Recovery Strategy for the Vancouver Island Marmot (*Marmota vancouverensis*) in British Columbia

Prepared by the Vancouver Island Marmot Recovery Team

BRITISH COLUMBIA
The Best Place on Earth
Ministry of Environment

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About the British Columbia Recovery Strategy Series

This series presents the recovery strategies that are prepared as advice to the Province of British Columbia on the general strategic approach required to recover species at risk. The Province prepares recovery strategies to meet its commitments to recover species at risk under the *Accord for the Protection of Species at Risk in Canada*, and the *Canada – British Columbia Agreement on Species at Risk*.

What is recovery?

Species at risk recovery is the process by which the decline of an endangered, threatened or extirpated species is arrested or reversed, and threats are removed or reduced to improve the likelihood of a species' persistence in the wild.

What is a recovery strategy?

A recovery strategy represents the best available scientific knowledge on what is required to achieve recovery of a species or ecosystem. A recovery strategy outlines what is and what is not known about a species or ecosystem; identifies threats to the species or ecosystem, and what should be done to mitigate those threats. Recovery strategies set recovery goals and objectives, and recommend approaches to recover the species or ecosystem.

Recovery strategies are usually prepared by a recovery team with members from agencies responsible for the management of the species or ecosystem, experts from other agencies, universities, conservation groups, aboriginal groups, and stakeholder groups as appropriate.

What's next?

In most cases, one or more action plan(s) will be developed to define and guide implementation of the recovery strategy. Action plans include more detailed information about what needs to be done to meet the objectives of the recovery strategy. However, the recovery strategy provides valuable information on threats to the species and their recovery needs that may be used by individuals, communities, land users, and conservationists interested in species at risk recovery.

For more Information

To learn more about species at risk recovery in British Columbia, please visit the Ministry of Environment Recovery Planning webpage at:

<http://www.env.gov.bc.ca/wld/recoveryplans/rcvry1.htm>

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Disclaimer

This recovery strategy has been prepared by the Vancouver Island Marmot Recovery Team, as advice to the responsible jurisdictions and organizations that may be involved in recovering the species. The British Columbia Ministry of Environment has received this advice as part of fulfilling their commitments under the *Accord for the Protection of Species at Risk in Canada*, and the *Canada – British Columbia Agreement on Species at Risk*.

This document identifies the recovery strategies that are deemed necessary, based on the best available scientific and traditional information, to recover Vancouver Island Marmot populations in British Columbia. Recovery actions to achieve the goals and objectives identified herein are subject to the priorities and budgetary constraints of participatory agencies and organizations. These goals, objectives, and recovery approaches may be modified in the future to accommodate new objectives and findings.

The responsible jurisdictions and all members of the recovery team have had an opportunity to review this document. However, this document does not necessarily represent the official positions of the agencies or the personal views of all individuals on the recovery team.

Success in the recovery of this species depends on the commitment and cooperation of many different constituencies that may be involved in implementing the directions set out in this strategy. The Ministry of Environment encourages all British Columbians to participate in the recovery of Vancouver Island Marmots.

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RESPONSIBLE JURISDICTIONS

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EXECUTIVE SUMMARY

This document 1) outlines a broad strategy for Vancouver Island Marmot recovery, 2) lists the approaches required in pursuit of that strategy, and 3) describes gaps in knowledge.

Background

The Vancouver Island marmot (*Marmota vancouverensis*) is an endemic ground squirrel that is native to mountainous regions of that island located off the west coast of British Columbia, Canada. Historical population sizes are not known, although paleontological records suggest that the geographic range of the species apparently declined over the past several thousand years. Populations increased significantly during the 1980s and 1990s, and was manifested mostly, but not exclusively by colonization of new man-made habitats created by forestry. Thereafter numbers declined precipitously, reaching a low of some ~30 individuals during the early 2000s. The proximate cause of decline was excessive predation by naturally occurring predators, which are believed to have responded both functionally and numerically to landscape changes. Present threats to the species include predation, inbreeding depression, possible deleterious effects due to climate change, and random effects due to small population size and geographic range. The current strategy is focused on restoring wild populations through an ongoing captive-breeding and reintroduction program.

Recovery efforts for the species began in 1988. The primary focus of the first recovery plan for Vancouver Island Marmots, published in 1994, was to obtain better scientific information about population sizes, distribution, and trends. The first plan was updated in 2000 and benefitted from new knowledge that wild populations were declining, and that a long-term captive-breeding and reintroduction program would be necessary to prevent extinction and restore wild populations. The later plan also acknowledged that a new management paradigm was needed to implement recovery activities given the scale of the recovery task; this ultimately led to the formation of a captive-breeding program and the non-profit Marmot Recovery Foundation.

Population goals and feasibility of recovery

The original recovery target was to achieve a self-sustaining wild population of 400–600 marmots, dispersed in three metapopulations on Vancouver Island. This population target was derived from a synthesis of historical occupancy records, habitat patch-specific estimates of carrying capacity, availability of natural habitat, and population simulation models. The stipulation of three metapopulations was based on the geography of Vancouver Island, in which several large water bodies provide barriers to marmot movement and therefore create, from a marmot's perspective, three different "islands" of habitat. The population goal remained unchanged in the updated (2000) plan, and was reinforced by new genetic data, population viability analyses, and mapping of potential reintroduction habitat. The 400-600 marmot goal remains in effect in this strategy.

Recovery of the Vancouver Island Marmot is considered to be biologically and technically feasible, as: reproductively capable individuals and sufficient suitable habitat are available, threats are manageable, and effective recovery techniques exist.

Recovery strategy

With a wild population containing fewer than 100 individuals, the emphasis must be on population restoration rather than population maintenance. To achieve this end, the existing captive-breeding programs must be continued and reintroduction efforts must be expanded. Additional effort is required to map available habitat and evaluate reintroduction success or failure. Fundraising and educational programs must be continued.

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Species Assessment Information from COSEWIC

Date of Assessment: April 2008. Designated Endangered in April 1978. Status re-examined and confirmed Endangered in April 1997, May 2000, and April 2008. Last assessment based on an updated status report

Common Name (population): Vancouver Island Marmot

Scientific Name: *Marmota vancouverensis*

COSEWIC Status: Endangered

Occurrence: British Columbia

Reason for Designation: Fewer than 30 mature wild-born individuals of this Canadian endemic remain in the wild. Despite the apparent initial success of reintroductions, the wild population of this species remains extremely small and could be subject to stochastic events. Ongoing predation remains high and there are potential threats from inbreeding and climate change.

Description of the Species

The Vancouver Island Marmot (*Marmota vancouverensis*) is a housecat-sized ground squirrel that is endemic to the mountains of Vancouver Island, British Columbia (Nagorsen 1987). Like all 14 currently recognized species of marmots, the Vancouver Island Marmot lives in burrows, feeds primarily on grasses and forbs, and hibernates during winter (Barash 1989). The species is closely related to the Hoary Marmot (*Marmota caligata*) and the Olympic Marmot (*M. olympus;* Kruckenhauser et al. 1999; Steppan et al. 1999), although it is distinct in its chocolate brown fur colour (Nagorsen 1987), skull morphology (Cardini et al. 2005), behaviour and vocalizations (Heard 1977; Blumstein 1999).

As is the case for most alpine-dwelling marmots, Vancouver Island Marmots take several years to become sexually mature, can live for a decade or more, and display a high level of social complexity (Bryant 1996; Blumstein 1999). Their natural habitat consists of subalpine meadows, generally located between 1050 and 1400 m above sea level (Bryant and Janz 1996). Colonies tend to be small compared to other species, with most containing one or a few family groups and fewer than a dozen adults (Bryant 1998).

Populations and Distribution

The global and Canadian distribution of the Vancouver Island Marmot is confined to Vancouver Island, British Columbia. Fewer than 160 animals were known to be alive in late 2005, including 123 in captivity (Recovery Team minutes, 2 Nov. 2005). Historically, marmots exhibited a pronounced metapopulation structure, in which small colonies were linked through dispersal of occasional immigrants (Bryant 1996). The recovery strategy is explicitly designed to restore this pattern of geographically isolated colonies that are linked by dispersal.

During the early 1980s, the size of local colonies, and the number of colonies, increased dramatically. This included colonization of habitats created by clearcut logging that led to a doubling of the overall population size (Bryant and Janz 1996). Later surveys revealed precipitous declines, from approximately 300 to 350 individuals during the mid-1980s to near-extinction in the wild by 2003 (Janz et al. 2000). Historical location records (Figure 1) suggest a more reduced geographic range than was estimated by post-1971 surveys (Nagorsen et al. 1996; Bryant 1998).

Vancouver Island Marmots presently occur on five mountains in the Nanaimo Lakes region of central Vancouver Island and a single mountain located approximately 95 km to the northwest on Mount Washington (Recovery Team minutes, 2 Nov. 2005). If all six occurrences are treated as a single unit, the total area occupied by this species is approximately 840 km² (BC Conservation Data Centre 2006). Records from tagging (Bryant 1998), radio-telemetry (Bryant and Page 2005), and DNA analysis (Kruckenhauser et al. in press) suggest that all recently occupied colonies in the Nanaimo Lakes region were connected through occasional between-mountain dispersal movements. However, genetic results suggest that the Mount Washington site has been isolated for at least several marmot generations, although the DNA evidence is not yet sufficient to estimate timing of isolation. Given two isolated populations as suggested by recent genetic data (Kruckenhauser et al. in press), the area of occurrence is approximately 160 km² in the Nanaimo Lakes region and 9–10 km² on Mount Washington, for a total area of occurrence of ~170 km² (BC Conservation Data Centre 2006). The actual area of occupancy varies by mountain, but the pooled estimate of the size of occupied meadows is a small fraction of the extent of occurrence (<5 km² in total).

In 1978 the Vancouver Island Marmot was among the first species listed as endangered by the newly formed Committee on the Status of Endangered Wildlife in Canada (COSEWIC; Shank 1999). The species is now listed as Endangered under the federal *Species at Risk Act* (SARA), the *B.C. Wildlife Act* (1980; Munro et al. 1985), and the *U.S. Endangered Species Act* (Federal Register, Jan. 23 1984). Although the Vancouver Island Marmot does not, and apparently never has occurred in the United States, the *U.S. Endangered Species Act* allows for the listing of “foreign species” in order to provide additional protection to species in danger of worldwide extinction. The International Union for the Conservation of Nature recently updated their assessment of the Vancouver Island Marmot from Endangered (Groombridge and Mace 1994) to Critically Endangered (D. Nagorsen, assessment submitted to IUCN, Feb. 2004).

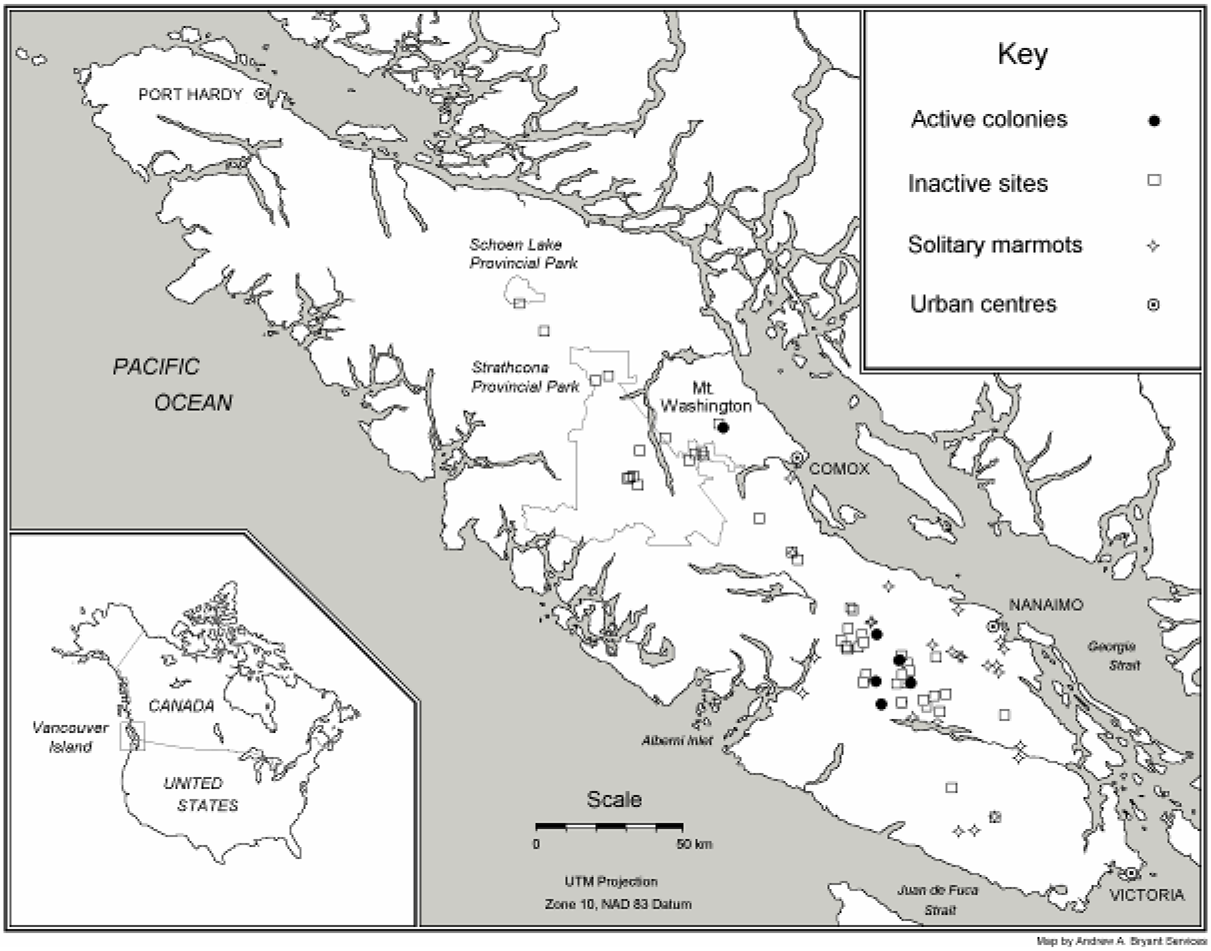


Figure 1. Distribution of active (as of 2005) and inactive (1896-2004) colony locations for the Vancouver Island marmot (*Marmota vancouverensis*) in Canada. Records of solitary marmots likely represent dispersing individuals.

Needs of the Vancouver Island Marmot

Habitat and biological needs

Habitat for Vancouver Island Marmots consists of subalpine meadows distributed in three broad areas (metapopulations) on Vancouver Island (Janz et al. 2000). In some cases, historical records make it straightforward to map suitable habitat (e.g., Bryant 1996; Bryant and Janz 1996). However, in other cases the suitability of habitats remains unclear. Routledge and Merilees (1980) ranked the apparent suitability of 89 mountains that they searched, describing 12 mountains as “excellent” and a further 21 as providing “moderate” habitat conditions for marmots. Bryant (1993b) mapped potential reintroduction sites in Strathcona Provincial Park, and Demarchi et al. (1995) conducted a detailed biophysical analysis of four potential sites.

Potential marmot habitats are generally restricted to the Coastal Western Hemlock and Mountain Hemlock biogeoclimatic zones of the Georgia Depression Ecoprovince (Demarchi et al. 1990).

The region lies in the leeward rain shadow of the Vancouver Island Mountains, and is consequently dryer than are sites to the west of that mountain range. The climate is submaritime, with precipitation falling as rain or snow depending on elevation, and with temperatures moderated depending on proximity to the sea (Klinka et al. 1989). Mountains in the Georgia Depression Ecoprovince are typically lower in elevation (1000–1500 m) and more heavily forested than are the mountains found further north and exemplified by Strathcona Provincial Park (Coast and Mountains Ecoprovince; Demarchi et al. 1990). Most mountains occupied by marmots have summits below tree line. Forests in valley bottoms (generally at 200–300 m) are dominated by Douglas-fir (*Pseudotsuga menzeisii*), western red cedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*). At higher elevations, these species are gradually replaced by varying mixtures of subalpine fir (*Abies lasiocarpa*), yellow-cedar (*Chamaecyparis nootkatensis*), and mountain hemlock (*Tsuga mertensiana*).

Within this landscape, marmots historically occupied small (0.5–8.0 ha) subalpine meadows located between 900 and 1450 m elevation, usually on moderately steep (30–45°) south- to west-facing slopes (Bryant and Janz 1996). Such meadows may be maintained by avalanches, snow-creep, or fire (Milko 1984; Milko and Bell 1985). Suitable habitat patches are rare, occupying less than 1% of the 1000 km² Nanaimo Lakes region (Bryant 1998). Subalpine meadows are characterized by high species diversity. Food plants commonly eaten by marmots included grasses, sedges and spreading phlox (*Phlox diffusa*) in spring, and forbs such as broadleaf lupine (*Lupinus latifolius*), woolly sunflower *(Eriophyllum lanatum*), and purple peavine (*Lathyrus nevadensis*) in summer (Martell and Milko 1986). Occupied sites invariably had numerous boulders and rock outcrops; these may provide thermoregulation opportunities in addition to providing “lookout” spots that help marmots to detect and avoid predators. Hibernation and birth burrows in natural habitats were typically constructed under the downhill side of large boulders. Secondary “escape burrows” were also constructed in open meadows and in forest edges. Soils in a few sampled meadows consisted of colluvial veneers overlying bedrock to a depth generally less than 1 m, which may mean that suitable sites for hibernation are also rare (Demarchi et al. 1995). Bedrock outcrops occur on the upper slopes at most sites, and these provided opportunities for early spring foraging of plants such as Phlox even in years of extremely late snow-melt.

Vancouver Island Marmots need three essential habitat features to fulfill their basic biological needs: 1) suitable soil structure that allows burrow construction, 2) suitable grass-forb vegetation to eat, and 3) microclimatic conditions that permit summer foraging and successful hibernation. These essential habitat features limit the extent and number of sites at which colonies can exist, and therefore constitute major limiting factors for the species (Bryant and Janz 1996).

Burrows

Vancouver Island Marmots construct burrows in which to hibernate, bear young, hide from predators, and avoid environmental extremes. Burrows (including hibernacula) are commonly re-used in multiple years by the same individuals and social groups (Bryant 1998). Escape burrows (used to avoid predators) may be merely a shallow excavation under a rock or tree root. Burrows used overnight or as birthing chambers are more elaborate and often feature multiple entrances. As with escape burrows, they are typically constructed underneath a boulder or tree root system, which presumably offers supporting structure. Hibernacula are presumably deep enough that marmots can hibernate beneath the frost-line. Work on Alpine Marmots (*M. marmota*) suggests that a critical feature of hibernacula may be their ability to maintain stable ambient temperatures close to 5°C (Arnold 1990).

Forage

Marmots have been observed to eat more than 40 species of plants. In general, marmots focus on grasses and sedges in early spring, shifting to forbs in summer and fall. Plants such as lupines (*Lupinus latifolius*) and woolly sunflower (*Eriophyllum lanatum*) appear to be especially important in late summer and fall, and spreading phlox (*Phlox diffusa*) is important in early summer (Martell and Milko 1986; Bryant 1998). Milko and Bell (1985) studied vegetation at several marmot colonies in natural subalpine meadows and concluded that open subalpine meadows may be maintained by avalanches or snow-creep. Some natural meadows may be created by wildfires (Hebda et al. 2005). Marmots have also lived successfully in habitats created by logging, ski-run development, and in other open high-elevation habitats (Bryant 1996; Bryant and Janz 1996). In such habitats, marmots feed on plants such as grasses, pearly everlasting (*Anaphalis margariticea*), strawberry (*Fragaria* spp.), and fireweed (*Epilobium angustifolium;* Bryant 1998).

Hibernation

Vancouver Island Marmots hibernate for about 210 days in the wild, typically from late-September-early October through late April-early May (Bryant and McAdie 2003). Snow accumulation and melt patterns are important factors in providing suitable, snow-free habitat at the appropriate time and this likely explains why most marmot colonies are located on south to west-facing slopes (Bryant and Janz 1996). Many high-elevation or north-facing sites that look suitable in August may be snow covered and therefore provide insufficient food resources in May or June. Similarly, low-elevation sites may not provide either suitable hibernacula (because of their increased temperature) or suitable forage. The lowest elevation site known to have hosted a wild marmot colony in modern times was at 719 m (Bryant and Janz 1996).

Dispersal

Vancouver Island marmots exhibit impressive dispersal capabilities. Based on radio-telemetry, sub-adults of both sexes have been observed to make movements of 1-27 km within a few days (A. Bryant and D. Doyle unpublished data). Most marmots apparently disperse as 2 year-olds (Bryant 1998). Dispersal does not appear to be either strongly sex-biased or related to colony size or success. Based on resightings of ear-tagged animals Bryant (1998) estimated that maximum dispersal distance was 11.2 km. Records of solitary marmots in low elevation habitats suggest many possible dispersal movements larger than this. Bryant and Janz (1996) compiled 22 records of solitary marmots during 1972-1995, including 1 found on the beach at Courtenay (12 July 1974), 1 photographed on Mount Demers (25 July 1977), and 1 in a vegetable garden at Coombs (7 July 1980). Some of these (e.g., Bell's Bay, Cassidy, Duncan, and Cedar) likely represent dispersal events >30 km.

Based on allozyme and recent DNA work (Bryant 1990, Kruckenhauser et al. in press), together, with records from tagged marmots, it appears that the entire population on central Vancouver Island (i.e., the Nanaimo Lakes region) functions as a metapopulation, with genetic structure strongly influenced by founder effects. The Mount Washington location is noteworthy for the presence of several private alleles, although it is impossible to suggest when isolation between that site and colonies further south occurred. There is no evidence to suggest that marmots employ particular "corridors" or prefer various types of terrain while dispersing. Plotted dispersal vectors are seemingly random, and neither logging roads, mature forests, nor logged habitats represent a physical impediment to dispersal. Dispersal movements apparently end with encountering another marmot. Thus, most of the clearcut colonies that were formed in the 1980s-90s were located in close proximity (< 5 km) to occupied colonies in natural meadows (Bryant and Janz 1996). Another noteworthy result is that very few radio-tagged marmots were killed by predators while in the course of dispersal (Bryant and Page 2005).

Ecological role

It is unclear if the Vancouver Island Marmot could be considered a "keystone" species. Although marmots do modify vegetation conditions through grazing, the degree of disturbance is far less than that imposed by other mammals (Milko 1984). Similarly, although Vancouver Island Marmots are prey for both terrestrial and avian predators, they do not constitute the major prey item for any species. However, Vancouver Island Marmots are the only large burrowing mammals in this habitat type and their burrows are known to be used by a variety of moths and other insects; the ecological significance of this is unclear. Finally, Vancouver Island Marmots are also the exclusive host to an endemic tapeworm species *Diandrya vancouverensis* (Mace and Shepard 1981), a species that must be considered as endangered as their host.

Limiting factors

The major limiting factors for the Vancouver Island Marmot are related to suitable habitat, genetic variability, and small population sizes.

Restricted suitable habitat

As described above, natural habitat patches that are suitable for marmots occur relatively infrequently within the broader landscape. Bryant (1998) measured the amount of natural subalpine meadow in the Nanaimo Lakes area and concluded that such habitats accounted for about 1% of the area that contained most marmots alive during the 1980s. Suitable habitat patches are believed to be rarer south of Lake Cowichan and in areas such as Strathcona Provincial Park, although historical marmot records occur for both areas (Bryant 1993b).

Suitable habitat is more restricted on Vancouver Island than in nearby Washington State for the more abundant, closely related Olympic Marmot, where similar subalpine meadow habitats are far more extensive (Fonda and Bliss 1969; Kuramoto and Bliss 1970).

Suitable habitat may have been more extensive in the past. Pollen analysis suggests that large changes in subalpine meadow habitat have taken place over the last few thousand years (Hebda et al. 2005). Warmer and dryer conditions 1000–2000 years ago may have created larger and more widespread open meadow parkland, and archeological and paeleontological discoveries at sites well outside the marmot's historical range indicate that Vancouver Island Marmots were more widely distributed, and probably far more abundant, in the recent prehistoric past (Nagorsen et al. 1996). Vancouver Island Marmots thus represent a good example of a naturally rare species that has successfully tracked changing environmental conditions over hundreds or thousands of years (Thomas 1994). However, this long-term process does not explain the very recent precipitous decline in distribution and abundance over the last few decades (Bryant 1998).

Loss of genetic variation

Inbreeding could depress reproductive or survival rates. Recent DNA analysis suggests that the Vancouver Island Marmot exhibits less genetic variation than other marmot species, although overall inbreeding coefficients were low (F_{is} = -0.09 to 0.02; Kruckenhauser et al. in press). The data also suggested significant genetic differentiation between marmots in the Nanaimo Lakes metapopulation and the apparently isolated Mount Washington colony.

It is unclear to what extent Vancouver Island Marmots may be vulnerable to the effects of inbreeding depression or loss of variation. Because population sizes have presumably been low for many generations, some researchers speculate that this species might be less vulnerable than others because deleterious genetic loads have already been purged (Janz et al. 2000). There is no evidence for inbreeding depression in the form of reduced reproductive rates (Bryant 2005), although one pair of wild-caught captive marmots produced two pups in two separate litters with congenital defects (M. McAdie, Marmot Recovery Foundation, pers. comm.).

Small populations, reproduction and survival rates

Based on mark-recapture evidence from 1987, wild Vancouver Island marmots bred at rates that were similar to other species of alpine-dwelling marmots in terms of the age of first reproduction, between-litter intervals, litter size, and sex ratio of offspring (Bryant 2005). There is no evidence suggesting that reproductive rates have declined in modern times, with one exception. Specifically, colony-specific data suggest numerous site-year combinations in which suitably aged females did not breed, apparently because the colony lacked a suitable male (Bryant 2005). Thus, low population densities may aggravate declines merely because individuals did not find a mate.

A study by Lichota et al. (2004) identified the existence of persistent organic pollutants in marmot blood and fatty tissues, a situation similar to that reported for various marine mammals (e.g., Ross et al. 1996). However, levels were extremely low compared to several other species that inhabited higher trophic levels, and the authors concluded that no adverse health or reproductive effects were likely.

Beyond that, it has been speculated that low population densities might create other problems, such as a reduced ability to detect or defeat predators (e.g., by reduced whistling or vigilance posture). However, the evidence for this is ambiguous. For example, Bryant (1998) found no strong relationships between survival rates and density, in fact, apparent survival rates were lower in high-density clearcut colonies, and the severity of population “crashes” of large colonies was comparable to those of small ones.

Threats

Threats to the survival of individuals

1. Predation
The major threat to the extant wild populations of Vancouver Island Marmots is predation, and this is also believed to be the proximate cause of recent population declines over the past few decades (Bryant and Page 2005). Roehmer et al. (2001) and others have shown that, in some cases, when the abundance of naturally occurring predators and their primary prey species change, abnormal mortality can be inflicted on secondary prey species.

Using radio-telemetry and known-fate analysis, Bryant and Page (2005) determined that at least 80% of marmot mortality since 1992 was attributable to predation, largely by wolves (*Canis lupis*), cougars (*Puma concolor*), and golden eagles (*Aquila chrysaetos*). Several other lines of evidence corroborate suspicion of abnormally high levels of predation in recent times. Count and mark-recapture results suggest that annual survival rates have declined since the 1980s, that losses at individual colonies were often dramatic within single years, and that colony-specific survival rates were spatially correlated. The inference is that recent population declines may have been caused by localized predation events (Bryant 2000). Numbers of cougars and wolves on Vancouver Island have increased dramatically since the early 1980s (B.C. Ministry of Environment, unpublished data), perhaps in response to changing deer populations (Bunnell 1990; Bryant and Page 2005). Increasing levels of predation on marmots may also reflect a functional response by predators, that is, predators hunted more often, or more successfully, in natural habitats surrounded by clearcuts that were also occupied by marmots (Bryant 1998).

That marmot populations increased in natural habitats, colonized 10 clearcuts, and doubled their known population during the 1980s—a period of relatively low predator abundance—lends credence to the idea that changing predator-prey conditions, not habitat or weather limitations, was the primary cause of the recent decline.

2. Disease and parasites
The impacts of disease outbreaks or parasites on marmots remain poorly understood but are potentially important. The loss of established colonies from places such as North Hooper (1982–83) and Gemini Peak (1986–87), combined with observed population crashes at places like Haley Lake and Butler Peak, suggest episodic mortality events. These events were consistent with a hypothesis of localized predation, but could also reflect disease outbreak (Bryant 2000).

Although Vancouver Island Marmots have been shown to harbour a variety of parasites including fleas, roundworms, tapeworms, ear-mites, and coccidia, there is no evidence to suggest that parasites have exerted a significant demographic population effect. Chronic mange has been diagnosed in most marmots from Mount Washington and some speculate that this could be associated with inbreeding at this site (M. McAdie pers. comm.). Four of six animals relocated from different colonies to a vacant historical location in 1996 died during hibernation, possibly as a result of a bacterial infection (Bryant et al. 2002a). The significance of these events remains unclear, although they underscore the inherent disease risk associated with a small population and restricted distribution.

Until recently, most animals in the captive program were wild-captured (*n* = 56). Although some of these individuals died as a result of poor adaptation to captivity (e.g., cecal perforation associated with a change to an artificial diet, septicemias and bacterial pneumonias associated with stress), most survived for at least several years and eventually died of disorders that were probably age-related (e.g., neoplasia, pancreatitis, cerebral hemorrhage). Survival rates in the captive population are very high (93%) compared to the wild. This, together with the results from extensive hematological, serological, and microbiological screening over more than 10 years and more than 200 wild and captive-born marmots, suggests that no specific pathogen is currently of serious management concern.

3. Climate change and altered marmot behaviour

Vancouver Island Marmots are obligate hibernators and thus require specific microclimatic conditions to fulfill this essential life-history pattern. A change in climate might influence hibernation timing (Inouye et al. 2000), and survival of hibernating marmots might depend on snow conditions (Barash 1989; Van Vuren and Armitage 1991). They could be more vulnerable to predation if they stay active later in the fall or emerge earlier in the spring. The evidence for any of these hypotheses is weak for Vancouver Island Marmots, but this should not be construed to mean that no possible threat exists. Records from radio-telemetry indicate no significant change in hibernation timing since records were first obtained in 1992 (Bryant and McAdie 2003), but show strong elevation and site effects.

Threats to marmot habitat

4. Climate and vegetation change

The extent and distribution of habitat suitable for the Vancouver Island Marmot is apparently limited by climatic conditions (Milko 1984; Milko and Bell 1985). This raises the possibility that climate change could have profound repercussions on future marmot habitat. For example, over the past 10,000 years, the mountains of western North America have been characterized by changing tree-line in response to changing climatic conditions (Rochefort et al. 1994). Recent analysis of pollen collected from natural subalpine marmot habitats indicates that significant changes in climate have occurred repeatedly over the last several thousand years and that marmot habitats were once much more extensive (Hebda et al. 2005). The same authors conclude that present patterns of global warming might increase the availability of marmot habitat.

Since the early 1900s, marmot habitat may also have been influenced by naturally occurring vegetation changes. A warmer and drier climate has resulted in tree invasion of subalpine meadows in most of the western mountains, including the Cascades, Olympics, and southern Coast Range. Forest growth could reduce the quality of naturally occurring sub-alpine meadows by altering food plant composition or the ability of marmots to detect predators. Using dendrochronology (tree-ring measurements) at historical and extant marmot colonies, Laroque (1998) determined that at least two sites (Gemini Peak and Green Mountain) experienced tree invasions over a few decades. However, other evidence suggests that in Strathcona Provincial Park, where marmots apparently disappeared 20 to 40 years ago, most trees above 1000 m elevation are more than 800 years old. There is little evidence of recent tree invasion despite close overlap of tree-ring sites with marmot records (e.g., Cruikshank Canyon, Circlet Lake, Greig Ridge, Philips Ridge; C. Laroque, University of Victoria, pers. comm.).

The role of fire in creating or maintaining marmot habitat is unclear, but it seems that this process is likely to be important at some sites. Milko (1984) speculated that a recent fire on Gemini Peak created open meadow habitat throughout the nearby ridge system, although later tree-ring analyses there did not support this scenario (Laroque 1998). Apparently, the different regions of Vancouver Island have experienced very different fire histories. Intervals between major fires were relatively short (<300 years) on southeastern Vancouver Island, whereas they were substantially longer (700–3000 years) in western and central regions (Lertzman et al. 1998; Brown and Hebda 2003, C. Laroque, pers. comm.).

Finally, post-logging forest succession in clearcuts has had a pronounced effect on marmot colonies. Of the 10 new colonies established in clearcuts described by Bryant (1996, 1998), all had become extirpated by 2000. The longest record for colony persistence in a clearcut was 19 years (1981 to 2000) in a habitat that was logged in 1979 (Road K44a). The median longevity of colonies in clearcuts was 10 years (range, 5–19 years), which equates to two or three marmot generations. Bryant (1996, 1998) produced some evidence that survival rates in habitats created by humans were slightly lower than in natural subalpine meadow habitats. However, in retrospect it now seems likely that clearcuts primarily functioned as population "sinks"; rapid forest succession quickly made habitat conditions unsuitable and therefore reduced the probability that surviving adults attracted new mates. Of the 10 clearcuts that were eventually colonized by marmots, 6 populations became extirpated after the last solitary or few surviving marmots were "rescued" by managers for transplant or captive-breeding purposes (Sherk Lake, Pat Lake, Mount Franklin, Road D13e, K44a, Butler Peak "west roads").

It is perhaps ironic that the future survival of Vancouver Island Marmots may in large measure depend on their temporary colonization of ephemeral habitats created by humans (Bryant 2005). The majority of marmots taken into captivity were from clearcuts (Bryant 2007). It is also unusual that the major climatically driven threat to habitat is apparently manifested by the growth of tree cover and not the loss of tree cover as is the case for many other endangered species (McTaggert-Cowan, 1980, unpubl.; Nagorsen et al. 1996; Laroque 1998; Hebda et al. 2005).

5. Development and direct habitat loss

Few direct threats to marmot habitat result from "development," but the indirect threats are important insofar as they relate to predator-prey conditions (Bryant and Page 2005) and the movements and distribution of marmots. Bryant and Janz (1996) documented the colonization of new habitats created by logging of high elevation forests, while (Bryant 1998) noted the propensity of both marmots and their naturally-occurring predators to utilize logging roads.

Most marmot habitat occurs on forest lands that are privately owned by Island Timberlands and TimberWest. The landscape surrounding natural habitat patches has been heavily modified by forestry activities (Bryant 1998). Logging of primary forests in the Nanaimo Lakes region began in the late 1940s and harvest rates accelerated rapidly during the 1960s and 1970s. Less than 15% of the primary forest in this portion of Vancouver Island remains intact, with most of the remnant stands located above 900 m elevation. The historical forest harvest pattern was to develop road access first along valley bottoms and then extend road networks upward as harvesting needs dictated. The result was a rapidly changing landscape that showed a progressive replacement of mature forests with younger ones, combined with a growing profusion of logging roads and an increasingly focused impact at higher elevations.

One direct result of anthropogenic change was that marmots colonized 10 clearcuts between 1981 and 1991 (Bryant 1998). Colonizations invariably occurred above 700 m (range, 719–1132 m), generally close to existing colonies in natural subalpine meadows (range, 0.41–4.56 km), and generally 5 to 15 years after harvest (Bryant and Janz 1996). Vegetation conditions in clearcuts occupied by marmots were quite dissimilar to those in natural meadows, being dominated by alder (*Alnus sitchensis*) and regenerating conifers. Many wildflower species found in natural meadows were not present in clearcuts, although broadleaf lupine and pearly everlasting were both common and commonly eaten by marmots. Marmots dwelling in clearcuts typically constructed burrows under stumps or under the downhill side of logging roads. An indirect effect of colonization was that marmot densities increased within a small geographic area, perhaps increasing the probability that predators hunt there, or hunt more successfully (Bryant and Page 2005). Another indirect effect of forestry may have been to increase the availability of primary prey such as Black-tailed deer, leading to increased predator abundance (Bunnell 1990).

The isolated Mount Washington colonies are potentially threatened by direct human disturbance or recreation activities. These colonies are located on lands owned by Mount Washington Alpine Resort (MWAR). The Mount Washington operation constitutes one of the largest ski-hill operations in British Columbia, with more than 300,000 skier-visits in 2001 (P. Gibson, General Manager, MWAR, pers. comm.). Marmots on Mount Washington live in patches of natural meadow and in ski-runs; burrows are occasionally constructed under artificial objects such as concrete ski-lift foundations. No negative impacts are known as a result of recreation activities, although the possibility exists (Dearden and Hall 1983).

Actions Already Completed or Underway

The Recovery Team was established in 1988, and published recovery plans in 1994 (Janz et al. 1994) and 2000 (Janz et al. 2000). In addition to the Recovery Team, a non-profit registered charitable organization (Marmot Recovery Foundation) was established in 1998 to raise funds and administer day-to-day recovery efforts. A novel funding partnership involving forest companies, various levels of government, and the general public has been created.

Vancouver Island Marmots have been the subject of many recent scientific studies. Topics have included population genetics (Bryant 1990; Kruckenhauser et al. in press), behaviour (Heard 1977; Blumstein et al. 1999; Blumstein et al. 2001; Casimir 2005), distribution, abundance, and population trends (Bryant and Janz 1996; Bryant et al. 2002b), timing and causes of mortality (Bryant 2000; Bryant and Page 2005), environmental contamination (Lichota et al. 2004), habitat structure and history (Hebda et al. 2005), hibernation ecology (Bryant and McAdie 2003), reproductive behaviour and physiology in captivity (Keeley et al. 2003; Bryant 2005; Casimir 2005), and behaviour and reintroduction success (Werner 2005, Bryant 2007).

A captive-breeding program was started in 1997. From 1997 through 2004, 56 wild-born marmots were taken into captivity and dispersed to four locations: the Toronto Zoo, Calgary Zoo, MountainView Breeding and Conservation Centre (a privately owned facility in Langley, BC), and a specially designed facility on Mount Washington (Bryant 2007). The program has been highly successful; the first reproduction occurred in 2000, and as of 2005 at least 115 pups had been weaned. Annual survival rates in captivity exceed 93% and birth rates are comparable to those of wild marmots (Bryant 2005).

Reintroduction to the wild began in 2003 with the release of 4 individuals; 9 were released in 2004, 15 in 2005, 28 in 2006, 37 in 2007, and 59 in 2008. The first breeding of a captive-born marmot after being released to the wild occurred in 2004, and as of 2008 some 11 litters have been produced by captive-born individuals after release to the wild. Another milestone was achieved in 2008, with two litters being produced by offspring of parents that were originally released in 2004.

Survival rates of released captive-born marmots to date are generally lower that those of wild-captured ones. As of spring 2008, the estimated annual survival rates with 95% confidence calculated using radio-telemetry methods (as per Bryant and Page 2005) were $S_{natural\ meadows}$ = 0.83 (0.76-0.89), $S_{clearcut}$ = 0.76 (0.50-0.91), and $S_{released}$ = 0.58 (0.47-0.68). The major difference in survival patterns resulted from increased frequency of winter mortality, which was observed in only a single wild marmot but in 11 released marmots. It appears that the timing of hibernation, which is known to change in captivity (Bryant and McAdie 2003), may take more than one year to return to conditions conducive to survival in the wild. Other deaths of released marmots reflect predation by eagles, wolves and cougars. One kill by a black bear (*Ursus americanus*) was confirmed in 2008 (Don Doyle pers. comm.).

Knowledge Gaps

1. General issues

There is still much that remains to be learned from Vancouver Island marmots (Elner 2000). For example it remains unclear when marmots first colonized Vancouver Island (Nagorsen 2005), or why they disappeared from relatively pristine areas such as Strathcona Provincial Park (Janz et al. 2000), or what the likely effects of factors such as climate change (Hebda et al. 2005) or forestry may be in the future (Bryant 1996). Unfortunately few of these questions lend themselves to short-term studies, and in some cases they may remain unanswerable until the success or failure of reintroductions can be evaluated.

2. Nutrition

Nutritional factors remain poorly understood, but are potentially important in facilitating hibernation and in maximizing reproductive rates (e.g., Thorp et al. 1994). The evidence to date suggests that captive marmots may have shorter between-litter intervals than their wild counterpart, that is, they more frequently breed in consecutive years (Bryant 2005). The possibility therefore exists that wild populations could be enhanced by supplementing natural foods. Conversely, although the gross reproductive success of captive marmots is highly encouraging, significant male-biased sex ratio exists in captivity, and it is possible that this may be related to diet. Research on nutritional conditions in captivity has begun at the Toronto Zoo. Baseline data will be compared to those obtained from the wild using a combination of scat analysis and direct measurement of nutritional characteristics of food plants. The focus of the research will be to evaluate possible differences among wild and captive-born marmots, and the role of nutrition in hibernation physiology, survival, and reproduction.

3. Behaviour
It is critical that animals reared in captivity display normal behaviour patterns (Griffith et al. 1989). Conversely, captivity offers the potential for experiments not possible in the wild, such as studies of mating behaviour, estrous cycles, and the importance of communal hibernation, which are not clearly understood. Captive animals will be maintained so as to maximize the research potential.

4. Genetics
Additional sampling and analytical work will be conducted to ensure maintenance of genetic diversity in captivity and to characterize natural patterns of variation. Collection of hair and blood will continue as new animals are captured. Paternity analyses using existing samples are currently underway. Maximizing genetic variation in the captive population will require continued maintenance of a studbook, which is also underway (J. Carnio, Canadian Association of Zoos and Aquaria, pers. comm.).

RECOVERY

Recovery Feasibility

The recovery team believes that recovery of Vancouver Island Marmots is biologically and technically feasible with existing guidelines (Government of Canada: Policy on feasibility of recovery, 1 Jun 2005 draft).

Are individuals capable of reproduction currently available to improve the population growth rate or population abundance?
Yes. The successful captive-breeding program displays a positive population growth rate (lambda = 1.31) and demographic projections suggest that annual releases of 15 to 25 marmots can be easily achieved and maintained (Bryant 2002, 2005, 2007).

Is sufficient suitable habitat available to support the species or could it be made available through habitat management or restoration?
Yes. Natural habitats capable of supporting at least 400–600 marmots have already been identified and rated for suitability (Routledge and Merilees 1980; Bryant and Janz 1996) and additional sites likely will be identified through more extensive application of a GIS-based terrain model combined with satellite imagery, aerial reconnaissance, and ground-truthing (Demarchi et al. 1995).

Can significant threats to the species or its habitat be avoided or mitigated through recovery actions?
Yes. Development pressures in natural marmot habitats are few. The history of successful marmot colonization of habitats created by humans (Bryant and Janz 1996) indicate that the problem of climate-induced tree invasion could be easily mitigated. Excessive predation by naturally occurring predators might be managed through fencing, shepherds, and other forms of

predator management, although the efficacy of such methods has not yet been demonstrated. It should be noted that current wild survival rates (~74%) would need to improve by only 5–10% before the population decline would be reversed (Bryant and Page 2005).

Do the necessary recovery techniques exist and are they demonstrated to be effective?
Yes. The captive-breeding program has been highly successful to date (Bryant 2005). In addition to positive demographic rates, the behaviour of captive-born marmots is very similar to wild-born marmots (Casimir 2005). Behaviour and survival rates of the few released marmots to date have been encouraging, although it would be premature to describe releases as a success.

Recovery Goal

The recovery goal is to achieve and maintain a total of 400 to 600 marmots dispersed in three metapopulations, in natural habitat, on Vancouver Island. This would represent a more than tenfold increase in the wild population that existed in 2000 (Bryant 2007), and would result in the restoration of marmots throughout the entirety of the entire known historical range of the species.

The population goal as originally proposed in the first Vancouver Island Marmot Recovery Plan (Janz et al.1994) was derived from a synthesis of historical occupancy records, habitat patch-specific estimates of carrying capacity, availability of natural habitat, and population simulation models. The goal remained unchanged in the updated plan (Janz et al. 2000), and was reinforced by new genetic data, population viability analyses, and mapping of potential reintroduction habitat. It is difficult to put timelines on recovery because survival and reproductive rates of released animals are unknown. Projections suggest that if annual survival rates return to a more normal 75–80%, the recovery goal could be achieved as quickly as 2020.

The stipulation of "three metapopulations" was based on the small size of individual habitat patches (i.e., "colonies"), and observed periodic between-colony dispersal, which is believed to be essential to maximize genetic variation and provide mate-choice (Bryant 1998). Recovery of marmots within separate geographic regions was based on patterns of historical marmot distribution (Bryant and Janz 1996), together with knowledge of water barriers (specifically, Buttle Lake, Alberni Inlet, and Lake Cowichan) that likely isolate many potential colonies from one another. The three areas include the Nanaimo Lakes region (where most marmots lived during the 1980s-90s), the Mount Washington-Forbidden Plateau region (with marmots still extant only at Mt. Washington), and the western Strathcona Park-Schoen Lake Park region (Janz et al. 2000).

Population simulation models (Bryant 1993a, 2002) and analyses of genetic effective population size (Bryant 1990) suggest that a metapopulation of 150 to 200 individuals would have, under stochastic conditions, a high probability of surviving 100 years or more. Part of the stipulation of three metapopulations is that this would yield additional opportunities for managers (if, for example one metapopulation suffers catastrophic disease outbreak, marmots could be transplanted from another).

We reiterate the point raised by an amalgam of conservation organizations with a wealth of experience in endangered species management (Society for Conservation Biology et al. 2006). Although recovery plans provide guidance over short time periods, ultimately success will depend on unpredictable opportunities, challenges, and continually changing information and conditions that affect the species. To quote their document, “few written recovery strategies will ever be able to provide a detailed and accurate site-specific blueprint for how long-term recovery can be achieved.”

Recovery Objectives

1. **Maintain a captive population of at least 125–150 marmots, with positive demographic rates, by 2020.**

2. **Maintain at least 95% of the existing genetic variability within the global population, until 2020.**

3. **Maximize wild breeding potential by providing solitary wild females with captive-bred potential mates when necessary.**

4. **Restore the wild population to a minimum of 400-600 individuals dispersed in 3 metapopulations by 2020.**

Approaches Recommended to Meet Recovery Objectives

The successful captive-breeding program has seemingly removed the immediate possibility of complete extinction of the species (2007). Given continued health monitoring and maintenance of existing genetic studbook procedures, it seems likely that Objective #1 has already been achieved, and that the existing captive population will supply more than 15 marmots annually for release to the wild in future years. At present the demographic statistics suggest a highly positive population growth rate (lambda) = 1.31, a value considerably higher than initially anticipated by the Recovery Team (Janz et al. 2000). Such high reproductive and survival rates allowed for release of 59 marmots in 2008, and this number should be similar for future years. Reintroductions and monitoring will be continued, with releases explicitly designed to broaden the geographic range and so avoid the dangerous “eggs in one basket” situation that so gravely threatened marmots during the 1980s. Ongoing work is designed to map potential marmot habitat using satellite imagery and digital terrain models; this may allow improved estimates of what the recovery objective should be given the carrying capacity of natural habitats (D. Doyle, pers. comm.). This work should be completed by late 2009.

Recent comparative DNA work on alpine marmots, Olympic marmots and Vancouver Island marmots (Kruckenhauser et al. in press) suggest that inbreeding depression is likely not a problem for *M. vancouverensis*, with the possible exception of the seemingly isolated Mount Washington site. These authors have recommended that the Team breed individuals from that site with others from the Nanaimo Lakes region, as opposed to attempting to manage two discrete genetic units. This approach seems reasonable given the loss of colonies in the Beaufort mountain range, which probably served to connect the northern and southern metapopulations through occasional dispersal, and which apparently became extinct as recently in the 1970s or 1980s (which would suggest a period encompassing only 4-8 marmot generations). In addition, analysis of data from both captive and wild marmots suggested that genetic diversity has been maintained in the captive population – in fact no allele detected in the wild has been lost to date. The studbook work and active management will be continued, with the objective of pairing high genetic priority individuals, and so maintain natural patterns of genetic variation.

Given successful reintroduction of marmots to solitary marmots that represented “last survivors” from formerly occupied colonies, there are few such cases presently (Bryant 2007). However, given that mortality often occurs in “episodes” in which several marmots are killed over short periods of time, we can confidently predict this situation will undoubtedly arise again in the future. The policy of the Recovery Team has been (and remains to be) that reproductive-age females without access to a potential mate will be provided one using either wild-transplanted or captive-born marmots. This strategy has produced at least 3 litters of pups in the wild since 2004, and will be continued. The corollary (i.e., solitary males without a mate) will be handled differently. Solitary wandering males consume a large amount of helicopter monitoring time, and have only rarely resulted in identifying additional occupied habitats or previously unknown females (n=4 cases since 1992).

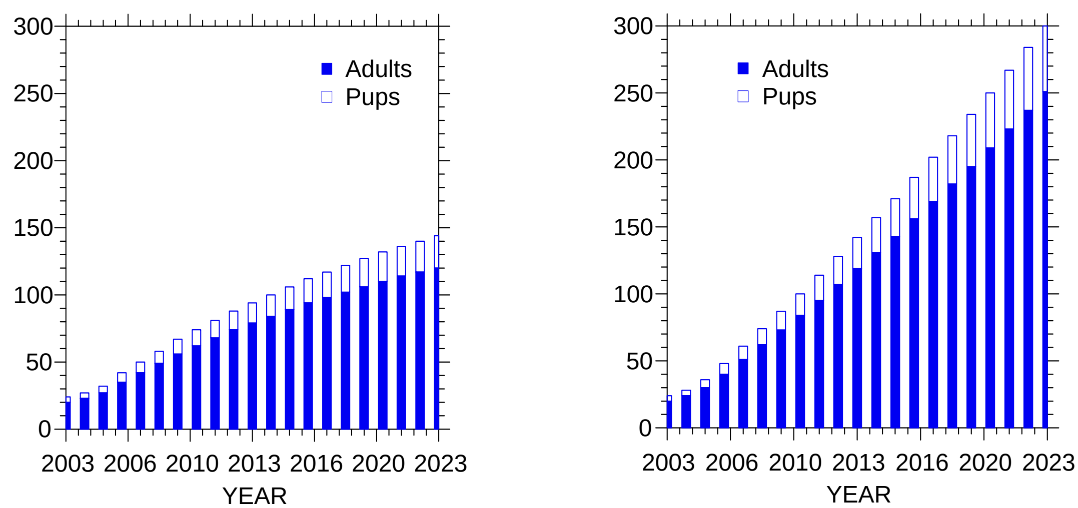
Threats facing wild marmots are more difficult to address given the highly altered landscape and predator-prey relationships that presently exist. Given a lifespan of 10 years or so and average reproductive performance (Bryant 1996, 2005), a simple life-table calculation suggests that survival rates approaching 80% would be necessary to create a self-sustaining wild population of Vancouver Island Marmots (Figure 2). Such survival rates are obtainable, and in fact have been observed before on numerous occasions at specific colonies. It was precisely such high survival rates that allowed for rapid expansion of the total population during the 1980s, together with colonization of man-made clearcuts (Bryant 1998, 2000). If wild survival rates continue to be low, further releases will to some extent offset mortality, but unless survival rates are improved, at the end of the exercise the result will still be a small, highly vulnerable population. In the short-term, managers need to focus on reducing losses from predation.

Page (2004) summarized available options for predator management, which vary from lethal removal (e.g., Archibald et al. 1991; Courchamp et al. 2003) to the use of fencing or other non-lethal methods such as human shepherds, and trained dogs. Determining which, if any, of these predator management methods may be effective is a high priority objective for the recovery team. What geographic distribution of marmots, or what release protocols, or what management methods would temper the predator pit that marmots nearly descended into during the 1990s?

The Recovery Team has identified several broad approaches to facilitate captive breeding:

1. Cause no harm to the captive population (i.e., don’t over-release).
2. Release only those animals that can contribute maximally to the wild population (i.e., preferential selection of two-year-olds).
3. So far as possible, strive to ensure maintenance of natural behaviour patterns in captivity (i.e., “stage” all animals targeted for release at the Mount Washington facility during the summer before release).

4. Whenever possible, strive to take advantage of existing wild marmot “culture” by providing appropriate mates for resident animals (i.e., continue the practice of “matchmaking” efforts at currently occupied sites).
5. Treat the captive and wild populations as a single genetic population and manage them as such, taking all possible precautions to minimize between-facility movements and risks of disease transmission.
6. Pursue reintroductions in the Nanaimo Lakes region first (i.e., attempt to save the wild culture that remains there as a first priority).
7. Use a “stepping-stone” approach to reintroductions (i.e., select reintroduction sites that are within dispersal distance of extant colonies).
8. Pursue reintroductions in natural habitats first.
9. Reintroduce small groups of marmots (i.e., 2–6 marmots per site) to mimic the natural process of colony formation.
10. Use available methods to enhance survival in the wild by reducing losses from predation.



A) Observed survival scenario B) Increased survival scenario

Figure 2. Projected population growth rates under two scenarios. The first scenario (A) assumes releases of 10 marmots per year and no difference in survival among captive-born and wild marmots. Population growth rate (lambda) remains lower than 1.0 ($\lambda = 0.89$) but declines are offset by immigration from the captive population. The second scenario (B) assumes the same 10 releases, but increased pup survival from 51% to 55%, and adult survival from 67% to 77%, in which case lambda becomes positive ($\lambda = 1.0$) and recovery objectives become achievable within 20–30 years. For simplicity only a deterministic model was employed.

Recovery planning table

Table 1. Recovery planning table.

Priority	Threat/concern addressed	Broad strategy to address threats	Recommended approaches to meet recovery objectives
Objective 1: Maintain captive population of 125–150 marmots, with positive demographic rates, until 2020.			
Urgent	Prevent extinction	Captive breeding	Maintain existing health monitoring and captive management approach.
Objective 2: Maintain at least 95% of the existing genetic variability within the global population, until 2020.			
Important	Genetic variability	DNA work	Monitor and maintain studbook and DNA analyses.
Objective 3: Ensure that solitary marmots have access to a potential mate, until 2020.			
Important	Allee effects - genetic variability	Transplants and releases	Maintain wild genome by maximizing breeding opportunities for wild individuals.
Objective 4: Restore wild population of 400-600 marmots in natural habitats by 2020.			
Critical	All	Transplants, releases, genetic management, habitat mapping, predator management, science	Continue operational measures as presently underway.

Performance Measures

The following performance measures are meant to evaluate progress towards achieving the recovery goals and objectives:

1. 15-20 marmots were released to the wild each year to priority habitats.
2. A captive population of 125-150 marmots with positive demographic rates was maintained.
3. 95% or more of the existing genetic variation is intact.
4. Breeding opportunities were maximized by ensuring that genetically important individuals were mated preferentially.
5. The wild population growth rate is stable or increasing.
6. Predation rates have decreased.
7. Priority research has been conducted to address threats and knowledge gaps.

The marmot recovery team has attempted to identify short-term measures of reintroduction-success that were designed to be sequential, explicit, and measurable. The intention is to test ideas about why reintroductions might fail or succeed (e.g., Griffith et al. 1989).
Short-term measures of success will include the following positive observable behaviour and traits exhibited by the released marmots:

1. Immediate post-release site-fidelity and survival.
2. Use of historical marmot habitat (burrows, vegetation, and lookout spots).
3. Weight gain (similar to that of wild marmots).
4. Social behaviour (grooming, nose-greeting, and sleeping behaviour).
5. Antipredator behaviour (whistling or retreat into burrows when approached).

6. Timing of hibernation (compared to wild marmots).
7. Survival rate during hibernation (compared to wild marmots).
8. Site-fidelity and appropriate social behaviour in subsequent spring.
9. Successful reproduction in subsequent years.

Critical Habitat

Identification of the species' critical habitat

No critical habitat, as defined under the federal *Species at Risk Act* [S.2], is proposed for identification at this time. It is anticipated that critical habitat for the Vancouver Island Marmot will be identified in the action plan(s) as appropriate.

Marmot habitats are relatively easy to identify (see Habitat and biological needs section), however, further work is necessary before critical habitat can be identified. A simple model based on GIS was successful in identifying most of the historically occupied habitat in natural subalpine meadows (J. Lewis, University of Calgary, pers. comm.). The model included elevation (900–1400 m), slope (30–60°), aspect (135–270°), no snow in July, herbaceous cover, and proximity to cliffs (<400 m). Additional work is needed to apply this model to areas on central and northern Vancouver Island, and this will be provided as a separate habitat supply analysis when funding becomes available. Once a draft identification of critical habitat has been developed, consultation with affected land owners and managers will be necessary before the final proposal is brought forward for consideration.

Recommended schedule of studies to identify critical habitat

The primary need is to expand the terrain and remote-sensing approach to mapping potential marmot habitat on central and northern Vancouver Island. If suitable satellite imagery, funding, and personnel can be found, this should be accomplished by late 2009.

1. Expand and complete terrain and remote-sensing model (in progress), 2009.
2. identify and map areas of potential critical habitat on the landscape based on habitat models (in progress), 2009.

Existing and Recommended Approaches to Habitat Protection

Some of the historically occupied habitat is protected within Strathcona Provincial Park (see Figure 1). Other habitats are protected under the *B.C. Ecological Reserves Act* within the Haley Lake Ecological Reserve (recently expanded to 926 ha) and under the *B.C. Wildlife Act* at the Green Mountain Critical Wildlife Management Area (300 ha). Because of the relative lack of direct development threats to natural subalpine meadows, and the potential habitat found in Strathcona Provincial Park and elsewhere, the recovery team believes that additional legal protection of habitats is not necessary at this time.

Effects on Other Species

The recovery team anticipates no significant effects on species other than marmots as a result of strategy implementation.

Socioeconomic Considerations

Marmota vancouverensis is one of only five endemic mammal species in Canada (Wilson and Reeder 1993). It is the only endemic mammal species that appears on the COSEWIC endangered list. There is presently no utilitarian value for Vancouver Island marmots. High potential exists to incorporate public viewing and extension opportunities within the context of recovery efforts.

Statement on Action Plans

It is anticipated that a critical habitat action plan will be completed by the recovery team in 2009. A comprehensive reintroduction action plan (including identification of recovery habitat) for Vancouver Island Marmots will be completed by 2010.

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