Develop detailed description for posting, including specific research questions that must be answered.

Measures of Success: The job posting is complete and ready for posting.

<u>Action:</u> Fill the VIM Population Ecologist Position. Determine and acquire the field support needed for this position (field crew, equipment, etc.).

Measure of Success: The job posting has been filled, and supporting field crew hired.

<u>Action:</u> Organize a subgroup of the VI Marmot Recovery Team (with appropriate expertise) to work with the Population Ecologist in evaluating various population and vital rate indices used for other mammals and selecting the indices that might work well for Vancouver Island marmots.

Responsibility: Cheyney Jackson and Chair of the VI Marmot Recovery Team

Timeline: Subgroup formed during the next VI Marmot Recovery Team Meeting (by March 31, 2015). (Note: this was not raised at the March 26, 2015 Recovery Team meeting because of higher priorities in preparing for the 2015 field season.)

Measures of Success: The Population Indices subgroup has been formed and monitoring options identified.

Objective 2: Create a management plan that details when and how to respond to changes in population size and/or vital rates.

<u>Action</u>**:** Determine important thresholds for changes in population size or vital rates that should trigger a management response.

<u>Action</u>**:** Determine the appropriate actions to take in response to changes in population size and/or vital rates.
(*Comment*: This objective was not addressed directly within our working group; however, it was suggested that this should be a priority to address in the future. In order to determine the thresholds for response, there must be first be robust estimates for population size and vital rates that can be incorporated into models of population viability. This will be achieved through the Actions listed for Objective 1. Once the population size and vital rate estimates have been created and drivers of population size are better understood, it will be easier to explore various management response scenarios and to conduct a cost-benefit analysis for each).

<u>Likelihood of success</u> at achieving goal: HIGH, if funding can be obtained. In the short-term, it will give managers a greater degree of confidence in the true status of the Vancouver Island marmot. This means that they will have a better understanding of vital rates and how they have changed over time, as well as recent population trends and current population size. Managers will also understand the drivers of population size, and will have developed long-term monitoring protocols using indices that have been validated in the field.

If funding cannot be obtained, it is possible that these objectives could be partially addressed using existing resources. For instance, the Recovery Team's Population Indices subgroup could elicit advice from experts to help them design the study, and it may be possible that FLNRO statisticians in Victoria could assist with analysis assistance. However, there were so many important statistical questions raised by this working group that progress without a designated population ecologist would be much slower and results likely less comprehensive.

<u>Relative impact</u> of success on population viability: HIGH, providing management actions are able to influence population size and vital rates, once the drivers are known.

Issue: Potential Threats to Marmot Health

The group's primary focus was on the potential impacts of disease, and several ways were identified in which disease may be introduced and spread through wild marmot populations, including through the translocations of animals with infection, the introduction of novel diseases and vectors by non-native species or as animal distributions shift with changes in climate, and the transmission from other wild and domestic animal species (Fig. 4). The susceptibility of marmots to disease may increase if there is low genetic diversity within the population. The impacts of disease may include increased marmot mortality, reduced reproduction, increased risk to other species in alpine ecosystems from marmots, and public concerns around disease transfer (i.e., sylvatic plague). The threat posed by disease will also be influenced by the number of populations on the landscape and the ability of disease to be transmitted between populations.

A topic that was raised during the working group's discussion was whether or not captive-born marmots are more susceptible to disease once released because they spend their captive life being protected from pathogens, including those commonly found in the environment in which wild marmots live. Time constraints prevented the group from discussing the likelihood and implications of this possible threat in any depth. This is a potential factor, however, that the VIM Captive Management Group and the Recovery Team may want to consider in the future.

Post-workshop comments (M. McAdie): Although the potential impacts of infectious disease are certainly important to consider, it is also important to think about other components that could influence marmot health. Genetic health and the association between marmot health and management practices are two components that were raised briefly during Working Group discussions, but only minimally, and they should be evaluated further.

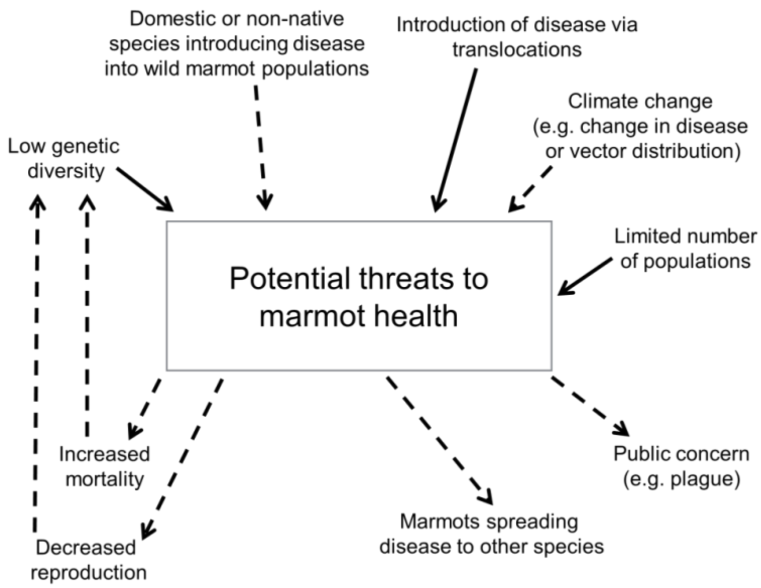

Figure 4. Factors that may contribute to diseases in Vancouver Island marmots and the potential impact of these diseases to wild populations. Solid arrows represent relationships for which there are data to support the relationship, and dotted arrows represent relationships where there are data to support the relation from species other than marmots. Dashed arrows represent relationships that are assumed to exist.

PROBLEM STATEMENT

Disease may pose a risk to the viability of wild and captive marmot populations. Although the risk of disease is real, the effects and frequency of disease is unpredictable. It is therefore impossible to accurately model the potential impact of disease on marmot populations at this time.

GOAL: Continue efforts to minimize and mitigate disease risk to Vancouver Island marmots.

Objective 1: Avoid introducing disease into the wild populations via releases of captive-bred marmots.

Action: Continue to quarantine captive-bred marmots prior to translocation to wild populations.

Responsibility: Zoos, VIM Captive Management Group, VIM Veterinarian on an ongoing basis.

Objective 2: Avoid introducing diseases into local wild populations via translocations from other wild populations.

Action: Continue to quarantine wild marmots prior to translocation to other wild populations.

Responsibility: VIM Veterinarian, on an ongoing basis.

Objective 3: Continue to identify existing diseases in captive and wild populations.

Action: Continue doing necropsies on animals found dead in captive and wild populations.

Responsibility: VIM Veterinarian, on an ongoing basis.

Objective 4: Ensure Captive Management Group and Recovery Team are kept aware of any novel disease and introduction of non-native vectors onto Vancouver Island.

Action: Review literature regularly.

Responsibility: VIM Veterinarian, on an ongoing basis.

Objective 5: Minimize disease exposure to captive population.

Action: Continue to use quarantine procedures at facilities that house the captive population.

Responsibility: Zoos, VIM Captive Management Group

Likelihood of success at preventing disease transmission during the captive care and movement of marmots. HIGH. There are many measures already in place that were designed to address this threat, and if protocols are followed, they should continue to be successful.

Likelihood of success at preventing disease transmission from other sources: UNKNOWN

Relative impact of success on population viability: LOW (at present levels of disease)

Issue: Loss of Genetic Diversity

Several factors may contribute to the loss of genetic diversity in wild marmot populations. For example, population fragmentation and barriers to dispersal lead to a small population size, which in turn leads to inbreeding and loss of genetic diversity. Disease may also select for specific alleles, which will also decrease genetic diversity. In turn, loss of genetic diversity can lead to reduced capacity to adapt, decreased survival, increased disease susceptibility, and decreased reproductive success (Fig. 5). These impacts may threaten the viability of Vancouver Island marmot populations, but we do not really know the degree to which they are important for this particular species. The Vancouver Island marmot is an isolated island endemic that must have persisted through previous bottlenecks in population size. It is possible that it is less sensitive to lower levels of genetic diversity than other, less isolated species, and that lethal and deleterious alleles have already been purged from the existing population. And yet, individuals with higher heterozygosity can have higher fitness than those with lower heterozygosity even in the absence of deleterious alleles. Because we do not understand the impact of a loss of genetic diversity on population viability for the Vancouver Island marmot, and because a loss of genetic diversity cannot be reversed if it is later found to be important, it is treated as a confirmed threat to population viability.

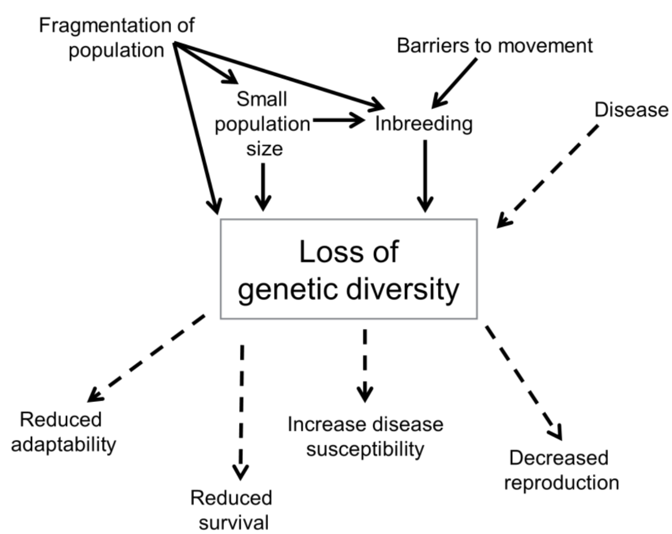

Figure 5. Factors that may have contributed to a loss of genetic diversity in Vancouver Island marmots, and the potential impact of this loss to wild populations. Solid arrows represent relationships for which there is data to support the relationship. Dashed arrows represent relationships that are assumed to exist.

PROBLEM STATEMENT

Although it is possible that deleterious alleles have been purged from the population when the population size became very low, there may still be deleterious alleles in the population. In addition, as outlined in Figure 5, a loss of genetic diversity can cause the population to become more susceptible to future environmental change.

GOAL: Minimize loss of genetic diversity in Vancouver Island marmot populations (wild and captive)

Objective 1: Maintain gene flow among wild populations.

<u>Action:</u> Create model to identify how often and how many individuals to achieve the goal.

Responsibility: Zoos and CBSG by the Spring of 2017. Models to be updated every 3 years.

<u>Action:</u> Translocate marmots among populations as recommended by model results.

Responsibility: VI Marmot Recovery Team and/or BC Ministry of Forests, Lands, and Natural Resource Operations (FLNRO).

Objective 2: Maximize genetic diversity within captive population given its current size.

<u>Action:</u> Continue to use mean kinship to manage the genetics of the captive population, and maintain an active studbook.

Responsibility: VIM Captive Management Group on a continuing basis.

<u>Action:</u> Continue to allow breeding in the captive population.

Responsibility: VIM Captive Management Group. A decision about whether or not to breed in 2016 must be made by the Captive Management Group, Marmot Recovery Foundation, and Marmot Recovery Team before Spring 2016.
[Update: The decision regarding whether or not to allow marmots to breed in 2016 was largely reliant upon the funding required to release surplus animals. This funding has now been secured, and it has been agreed that breeding in 2016 can proceed.]

<u>Action:</u> Maintain as large a captive population as possible.

Responsibility: VIM Captive Management Group until population size and distribution goals have been achieved in the wild.

Objective 3: Maintain gene flow between captive and wild populations.

<u>Action:</u> Conduct population viability analysis modeling to determine the impact of removal of male marmots from one wild population in order to genetically augment the captive population or to facilitate gene flow between wild populations.

Responsibility: This scenario was not included in this PVA exercise; however, it could be included in a future modeling project.

<u>Action:</u> Conduct research to determine if and how marmots can be artificially inseminated.

Responsibility: VIM Captive Management Group and zoos while there is still a captive population

<u>Action:</u> Continue to release captive-born marmots into the wild populations as needed for demographic and genetic reasons.

Responsibility: VIM Recovery Team, with VIM Captive Management Group providing marmots.

Objective 4: Avoid low population sizes in the wild and expand wild population distribution to additional historical and extra-limital sites.

Action: Continue to release marmots to augment northern populations and establish additional sites in the northern region.

Responsibility: VIM Recovery Team, with VIM Captive Management Group providing captive born marmots when necessary

Action: Conduct research to determine if and how marmots can be artificially inseminated.

Responsibility: VIM Captive Management Group and zoos while there is still a captive population.

Objective 5: Store gametes of captive and potentially wild marmots to provide a future gene bank if needed.

Action: Obtain and store gametes from captive marmots.

Responsibility: VIM Captive Management Group, if it has not already been initiated. May require research if the feasibility of gamete storage for this species is not yet known.

Likelihood of success at achieving goal: HIGH

Relative impact of success on population viability: LOW (although it may be higher over the long term).

Issue: Potential Allee Effect

An Allee effect occurs when changes in sex ratio or animal behavior cause reproductive rates to decrease and/or mortality rates increase at low population densities.

Factors contributing to an Allee effect in Vancouver Island marmots:

- Low local population size (supported by data for VIM)
- Low landscape level population size (supported by data for other species)

Note: Local and landscape population size influence each other.

Impact of Allee effect on Vancouver Island marmots (VIM):

- Increased predation (assumed)
- Decrease reproduction (assumed)

See Werner 2005 and Brashares *et al*. 2010 for more details.

Vancouver Island Marmot
Population and Habitat Viability Assessment Workshop
Final Report

Calgary, Canada
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Section 5
Working Group Report: Resources

Working Group Report: Resources

Members: Colleen Baird, Maria Franke, Jill Hockaday, Viki Jackson, Malcolm McAdie, Axel Moehrenschlager, Sean Pendergast

Primary Resources: A History of the Stakeholder Partnership Model

British Columbia (BC) Government: Retains ownership and legal responsibility for the Vancouver Island marmot (VIM), listed as endangered under the BC Wildlife Act (1980) and a priority 1 Red-Listed species under the BC Conservation Framework, and has a responsibility to develop and implement a recovery plan for VIM under the Federal Species At Risk Act (SARA).

Vancouver Island Marmot Recovery Team (the Recovery Team): Formed by the BC Ministry of Environment, Lands and Parks in 1988, the Recovery Team consists of scientists and wildlife managers from government, industry, the zoo community and environmental organizations, and is responsible for producing the VIM Recovery Plans (1994, 2000) and Recovery Strategies (2008) on behalf of the BC Government. The Captive Management Group is considered to be an implementation group of the Recovery Team.

Marmot Recovery Foundation (the Foundation): Established in 1998, the Foundation is an independent registered public charity formed in partnership with government, industry, and public donors across Canada, to raise funds and implement the VIM Recovery Strategy. The Foundation coordinates with the Recovery Team to ensure annual work plans comply with VIM recovery strategy objectives and comply with the annual budgets approved by the Foundation's Board of Directors.

Landowners' Partnership (**BC Government, Island Timberlands and TimberWest):** Recognizing the imminent threat and implications of VIM extinction, the major landowners agreed to share the burden of costs and responsibilities to recover the species. An initial funding agreement of $1 million from each of the landowners over five years (1998-2002) initiated the recovery program. In 2003, a new funding agreement was structured, referred to as the Landowners' Partnership Fund (LPF), comprised of annual contributions of $133,000 from each of the three landowners for the length of time remaining in the recovery plan estimated to be required to reach the recovery goals (10 yrs). In 2008, in the midst of a global recession, the landowners were compelled to reduce their contributions to the LPF by 50% to $66,500 per year (2009-2014) and, in 2015, the LPF contributions were reduced again to $35,000 annually, as part of a Five Year Exit Strategy (2013-2017).

Fish & Wildlife Compensation Program (FWCP) (2007-2015): The FWCP has supported efforts to reintroduce VIM to Strathcona Provincial Park, specifically to the east and west sides of Buttle Lake, in response to the probable loss of connectivity of historical VIM colonies in this region associated with the flooding of Buttle Lake for hydro purposes (1958). Applications for FWCP funding are submitted and considered annually. The funding cycle for most FWCP projects is 3-5 years, but the FWCP has made the return of VIM to the Buttle Lake area a priority by supporting the reintroduction efforts for nine consecutive years.

Federal Government, Environment Canada: The Federal Government provided a $500,000 contribution to the Science Advisory Group (SAG) at the University of British Columbia in 2000 (matched by funding from TimberWest) and leveraged by the university, to broaden the scope of Vancouver Island marmot research.

Mt Washington (resort): Provided the land on which to build a dedicated marmot facility, the Tony Barrett Mt Washington Marmot Recovery Centre (TBMWMRC) and continues to contribute in-kind support for building maintenance, snow removal, security and other operational needs at the facility on an annual basis.

Captive Breeding Partners

Toronto Zoo and Calgary Zoo have been partners in the breeding, care and management of the captive population since (1997 and 1998 respectively). Their in-kind support, which has been conservatively estimated at $90,000 per year for each facility and more recently assessed at $150,000 annually per facility, ranks them as major contributors and partners in the recovery efforts.

Mountain View Conservation Society is a private breeding facility in Langley, BC that participated as a captive breeding partner from 2000-2013, at which time it concluded its marmot breeding program. All VIMs at Mountain View were transferred to the zoos or to the TBMWMRC for release.

Tony Barrett Mt Washington Marmot Recovery Centre (TBMWMRC) maintained by the Foundation, it is currently operated as a seasonal facility, to receive captive-born marmots from the zoos and prepare them for release, along with wild recruits, for translocation to wild sites. The TBMWMRC operated as a full-time breeding facility prior to from 2001-2011.

Primary Resource Issue: The financial needs to implement, monitor and assess the recovery strategy have remained consistent, while the funding levels have, and will likely continue, to decline.

IMPLICATIONS

Captive Population: The Toronto and Calgary zoos will not be able to continue to support the breeding program if there are not adequate resources in place to maintain a viable conservation program which incorporates ex situ breeding. Without the captive program there would be no "life boat" assurance population to be source of animals for reintroductions. This loss would increase the probability of extinction should the population in the wild fall into serious decline again. It is also very unlikely, from the zoos' perspective, that VIM captive breeding would be redeveloped in the future without significant accompanying funding in place for the zoo partners (it has been 100% zoo funded to this point) with so many other competing species requiring help.

Tony Barrett Mount Washington Marmot Recovery Centre: Currently an asset valued at over $1.4 million built in marmot habitat on land donated by Mount Washington. Its purpose, as a dedicated marmot facility, was to receive, quarantine and prepare marmots born in captivity off-island prior to their introduction to wild habitat, and to function as a fourth breeding center. The alpine location presents logistical challenges for staffing and for preventing damage to the facility due to the harsh winter conditions. A high snow load one year caused considerable damage to the facility. If the facility is not adequately maintained and staffed, it will increase the risk of the facility becoming a liability to the program rather than an asset. But, in part because of its mountain location, it requires significant operating funds to remain open year round, funds that are currently prioritized elsewhere to support the reestablishment of the wild populations.

Loss of Continuity of Resources: This threatens the developmental and scientific integrity of the recovery program because of the lack of staff and resources. The loss of historical knowledge and expertise, and the loss of data at all levels (donor development, maps, databases, partnerships, stakeholder commitment) is more likely with a turnover of caretakers and staff, prudent succession planning is impossible without adequate trained staff, and staff are more likely to leave if they cannot be assured of their positions.

Inadequate Monitoring & Scientific Analysis: Field crews are monitoring an increasing number of sites in a broadening range of habitat, while maintaining the same reintroduction and translocation workload as crew in previous years. If releases and translocations continue at current levels, to continue to work toward the recovery goals, the number of field crew individuals cannot be decreased, as currently called for in the Ten Year Plan. It is far more likely additional crew members will be required to ensure the quality of monitoring is achieved to inform a recovery plan update.

Data collection is a priority, as it has been since the recovery of VIMs began, but it is critical the data be organized and integrated in way that supports meaningful population analysis. Additional resources are needed to hire a person skilled in database development to build a relational database, and ongoing resources will be needed to employ a population modeler to run the analysis required to assess the status of the species, identify the key drivers of the populations, and determine if, or when, intervening measures are required to reduce probability of extinction.

All of these risks increase the probability of extinction of the VIM species by reducing future recovery options, which in turn, threaten the investments made by our multiple partners in the recovery of this important Canadian species.

PROBLEM STATEMENT: There are inadequate resources (space/capacity and funding) to maintain a viable captive population for species assurance.

History: The first Vancouver Island marmots were brought into captivity in 1997 to initiate a captive breeding program. From an original 55 wild captures, 551 weaned pups have been produced (9.7 pups for every wild-capture), in 162 litters (average litter size of 3.42). (McAdie, Captive Breeding Management Meeting Minutes 2014). [2015 post-workshop update: 556 weaned pups have been produced (10.3 for ever wild-capture), in 167 litters (average litter size of 3.39) (McAdie, Captive Breeding Management Meeting Minutes 2015)].

From 2005-2010, ~150 marmots were maintained in four separate facilities (the Calgary zoo, the Toronto zoo, Mountain View Breeding Centre in Langley, and the Tony Barrett Mt Washington Marmot Recovery Centre). At this size the captive population produced ~ 63 pups annually, and 96.8% of the existing genetic variability was retained, surpassing the targets every year.

The recovery plan objective was to maintain the captive population at 125-150 individuals until 2020, or until the recovery goals are achieved. This was not achieved because a BC Government-imposed exit strategy led to funding cuts to the Landowners' Partnership Fund, necessitating the implementation of a phased plan to reduce the risks a premature exit would have on the species (the marmots in captivity and the marmots in the wild) and the stakeholders.

To comply with the demands, it was necessary to reduce the captive population to avoid the risks and liabilities to the Province and the zoos of having marmots in captivity without the resources required to release them, and to minimize the production of captive-born marmots requiring release in the future. Facility capacity to house a *non-breeding* population was untenable at the zoos making carefully planned reductions over time necessary, which the landowners agreed to. In the last seven years the captive population has been systematically decreased from 177 individuals producing 85 pups (2008) to 46 individuals (15 breeding pairs) expected to produce fewer than 15 pups annually. This is well below the 100-150 individuals originally endorsed in the recovery strategies.

<u>Genetic Implications of the Captive Population Reductions</u>: The studbook data, used to manage the breeding stock, is analyzed using PMx, a genetic management program (Ballou *et al*, 2010). For the purpose of the captive breeding analysis the wild marmots and those marmots scheduled to be released were excluded from the calculations. As of 2013 the captive population had retained 96.2% of the genetic diversity of the original wild population (Carnio, 2013 Studbook). [A July 2015 analysis indicated that genetic diversity had dropped to 95.3%, (Carnio, 2015 Studbook Report).] A captive breeding population of ~80 marmots is required to maintain at least 90% gene diversity for 5-10 years. By reducing the population below this level we are reducing and possibly eliminating our support and safety net to the wild population – in fact, we will probably require support from the wild population in order to keep the captive population going for a reasonable length of time (+15 yrs). (Post workshop update: In 2015 the Captive Management Group proposed that one or two wild individuals be opportunistically added to the captive population in 2016).

<u>Risk Assessment</u>: In 2013, the mean inbreeding of the captive population decreased to mean F = 0.0001 from 0.0005. Retaining a smaller captive population will likely increase this coefficient in the future. Originally the captive population was developed as the first stable and self-sufficient Vancouver Island marmot population. This population allowed us to proceed with the reintroduction of marmots to depleted or needy wild populations with the knowledge that we still had a viable resource to rely upon in case of failure. Now, with the captive population heading towards a slow decline, it will soon be dependent upon the wild populations to survive.

In my opinion we are a little premature in reaching this dilemma as the wild populations have only been established (mainly in the south) for a relatively short period of time and may still be vulnerable (Carnio, 2013 Captive Management Group meeting).

***GOAL: Maintain a captive population of sufficient size to ensure >90% of the genetic diversity of the founder population for the desired length of time*.** If for 20 years this will require 102 individuals; if for 5 to 10 years will require a breeding population of about 80; and if for 6 years, then 60 individuals.

PROBLEM STATEMENT: We currently do not have resources that can adequately support recovery of the Vancouver Island Marmot in the wild.

The stakeholder coalition is a strong model of good governance for species recovery. With the majority of Vancouver Island marmots located on private lands, the continued involvement of the landowners is imperative to a successful outcome for the species. If one of the major landowner partners were to pull out of the coalition it could destabilize the public, private, and government agreement that is the strength and weakness of the stakeholder model.

There is a direct positive correlation between stakeholder involvement and the probability of recovery. Immediate action by the landowners was necessary to support the recovery and reduce the probability of extinction, but contribution agreements have understandable funding and timeline limitations (i.e. 15-20 year funding agreements based on the Recovery Plans and Strategy, government timelines, etc.).

Any of the stakeholders may choose to exit the program before the recovery goals have been met if their individual assessment of the risk, over time, is acceptable to them. This includes public support and would reduce the probability of achieving the recovery plan goals, increasing the probability of extinction in the future.

The stakeholder coalition was necessary to launch and support the VIM recovery program because it was such a high-risk investment at that time (near extinction, versus a recovering species with measurable successes) that potential outside funders saw no hope for recovery without government and industry taking the lead.

Now that the VIM recovery program has a proven track record and a successful implementation record to point to, there may be an opportunity to expand funding to include high capacity donors or other partners interested in the appeal and potential of VIM recovery to reach a successful conclusion within a reasonable length of time and cost.

It is imperative that the landowners (BC Government, Island Timberlands, TimberWest) stay at the table at an agreed upon level of giving, because their involvement remains critical to the recovery outcomes. Their continued support also provides a strong case statement for potential new donors who will expect the stakeholders to demonstrate their belief in and commitment to a successful recovery outcome.

GOAL: Affirm the Vancouver Island Marmot Foundation's governance structure – assess/increase Board membership in light of the need to expand fundraising capacity.

GOAL: Develop a sound, realistic business model to support recovery efforts at a level that continues to meet the objectives of the Recovery Strategy.

Objective 1: Identify what is needed to support the various aspects of the program and associated costs.

Action: Identify the resource capacity currently in place

Action: Identify future needs/costs, prioritized in accordance with their impacts of recovery results

Action: Identify capacity funding gaps as well as potential opportunities to fill these gaps (partnerships, shared research, etc.).

Objective 2: Identify priorities for use of existing resources.

Objective 3: Identify priorities for future funding.

Objective 4: Identify timeline requirements.

GOAL: Investigate new funding models.

Objective: **MRF will explore development of a new fundraising strategy** to increase funding levels and transition the Foundation from a primarily landowner/public funding model, to a more broad-based funding model less reliant on Landowner support (estimated need for new funding is $300-$500 annually for 10 years).

GOAL: Keep and build relationships.

Objective 1: Re-engage existing stakeholders/donors.

Objective 2: Reach out to potential new donors.

PROBLEM STATEMENT: There is a lack of continuity of resources.

The lack of financial continuity has jeopardized our ability to sustain, or enhance, all other resources, and to protect future recovery options for the species (TBMWMRC, captive/wild populations, field efforts, zoos, the Foundation, public support, other scientists).

Without continuity of resources, staff expertise, relationships, partnerships and goodwill are all placed in jeopardy. Each piece of the puzzle is reliant on the support of the other, and the pieces may not be able to be reassembled (such as the captive breeding component) if there is a break in the program. Loss or lack of continuity in staff puts historical knowledge, access and management of data, and the veracity of the data sets at risk not to mention the emotional commitments to the recovery by the parties that may not be replaceable.

GOAL: Develop a 10-year funding strategy that provides certainty around funding.

> ***Objective: Identify high capacity individuals, additional partnerships and any other sources of revenue that will enable the Foundation to implement the most effective recovery options possible to recover the Vancouver Island marmot population in the wild.***

PROBLEM STATEMENT: The reduction in the number of captive breeding facilities has put the captive population and hence the recovery program at risk.

Cost reduction measures included the transition of the Tony Barrett Mount Washington Marmot Recovery Centre from a 12-month operational captive-breeding and release center to a seasonally operated release preparation center. In 2014, the captive breeding partners also decreased from three breeding facilities to two (the Calgary and Toronto zoos) when Mountain View Conservation Centre, a private facility in Langley, BC, ended its marmot breeding program. Priority breeding marmots were relocated to the Calgary and Toronto zoo facilities and the remaining marmots were transferred to TBMWMRC for release.

The breeding facilities make substantial contributions to the recovery efforts, and it is necessary for the zoos to retain their internal resource allocations, and that there be active breeding and a release component to their program to meet their mandates and add value to the costs of maintaining VIM at their facilities.

GOAL: Support and maintain the relationships and commitments of the zoo partners and protect the genetic health and viability of the captive population.

> ***Objective 1: Maintain an operational, captive population at more than one facility.***
>
> ***Objective 2: Maintain engagement of existing zoo partners, and explore other potential partnerships with the zoos and the recovery program.***
>
> ***Objective3: Find additional resources/space within the zoos.***
>
> ***Objective 4: Engage another captive breeding partner.***
>
> ***Objective 5: Secure resources to operate the TBMWMRC as a full-time breeding facility as well as to prepare marmots for release if appropriate.***

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Calgary, Canada
3-6 March 2015

Section 6
Working Group Report:
Environmental and Ecological Issues

Working Group Report: Environmental and Ecological Issues

Members: John Carnio, Jamie Dorgan, Don Doyle, Sally Leigh-Spencer, Dave Lindsay, Doug Whiteside

Issue: Potential High Predation Rates

There is a reasonable assumption that marmot populations may be unsustainable currently due to high predation rates. It was suggested that perhaps it is the rate of predation on a specific life stage (i.e. adult females) that is causing the unsustainability. Over-winter survival also appears to be a significant factor in mortality of reintroduced marmots. The impact of predation needs further study.

Discussion

What drives predation?

- Ungulate population dynamics and distribution change in relation to availability of forage habitat and predation pressure.
- Ungulate populations have decreased. Deer research on Vancouver Island suggests low elevation logging created a shift in deer behavior from migratory to resident. Resident herds are theorized to be much more susceptible to predation (wolves especially) creating instability in the predator prey dynamics.
- There is greater accessibility for predators to prey species through increased roads in relation to the proximity of the marmot populations.
- Landscape changes, logging roads, habitat linkages/connectivity.
- Golden eagle population numbers have increased on southern Vancouver Island possibly due to an increase in prey species such as the invasive Eastern cottontail rabbit. The data for golden eagle impacts on marmots is very speculative, however, there is kill data that points to them having a significant impact at times in certain colonies, especially early in the season. Based on anecdotal observations it is believed that golden eagles predate all age classes of marmot.
- Wolves will prey on marmots; wolves are extremely mobile with high productivity and recolonize vacant habitat quickly. Wolf population size can be controlled through trapping.
- Cougar population numbers currently are thought to be high (Fish and Wildlife Branch problem animal data). Numbers have increased as predator control measures have been directed at wolves and eagles. The recreational hunting of cougars is both limited (directed at mature males) and ineffective as a population control method. Individual problem cats could be selectively removed through the use of contract houndsmen.
- Shepherding (having a constant 24/7 human presence in the high-use marmot meadows) can be effective against cougar and wolf predation; however it is very expensive and extremely labor intensive.
- Fenced exclusions and fladry have been found to be ineffective in reducing predation due to rugged, uneven terrain.

Modeling questions:

1. What is the effect on populations by increasing/decreasing the level of predation?
2. Model predator-prey dynamics and the effect of targeted controls based on population cycles.

PROBLEM STATEMENT**: **There is a need for a clearer understanding of the relationship between the drivers of predator density, predator/prey dynamics, and marmot mortality.

GOAL**: **Determine the impact of predators on marmot survival.

Objective 1: On an annual basis, monitor marmot survival through radio telemetry (marmots) and other population monitoring techniques. This is a high priority (how it relates to drivers of N) and should be carried out by MRF contractors. Exact costs need to be determined by MRF.

Actions**:**

- Determine predator-specific population estimates in relation to prey-specific populations, and relate it to marmot mortality rates.
  - High priority action (how it relates to drivers of N)
  - Prey data exist for deer and elk; need to review data and relate it to predator and marmot population indices.
  - FLNRO to lead. ($1-2K annually to review)
  - Predator data is weak. Standardized species specific protocols needed for data collection. FLNRO to lead (grad students?).
- Cougars and golden eagles are the highest priority species, with wolves a moderate priority because their numbers are being controlled currently through trapping seasons.
  - Raptor populations are difficult to measure due to floater populations (versus breeder populations).
  - Exact costs need to be determined for annual or biennial review.

Objective 2: Identify and implement predator control methods if deemed appropriate for management purposes.

Actions:

- Implementation of lethal control methods (e.g., hunting, trapping) and/or non-lethal control methods (e.g., sterilization/contraception, exclusion of predators or prey species, shepherding, adversive conditioning)
  - High priority action (how it relates to drivers of N)
  - Costs are variable dependent on species.
  - Maximal predator control measures needed when colonies are first established for a minimum of two years.
  - For more public acceptance, implementation of greater predator control measures should be linked with declines in marmot populations.

Cougars:
  - Contractors for removal or adversive conditioning ($250-300/day).
  - Vasectomize males/hysterectomize (removing uterus) from females (more resources and costs associated with this); however, cats will maintain their territories and it is easier to selectively remove individual cougars that are predating marmots.

Wolves:
  - Use current trapping regulations to remove problem wolves.
  - If further population control is needed, then hire contractors to trap ($250-300/day).

Golden Eagles:

- More research on population demographics and the effect on marmot populations is needed before a control program can be effectively created and implemented.
- Contractors and/or MRF lead on demographic studies ~ $100k

- And/or augment population with translocated wild marmots or captive-bred marmots.
- High priority action, especially if populations are declining.
- Captive population needs to be retained for another 5-10 years to maintain genetics/insurance population until a clearer picture of marmot population dynamics is known.
- Resource/financially intensive.

Issue: Potential Decline in Marmot Habitat Carrying Capacity

There have been changes in the herbaceous community due to forest ingress (smaller sub-alpine), warmer forests, climate change, lack of forest fires, lower snow pack, fewer avalanches, and the lack of early seral stages due to logging. Eventual reforestation can be a population sink. Climate change will likely result in shorter, warmer winters, which leads to shorter hibernation period with possible impacts on the over-winter survival rate. Climate change may also lead to changes in hibernaculum insulation. Ungulates may spend more time in marmot colonies because of lack of snow. Summer droughts negatively affect forage quality and quantity.

PROBLEM STATEMENT*: *Marmot habitat carrying capacity may be negatively influenced by changes in both forage and hibernaculum habitat suitability associated with climate change and anthropogenic factors.

GOAL: Maintain suitable marmot habitat throughout natural range.

Objective*: *Determine extent of current suitable habitat and monitor changes.

Actions**:**

- Establish monitoring program to measure components of suitable habitat such as drought, winter snowpack, forest ingrowth, and fire history.
  - Low to moderate priority
  - Establish a working group with MRT and stakeholders (e.g., timber companies) to accomplish this.
  - Costs to be determined

- Apply/develop mitigative measures where appropriate (e.g., mechanical removal and/or burning of forest growth).
  - Low priority currently, may increase long term
  - Easiest action to carry out. Already implemented at 2 sites – need better before and after monitoring to document results.
  - Costs to be determined

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Section 7
Working Group Report: Population Modeling

Population Modeling Working Group Report

Modelers: Kathy Traylor-Holzer, Cheyney Jackson, Tara Stephens

Purpose

The task of the Population Modeling Working Group was to develop a *VORTEX* population model for the Vancouver Island marmot (VIM) that could be used to identify those factors that are most critical to population viability and to provide a tool to the other PHVA working groups to investigate the impact of various management actions on the viability of VIM populations. Specific modeling objectives were to:

1) Develop an individual-based stochastic population model that characterizes the VIM population in the Nanaimo Lakes (NL) region, parameterized using data from this population when possible and augmented as necessary with data from other marmot populations.
2) Conduct a sensitivity analysis to determine those factors that most influence population growth and identify important data gaps.
3) Assess the projected viability of the NL VIM population without additional supplementation. Assess the potential for additional supplementation to improve viability.
4) Assess the level of mortality reduction needed to reverse a population decline comparable to that observed historically in the NL VIM population.
5) Develop population models for the other VIM populations in the Forbidden Plateau and Western Strathcona regions, using the NL model as a basis with appropriate modifications. Assess the projected need for augmentation to develop viable populations in these regions.

Due to time and data constraints, the final modeling results were not available during the PHVA workshop but have been included here to help guide future VIM conservation and population management discussions.

VORTEX Model Description

Computer modeling is a valuable and versatile tool for quantitatively assessing risk of decline and extinction of wildlife populations, both free ranging and managed. Complex and interacting factors that influence population persistence and health can be explored, including natural and anthropogenic causes. Models can also be used to evaluate the effects of alternative management strategies to identify the most effective conservation actions for a population or species and to identify research needs. Such an evaluation of population persistence under current and varying conditions is commonly referred to as a population viability analysis (PVA).

A stochastic, individual-based population model was developed for the Vancouver Island marmot using the *VORTEX* 10.0.8 (Lacy and Pollak 2014) software program. *VORTEX* is a Monte Carlo simulation of the effects of deterministic forces as well as demographic, environmental, and genetic stochastic events on wild or captive small populations. *VORTEX* models population dynamics as discrete sequential events that occur according to defined probabilities. The program begins by either creating individuals to form the starting population or importing individuals from a studbook database and then stepping through life cycle events (e.g., births, deaths, dispersal, catastrophic events), typically on an annual basis. Events such as breeding success, litter size, sex at birth, and survival are determined based upon designated probabilities that incorporate both demographic stochasticity and annual environmental variation. Consequently, each run (iteration) of the model gives a different result. By running the model hundreds of times, it is possible to examine the mean and range of probable outcomes. For a more detailed explanation of *VORTEX* and its use in population viability analysis, see Lacy (1993, 2000) and Lacy *et al.* (2015).

CAUTION: Models are a simplified representation of real world complexities. The projected results presented in this report are based on the best available information and understanding of VIM life history characteristics and important factors affecting demographic rates. This *VORTEX* model provides a tool that can be revised as information improves or transferred to a different modeling platform as appropriate.

Quantifying VIM Population Trends and Vital Rates

Inconsistencies in the historical collection and analysis of VIM field data and population estimates, combined with significantly fluctuating population trends and changing threats, habitat, and management actions over time, handicap the development of a robust VIM model.

Figure 1 depicts the best available annual estimates of total VIM meta-population size in the wild, from 1972 to 2014. This combines census estimates for all areas, including Nanaimo Lakes as well as other populations to the north on Mount Washington and in Forbidden Plateau and Western Strathcona regions. Bar areas in red or yellow indicate marmots released into Nanaimo Lakes (red) or other wild locations (yellow) from captivity and surviving to their first fall (2004-2011); green bars represent wild-born marmots and released captive-born marmots that had survived at least one winter in the wild. Early data are less reliable than later estimates, primarily because census estimation methods were not consistent over time. While this has been standardized for census data from 2010 to present, it is difficult to make precise estimates in population trends across years prior to 2010, and only relative trends can be inferred.

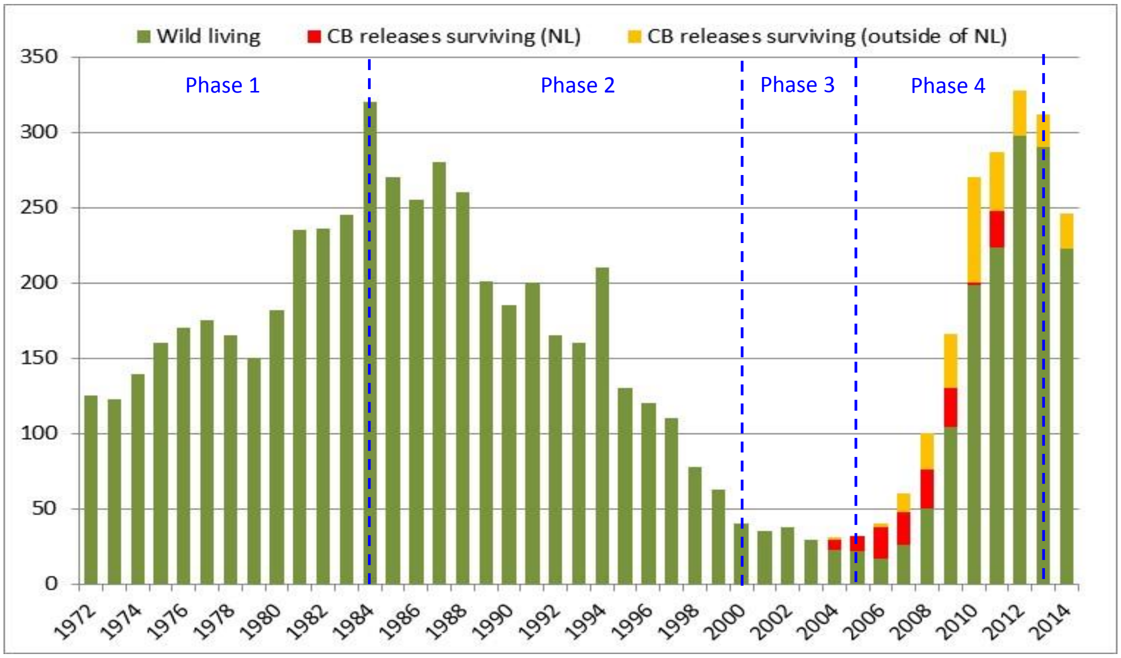


Figure 1. Total meta-population estimates for wild Vancouver Island marmots from 1972 to 2014. Red and yellow bar portions represent marmots released in that year and that survived to fall counts. Phases indicate different population trends specified for modeling purposes.

Despite methodological challenges, several distinct phases can be seen in the VIM meta-population over the past 40 years, as seen on Figure 1 and described below:

- <u>Phase 1</u>: General growth was observed until the mid-1980s, due at least in part to marmots colonizing cut blocks in the Nanaimo Lakes region.
- <u>Phase 2</u>: A dramatic decline in total species numbers was observed for ~15 years, as a consequence of heavy predation at marmot colonies in both natural habitat and in cut blocks. It has been

hypothesized that forest regrowth in harvested areas increased the vulnerability of those colonies to predation and also that there may have been higher predator densities across the region as other prey species increased in density (Bryant 1996; Bryant and Page 2005; Aaltonen *et al*. 2009).

- Phase 3: Once VIM colonies in harvested areas were extirpated (~2000-2001), the remaining VIM populations stabilized at low numbers (~90% decline in total number from the mid-1980s).
- Phase 4: Releases from captive stock began in 2003 and potentially catalyzed rapid growth of the wild population. Brashares *et al*. (2010) suggests that reproduction may be limited at low density through an Allee effect. It is unknown whether or not captive releases increased the biological growth rate by contributing to demographic (increased density that promoted survival and/or reproduction) and/or genetic (reduced inbreeding) effects.

It is yet unclear whether the lower population estimate for 2014 is inaccurate (e.g., untelemetered VIMs dispersed to non-surveyed areas, early hibernators not counted), represents expected variation in census numbers due to stochastic processes such as environmental variation, or is the beginning of a new long-term decline in the population.

VIM colonies in the Nanaimo Lakes region account for a significant portion of the entire wild meta-population. Historical population estimates for the NL population appear to follow the same general trends described above.

Small populations are expected to fluctuate in size from year to year due to stochastic processes such as demographic variation and environmental variation. While VIM population estimates show such annual fluctuations, the extended multi-year trends in the phases above indicate differing vital rates among these phases, especially in harvested areas. It is therefore important to consider the year and location for all field data reviewed for model parameterization.

Development of a VIM Model for Nanaimo Lakes Region

A preliminary baseline *VORTEX* model for the Nanaimo Lakes VIM population was developed by the working group during actual and virtual working meetings prior to the PHVA workshop. Model input values were derived using a wide range of scientific publications specific to VIMs as well as publications on general marmot life history, VIM recovery plans, and field updates. Additional VIM historical and current field data were provided by C. Jackson. Captive population data were gleaned from the Vancouver Island marmot studbook database (SPARKS format) compiled by J. Carnio (2015). This preliminary population model was reviewed, discussed and revised during the PHVA workshop by participating marmot and population biologists. Input from this group led to the final baseline model that was used as a basis for sensitivity testing, approximate viability projections, and general assessment of management actions.

Initial Population Parameters

The NL VIM population was modeled as a single population, with no genetic substructure (Griffin and Bryant 2008; Kruckenhauser *et al*. 2009) or colony substructure, and the model was not spatially explicit. Carrying capacity (K) for Nanaimo Lakes was set at 250 based on expert opinion from PHVA participants. While it was hypothesized that there is sufficient habitat to support a larger number of marmots (~300+), K is believed to be effectively lower due to intense predation pressure at higher densities.

The initial population was based on 2014 fall population estimates, with 112 marmots (54 males, 58 females) with a non-stable age distribution of proportionately fewer juveniles and more adults based on field estimates. Initial individuals were assumed to be related. Relatedness was modeled in two ways, as each has a separate but important impact in the model:

1) Alleles for a single neutral locus (used in the model to measure loss of gene diversity in the population) were drawn from 40 alleles to represent a bottleneck of ~20 individuals with two unique alleles each; and

2) All initial kinships and inbreeding coefficients were set to 0.03 (this affects inbreeding impacts in the model).

These two different measures correspond to about the same level of overall relatedness. Initial kinships of 0.03 was based on heterozygosity (H) = 0.97 represented by 40 alleles at equal frequencies. This may be a conservative estimate of relatedness in the population, as it assumes no genetic drift since the bottleneck.

Inbreeding Effects

Inbreeding can have major effects on many aspects of reproduction and survival, especially in small populations, and so was included in the model. *VORTEX* models inbreeding depression as reduced survival in inbred juveniles (default setting); the severity of the effect is determined by the number of lethal equivalents (LE) in the model. O'Grady *et al*. (2006) concluded that 12.29 lethal equivalents spread across survival and reproduction is a realistic estimate of inbreeding depression for wild populations. In the absence of species- or population-specific data, the default value is to incorporate 6.29 LE in the model as a conservative estimate, 50% of which are assigned to lethal alleles and subject to purging. Given that the VIM population successfully passed through a severe bottleneck, it is possible that this population has a smaller than average genetic load and may have experienced purging of lethal alleles. LE = 3 were used for the VIM model (with 2 due to detrimental alleles and 1 as a lethal allele), based on the reasoning of a reduced genetic load (4 vs 6.29 LE), with 1 of the 2 lethal alleles already purged from the population. No additional inbreeding effects were added to the model (e.g., reduced fecundity).

Variation in Vital Rates

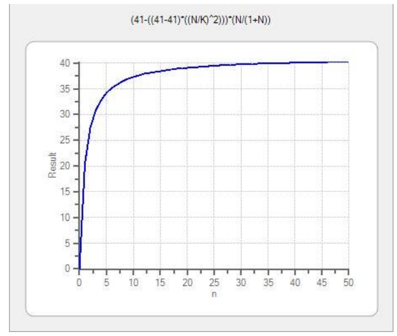
Demographic rates vary over time due to various stochastic processes. Variance estimates from field data often combine different sources of variation (as well as potential sampling error); these are implemented differently in *VORTEX* and thus need further consideration. Three sources of variation in reproductive and survival parameters are included in the model.

Demographic variation (chance variation in rates due to small population size) is an inherent characteristic of the model and is implemented through a random number generator that determines the specific fate of each individual each year (e.g., sex determination, survival, reproduction, litter size).

Environmental variation (EV) is the annual variation in reproduction and survival due to random variation in environmental conditions. The VIM model assumes a relatively stable environment across the NL meta-population (i.e., small fluctuations in mean vital rates between 'good' and 'bad' years), and used a COV for $EV_{mortality}$=20% and COV for $EV_{\%\ females\ breeding}$=10% based in part on field data estimates of variation in survival and reproduction. EV for reproduction and survival were correlated in the model (Armitage 1991 found survival and litter size both to be positively correlated with length of growing season for yellow-bellied marmots). EV determines the distribution from which the mean rate is selected for a given year, around which demographic stochasticity then acts as described above.

A generic catastrophe (outlier event in vital rates) was included in the model. Reed *et al.* (2003) examined 88 vertebrate populations and found the risk of severe population decline ($\geq$50% in one year) to be about 14% per generation. Therefore, in the absence of specific catastrophe data, a recommended risk of catastrophic events for VIM populations would be about 2.6% per year (i.e., once per 7 generations), with a severity factor of 50% reduction in survival in a catastrophic year. This is considered to be prudent to include in the model, as not all catastrophic events can be foreseen (e.g., emerging diseases, toxic spills), and it represents an intensity and rate of occurrence demonstrated across a variety of taxa, habitats and circumstances.

Reproductive Parameters



VIMs form long-term pair bonds, although males sometimes mate with more than one female (Bryant 1996). To prevent males from being the limiting sex under skewed sex ratio conditions in the model, the mating system was modeled as long-term polygyny, which allows males to mate with more than one female (up to a maximum of 4 females per male). For the most part, reproductive rates were assumed to be independent of population density. There was some discussion that colony density and/or size may influence reproductive rates; however, no data were available to quantify these relationships for specific inclusion into the model. A small Allee effect was incorporated that imposed lower reproductive rates at low densities at the population level (from half of the normal rate up to the full normal rate at N=50 for the meta-population – see graph inset).

Reproductive lifespan initially was set to 3 to 10 years of age for both sexes (Armitage 1999; Bryant 2005), with no reproductive senescence or age-specific fecundity rates. All adult males were considered in the breeding pool.

For modeling purposes, ‘reproduction’ was defined as the production of weaned pups, based on the stage at which pups may be detected during field inventory. Mean litter size used was 3.38 weaned pups (SD = 1.14; max = 6) with an equal sex ratio (Bryant 2005).

Bryant (2005) examined reproductive data collected for wild, tagged VIMs from 1987 to 2004, representing Phase 2 (population decline). Data represented colonies in both natural areas and clear cuts. Wild adult females were observed weaning pups in consecutive years (46.4% of observed litters) but often skipped a year (39.3%) or two years (14.3%), with the mean interval between litters of 1.9 years for females for which >1 litter was observed. Furthermore, Bryant reported that 41% of females 3+ years of age weaned pups in a given year (based on 134 female-years), with no significant difference with age. In the model the mean percent of adult females producing a litter (i.e., weaned at least 1 pup) in a given year was set at 41%, with environmental variation (EV) included at COV = 10%.

Population Trends – Growth vs Decline

The baseline model was developed to represent the best estimate of the current situation for the Vancouver Island marmot in Nanaimo Lakes. Given the positive growth in NL from 2005 to 2013, one assumption is that the NL population is operating under conditions that allow growth. The potential decrease in the population in 2014 may indicate that the population has reached a plateau in numbers imposed by predators, habitat and/or other factors and may have effectively reached or exceeded its carrying capacity under current ecological conditions. Another possibility is that this represents the onset of an extended period of decline

We do not have a good understanding of what factors are driving vital rates in the fluctuating VIM population. Colony size, density and composition, combined with predator densities, may be important; some have hypothesized that vulnerability to predation may increase at both low and high densities. No data were available, however, to substantiate or quantify such relationships. It is therefore difficult to project future vital rates, trends and viability of the VIM population until there is a better understanding of these relationships.

To address this challenge, two sets of annual age- and sex-specific mortality rates were developed to build different models that characterize VIM populations under different sets of conditions. The initial model (Healthy Population) was developed to represent a population with the capacity for positive intrinsic growth as observed in Phase 4. An additional model was developed to represent a declining population as characterized by Phase 2, in which mortality outpaces reproduction (Declining Population). This enabled the exploration of the level of supplementation needed and/or degree of change in vital rates needed to halt decline and push the population toward positive growth.

Survival Parameters

Limited data are available for survival/mortality rates from 2005-2013 when population growth greatly increased (Phase 4). Aaltonen et al. (2009) examined radio-telemetry from 2003 to 2007 to compare annual survival of wild-born (85.4%) vs. released captive-born (60.5%) marmots. This suggests a much lower adult mortality rate during the growth phase (~15%) than observed during years of population decline. Survival data for Nanaimo Lakes region for 2012-2013 were examined by P. Griffin (pers. comm.) using intrinsic models and suggested a significant origin difference (11.6% mortality for wild-born, 57.4% for captive-born marmots). Age class (pup, yearling, adult) census data for NL from 2011-2013 were examined for wild-born marmots to estimate mortality rates by comparing yearly population counts. Pup mortality for each year was 37% and 30%, respectively, and annual mortality for the older age class was 14% and 20%.

Most available survival/mortality data are from 1987 to 2004 (Phase 2), when the VIM population was in decline. Annual mortality rate estimates for adults range from: 27% (female) and 46% (male) in natural habitats from 1987-1995 (Bryant 1996); to 26% in both natural habitats and clear cuts from 1992-2004 (Bryant and Page 2005); to 32.2% for 1987-2004 combining radio-telemetry and mark-recapture data for natural habitat and clear cuts in Nanaimo Lakes (Aaltonen *et al*. 2009). Sex effect was significant only for two-year-old (53% mortality for males, 21% for females), and age effects only for pups (50%) vs older age classes (Aaltonen *et al*. 2009). Data for 2013-2014 age class census counts (when the population appeared to have experienced a substantial decline) suggest higher mortality rates (62% for pups, 46% for older animals) than those observed during times of population growth.

The following age-specific annual mortality rates were used in the model (EV in parentheses). These rates were derived from consideration of all sources listed above. No density-dependent survival was imposed.

Table 1. Age- and sex-specific mortality rates used for the Healthy Population and Declining Population models.

	Healthy Pop		**Declining Pop**	
Age class (yr)	**Female**	**Male**	**Female**	**Male**
0-1	33 (6.6)	33 (6.6)	50 (10)	50 (10)
1-2	15 (3)	15 (3)	30 (6)	30 (6)
2-3	15 (3)	25 (5)	21 (4.2)	50 (10)
3-8 (annually)	15 (3)	15 (3)	30 (6)	30 (6)
9-10	50 (10)	50 (10)	30 (6)	30 (6)
10-11	100	100	100	100

Modeling Parameters

Unless otherwise noted, each model scenario was run for 1000 iterations over 100 years (about 19 generations). Extinction was defined as only one sex remaining in the population.

Sensitivity Testing of Model Parameters

General sensitivity analyses were performed on the primary demographic rates to determine which parameters most affect population viability. The Healthy Population model was used as a base, as it approximates a demographically healthy population with intrinsic growth potential and recent NL trends, using an initial N (112) and K (250) estimated for the NL population. The following parameters were tested with an increase and decrease in the baseline value as outlined below (base value in **bold**). Most values were tested at ±10% of base value; exceptions are EV, ages of first reproduction, maximum age, inbreeding, and initial kinships. Model results are shown in Figure 2.

Mortality parameters

Female pup mortality: 29.7, **33**, 36.3
Female yearling mortality: 13.5, **15**, 16.5
Female 2yr mortality: 13.5, **15**, 16.5
Female adult mortality: 13.5, **15**, 16.5
Male pup mortality: 29.7, **33**, 36.3
Male yearling mortality: 13.5, **15**, 16.5
Male 2yr mortality: 22.5, **25**, 27.5
Male adult mortality: 13.5, **15**, 16.5
EV COV: 10%, **20%**, 30%
Catastrophic events (annual risk): 2.34%, **2.6**%, 2.86%

Reproduction

% females producing at least one weaned pup: 36.9, **41**, 45.1
EV COV: 5%, **10%**, 15%
Litter size: 3.042, **3.38**, 3.718
Age of first reproduction (females): 2, **3**, 4
Age of first reproduction (males): 2, **3**, 4
Maximum age: 9, **10**, 11

Genetics

Inbreeding (LEs): 0, **3**, 6
Initial kinships: 0, **0.03**, 0.06

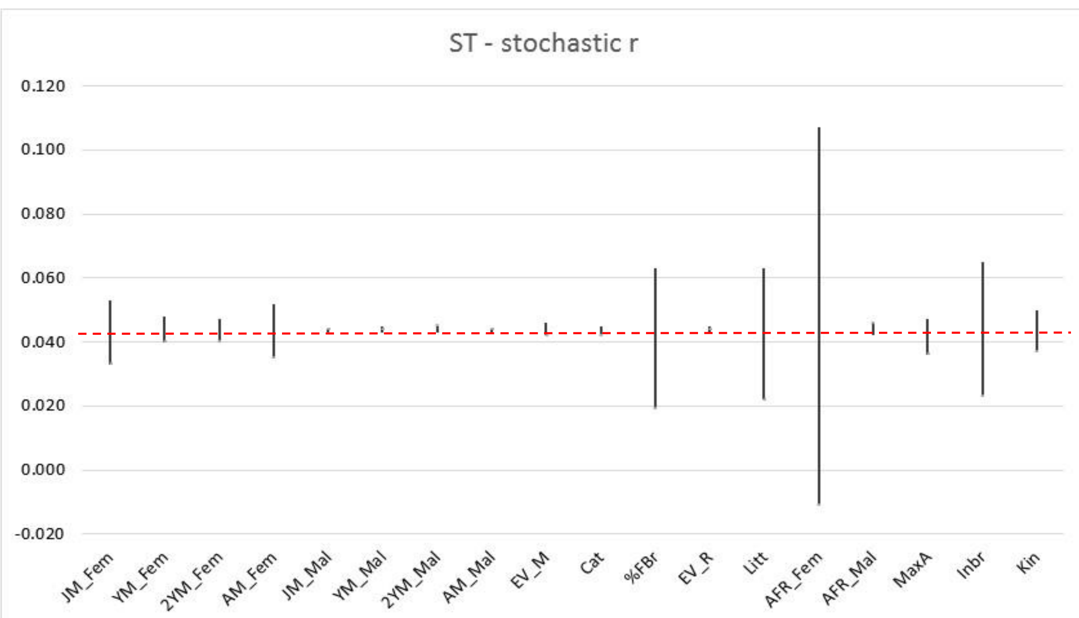


Figure 2. Stochastic r for input values tested in sensitivity analysis. High and low values are indicated by the line for each parameter; red dashed line indicates base model values. Parameters follow the order in the list above.

Figure 2 shows the resulting stochastic growth rates for each parameter across those values tested. The ranges tested were within reason for VIMs with the exception of first age of reproduction for females (see discussion below). Similar relative patterns of sensitivity were seen among these parameters when measured by population persistence or retention of genetic diversity (see Table 3 at end of group report).

Model results were not sensitive to male mortality rates, environmental variance around mortality rates, or frequency of catastrophic mortality events (within ±10% of mean value), and only moderately sensitive to female mortality rates. In contrast, many parameters related to reproduction had substantial impacts on population growth in the model. Varying the proportion of females weaning pups each year and mean litter size (±10%) resulted in a range of annual growth from 2% to 6% (±50% compared to base value).

Change in the age of first reproduction (AFR) for females has by far the most significant impact on model results. Increasing AFR to 4 years results in population decline and is not consistent with field data, as a significant proportion of females first reproduce at age 3 (Bryant 2005). Decreasing AFR to 2 years likewise is not realistic in the absence of age-specific breeding rates, as only a small proportion of females reproduce at age 2. Bryant (2005) reported the mean AFR observed in the wild of 3.6 years for females. *VORTEX* treats AFR as a minimum age and, in combination with constant adult female breeding and survival rates, setting AFR= 3 results in mean age of first reproduction in the model of 4.0. Model input values were revised to allow a low level of breeding in two-year-old females (9%), which results in a mean AFR = 3.7 in the model. This revision was adopted for further scenarios.

Relatively small changes in reproduction can have significant impact on measures of population viability. *Data compilation and analysis to better understand wild VIM reproduction may lead to more confidence in PVA projections. In addition, management strategies that improve reproduction*, such as increasing the proportion of females (especially young females) that wean pups each year and increasing the number of weaned pups per litter, *likely will improve population viability*. While changes in similar magnitude in mortality rates have a relatively smaller impact, there may be both greater uncertainty (due to difficulty in confirming fates of individuals) and greater fluctuation in mortality rates (due to changes in threats over time); thus, *improved survival especially in females also promotes population viability*.

Inbreeding depression has the potential to significantly impact the VIM population. Impact levels tested ranged from no inbreeding effects (even among highly inbred individuals) to levels that represent a conservative average for vertebrates (O'Grady *et al*. 2006). There is substantial uncertainty regarding the genetic load and vulnerability of this species and population to inbreeding depression and represents a current data gap and management challenge. Analysis of captive studbook data may add some insight. Population management strategies, such as active genetic management of the *ex situ* population and periodic transfer of animals between disconnected populations (*in situ* and/or *ex situ*), may promote viability by slowing genetic drift and inbreeding until this issue is better understood.

Model Validation

Two models were developed to bracket observed conditions in wild VIM populations:

1) *Healthy Population Model*: favorable conditions with available habitat that allow population growth (about 5-7% annually for a large population); and
2) *Declining Population Model:* conditions in which high mortality outpaces reproduction, leading to population decline (about 11-13% annually for a large population).

The only difference in input values between these two models were in the annual age- and sex-specific mortality rates, as described in Table 1. These models were validated against VIM census estimates during time periods (phases) characterized by population growth or decline.

Healthy Population Model

The Healthy Population model results in a demographically growing population (stochastic r = 0.065 for a population of 500 individuals) with a generation time (T) = 5.3 years, with a stable age distribution of 30:18:52 (pups: yearlings: 2+yrs) and an adult sex ratio of 53% female, 47% male. These attributes are reasonable for this species under good conditions. To validate this model retrospectively against Phase 4 conditions, a scenario was developed to represent the NL population from 2005 to 2013. An initial population of 30 marmots (stable age distribution) was simulated for 8 years, with the supplementation of additional marmots matching actual VIM releases (by sex and age class) that survived to fall hibernation. Figure 3 shows the *VORTEX* projected census in blue (with SD bar) and the best estimate (mean count) census for each year in red. *VORTEX* projections might be expected to be lower than actual counts, as the model census includes all mortality for the year while the census counts in red do not include winter mortality. However, the same vital rates were used in the model for captive-born releases as for wild marmots and likely inflated the model projections. These two factors may have offset each other to some extent. The retrospective projection demonstrates a similar growth rate (r = 0.227) and trend as the census counts (r = 0.238) and appears to be a reasonable representation of marmot demography in the NL region during this phase of population growth. Re-running the scenario without supplementation (releases) results in a modest growth rate of r = 0.052.

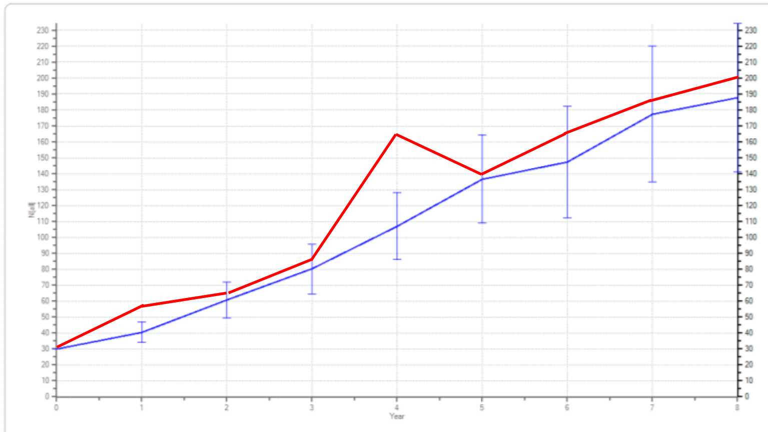


Figure 3. Retrospective model projection (in blue) of NL VIM population from 2005 to 2013 (bars indicate SD). Mean census counts shown in red.

Declining Population Model

The Declining Population model results in a demographically declining population. To validate this model retrospectively against Phase 2 conditions, a scenario was developed to represent the entire VIM meta-population starting in 1984 to 2000. An initial population of 320 marmots (stable age distribution) was simulated for 16 years with no supplementation. Figure 4 shows the *VORTEX* projected census in blue (with SD bar) and the best estimate (mean count) census for each year in red. *VORTEX* projections might be expected to be lower than actual counts, as the model census includes all mortality for the year while the census counts in red do not include winter mortality. The model retrospective projection demonstrates a similar rate of decline (r = -0.107) as the census counts (r = -0.130) and appears to be a reasonable representation of marmot demography during this rapid decline.

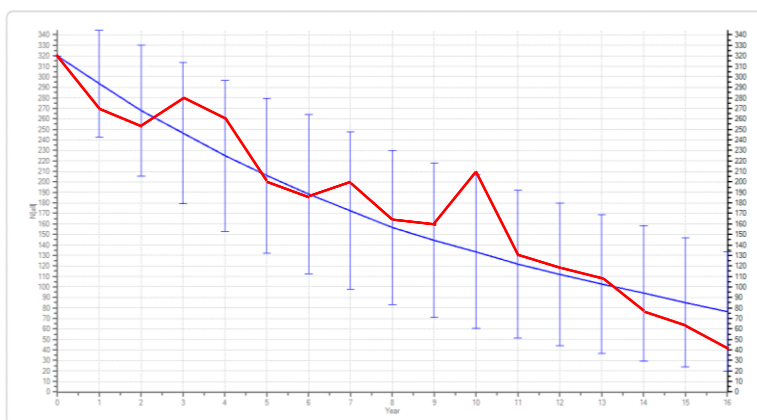


Figure 4. Retrospective model projection (in blue) of VIM meta-population from 1984 to 2000 (bars indicate SD). Mean census counts shown in red.

Interpreting Graphs of Model Results
Each iteration of the model simulates a population that typically fluctuates in size over time in response to various stochastic processes. Figure 5 illustrates 10 iterations using the same model input values (blue lines). In practice, a greater number of iterations is run to reduce standard error and typically leads to a smooth mean trend (red line) that might be misinterpreted as a projected population that is constant and does not fluctuate. In reality, populations may be at carrying capacity during some periods and may decline due to environmental variation, catastrophes or other reasons in other years. Large populations with a positive intrinsic growth rate have a greater capacity to recover from such stochastic declines.

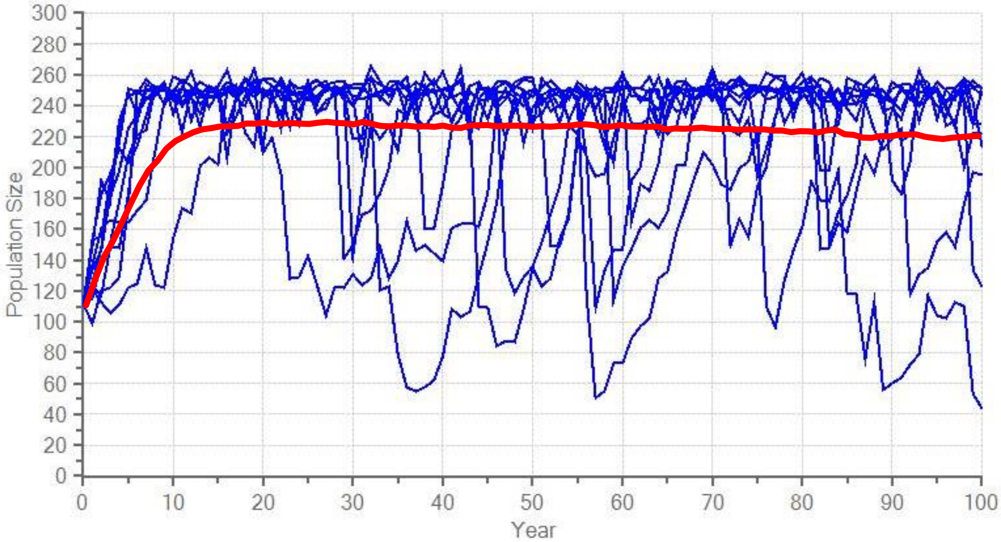


Figure 5. Example projection of population size over time for 10 iterations (blue lines). Mean population size for 1000 iterations is indicated by the red line.

The following graphs in this report depict the mean result and general trend over time for comparative purposes based on 1000 iterations per scenario. Standard deviation bars have been omitted in most instances for visual clarity, but these data can be found in Table 3 at the end of the modeling report and generally show a high degree of variability.

Viability Projections for NL Population

The Nanaimo Lakes population of VIMs described in this report is presently composed of 12-16 colonies, each located on a geographically distinct mountain with two or more marmots. Members of a colony may live in the same continuous patch of habitat or, more commonly, may be distributed in small groups across several pockets of habitat. The 2014 mean count estimated 14 colonies and 112 marmots: 96 marmots of 1+ years of age and 16 pups (young of the year). This represents a significant decrease from the 2013 count of 202 marmots in both age groups, with a disproportionately greater drop in pups. While the 2015 census was not yet available at the writing of this report, preliminary observations in early summer 2015 suggest that if a population decrease did occur from 2013 to 2014, the population may have stabilized rather than continuing to decline significantly. The NL model was initiated with 112 marmots, with an age structure skewed to older animals and fewer pups than stable age distribution proportions.

Four groups of scenarios were explored to address modeling questions identified either prior to or during the PHVA workshop. These scenarios projected the viability of the NL VIM population:

- Under favorable conditions with no further supplementation;
- Under favorable conditions, with supplementation;
- Under conditions of high mortality, with supplementation; and
- Under conditions of high mortality, with management to reduce mortality.

Scenario 1: Healthy Population with No Supplementation

This scenario projects the future viability of the NL population if favorable conditions continue that allow growth as observed from 2005 to 2013. Input values from the Healthy Population model were used, with carrying capacity (K) set at 250. Alternative values of K (200, 300, 350) were explored as requested by the workshop participants, who acknowledged that sufficient habitat exists for 350 marmots but that predator pressure may limit functional K to be lower. Initial population sizes ±25 % around the 2014 estimate (N_0=84 and 140, respectively) were also tested to consider estimate error in monitoring efforts.

Model results suggest that under favorable conditions (under which mortality is low enough to allow growth) the NL VIM population has a high probability of persistence (probability of extinction PE_{100} < 1%), with a mean population size of 215 marmots (SD=54.5) and reduced genetic diversity GD (GD_{100}=85.3%) after 100 years. PE_{100} remains low (<1%) across K values of 200-350 and initial population sizes of 84-140. Initial population had no impact on final population size and only a small effect on remaining gene diversity (84.7%-85.7%) after 100 years at K=250, reflective of the population's ability to grow quickly under conditions of low mortality.

Both final population size (mean and SD) and gene diversity retention are impacted by K. While populations on average grow to and fluctuate around K, a smaller K leads to smaller final population size, which leads to more rapid loss of GD due to genetic drift (Figure 6).

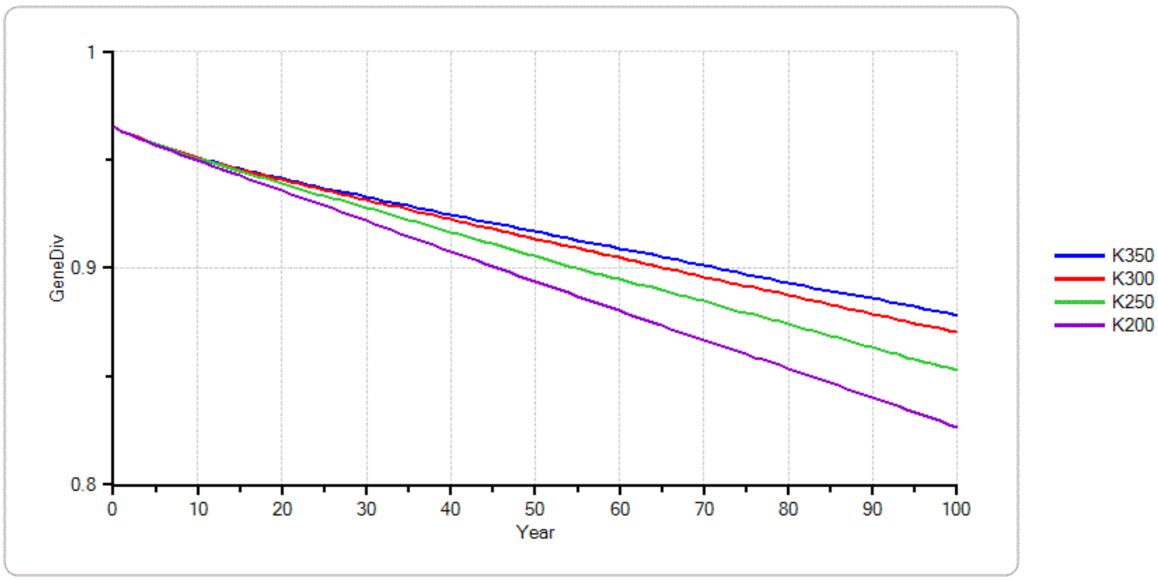


Figure 6. Projected loss in GD in NL VIM population under favorable conditions under different carrying capacity values.

Under conditions of strong growth, population supplementation (from captive releases and/or wild-to-wild translocations) *is not projected to be necessary for demographic stability or population persistence. However, population supplementation likely will be needed to maintain gene diversity above 90%.*

Scenario 2: Healthy Population with Supplementation

This scenario projects the impacts of supplementation on the future of the NL population under favorable conditions. The scenario specifically explores the genetic impacts of supplementation (from captive releases and/or wild-to-wild translocations) on offsetting genetic drift and promoting greater retention of gene diversity in the NL population.

Many factors influence the effectiveness of supplementation to preserve gene diversity, including:

- Release schedule (i.e., interval between releases, length of release program)
- Number of individuals released
- Characteristics of the released individuals (age, sex, genetic relatedness to NL population)
- Survival and reproductive rates of released individuals

Most of these factors were explored using the NL healthy population model used in Scenario 1 (with K=250) as a base and with the following assumptions:

1) *Supplements come from the same genetic background as the initial NL population* (i.e., alleles at the neutral locus of the supplements were randomly chosen from the initial 40 alleles of equal frequency). This assumes that there will be no genetic drift, selection or mutation in the source population(s); this in turn *assumes intensive genetic management of the captive population* (if used as the source) and/or translocations from a *large wild source population* with only low genetic relatedness to the NL VIM population.

2) In the model, supplements incur no mortality until the spring following their release; therefore, *the number of supplements stated in the model scenarios represents the number of released VIMs that survive to the following spring (number of "effective releases").* If, for example, only 50% of released marmots survive to the following spring, then the actual number of marmots released would need to be twice the number modeled in the scenario.

3) *Supplements have the same vital rates as wild-born VIMs* beginning in the spring following their release.

Effect of Release Schedule

The schedule of releases has a large influence on the effectiveness of genetic supplementation. Small populations lose genetic variation through genetic drift. Supplements can provide additional genetic variation to produce a temporary rise in GD, but genetic drift takes over in years without supplementation. Figure 7 demonstrates this by depicting GD over time for scenarios that all include 10 release events of 10 VIMs each (total of 100 VIMs released per scenario) but vary in release schedule (i.e., releases every year for 10 years; every 2 years for 20 years; every five years for 50 years; every 10 years for 100 years). Unless otherwise indicated, releases were modeled as yearlings of equal sex ratio.

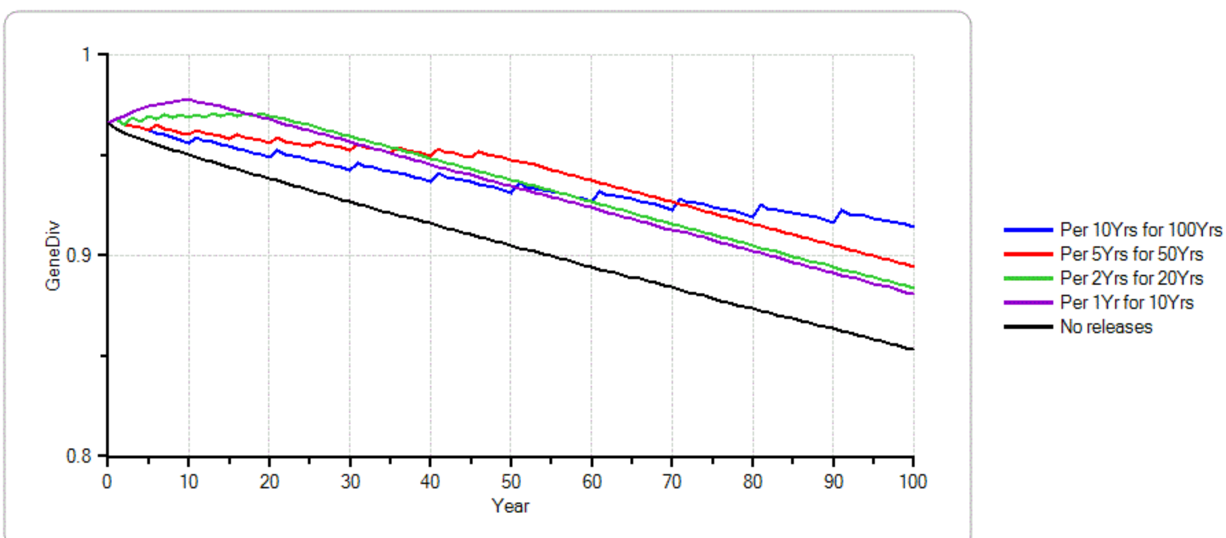


Figure 7. Projected loss in GD in NL VIM population under favorable conditions under different supplementation schedules (100 VIMs released per scenario) and with no supplementation (black line).

All supplementation scenarios retain more GD than the base scenario with no future releases. Stacking all releases in the first 10 years boosts GD initially but then GD declines once supplementation ends. Supplementation every other year maintains GD until releases end. Less frequent releases at the levels modeled lead to slow declines in GD. Only the scenario with continued releases (every 10 years for 100 years) results in at least 90% GD after 100 years. While precise estimates of GD are not possible given parameter uncertainties, this underscores *the genetic benefit of continued periodic genetic exchange with other genetically robust VIM populations*. The larger the population, the less genetic exchange will be needed to retain GD.

Number of VIMs per Release

The impact of the number of VIMs released depends upon the release schedule. Two situations were considered: a short-term intensive release program and a long-term periodic release program. Intensive releases (every year for 10 years) was modeled for the 'effective' release of 10, 20, 30 and 40 VIMs. Figure 8 depicts the initial increase in GD with yearly releases, followed by genetic drift and GD loss when releases stop. Ten marmots released per year substantially improves GD retention (GD_{100} = 88.1%, vs 85.3% with no releases) with a corresponding reduction in inbreeding (F_{100} = 0.124 vs 0.133). Increasing the number of marmots released per year to 20, 30 or 40 provides additional benefit but with proportionally diminishing returns. Even with the most intense scenario (40 marmots per year for 10 years), the resulting GD after 100 years is 89.5%. In contrast, the long-term periodic release of 4 marmots per year each year (4 marmots per year for 100 years) is sufficient to maintain GD at 96.6% (red dashed line).While precise estimates of GD are not possible given parameter uncertainties, these results underscore *the relatively greater importance of the length of the supplementation program vs the number of marmots released.*

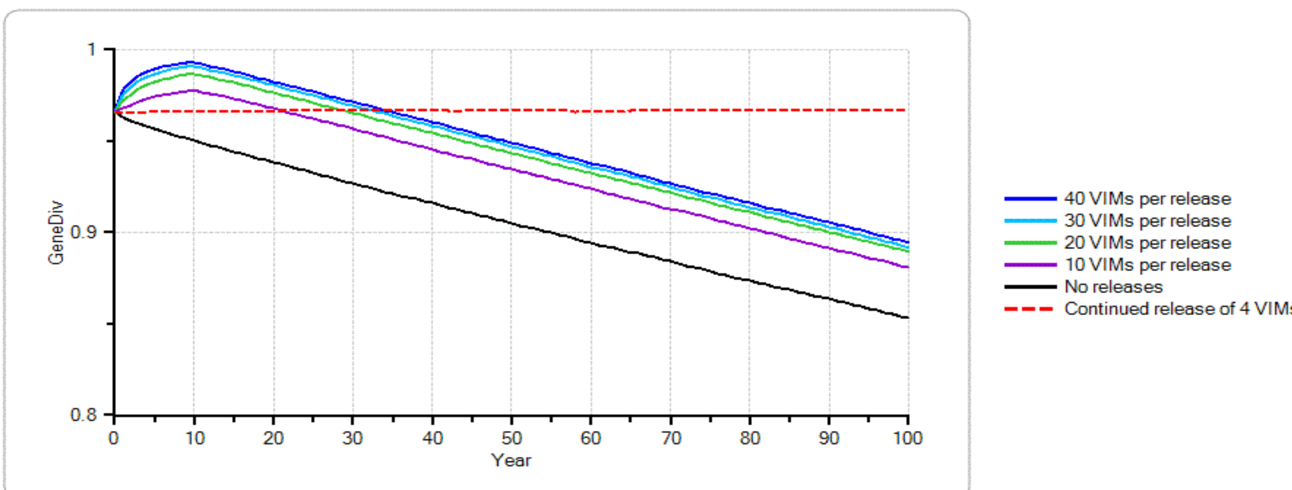


Figure 8. Projected loss in GD in NL VIM population under favorable conditions with different number of VIMs per release (10, 20, 30, 40) for 10 years, with 4 VIMs per year for 100 years, and with no supplementation.

Age and Sex of Released VIMs

Scenarios were run to test the impacts of varying the sex ratio and age of released VIMs using the continued release of 4 VIMs per year as a base, as this is the most effective release schedule to maintain GD. Varying the male:female sex ratio from 2:2 (to 4:0, 3:1, 1:3, and 0:4) has a small but negative impact on GD retention (see Table 3). Altering the sex ratio of released marmots might be more effective if done adaptively to help balance skewed sex ratios observed in the wild. Releasing older marmots has a modest positive effect on GD retention (see Table 3), as they are more likely to survive to reproduce in the model. In reality, *the best strategy would be to release marmots at the age at which they are most likely to survive and reproduce in the wild.*

Scenario 3: Reversing Decline Via Supplementation

This scenario explores the level of supplementation needed (from captive releases and/or wild-to-wild translocations) to stabilize a declining VIM population. The model was initialized with 202 VIMs (2013 census estimate) and with mortality rates used in the Declining Population model. These high mortality rates were held constant (resulting in a negative deterministic r), and various levels of demographic supplementation were explored to determine the intensity of releases needed to offset high mortality.

Model results suggest that *when high mortality rates similar to those observed in Phase 2 continue, the population will require substantial supplementation to maintain population size* (~25 "effective" releases needed each year to maintain the population at ~ 200 VIMs) (Fig. 9). Lower rates of supplementation can maintain the population but at a small size. Continual releases support population persistence (PE=0) and may promote high GD due to reintroduction of alleles lost through genetic drift (if present in the source population). Improved survival would require fewer releases to maintain population size.

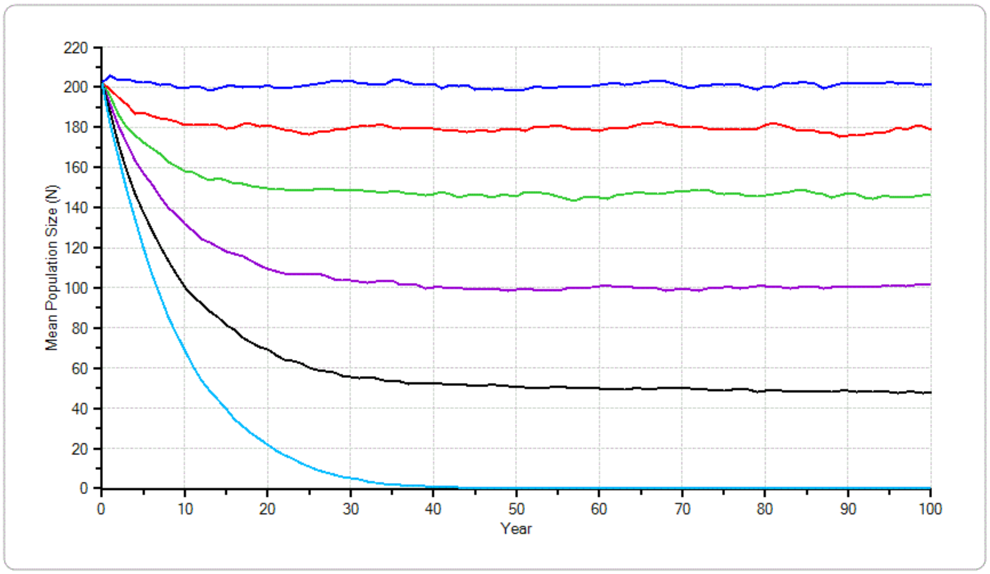


Figure 9. Projected mean population size for VIM populations under high mortality conditions (baseline) and with various levels of mortality reduction.

Scenario 4: Reversing Decline Via Increased Survival

This scenario explores the level of reduction in mortality (i.e., increased survival) needed to demographically stabilize a declining VIM population. Two strategies were modeled: 1) permanent and continuous reduction in mortality; and 2) temporary reduction in mortality in response to a minimum population size threshold. All scenarios were initialized with 202 VIMs (2013 census estimate) with mortality rates used in the Declining Population model.

<u>Permanent Reduction in Mortality</u>

Scenarios were run in which all mortality rates (i.e., all age- and sex-classes) were reduced by 5% increments from 100% to 50% of those mortality rates in the Declining Population model (i.e., 50% pup mortality, 30% adult mortality, etc. – see Table 1). Given the other model input values, a 30% reduction in mortality (i.e., 70% of baseline mortality) is needed for an overall stochastic r = 0; however, populations with these vital rates still have a relatively high risk of extinction (PE = 0.194 in 100 years). Figure 10 depicts the mean population size under each scenario, which includes extinctions. A 40% reduction in mortality is necessary for the population to maintain its initial size and to ensure a high probability of persistence (PE = 0.011) for 100 years. This level of mortality reduction results in mortality rates that begin to approximate those used in the Healthy Population model. These results serve only as a guide; the exact amount of mortality reduction needed to produce a precise result cannot be concluded due to parameter uncertainty as well as a high degree of variation in the results. *These results suggest, however, that a significant reduction in mortality may be needed to achieve long-term viability of a deterministically declining population* similar to that observed in Phase 2.

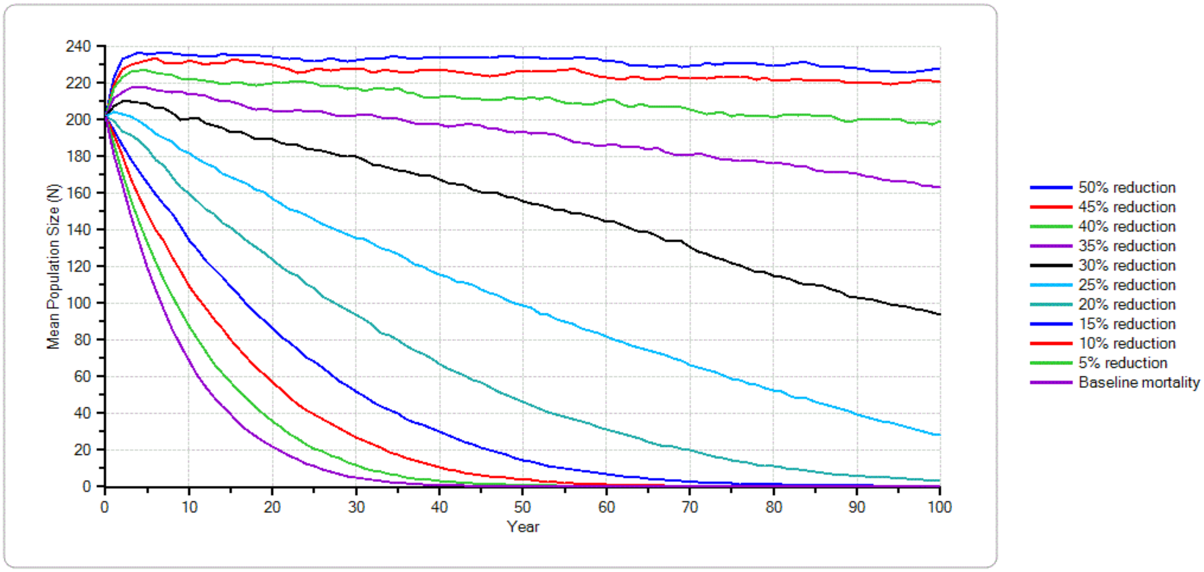


Figure 10. Projected mean population size for VIM populations under high mortality conditions (baseline) and with various levels of mortality reduction.

<u>Periodic Reduction in Mortality</u>
Scenarios also were run in which mortality reduction was only implemented after the population size was under 200 marmots for two consecutive years (i.e., mortality reduction occurring in the third year and continuing until $N \geq 200$). As might be expected, this *strategy of periodic mortality reduction is less effective than continual reduction* – see Table 2 for a comparison of these two strategies at 40% reduction and Table 3 for higher reduction levels. Other strategies for periodic reduction of mortality using different thresholds and/or levels of reduction may lead to different results.

Table 2. Projected results at Year 100 under continual vs periodic mortality reduction.

Method	Mean N_{100}	Mean GD_{100}	PE_{100}	Mean # yrs with reduction
Continual reduction (40%)	199	84.5%	0.011	100
Periodic reduction (40%)	127	79.1%	0.041	73

Viability Projections for Other VIM Populations

The initial list of modeling objectives included the development of population models for the VIM populations in the Forbidden Plateau and Western Strathcona regions of Vancouver Island. However, after further exploration of existing data the modeling working group concluded that the relatively large degree of uncertainty surrounding current population size, carrying capacity, trends, vital rates, and factors impacting those rates for these VIM populations make such modeling exercises of little value at this time. Once the status and threats of these populations are better understood, this *VORTEX* model is may be adapted to explore management options for developing viable VIM populations in these regions.

Conclusions Based on Modeling Results

Precise viability projections for VIMs under current and alternative management conditions are not reliable given the current uncertainty in population status, vital rates and factors affecting those rates. However, some general conclusions can be reached from this modeling exercise that may inform management decisions on conservation strategies for this species.

If the Nanaimo Lakes (or other interconnected) VIM populations are relatively large with sufficient habitat to expand up to at least 200 individuals and have vital rates that allow the population to grow, such as the conditions observed in Phase 4, then such a population is likely to be relatively viable demographically but would benefit from periodic genetic supplementation. Genetic supplementation can occur at a relatively low level but should be long-term to be effective in maintaining genetic variation and reducing inbreeding. Such populations should be able to recover from temporary declines that may occur due to stochastic processes as long as vital rates improve quickly. The larger the population, the greater its ability to recover from temporary declines and to maintain genetic variation.

If the NL (or other large) VIM population undergoes a severe and prolonged decline, significant demographic supplementation may be needed until vital rates improve. An alternative to supplementation would be to implement other management actions that improve vital rates. Historical data suggest that increased mortality may be a probable threat that may require attention. In either case, continued management – to reduce threats or to mitigate the impact of these threats – will be necessary until vital rates improve to the level that allow the population to be demographically self-sustaining.

These assessments lead to the following recommendations to promote viable VIM populations:

1) *Maximize population size, reproduction and survival as feasible.*
   Viability is linked to population size and sustainability (positive growth rates). Therefore any management actions that maximize population size (e.g., increased available habitat) and/or maximize growth (e.g., promote reproduction and survival) will improve long-term viability.

2) *Support at least two large VIM populations, either in the wild and/or captivity.*
   A single VIM population of the size of the Nanaimo Lakes population is vulnerable to both demographic (population decline) and genetic (inbreeding, reduced adaptive potential) threats. To ensure long-term viability there is a need for a large genetically and demographically robust source population to provide VIMs for periodic low level genetic supplementation, and potentially for more intensive demographic supplementation if severe population decline occurs. The source population could be the captive population or a second large self-sustaining wild population, with numerous advantages and disadvantages to both options. To be an effective genetic source, a captive population should be genetically managed to minimize loss of GD. For a wild population to be effective as a source, it should be large and healthy to minimize loss of GD and to be capable of providing surplus VIMs without jeopardizing its own viability. If large and demographically healthy, two wild populations can serve as backup source populations for each other, provided that they do not experience the same threats simultaneously that cause decline.

3) *Improve data collection and management to better inform management decisions.*
   There is a need for better data so that more precise estimates of viability can be made, and to allow better evaluation of management options and level of management needed to promote viability. This may include changes in data collection as well as improved compilation and assessment of existing data. The *VORTEX* model can be revised and/or new models developed as additional data are available.

While precise viability estimates are not feasible at this time, the relative uncertainty and vulnerability of existing wild VIM populations suggest the *importance of continued monitoring and management until at least two large demographically and genetically robust wild populations can be established*.

Table 3. Model scenario results (stoch-r = stochastic r; PE = probability of extinction; N = population size (all iterations); GD = gene diversity; MTE = mean time to extinction in years).

Scenario	N_0	*K*	*Stoch-r (mean)*	*Stoch-r (SD)*	PE_{100}	N_{100} *(mean)*	N_{100} *(SD)*	GD_{100} *(mean)*	GD_{100} *(SD)*	*MTE*
Base Models										
Healthy Pop	400	500	0.065	0.150	0	448	94	0.9133	0.0155	--
Declining Pop	400	500	-0.126	0.248	1.000	0	0	--	--	38
Demographic ST										
Base Values	*112*	*250*	*0.058*	*0.155*	*0.006*	*215*	*54*	*0.8528*	*0.0282*	*65*
FemPupMort=29.7	112	250	0.053	0.151	0.005	212	59	0.8516	0.0393	72
FemPupMort=36.3	112	250	0.033	0.154	0.028	189	74	0.8405	0.0471	74
FemYrlgMort=13.5	112	250	0.048	0.150	0.007	207	60	0.8518	0.0338	66
FemYrlgMort=16.5	112	250	0.040	0.153	0.022	199	66	0.8475	0.0387	77
Fem2YrMort=13.5	112	250	0.047	0.151	0.016	206	64	0.8499	0.0373	79
Fem2YrMort=16.5	112	250	0.040	0.152	0.018	201	68	0.8434	0.0512	63
FemAdMort=13.5	112	250	0.052	0.150	0.004	215	55	0.8542	0.0319	66
FemAdMort=16.5	112	250	0.035	0.153	0.026	189	74	0.8397	0.0544	68
MalPupMort=29.7	112	250	0.044	0.151	0.009	206	61	0.8492	0.0413	74
MalPupMort=36.3	112	250	0.044	0.152	0.013	202	66	0.8482	0.0417	66
MalYrlgMort=13.5	112	250	0.045	0.149	0.017	204	65	0.8493	0.0422	76
MalYrlgMort=16.5	112	250	0.044	0.151	0.014	204	65	0.8473	0.0478	65
Mal2YrMort=22.5	112	250	0.044	0.151	0.015	205	63	0.8495	0.0413	74
Mal2YrMort=27.5	112	250	0.045	0.150	0.012	203	66	0.8485	0.0452	67
MalAdMort=13.5	112	250	0.044	0.152	0.015	204	65	0.8499	0.0368	67
MalAdMort=16.5	112	250	0.044	0.151	0.014	203	66	0.8472	0.0385	59
EV_{Mort} COV=10%	112	250	0.046	0.137	0.008	212	60	0.8535	0.0348	70
EV_{Mort} COV=30%	112	250	0.042	0.162	0.020	195	70	0.8440	0.0441	66
Catastr Risk=2.34%	112	250	0.045	0.149	0.011	205	62	0.8512	0.0309	74
Catastr Risk=2.86%	112	250	0.042	0.155	0.013	200	66	0.8440	0.0507	72
%FemBreed=36.9	112	250	0.019	0.159	0.082	155	87	0.8229	0.0693	71
%FemBreed=45.1	112	250	0.063	0.149	0.002	221	50	0.8581	0.0260	49
EV_{Repro} COV=5%	112	250	0.045	0.143	0.009	210	61	0.8511	0.0378	67
EV_{Repro} COV=15%	112	250	0.044	0.158	0.013	198	68	0.8467	0.0382	73
LitterSize=3.042	112	250	0.022	0.154	0.059	163	85	0.8302	0.0621	69
LitterSize=3.718	112	250	0.063	0.151	0.004	218	53	0.8548	0.0281	73
FemFirstRepro=2	112	250	0.107	0.152	0.001	235	36	0.8569	0.0108	31
FemFirstRepro=4	112	250	-0.011	0.169	0.285	69	77	0.7710	0.1055	71
MalFirstRepro=2	112	250	0.042	0.153	0.020	200	68	0.8399	0.0433	67
MalFirstRepro=4	112	250	0.046	0.150	0.010	205	64	0.8551	0.0396	79
MaxAge=9	112	250	0.036	0.152	0.030	191	74	0.8409	0.0499	64
MaxAge=11	112	250	0.047	0.151	0.012	205	63	0.8516	0.0356	62
LE=0	112	250	0.065	0.151	0.002	226	44	0.8536	0.0224	37
LE=6	112	250	0.023	0.155	0.071	151	86	0.8348	0.0615	75
InitKinships=0	112	250	0.050	0.151	0.010	211	58	0.8781	0.0345	73
InitKinships=0.06	112	250	0.037	0.152	0.019	194	70	0.8173	0.0434	71
Data Validation										
Retrosp 2005-2013* (*Results after 8 yrs)	30	250	0.227	0.196	0	188	47	0.9855	0.0025	--
Retrosp 1984-2000* (*Results after 16 yrs)	320	500	-0.107	0.209	0.001	76	57	0.9247	0.0298	16

Scenario	N_0	*K*	*Stoch-r (mean)*	*Stoch-r (SD)*	PE_{100}	N_{100} *(mean)*	N_{100} *(SD)*	GD_{100} *(mean)*	GD_{100} *(SD)*	*MTE*
NL Healthy No Sup										
K=200	112	200	0.054	0.156	0.003	169	47	0.8266	0.0401	67
K=250	112	250	0.058	0.155	0.006	215	54	0.8528	0.0282	65
K=300	112	300	0.060	0.150	0.003	266	58	0.8704	0.0187	69
K=350	112	350	0.060	0.152	0.005	308	71	0.8783	0.0311	61
N_0=84	84	250	0.057	0.154	0.006	217	54	0.8465	0.0321	55
N_0=140	140	250	0.059	0.153	0.004	218	52	0.8565	0.0354	86
NL Healthy w/Sup										
No releases (base)	112	250	0.058	0.155	0.006	215	54	0.8528	0.0282	65
10 per Yr for 10Yrs	112	250	0.068	0.154	0.002	220	49	0.8808	0.0233	58
10 per 2Yrs for 20Yrs	112	250	0.069	0.155	0.004	218	50	0.8838	0.0222	84
10 per 5Yrs for 50Yrs	112	250	0.070	0.153	0	221	49	0.8942	0.0211	--
10 per 10Yr for 100Yr	112	250	0.069	0.153	0	227	41	0.9142	0.0096	--
20 per Yr for 10Yrs	112	250	0.075	0.155	0	222	49	0.8896	0.0183	--
30 per Yr for 10Yrs	112	250	0.079	0.158	0.003	220	51	0.8918	0.0315	73
40 per Yr for 10Yrs	112	250	0.082	0.162	0.003	221	49	0.8946	0.0199	74
Continual (4M0F, A1)	112	250	0.071	0.149	0.002	231	38	0.9647	0.0043	80
Continual (3M1F, A1)	112	250	0.081	0.150	0	233	36	0.9662	0.0040	
Continual (2M2F, A1)	112	250	0.089	0.149	0	236	32	0.9664	0.0040	--
Continual (1M3F, A1)	112	250	0.096	0.150	0	237	31	0.9656	0.0038	
Continual (0M4F, A1)	112	250	0.102	0.152	0	239	28	0.9636	0.0038	
Continual (2M2F, A0)	112	250	0.083	0.149	0	234	35	0.9597	0.0051	--
Continual (2M2F, A2)	112	250	0.094	0.150	0	235	34	0.9730	0.0029	--
NL Declining w/Sup										
No releases (base)	202	250	-0.144	0.263	1.000	0	0	--	--	28
5 VIMs released/year	202	250	-0.015	0.213	0	48	21	0.9657	0.0063	--
10 VIMs released/year	202	250	-0.007	0.194	0	101	39	0.9825	0.0025	--
15 VIMs released/year	202	250	-0.001	0.186	0	146	47	0.9883	0.0014	--
20 VIMs released/year	202	250	0.007	0.181	0	179	46	0.9910	0.0010	--
25 VIMs released/year	202	250	0.019	0.178	0	202	43	0.9925	0.0008	--
NL Decline MortRed										
Full mort rate (base)	202	250	-0.144	0.263	1.000	0	0	--	--	28
5% reduction	202	250	-0.124	0.256	1.000	0	0	--	--	33
10% reduction	202	250	-0.099	0.249	1.000	0	0	--	--	41
15% reduction	202	250	-0.078	0.234	0.993	0	3	0.6231	0.1121	52
20% reduction	202	250	-0.054	0.223	0.875	3	11	0.6529	0.1219	63
25% reduction	202	250	-0.027	0.207	0.542	28	49	0.7316	0.1086	73
30% reduction	202	250	0.001	0.189	0.194	94	84	0.7842	0.0908	75
35% reduction	202	250	0.027	0.178	0.048	163	81	0.8283	0.0563	76
40% reduction	202	250	0.050	0.175	0.011	199	64	0.8448	0.0420	73
45% reduction	202	250	0.073	0.170	0.003	221	49	0.8583	0.0189	69
50% reduction	202	250	0.093	0.169	0	228	42	0.8625	0.0137	--
40% reduct (periodic)	202	250	-0.006	0.208	0.041	127	59	0.7914	0.0568	69
50% reduct (periodic)	202	250	-0.002	0.224	0.003	160	48	0.8183	0.0267	86
60% reduct (periodic)	202	250	0.000	0.241	0	171	45	0.8254	0.0169	--
70% reduct (periodic)	202	250	0.002	0.255	0	175	44	0.8301	0.0122	--
80% reduct (periodic)	202	250	0.004	0.270	0	180	45	0.8321	0.0109	--

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Section 8
Priority Goals and Actions

Priority Goals and Actions

During the final plenary of the workshop the participants considered the goals and objectives across all working groups (see Table 1) and prioritized goals that are most important for the recovery of the species as High, Medium, or Low based on two criteria – importance and urgency. Goals fell into one of two broad categories: the first related to the biological aspects of Vancouver Island marmot recovery, and the second related to infrastructure needs. This prioritization does not imply that any of the other goals are not important; rather, prioritization can be a useful tool to determine timelines and allocation of limited resources if appropriate.

Within the goals identified below, two were deemed critical:

1) Existing and future data must be recorded in a consistent manner so that it is easily accessible and useable for decision making and population management.
2) In order to meet this and other goals, the project must achieve financial stability now and into the future.

Population Level Goals – Highest priority

- ***Ensure all data are available in an accessible and usable form.***
- ***Enable better detection of changes in N (long-term) and vital rates, and be ready to respond accordingly.***
- ***Determine the impact of predators on marmot survival.***
- ***Support at least two large VIM populations, either in the wild and/or in captivity.***

Population Level Goals – Medium to Low priority

- ***Continue efforts to minimize and mitigate disease risk to Vancouver Island marmots (*****risk is low at present levels of disease).**
- ***Minimize loss of genetic diversity in wild and captive Vancouver Island marmot populations. (Risk is low at present and will remain low if populations in the wild are large and population trends are stable or increasing, and if the captive population is maintained at an adequate size. The risk will rise quickly if the captive population is small and wild populations are simultaneously small and/or declining).***
- ***Maintain suitable marmot habitat throughout the species' natural range.***

Infrastructure Level Goals

- ***Solidify the Vancouver Island Marmot Foundation's governance structure.***
- ***Develop a sound, realistic business model.***
- ***Keep and build relationships.***
- ***Support and maintain the relationships and commitments of the zoo partners.***
- ***Investigate new funding models.***
- ***Develop a 10-year funding strategy that provides certainty around funding.***

To assist with developing priorities, participants also evaluated each existing meta-population of Vancouver Island marmots with respect to the carrying capacity of the environment, the potential long-term viability, the risk of extinction, its potential role, the investment needed, and the benefits and costs of that investment. Results are shown in Table 2.

Table 1: A summary of problems, goals, and objectives important for Vancouver Island marmot recovery.

Problem	Goal	Objective
Population Management		
Data not fully utilized	Ensure all data are available in an accessible and usable form	a) Create and fill a database manager position b) Consolidate all past and current raw data c) Create and populate the database d) Debug database e) Develop a manual for use of database and system to archive data f) Ensure all future data are incorporated into database g) Ensure that data are accessible to other researchers
Limited ability to detect and respond to changes in population size	1. To be able to better detect changes in N (long-term) and vital rates and respond accordingly. 2. Create a management plan that details when and how to respond to changes in N and/or vital rates	Create and fill a population ecologist position
Frequency and impact of diseases are unpredictable	Continue efforts to minimize and mitigate disease risk	a) Avoid introducing disease into the wild population via releases of captive-bred marmots b) Avoid introducing disease into local wild populations via translocations from other wild populations c) Continue to identify existing diseases in captive and wild populations d) Ensure Captive Management Group and Recovery Team are kept aware of any novel disease and introduction of non-native vectors onto Vancouver Island
Potential loss of genetic diversity	Minimize loss of genetic diversity in Vancouver Island marmot populations (wild and captive)	a) Maintain gene flow among wild populations b) Maximize genetic diversity within captive population given its current size c) Maintain gene flow between captive and wild populations d) Avoid low population sizes in the wild and expand wild population distribution
Potential Allee Effect	Minimize loss of genetic diversity as above	

Resources		
Inadequate resources to maintain a viable captive population.	Maintain a captive population of sufficient size to ensure >90% of the genetic diversity of the founder population for the desired length of time	Maintain 102 individuals for 20 years, 80 individuals for 10 years, 60 individuals for 6 years.
Inadequate resources to support recovery of VIM in the wild	1.Affirm the Vancouver Island Marmot Foundation's governance structure 2.Develop a sound, realistic business model to support recovery efforts at a level that continues to meet the objectives of the Recovery Strategy beyond the current Five Year Plan (2012-2017) 3.Investigate new funding models 4.Keep and build relationships	Assess/increase Board memberships in light of need to expand fundraising capacity a) Identify what is needed to support the various aspects of the recovery program b) Identify priorities for use of existing resources c) Identify priorities for future funding d) Identify timeline a) Re-engage existing stakeholders/donors b) Reach out to potential new donors
Lack of continuity of resources	Develop a 10-year funding strategy that provide certainty around funding	Identify high capacity individuals
Reduction in the number of captive breeding facilities has put the captive population and hence the recovery at risk	Support and maintain the relationships and commitments of the zoo partners and protect the genetic health and viability of the captive population.	a) Maintain an operational, captive population at more than one facility b) Maintain engagement of existing zoo partners c) Find additional resources/space with the zoos d) Engage another captive breeding partner e) Secure resources to operate TBMWMRC as a full-time breeding facility as well as to prepare marmots for release
Environment and Ecology		
Need for a clearer understanding of the relationship between drivers of predator density, predator/prey dynamics, and marmot mortality	Determine the impact of predators on marmot survival	a) On an annual basis, monitor marmot survival through radio telemetry(marmots) and other population monitoring techniques b) Identify and implement predator control methods if appropriate for management purposes
Marmot habitat carrying capacity may be negatively influenced by changes in both forage and hibernaculum habitat suitability associated with climate change and anthropogenic factors	Maintain suitable habitat throughout natural range	Determine extent of current suitable habitat and monitor changes

Table 2: Evaluation of existing meta-populations of Vancouver Island marmots.

Population	Current size/ trend/status	Carrying capacity	Potential long-term viability	Certainty	Risk	Potential role	Relative investment needed for viability	Relative benefit	Relative cost
Nanaimo Lakes wild pop	100-200 Fluctuations in past, incl. dramatic declines; recent increase in 2000-2013 (in conjunction w/ extensive augmentation Status: hopeful	About 200 (10-14 marmots on 14 hills)	Moderate (with occasional augmentation, for either demographic or genetic reasons)	Moderate to Low	Moderate (given possible habitat-level changes)	Essential (for recovery) Long-term role as a potential genetic source (no adult female removal; not a "Mount Washington" – too risky)	Short-term: medium Long-term: low (less intensive monitoring needed)	High	Moderate
Mt Washington wild colony	45 High repro Low mortality	40-60	High (as part of a larger northern population)	High	Low (but dependent upon persistence of ski hill?)	Essential (for recovery) Potential source for WB VIMs for translocation (demographic and genetic)	Low	High	Low (monitoring) Moderate (translocation)
Forbidden Plateau and Western Strathcona wild pops	64-82	500+?	Low w/o intensive management; Potential to be relatively high (w/ ST augmentation)	Uncertain	Uncertain	Essential (for recovery), esp. for WS with climate change	High	High	High
Other wild pops (current or future?)	Schoen Lake: 2-5 Steamboat: 10-20	SL: 20-50? Steamboat: 150?	Low in isolation; may be connected to WS	Uncertain	Uncertain	Unknown	High	High if can be made viable	High
Ex situ population (zoos)	Current pop: 55 Declining Status quo	Calgary = 8 breeding pairs Toronto = 6 breeding pairs Total 28 breeding animals (dependent upon removal of offspring; can hold offspring and post-reproductive short-term) Calgary = 10 pens Toronto = 10 pens	Low at current level; potential viability is high if expanded	High	Relatively high at current levels and/or if breeding is curtailed	High/ Critical Source for marmots for augmentation; Assurance population (genetic reservoir); Potential research pop (e.g., disease, ART)	Pop needs to double at least; additional costs to release component	High	Moderate (to zoos for maintaining captive pop)
Ex situ Mount Washington facility	No marmots at present	Up to 120 marmots short term, for quarantine/release (dependent upon grouping) Potential for up to 20 breeding pairs (if space is not used for other purposes)	Potentially high (if integrated with rest of the *ex situ* population)	High	High (dependent upon secure long-term funding)	Quarantine and staging/release facility for WB or CB marmots (current role) Potential breeding facility (past breeding facility)	High	High (if used to support wild pop) High (as a part of a larger managed *ex situ* pop)	High ($250k annual if open year-round)

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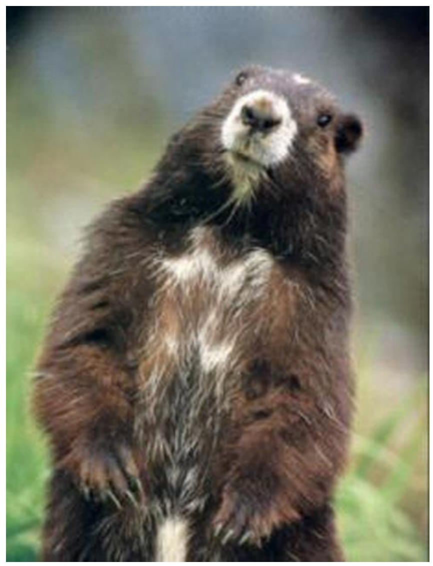

Appendices

Appendix I. Summary of Captive Population 1997-2015

Captive Population Numbers (1997 to 2015). 55 wild captures + 566 weaned pups - 477 releases - 100 mortalities + 2 recaptures = 46

Year	Wild marmot captures excluding pups	Wild pup captures	Total wild captures	Weaned captive litters	Breeding Pairs (from 2005 to 2015)	Proportion of Pairs Breeding (2005 to 15)	Weaned captive pups	Weaned males (54.9%)	Weaned females (45.1%)	Unknown	Average weaned litter size	Captive Mortalities	Releases of captive marmots	Recaptures	Captive Total	Pop Size Relative to Previous Year
1997	4	2	6	0			0	0	0	0	0.00	0	0	0	6	-
1998	5	3	8	0			0	0	0	0	0.00	2	0	0	12	200%
1999	9	10	19	0			0	0	0	0	0.00	4	0	0	27	225%
2000	1	4	5	2			8	5	3	0	4.00	1	0	0	39	144%
2001	2	5	7	1			2	1	1	0	2.00	1	0	0	47	120%
2002	2	4	6	5			13	8	5	0	2.60	3	0	0	63	134%
2003	1	2	3	7			18	10	8	0	2.57	4	4	1	77	122%
2004	0	1	1	8			26	19	7	0	3.25	2	9	0	93	120%
2005	0	0	0	13	26	0.50	48	31	17	0	3.69	5	15	0	121	130%
2006	0	0	0	14	30	0.47	56	27	28	1	4.00	5	31	1	142	117%
2007	0	0	0	15	37	0.41	60	33	27	0	4.00	3	37	0	162	114%
2008	0	0	0	23	46	0.50	85	41	40	4	3.70	11	59	0	177	109%
2009	0	0	0	20	48	0.42	71	33	38	0	3.55	9	68	0	171	97%
2010	0	0	0	18	49	0.37	55	33	22	0	3.06	11	85	0	130	76%
2011	0	0	0	18	36	0.50	51	26	24	1	2.83	8	66	0	107	83%
2012	0	0	0	6	26	0.23	22	11	11	0	3.66	9	34	0	86	80%
2013	0	0	0	6	25	0.24	18	11	7	0	3.00	6	16	0	82	95%
2014	0	0	0	6	19	0.36	18	10	8	0	2.83	16	29	0	55	60%
2015	0	0	0	5	12	0.42	15			15	3.00	0	24	0	46	80%
Total	**24**	**31**	**55**	**167**	**354**	**0.41**	**566**	**299**	**246**	**21**	**3.39**	**100**	**477**	**2**	**46**	

Appendix II. Draft Talking Points for Media

Vancouver Island marmots were certain to go extinct at the start of the century, unless dramatic conservation action would be attempted. Through courageous, science-driven conservation management by many collaborative partners and supporters, comprised of government, non-profit, zoo, corporate, and academic institutions, certain extinction has been prevented.

- Vancouver Island Marmot populations have grown dramatically in the wild through a sound integration of captive-breeding based reintroductions and innovative wildlife management.
- The dramatic recovery of Vancouver Island Marmots represents one of the world's greatest reintroduction successes in a short period of time. Nevertheless, the group agrees wild populations are not yet able to be down-listed from Endangered Status on SARA.
- Despite remaining needs to save the species, the successful development and use of proven tools for species recovery, and effective collaboration mechanisms for a harmonious multi-stakeholder team, captive-breeding, research, and effective management on the ground has been diminished over 7 years because of financial constraints.

The group agrees that to achieve sustainability, the following goals must be realized:

- Maximize existing biological information as a crucial foundation that can guide wise wildlife management and financial investment.
- Accurately determine the size, trend, and drivers of Vancouver Island Marmot populations in the wild.
- Determine how the landscape, and other species on Vancouver Island can be managed to maximize Vancouver Island Marmot recovery.
- Grow a captive-breeding population that serves primarily to grow wild marmot populations towards the goal of down-listing the species to Special Concern on SARA. A secondary purpose of the captive breeding population is as a safe-guard for wild populations long-term.
- Achieve certain short and long-term financial support without which all recovery actions are threatened, and the sustainability of the species may be compromised.

The group remains committed to growing the population of Vancouver Island Marmots in the wild until it is sustainable without intensive management actions such as captive-breeding or large-scale translocations among wild populations. The group is confident that necessary financial investments in sound collaboration, science, and management actions will eventually result in the long-term recovery of this critically endangered species.

Appendix III. Workshop Participants and Agenda

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Jim Walker	Marmot Recovery Foundation
Helen Schwantje	Ministry of Forests, Lands, Natural Resource Operations
Chris Ritchie	Ministry of Forests, Lands, Natural Resource Operations
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Peter Gibson	Mount Washington Alpine Resort
Bob Morris	BC Wildlife Federation
Dr. Richard Young	IUCN Small Mammal Specialist Group

Vancouver Island Marmot PHVA Workshop Agenda
3-6 March 2015
(*topics and times subject to change*)

<u>3 March (Tuesday)</u>

8:30 – 8:45	Introduction to workshop (C. Lanthier, A. Moehrenschlager, V. Jackson) - Welcome to the Calgary Zoo - Welcome from the Marmot Recovery Foundation
8:45 – 9:30	Brief introduction to CBSG; Scope of this meeting: objectives for this workshop; participant introductions (each person to introduce his/her self, area of relevant expertise, personal hope for Vancouver Island marmots (Baker, C Jackson)
9:30 – 9:45	Review/revision of agenda, workshop ground rules (Baker)
9:45 – 10:15	Overview of IUCN guidelines for reintroduction and *ex situ* management as part of an integrated species conservation strategy (Traylor-Holzer, Moehrenschlager)
10:15 – 10:30	Break
10:30 – 12:00	Brief overview presentations (15 min each) - 1994, 2000 and 2008 recovery plans, goals, management approaches, successes and failures (Doyle) - Nanaimo Lakes population, current status, population trends (C. Jackson) - Forbidden Plateau and Western Strathcona regions, current status, population trends (C. Jackson) - Captive population, current status, trends (McAdie)
12:00 – 1:00	Lunch
1:00 – 2:00	Overview of PVA/Vortex/VI marmot model and preliminary results (Traylor-Holzer)
2:00 – 3:00	Plenary session: Identification and diagramming of issues related to VI marmot viability and recovery (Traylor-Holzer)
3:00 – 3:30	Prioritization of issues related to VI marmot viability and recovery (Baker)
3:30 – 3:45	Break
3:45 – 4:00	Working group introduction (topics and instructions) (Baker)
4:00 – 5:00	Working groups: Issue evaluation (3 working groups each addressing different issues) - Group convenes, assigns roles, defines scope - Further issue description - Identification of facts vs hypotheses and data gaps - Identification of intervention opportunities
5:00	Adjourn for day

4 March, Wednesday

8:30 –11:00	Working groups from yesterday continue (break as needed)
11:00 – 12:00	Plenary session - Working group reports, discussion, recommendations - Identification of additional modeling questions
12:00 – 1:00	Lunch
1:00 – 4:00	Working groups: Goals and Objectives (break as needed) - Generation of long-term goals that address issues - Identification of measurable short-term objectives - Identification of potential actions needed to meet objectives - Identification of additional modeling questions
4:00 – 5:00	Plenary session - Working group reports, discussion, recommendations - Group prioritization of goals

5 March, Thursday

8:30 –9:00	Plenary session: Modeling report (additional scenarios) (Traylor-Holzer)
9:00 – 12:00	Working groups: - Analysis of proposed actions, benefits, costs, likelihood of success - Evaluation and selection of proposed actions - Detailed description and timeline for proposed actions
12:00 – 1:00	Lunch
1:00 – 2:00	Plenary session: working group reports and discussion
2:00 – 2:30	Overview of VI marmot model results for Forbidden Plateau and Strathcona populations. (Traylor-Holzer)
2:30 – 3:30	Plenary session: discussion of appropriateness of initial (and still current) recovery program goals (C. Jackson)
3:30 – 5:00	Working groups: Revisions to goals, objectives and recommended actions

6 March, Friday

8:30 –9:30	Plenary session: Final working group recommendations, identify and reach agreement on major program components and recommendations
9:30 – 10:15	Timeline for metapopulation recovery goals for all three metapopulations
10:15 – 11:45	Plenary session: Identification of major workshop outcomes, next steps, and responsible parties
11:50 – 12:00	Closing remarks (V. Jackson, A. Moehrenschlager)

Appendix IV: Key Reference Literature

Aaltonen, K., A.A. Bryant, J.A. Hostetler, and M.K. Oli. 2009. Reintroducing endangered Vancouver Island marmots: survival and cause-specific mortality rates of captive-born versus wild-born individuals. *Biological Conservation* 142: 2181-2109.

Armitage, K.B. 1991. Social and population dynamics of yellow-bellied marmots: Results from long-term research. *Annual Review of Ecology and Systematics* 22: 379-407.

Armitage, K.B. 1999. Evolution of sociality in marmots. *Journal of Mammalogy* 80: 1-10.

Armitage, K.B. 2013. Climate change and the conservation of marmots. *Natural Science* 5: 36-43.

Ballou, J.D., R.C. Lacy, and J.P. Pollak. 2010. PMx: software for demographic and genetic analysis and management of pedigreed populations. Chicago Zoological Society, Brookfield, Illinois, USA.

Blumstein, D.T. and J.M. Foggin. 1997. Effects of vegetative variation on weaning success, overwinter survival, and social group density in golden marmots (*Marmota caudata aurea*). *Journal of Zoology* 243(1): 5769.

Blumstein, D.T., A. Ozgul, V. Yovovich, D.H. Van Vuren and K.B. Armitage. 2006. Effect of predation risk on the presence and persistence of yellow-bellied marmot (*Marmota flaviventris*) colonies. *Journal of Zoology* 270: 132-138.

Brashares, J.S., J.R. Werner and A.R.E. Sinclair. 2010. Social 'meltdown' in the demise of an island endemic: Allee effects and the Vancouver Island marmot. *Journal of Animal Ecology* 79: 965-973.

Bryant, A.A. 1996. Reproduction and persistence of Vancouver Island marmots (*Marmota vancouverensis*) in natural and logged habitats. *Canadian Journal of Zoology* 74: 678-687.

Bryant AA. 1997. Updated status of the Vancouver Island marmot (*Marmota vancouverensis*) in Canada. Committee on the Status of Endangered Species in Canada, Ottawa, ON. pp. 1-21.

Bryant A.A. 1998. Metapopulation ecology of Vancouver Island marmots (*Marmota vancouverensis*). PhD thesis. University of Victoria. 96pp.

Bryant, A.A. 2000. Relative importance of episodic versus chronic mortality in the decline of Vancouver Island marmots (*Marmota vancouverensis*). Pages 189-195 in: *Proceedings of a Conference on the Biology and Management of Species and Habitats at Risk*, L. Darling (ed.). Queen's Printer. Victoria. pp. 189-195.

Bryant, A.A. 2005. Reproductive rates of wild captive Vancouver Island marmots (*Marmota vancouverensis*). *Canadian Journal of Wildlife* 83(5): 664-673.

Bryant, A.A., D.W. Janz, M.C. deLaronde and D. Doyle. 2002. Recent Vancouver Island marmot (*Marmota vancouverensis*) population changes. Pages 88-100 in: *Holarctic Marmots and a Factor of Biodiversity*, K.B. Armitage and V.U. Rumianstev (eds.). ABF Publishing House: Moscow.

Bryant. A.A. and D.W. Janz. 1996. Distribution and abundance of Vancouver Island marmots (*Marmota vancouverensis*). *Canadian Journal of Zoology* 74: 667-677.

Bryant, A.A. and R.E. Page. 2005. Timing and causes of mortality in the endangered Vancouver Island marmot (*Marmota vancouverensis*). *Canadian Journal of Zoology* 83: 674-682.

Carnio, J. 2015. Vancouver Island marmot studbook database (SPARKS format). Current to 1 February 2015.

COSEWIC. 1979. Status of the Vancouver Island marmot in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. pp. 1-12.

COSEWIC. 2008. COSEWIC assessment and update status report on the Vancouver Island marmot *Marmota vancouverensis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 29 pp. (www.sarareregistry.gc.ca/status/status_e.cfm).

Dobson, F.S. and J.D. Kjelgaard. 1985. The influence of food resources on life history in Columbian ground squirrels. *Canadian Journal of Zoology* 63: 2105-2019.

Griffin, S.C. and A.A. Bryant. 2008. Microsatellite analyses of Vancouver Island marmots. Vancouver Island Marmot Recovery Project Final Report. 27 pp.

Grimm, V., N. Dorndorf, F. Frey-Roos, C. Wissel, T. Wyszomirski, and W. Arnold. 2003. Modelling the role of social behavior in the persistence of the alpine marmot *Marmota marmot*. *OIKOS* 102: 124-136.

Hackländer K, Arnold W. Male-caused failure of female reproduction and its adaptive value in alpine marmots (*Marmota marmota*). *Behavioral Ecology* 10(5): 592-597

Hebda, R.J., O. McDadi and D. Mazzucchi. 2004. Habitat history and the decline of the Vancouver Island marmot (*Marmota vancouverensis*) in: Hooper TD. (Ed). Proceedings of the Species at Risk 2004 Pathways to Recovery Conference. BC Species at Risk 2004 Pathways to Recovery Conference Organizing Committee. Victoria, BC. pp. 1-11.

Jackson C.L. 2012. First year site fidelity and survival in reintroduced captive-bred Vancouver Island marmots (*Marmota vancouverensis*). MSc thesis. University of British Columbia. pp. 1-72.

Jackson, C. and D. Doyle. 2013. Vancouver Island Marmot Project Final Report 2013. 42 pp.

Jackson, C., C. White, C. Reid, and D. Doyle. 2013. Vancouver Island Marmot – Butte Lake Supplementation Project Prepared for BC Hydro Bridge Coastal Fish and Wildlife Restoration Program. 45 pp.

Janz, D., C. Blumensaat, N.K. Dawe, B. Harper, S. Leigh-Spencer, W. Munro, and D. Nagorsen. 1994. *National Recovery Plan for the Vancouver Island Marmot*. Report No. 10. Ottawa: Recovery of Nationally Endangered Wildlife Committee, 32 pp.

Janz, D.W., A.A. Bryant, N.K. Dawe, H. Schwantje, B. Harper, D. Nagorsen D. Doyle, M. deLaronde, D. Fraser, D. Lindsay, S. Leigh-Spencer, R. McLaughlin, and R. Simmons. 2000. *National Recovery Plan for the Vancouver Island Marmot (2000 Update)*. Report No. 19. Recovery of Nationally Endangered Wildlife. Ottawa, ON.

King, W.J. and D. Allainé. 2002. Social, maternal, and environmental influences on reproductive success in female Alpine marmots (*Marmota marmota*). *Canadian Journal of Zoology* 80: 2137-2143.

Kruckenhauser, L., A.A. Bryant, S.C. Griffin, S.J. Amish and W. Pinsker. 2009. Patterns of within and between-colony microsatellite variation in the endangered Vancouver Island marmot (*Marmota vancouverensis*): Implications for conservation. *Conservation Genetics* 10: 1759-1772.

Lacy, R.C. 1993. Vortex: A computer simulation model for population viability analysis. *Wildlife Research* 20:45-65.

Lacy, R.C. 2000. Structure of the Vortex simulation model for population viability analysis. *Ecological Bulletins* 48:191-203.

Lacy, R.C., P.S. Miller and K. Traylor-Holzer. 2015. *Vortex 20 User's Manual*. 20 February 2015 update. IUCN SSC Conservation Breeding Specialist Group, and Chicago Zoological Society, Apple Valley, MN, USA.

Lacy, R.C. and J.P. Pollak. 2014. Vortex: A Stochastic Simulation of the Extinction Process. Version 10.0. Chicago Zoological Society, Brookfield, IL, USA.

Milko, R.J. 1984. Vegetation and foraging ecology of the Vancouver Island marmot (*Marmota vancouverensis*). M.Sc. thesis. University of Victoria. Victoria.

Munro, W.T., D.W. Janz, V. Heinsalu, and G.W. Smith GW. 1985. The Vancouver Island marmot: status and management plan. BC Ministry of Environment. Wildlife Branch. *Wildlife Bulletin* No. B-39. Victoria, BC.

O'Grady, J.J., B.W. Brook, D.H. Reed, J.D. Ballou, D.W. Tonkyn, and R. Frankham. 2006. Realistic levels of inbreeding depression strongly affect extinction risk in wild populations. *Biological Conservation* 133:42-51.

Oli, M.K. and K.B. Armitage. 2004. Yellow-bellied marmot population dynamics: Demographic mechanisms of growth and decline. *Ecology* 85: 2446-2455.

Ozgul, A., K.B. Armitage, D.T. Blumstein, and M.K. Oli. 2006. Spatiotemporal variation in survival rates: Implications for population dynamics of yellow-bellied marmots. *Ecology* 87: 1027-1037.

Ralls, K., J.D. Ballou, and A.R. Templeton. 1988. Estimates of lethal equivalents and the cost of inbreeding in mammals. *Conservation Biology* 2:185-93.

Reed, D.H., J.J. O'Grady, B.W. Brook, J.D. Ballou, and R. Frankham. 2003. Estimates of minimum viably population sizes for vertebrates and factors influencing estimates. *Biological Conservation* 113:23-34.

SARA. 2002. Species at Risk Act (S. C. 2002, c.29).

Schwartz, O.A., K.B. Armitage, and D.Van Vuren. 1998. A 32-year demography of yellow-bellied marmots (*Marmota flaviventris*). *Journal of Zoology* 246: 337-346.

Tafani, M., A. Cohas, C. Bonenfant, J-M. Gaillard and D. Allaine. 2013. Decreasing litter size of marmots over time: A life history response to climate change? *Ecology* 94: 580-586.

Van Vuren, D. and K.B. Armitage. 1991. Duration of snow cover and its influence on life-history variation in yellow-bellied marmots. *Canadian Journal of Zoology* 69(7): 1755-1758.

Vancouver Island Marmot Recovery Team. 2008. *Recovery Strategy for the Vancouver Island Marmot (Marmota vancouverensis) in British Columbia*. Prepared for the B.C. Ministry of Environment. Victoria, BC. 25 pp.

Werner, J.R. 2005. The endangered Vancouver Island marmot: Allee effects and reintroduction success. MSc thesis. University of British Columbia. pp. 1-86.

White, C., C. Reid, and D. Doyle. 2012. Vancouver Island Marmot Buttle Lake Supplementation Project. Prepared for BC Hydro Bridge Coastal Fish and Wildlife Restoration Program. 40pp.

Woods, B.C. and K.B. Armitage. 2003. Effects of food addition on life history of yellow-bellied marmots. *Oecologia Montana* 12: 29-36.