British Columbia Recovery Strategy Series

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

Prepared by the Vancouver Island Marmot Recovery Team

August 2017

About the British Columbia Recovery Strategy Series

This series presents the recovery documents that are prepared as advice to the Province of British Columbia on the general approach required to recover species at risk. The Province prepares recovery documents to ensure coordinated conservation actions and 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 provincial recovery document?

Recovery documents summarize the best available scientific and traditional information of a species or ecosystem to identify goals, objectives, and strategic approaches that provide a coordinated direction for recovery. These documents outline what is and what is not known about a species or ecosystem, identify threats to the species or ecosystem, and explain what should be done to mitigate those threats, as well as provide information on habitat needed for survival and recovery of the species. The provincial approach is to summarize this information along with information to guide implementation within a recovery plan. For federally led recovery planning processes, information is most often summarized in two or more documents that together make up a recovery plan: a strategic recovery strategy followed by one or more action plans used to guide implementation.

Information in provincial recovery documents may be adopted by Environment and Climate Change Canada for inclusion in federal recovery documents that federal agencies prepare to meet their commitments to recover species at risk under the *Species at Risk Act*.

What's next?

The Province of British Columbia accepts the information in these documents as advice to inform implementation of recovery measures, including decisions regarding measures to protect habitat for the species.

Success in the recovery of a species depends on the commitment and cooperation of many different constituencies that may be involved in implementing the directions set out in this document. All British Columbians are encouraged to participate in these efforts.

For more information

To learn more about species at risk recovery in British Columbia, please visit the B.C. Recovery Planning webpage at:
<http://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/species-ecosystems-at-risk/recovery-planning>

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Jared Hobbs

Additional copies

Additional copies can be downloaded from the B.C. Recovery Planning webpage at: <http://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/species-ecosystems-at-risk/recovery-planning>

Disclaimer

This recovery plan 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 B.C. Ministry of Environment has received this advice as part of fulfilling its 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 and actions 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 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 plan. The B.C. Ministry of Environment encourages all British Columbians to participate in the recovery of the Vancouver Island Marmot.

ACKNOWLEDGEMENTS

This recovery plan was drafted by Elizabeth Gillis and Sally Leigh-Spencer, with advice from Cheyney Jackson, Malcolm McAdie, and Adam Taylor. It is an update to the Recovery Strategy for the Vancouver Island Marmot (*Marmota vancouverensis*) in British Columbia (Vancouver Island Marmot Recovery Team 2008). Funding for this document was provided by Environment and Climate Change Canada. Dave Fraser, Elizabeth Gillis, Cheney Jackson, Sally Leigh-Spencer, Malcolm McAdie, Sean Pendergast, and Adam Taylor participated in the threats assessment. Kella Sadler reviewed and provided comments on an early draft of the Recovery Feasibility and Recovery Goals sections, and Sue Griffin reviewed and provided comments on the first draft of the Recovery Strategy. Leah Westereng, Peter Fielder and Excedera St. Louis provided clarification on the formatting and organization of the plan.

The development of this recovery plan was greatly aided by a Vancouver Island Marmot population and habitat viability assessment workshop that was held March 3–5, 2015, at the Calgary Zoo. The workshop brought together more than 40 participants from captive breeding facilities, non-governmental organizations, representatives from both government and timber companies, academics, biologists, and conservation organizations from across North America. In addition to the viability assessment, management actions were identified and prioritized. The Calgary Zoo, the Marmot Recovery Foundation, the IUCN Species Survival Commission Reintroduction Specialist and Conservation Breeding Specialist groups organized the workshop, and the Vancouver Island Marmot Recovery Team thanks these organizations for their support of the recovery program. We thank Axel Moehrenschlager for initiating the workshop, Anne Baker for facilitating the workshop, Kathy Traylor-Holzer, Tara Stephens, and Cheyney Jackson for developing the model, and all the participants for their thoughtful discussion and their contributions.

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EXECUTIVE SUMMARY

The Vancouver Island Marmot (*Marmota vancouverensis*) is British Columbia's only endemic mammal species; it lives only in mountainous areas on Vancouver Island. For 7–8 months of the year (approximately early October to May), family groups of Vancouver Island Marmots hibernate in underground burrows called hibernacula. During the 4–5 month active season in which they breed, raise young, and regain weight, marmots continue to use their underground burrow systems for resting, avoiding summer heat, and protection from predators. They also spend considerable time above ground foraging, resting, sunning, and interacting with other marmots. Marmots typically live in colonies and when above ground, they rely on alarm calls to warn others in the colony that a predator is nearby. The main predators of the Vancouver Island Marmot are Golden Eagles, Cougars, and Grey Wolves.

The Vancouver Island Marmot was originally designated in 1978 as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The status of the Vancouver Island Marmot was re-evaluated by COSEWIC and confirmed as Endangered in 1997, 2000, and 2008. The COSEWIC rational for 2008 designation was small population size (< 30 mature wild-born marmots), making them susceptible to stochastic events; high predation; risk from inbreeding; and climate change. It is listed as Endangered in Canada on Schedule 1 of the *Species at Risk Act*. In British Columbia, the Vancouver Island Marmot is ranked S1 (critically imperiled) by the B.C. Conservation Data Centre and is on the provincial Red list. The B.C. Conservation Framework ranks the Vancouver Island Marmot as a priority 1 under goal #1 (contribute to global efforts for species and ecosystem conservation) and goal #3 (maintain the diversity of native species and ecosystem). It is protected from capture and killing under the province's *Wildlife Act*. It is also listed as a species that requires special management attention to address the impacts of forest and range activities under the *Forest and Range Practices Act* and/or the impacts of oil and gas activities under the *Oil and Gas Activities Act* on Crown land.

The recovery (population and distribution) goal is to maintain or increase the abundance of Vancouver Island Marmots in at least two geographically separated areas within the species' historic range, and to ensure connectivity within each of these areas. The recovery goal will be met when, in the absence of population augmentation using captive-bred individuals, the metapopulation in each of the two areas (and therefore the species overall) has a > 90% probability of persistence over 100 years.

The recovery plan has the following seven objectives.

1. Increase the number of marmots through augmentation and, if possible, by increasing survival rates and reproductive rates in the wild.
2. Maximize opportunities for successful dispersion between colonies.
3. Maintain a large and genetically diverse captive-breeding population that can produce adequate numbers of release candidates to support population recovery.
4. Prioritize the maintenance of genetic variability in the global population until recovery goals are met.

5. Reduce knowledge gaps surrounding: (a) natural levels of variability in survival and reproductive rates in the wild; (b) factors that determine key demographic rates; and (c) the best method to monitor population size and key demographic rates long term.
6. Develop and implement a plan for reducing intensive management as metapopulations recover.
7. Develop and implement a sound strategy to ensure sufficient resources are available to support recovery efforts until recovery goals are met.

RECOVERY FEASIBILITY SUMMARY

Based on the following four criteria that Environment and Climate Change Canada uses to establish recovery feasibility, there are unknowns regarding the feasibility of recovery of Vancouver Island Marmot.[1] In keeping with the precautionary principle, a full recovery strategy has been prepared as would be done when recovery is determined to be feasible.

1. **Individuals of the wildlife species that are capable of reproduction are available now or in the foreseeable future to sustain the population or improve its abundance.**

   Yes. The captive-breeding program, which has demonstrated successful augmentation of the wild metapopulations over the past 10 years, is ongoing (Jackson *et al.* 2015). The Nanaimo Lakes metapopulation has demonstrated that when survival rates are high, it is possible for reproduction in wild metapopulations to maintain and increase numbers. For the foreseeable future (5 years), releasing captive-bred marmots into wild populations can also be used to mitigate the impacts of predation (a primary threat) by increasing population numbers directly. Modeling by the International Union for Conservation of Nature (IUCN) suggests that the continuation of the captive-breeding program over the next 10 years can sustain the metapopulations or improve Vancouver Island Marmot abundance in the future (Jackson *et al.* 2015).

2. **Sufficient suitable habitat is available to support the species or could be made available through habitat management or restoration.**

   Yes. Sufficient habitat is currently available to support the species. The spatial distribution of suitable habitat has changed due to historical climate change, which may affect the connectivity of suitable habitat in the southern portion of the species' distribution. Over time, ecosystems such as higher-elevation meadows will be altered by climate change. This may result in reduced habitat suitability in some regions of the historical distribution of the species if changes to vegetation communities occur from reduced snowpack, fewer avalanches, warmer temperatures, reductions or changes in primary forage species availability, or establishment of trees within alpine and subalpine meadows, which reduces the ability of marmots to visually detect predators. Habitat management and restoration in the form of manual clearing of trees has occurred and is feasible at a small scale.

[1] The current strategy's reference to unknowns does not represent a change in the Vancouver Island Marmot Recovery Team's previous assessments in the probability of recovery; it represents a refinement in the certainty required by Environment and Climate Change Canada to classify recovery as being biologically and technically feasible. "Unknowns" regarding recovery feasibility are identified in alignment with significant knowledge gaps presented in the Recovery Action Table (see Table 4).

3. The primary threats to the species or its habitat (including threats outside Canada) can be avoided or mitigated.

Unknown.[2] The primary threats include native predators, ecosystem modification arising from post-logging forest succession, and longer-term predicted habitat loss associated with climate change.

Augmenting wild metapopulations with captive-bred individuals currently helps mitigate predation, but it is currently unknown whether a threshold metapopulation size exists above which predation is no longer a threat. Additionally, the long-term threat posed by native predators is difficult to predict because it will vary based on predator abundance, and the abundance and distribution of the predator species' primary prey. Predation of marmots by Cougar (*Puma concolor*) and the Grey Wolf (*Canis lupus*) is reduced in many areas through human activities. Continued recreation use (e.g., in ski areas and other areas of higher recreation activities) reduces predation because Grey Wolves and Cougars avoid these areas. In some areas on Vancouver Island, predation is reduced through regulated hunting and trapping of Grey Wolves and Cougars, as in the Nanaimo Lakes metapopulation.

Ecosystem modification from post-logging succession can mimic subalpine habitat during early succession, thereby creating ephemeral suitable habitat that has served as sink habitat in the past. As forest succession occurs and the cutblocks become less suitable marmot habitat, individuals do not immigrate to the area. These cutblock habitats are also associated with higher predation rates. If marmots are found to have colonized cutblocks, now known to be unsuitable habitat, they can be translocated into more suitable habitat.

The effects of climate change, such as the in-growth of coniferous trees in lower subalpine habitats, has been successfully mitigated to date at a small scale with the removal of trees that established in meadows; however, it is currently unknown on what scale tree removal may be a feasible mitigation strategy.

4. Recovery techniques exist to achieve the population and distribution objectives or can be expected to be developed within a reasonable time frame.

Yes. Successful recovery techniques are in place and have proven successful. A captive-breeding program has been established and has successfully produced a large number of animals for release so that the numbers and distribution of marmots have increased in two metapopulations. Population viability analysis based on estimated demographic rates indicates it is possible to establish naturally self-sustaining metapopulations (Jackson *et al.* 2015). For example, as metapopulation size in the wild increases from population augmentation, new colonies have been established by naturally dispersing marmots (Jackson 2014). New release techniques aimed at improving overwinter survival of released marmots are currently being evaluated, and an experiment is under way to determine whether providing supplemental food in early spring can increase reproduction.

[2] This "unknown" does not represent a change in the Vancouver Island Marmot Recovery Team's previous assessments. It represents a refinement in the certainty required by Environment and Climate Change Canada to answer "yes" to the questions regarding whether primary threats can be avoided or mitigated.

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1 COSEWIC* SPECIES ASSESSMENT INFORMATION

Assessment Summary: April 2008
Common Name: Vancouver Island marmot
Scientific Name: *Marmota vancouverensis*
Status: Endangered
Reason for Designation: [a] 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.
Occurrence: British Columbia
Status History: Designated Endangered in April 1978. Status re-examined and confirmed Endangered in April 1997, May 2000, and April 2008. Last assessment based on an update status report.

* Committee on the Status of Endangered Wildlife in Canada.
[a] Criteria: A2a; C2a(i); D1. See COSEWIC quantitative criteria and guidelines for the status assessment of wildlife species (Table 2) of the COSEWIC assessment process guidelines.

2 SPECIES STATUS INFORMATION

Vancouver Island Marmot[a]			
Legal Designation:			
FRPA:[b] Species at Risk OGAA:[b] Species at Risk	B.C. *Wildlife Act:*[c] Schedule A, Schedule E	SARA:[d] Schedule 1 –Endangered (2003)	
Conservation Status[e]			
B.C. List: Red	B.C. Rank: S1 (2015)	National Rank: N1 (2015)	Global Rank: G1 (2015)
Other Subnational Ranks:[f] none			
B.C. Conservation Framework (CF)[g]			
Goal 1: Contribute to global efforts for species and ecosystem conservation.			Priority:[h] 1 (2009)
Goal 2: Prevent species and ecosystems from becoming at risk.			Priority: 6 (2009)
Goal 3: Maintain the diversity of native species and ecosystems.			Priority:1 (2009)
CF Action Groups:[g]	Compile Status Report; Planning; List under *Wildlife Act*; Send to COSEWIC; Habitat Protection; Habitat Restoration; Private Land Stewardship; Species and Population Management		

[a] Data source: B.C. Conservation Data Centre (2016) unless otherwise noted.
[b] Species at Risk = a listed species that requires special management attention to address the impacts of forestry and range activities on Crown land under the *Forest and Range Practices Act* (FRPA; Province of British Columbia 2002) and/or the impacts of oil and gas activities on Crown land under the *Oil and Gas Activities Act* (OGAA; Province of British Columbia 2008) as described in the Identified Wildlife Management Strategy (Province of British Columbia 2004).
[c] Schedule A = designated as wildlife under the B.C. *Wildlife Act*, which offers it protection from direct persecution and mortality (Province of British Columbia 1982). Schedule E = listed as Endangered under the B.C. *Wildlife Act* (Province of British Columbia 1982).
[d] Schedule 1 = found on the List of Wildlife Species at Risk under the *Species at Risk Act* (SARA; Government of Canada 2002).
[e] Red: Includes any indigenous species or subspecies that have, or are candidates for, Extirpated, Endangered, or Threatened status in British Columbia. S = subnational; N = national; G = global; 1 = critically imperiled; 2 = imperiled; 3 = special concern, vulnerable to extirpation or extinction; 4 = apparently secure; 5 = demonstrably widespread, abundant, and secure; NA = not applicable; NR = unranked; U = unrankable.
[f] Data source: NatureServe (2016).
[g] Data source: B.C. Ministry of Environment (2009).
[h] Six-level scale: Priority 1 (highest priority) through to Priority 6 (lowest priority).

3 SPECIES INFORMATION

3.1 Species Description

The Vancouver Island Marmot (*Marmota vancouverensis*; Figure 1) is a large, sciurid rodent found in higher-elevation burrows within the mountains of Vancouver Island, British Columbia (Nagorsen 2005; Blumstein 2009). Fifteen species of marmot occur in the world, all inhabiting the northern hemisphere. Three other marmot species—the Hoary Marmot (*M. caligata*), the Yellow-bellied Marmot (*M. flaviventris*), and the Woodchuck (*M. monax*)—are found in Canada and are common on British Columbia's mainland (Nagorsen 2005; Blumstein 2009). Although closely related to the Hoary Marmot and the Olympic Marmot (*M. olympus*), which occurs on Washington's Olympic Peninsula (Steppan *et al.* 1999; Kerhoulas *et al.* 2015), the Vancouver Island Marmot is distinct in its skull morphology, vocalizations, highly social nature, and dark brown pelage (Heard 1977; Blumstein 1999; Nagorsen 2005; Cardini *et al.* 2007). The average total body length of the Vancouver Island Marmot is 668 mm (580–750 mm) and the average weight is 3.76 kg (3.20–4.40 kg), with males weighing up to 7.5 kg (Nagorsen 2005; Marmot Recovery Foundation 2016). Both sexes can lose up to one-third of their body mass during hibernation. They have brown to black dorsal pelage, a white nose, and white markings on the forehead, chin, and belly. Young marmots have nearly black pelage. As the adults age, the pelage can fade to a light rufous (sun-faded) in patches on their dorsal surface, where new hair has not yet replaced old, and then becomes variegated with dark brown fur as new hair grows in (Nagorsen 2005).

Figure 1. Vancouver Island Marmot pup (left) and adult female (right) (Jared Hobbs).

3.2 Populations and Distribution

Canada has 100% of the global distribution of the Vancouver Island Marmot. The Vancouver Island Marmot is the only mammalian species endemic to British Columbia and is found only in mountainous areas on Vancouver Island (Nagorsen 2005). Historically, the distribution of marmots on Vancouver Island was probably more widespread (Nagorsen *et al.* 1996). Fossil evidence of Vancouver Island Marmot, Mountain Goat (*Oreamnos americanus*), and Townsend's Vole (*Microtus townsendii*), which was found in a sea cave on the northwest coast near Port Eliza and radiocarbon dated at 16 000–18 000 years before present, suggests that Vancouver Island's west coast previously had a cool parkland environment that contained a mix of forest and open areas (Nagorsen *et al*. 1996). Faunal remains of Vancouver Island Marmot radiocarbon dated at 800–2630 years before present were also discovered in four high-elevation caves (Clayoquot Plateau, Mariner Mountain, Limestone Mountain, and the Golden Hinde). The location and context of these remains suggests that Indigenous peoples once hunted the species and provides further evidence for a range decline in the Vancouver Island Marmot (Nagorsen *et al.* 1996).

Because of their reliance on alpine and subalpine habitat, Vancouver Island Marmots are not distributed uniformly on the landscape. On a small spatial scale, marmots live in colonies that typically include one to two family groups (Nagorsen 2005). Multiple colonies can live on a single mountain. Within this document, the term "site" is synonymous with "mountain." Marmots living at the same site can, therefore, disperse or move between colonies without leaving the alpine or subalpine habitat; marmots dispersing between sites must travel through lower-elevation forest habitats. Because alpine and subalpine areas on mountains are separated by areas of unsuitable marmot habitat, it is thought that Vancouver Island Marmots have a metapopulation structure (Bryant 1996); marmot colonies on the same mountain form a subpopulation, and subpopulations are linked by occasional dispersal. The subpopulations that are (or could be) linked by these dispersal events comprise the metapopulation. Dispersal events do not occur between marmot metapopulations because they are isolated by distance. Two metapopulations of Vancouver Island Marmots currently exist, one in the Nanaimo Lakes area of south-central Vancouver Island and one further north in the Strathcona region (Figure 2; Table 1). Marmots also occupy two extralimital (i.e., outside of recent historical distribution) sites at Schoen Lake and on the Clayoquot Plateau (Jackson, pers. comm., 2016; Figure 2; Table 1). Within this document, the term "population" is used to refer to the total number of Vancouver Island Marmots (i.e., all metapopulations and extralimital sites combined; after COSEWIC 2016).

Before reintroductions began in 2003, the distribution of Vancouver Island Marmot had been reduced to four mountains in the Nanaimo Lakes region and one mountain (Mount Washington) in the Strathcona region (Vancouver Island Marmot Recovery Team 2008). Currently, Vancouver Island Marmots occupy 14 mountains in the Nanaimo Lakes region and nine in the Strathcona region (Figure 2). For a site to be classified as an "occupied" site, marmots had to be detected during the active season of 2016 and had a record of successful hibernation on the mountain. This ensures that locations used only temporarily during the active season for dispersal or exploratory movements are not misclassified as a site. The number of marmots in the 1980s doubled relative to the numbers counted in the late 1970s (Figure 3), probably in response to increased use of early seral habitats created by logging. Nevertheless, these relatively high population numbers were short lived, with the wild population decreasing to approximately 70 marmots by the late 1990s (Nagorsen 2005; Vancouver Island Marmot Recovery Team 2008).

In 1997, a captive-breeding program was initiated. To date, 482 captive-bred marmots have been reintroduced to the wild. In addition, eight wild-born marmots were taken into the captive population and were later returned to the wild. As of November 2016, the captive breeding population consisted of 43 individuals (11 breeding pairs) in two locations (Toronto Zoo and Calgary Zoo), with 94.3% of the genetic diversity from the original captive population (McAdie, pers. comm., 2016). Based on field counts, the most conservative (lowest) estimate of marmots in the wild at the end of the 2016 season was 140–190.

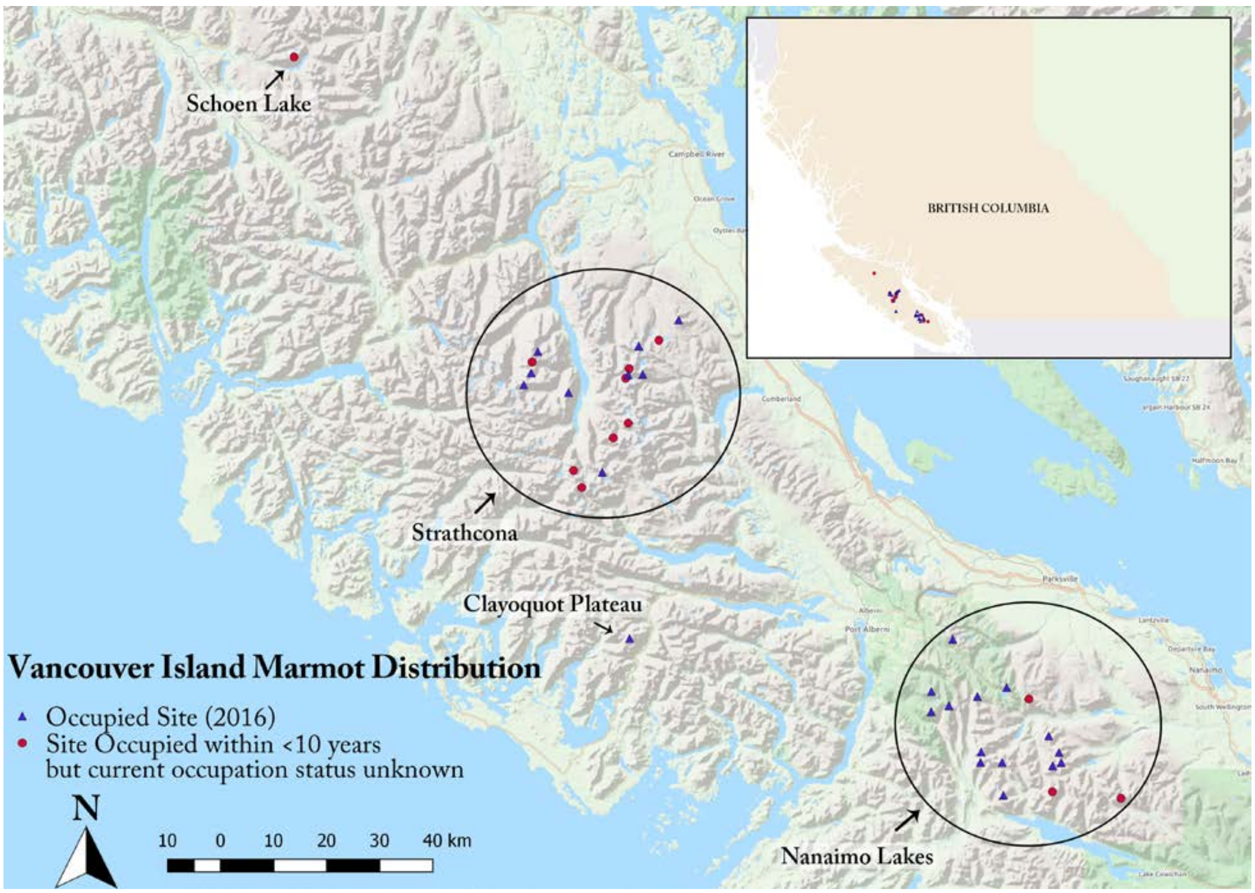

Figure 2. Vancouver Island Marmot distribution. The two metapopulations are circled in black. Sites outside of metapopulations are extralimital (Marmot Recovery Foundation).

Table 1. Status and description of Vancouver Island Marmot wild metapopulations (Nanaimo Lakes and Strathcona) and extralimital sites (Schoen Lake and Clayoquot Plateau) in British Columbia.

General location	# of sites[a]	Status[b] and description	Minimum # of marmots[c]	Land tenure
Nanaimo Lakes[d]	14	Extant. Metapopulation composed of natural and reintroduced colonies; intensive augmentation from captive-bred marmots (2003–2011) and some removal for captive breeding (1997–2004; 2016).	63–83	Private land, ecological reserve
Strathcona[e]	9	Extant. Metapopulation composed of natural and reintroduced colonies; metapopulation has been augmented with individuals from captive breeding and some individuals have been removed from metapopulation for captive breeding.	73–100	Private land, provincial Crown land, provincial park
Schoen Lake	Possibly one	Possibly Extant. Last survey conducted in 2015 when marmots were detected at one site; three sites had marmots introduced from 2007 to 2014.	0–2	Provincial park and private land
Clayoquot Plateau	1	Extant (at least 1 site). Three sites have had marmots introduced since 2009.	4–6	Provincial park and private land

[a] Indicates the number of mountains on which marmots were detected in 2016 (Jackson, pers. comm., 2016). To be considered a "site," a previous record of successful hibernation on the mountain was also required; this excludes from the count mountains used temporarily during the active season during dispersal or exploratory movements.
[b] Extant: occurrence of Vancouver Island Marmots was verified in 2016.
[c] Numbers based on 2016 field data (Jackson, pers. comm., 2016)
[d] Site/mountain names: Arrowsmith, Butler, Douglas, Gemini, Green, Haley, Heather, Hooper, Sadie Peak, Limestone, Marmot Mountain, McQuillan, Moriarty, and P Mountain. Mountains Buttle, Tangle, and Whymper were previously sites with Vancouver Island Marmots but none were detected in 2016.
[e] Site/mountain names: Castlecrag, Frink, Sunrise, Washington, Flower Ridge, Greig Ridge, Marble Meadows, Phillips, and Tibetan. Additional mountains on which no Vancouver Island Marmots were detected but which had marmot colonies in the past include Drinkwater, Henshaw, and Morrison Spire
Note: **Extralimital sites are found on mountains:** Seth (Schoen Lake location) and Steamboat (Clayoquot Plateau location). Additional extralimital sites where marmots have been released but did not successfully hibernate (due to dispersal or death) include Mount Cain and Mount Hapush in the Schoen Lake location, and the Limestone Lions and Mt. 5040 in the Clayoquot Plateau location.

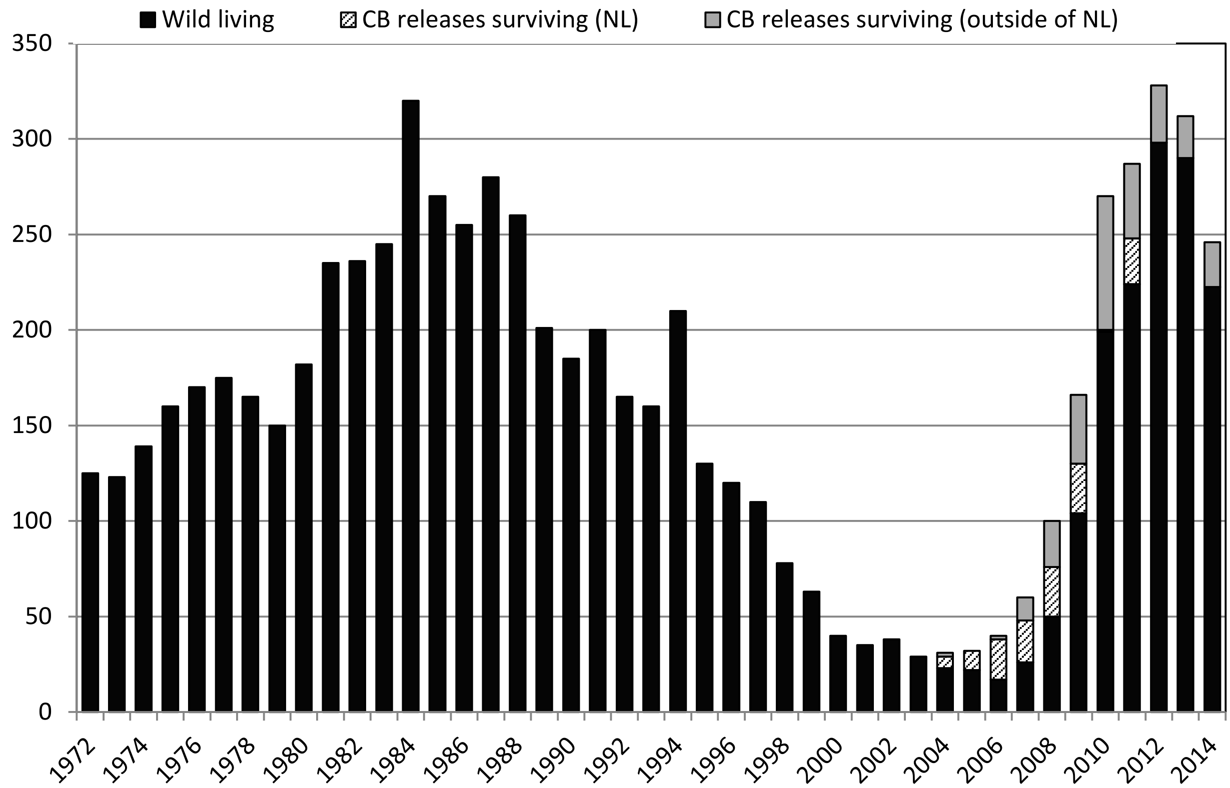

Figure 3. Estimated number of Vancouver Island Marmots, 1972–2014. The lined portion of bars represents the number of marmots released inside the Nanaimo Lakes (NL) region and the grey portion represents the number of captive-bred (CB) marmots released outside this area. To be included, the released marmots had to survive to the fall of their release year. The black portion of bars represents wild living marmots, which after 2004 included captive-born animals released before that year. The procedure for obtaining estimates has varied over time but has been standardized since 2010; thus, only relative trends in numbers should be inferred before 2010. Adapted from Jackson *et al.* 2015.

3.3 Habitat and Biological Needs of Vancouver Island Marmot

Vancouver Island Marmots excavate and use burrows in small, fragmented alpine and subalpine meadows and bowls, usually on moderately steep (30–45°) slopes that have a south- to west-facing aspect. They are typically found at 700–1500 m elevations within the Coastal Western Hemlock, Mountain Hemlock, and Coastal Mountain-heather Alpine biogeoclimatic zones (Bryant and Janz 1996; Nagorsen 2005; Vancouver Island Marmot Recovery Team 2008; Thelin 2016). The climate in these biogeoclimatic zones is montane with long, wet, cold winters and shorter, cool, moist summers. Frozen soils are rare because of the insulating snowpack (Green and Klinka 1994). The natural mountain meadow habitats in which Vancouver Island Marmots live are complexes of vegetated slopes with a variety of suitable forage species, interspersed with patches of suitable soils and talus slides that support the construction of complex burrows, which are used for protection from predators, pup-rearing, and hibernacula (Jackson 2012). Table 2 provides a summary of the features and attributes that Vancouver Island Marmots require for their life history functions. These essential habitat features are restricted to a narrow range of elevations. For example, at higher elevations, soil development is usually inadequate for burrow construction. At lower elevations, the vegetation is denser, preferred forage species are less abundant, and the ability of marmots to visually detect predators is reduced. All these factors generally make habitat at lower elevations unsuitable for Vancouver Island Marmots.

Table 2. Summary of essential functions, features, and attributes of Vancouver Island Marmot habitat in British Columbia. The summary is based on the ideal conditions and assume a moderate to high level of predators on the landscape.

Life stage	Function[a]	Timing	Feature(s)[b]	Attributes[c]
All life stages	Foraging, including pup-weaning	May to October	Alpine and subalpine meadows	• Early green-up of forage suitable for consumption by the species (e.g., grasses, sedges, forbs). • Escape features and cover objects, such as burrows, talus, and boulders in proximity to forage. • Usually between 700 and 1500 m elevation on moderately steep (30–45°) slopes that have a south- to west-facing aspect. • Snow conditions that maintain the meadows, limit tree encroachment, and maintain high visibility for predator avoidance.
	Dispersal of sub-adults (both sexes; primarily male)	April to August	Suitable distances and connectivity between habitats that can support colonies; other colonies nearby	• Safe dispersal matrix with absence of intense predation pressure between suitable colony locations.
Adults, yearlings, and juveniles	Hibernating	October to May	Hibernacula (home) burrows	• Deep colluvial soils that allow construction of burrow below frost-line; snow cover to insulate soil and reduce energetic costs of thermoregulation in occupied hibernacula.
Adults and pups	Pup-rearing	May to June		

[a] **Function:** a life-cycle process of the species.
[b] **Feature**: the essential structural components of the habitat required by the species.
[c] **Attribute**: the building blocks or *measurable* characteristics of a feature.
[d] "Colluvial" refers to loose, unconsolidated sediments that accumulate at the base of hills.

Burrows

Marmots use their underground burrow system for rest and escape during a 4–5 month active season (May–September) before a lengthy hibernation of approximately 7–8 months (October–April) (Brashares *et al.* 2010). Their winter hibernacula and burrows are also used for bearing young, hiding from predators, and avoiding environmental extremes, and are commonly re-used during multiple years by the same individuals and social groups (Vancouver Island Marmot Recovery Team 2008). Hibernating burrows, as with escape burrows, are typically constructed underneath a boulder or tree root system and can have multiple entrances; burrows are deep enough that hibernation occurs below the frost level (Vancouver Island Marmot Recovery Team 2008; Brashares *et al.* 2010; Jackson 2012).

Work on Alpine Marmots (*M. marmota*) suggests that a critical feature of hibernacula may be the appropriate depth to maintain stable ambient temperatures close to 5°C (Arnold 1990). 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; Vancouver Island Marmot Recovery Team 2008).

Meadows

Vegetation within the mountain meadow habitats consists of scattered mountain hemlock (*Tsuga mertensiana*), subalpine fir (*Abies lasiocarpa*), yellow-cedar (*Xanthocyparis nootkatensis*), bracken fern (*Pteridium aquilinum*), grasses, sedges, and various forbs (Martell and Milko 1986; Nagorsen 2005). Forage commonly eaten by marmots includes 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). Milko (1984) stated that the meadows are maintained by avalanches or snowcreep, whereas some natural meadows, such as those on Mount Whymper and Hooper North, may be created by wildfires. Vancouver Island Marmots also inhabit recent forestry cutblocks (although this is unsuitable habitat, as discussed in Section 4.2.1, Threats 5 and 7), human-made meadows created by ski-run development (Mount Washington and Green Mountain), and mine tailings (Mount Washington) (Bryant 2004).

Habitat Features that Reduce Risk of Predation

Boulders, talus, or rock piles are also important components of Vancouver Island Marmot habitat as they are used as viewing platforms and refuges from predators. In some areas, steep rocky cliffs are also used to escape terrestrial predators that may find this terrain difficult to navigate.

The vegetation is denser at lower elevations, thus reducing the ability of marmots to visually detect predators. When dispersing between mountains, marmots must travel through these lower-elevation habitats. For successful dispersal, it is important that marmots have access to a “safe” dispersal matrix in which human activities that increase predation risk, such as roads and cutblocks (discussed in Section 4), are absent or minimal.

Home Range, Dispersal, and Habitat Interspersion

Marmots spend most of their time within 100–1000 m of a home burrow (Bryant and Page 2005); thus, good interspersion of the essential habitat components is critical. Heard (1977) documented home ranges of several hectares for individual adult marmots at one colony. In a later study of 38 marmots, Brashares *et al.* (2010) found the mean home range to be 88.6 ± 8.1 ha. The home ranges of females were 32% smaller than those of males, and adult males that emerged from hibernation with a female had a smaller home range than unpaired males. Subsequently, females with pups in an active season had significantly smaller home ranges than non-breeding females (Brashares *et al.* 2010).

Most wild-born marmots known to have dispersed did so when 2–3 years old (Jackson 2014; Jackson and Doyle 2013). Dispersal is male-biased; for example, from 2009 to 2013, 7 of the 10 marmots that dispersed in the Strathcona metapopulation were males (Jackson and Doyle 2013). Records of solitary marmots in low-elevation habitats suggest dispersal distances of 20–50 km are possible (Bryant and Janz 1996; Bryant 2005), and radio-telemetry and sightings of individually ear-tagged marmots confirm that, for the marmots which dispersed, distances of more than 10 km are not uncommon (Jackson 2014). Such dispersal events are important for gene flow and the viability of subpopulations (Bryant and Janz 1996; Bryant 2005). Aaltonen *et al.* (2009) found that dispersing 2-year-old male Vancouver Island Marmots have a lower survival rate than other age classes (as with other species of marmot).

3.4 Ecological Role

Vancouver Island Marmots play a unique ecological role in the alpine and subalpine ecosystems of Vancouver Island as they are the largest burrowing mammal living in this habitat. Their burrows and underground tunneling complex can provide a cool, dark hiding place for various organisms, including moths and other insects, snakes, and amphibians such as the Western Toad (*Anaxyrus boreas*) (Marmot Recovery Foundation 2016). In excavating their burrows, marmots also create huge mounds of soil and rocks, which are exploited by other organisms such as the Sooty Grouse (*Dendragapus fuliginosus*). This bird uses these mounds as a dust bath and a source of grit.

Although it is unclear to what extent marmots modify vegetation conditions through grazing, the degree of disturbance is far less than that imposed by other herbivores, such as Black-tailed Deer (*Odocoileus hemionus columbianus*) and Roosevelt Elk (*Cervus elaphus roosevelti*) (Milko 1984). Vancouver Island Marmots are also prey for both avian and terrestrial predators, such as the Golden Eagle (*Aquila chrysaetos*), Cougar (*Puma concolor*), and Grey Wolf (*Canis lupus*). Golden Eagles tend to select smaller- and medium-sized mammals as prey (Watson and Davies 2015); therefore, Vancouver Island Marmots may be actively (as opposed to opportunistically) hunted by this avian predator. Marmots do not constitute the major prey item for Cougars and Grey Wolves, which focus more on ungulates (Hatler *et al.* 2008).

The Vancouver Island Marmot is the only known host for the tapeworm *Diandrya vancouverensis* (Mace and Shepard 1981), and possibly an intrafollicular mite, and the genetically unique *Mycoplasma* sp., which inhabits the marmot's airways (McAdie, pers. comm., 2016). An unspecified tick of the *Ixodes* genus has been found on the Vancouver Island Marmot (Heard 1977), but it is not known whether it is *Ixodes marmotae*, a species found in British Columbia and Washington on other species of marmots and ground squirrels (Lindquist *et al.* 2016).

3.5 Limiting Factors

Limiting factors are generally not human-induced and include characteristics that make the species less likely to respond to recovery/conservation efforts (e.g., inbreeding depression, small population size, low rate of reproduction, genetic isolation).
Population viability analysis confirms that Vancouver Island Marmot metapopulations persist over the long term within the range of survival and reproductive rates observed in wild and established marmots living in the Nanaimo Lakes metapopulation (Jackson *et al.* 2015); however, when mortality rates are increased to the higher mortality rates observed during the decline (1984–2000; Figure 3), the metapopulation cannot persist (Jackson *et al.* 2015).

The major limiting factors intrinsic to the life history of the Vancouver Island Marmot are related to genetic isolation, small population size, low reproductive rate, and the lack of suitable habitat within dispersing proximity to active colonies. External factors that limit the population size, such as predation, are considered in Section 4 (Threats).

Genetic Isolation

It is unclear to what extent Vancouver Island Marmots may be vulnerable to the effects of genetic isolation. Anecdotal evidence from Mount Washington suggests that inbreeding was a likely contributor to poor reproductive success and a skin condition seen in the late 1990s (McAdie, pers. comm., 2016). Several adult females at that time also did not breed for multiple years despite the presence of adult males (McAdie, pers. comm., 2016).

Compared to other marmot species, Vancouver Island Marmots have very low genetic variation at multiple microsatellite loci, most likely arising from founder effects and genetic bottlenecks (Kruckenhauser *et al.* 2009). Low intraspecific genetic diversity may increase a species' susceptibility to diseases (O'Brien and Evermann 1988; Lacy 1997) and, therefore, Vancouver Island Marmots may be more at risk to novel and established diseases than more genetically diverse species. A further reduction in genetic diversity because of inbreeding within either of the two Vancouver Island Marmot metapopulations could result in a decrease in reproductive success and a possible decrease in survival rates. Nevertheless, the genetic distances between the Mount Washington colony (11 individuals sampled) and those of the Nanaimo Lakes colonies (94 individuals sampled) were large, suggesting that crossbreeding marmots from the two different areas is beneficial to maintaining the overall genetic variability (Kruckenhauser *et al.* 2009).

Small Population Sizes

As with any small population, the Vancouver Island Marmot is at greater risk of extinction related to stochastic events (Jackson *et al.* 2015). In addition, the small population size may amplify other limiting factors.

At very small sizes, populations may exhibit an Allee effect, which is a decline in reproductive or survival rates as population size declines (Courchamp *et al.* 1999). This can arise from inbreeding, an inability to find mates, or behavioral changes at low population density (Courchamp *et al.* 1999). Evidence suggests that Vancouver Island Marmots exhibit an Allee effect at low population size (i.e., less than approximately 250 individuals based on Figure 1 in Brashares *et al.* 2010). Marmots may engage in less alarm-calling at very low population density (Brashares *et al.* 2010), and in some instances adult females did not have access to a mate (Bryant 2005).

At very low populations, genetic drift could dominate selection, and any remaining variation at loci under selection could be lost (Allendorf and Luikart 2006). In the short term, genetic depletion can harm a declining population owing to the fixation of deleterious alleles through inbreeding (Amos and Balmford 2001; Frankham *et al.* 2004).
Finally, fewer Vancouver Island Marmots and marmot colonies on the landscape also decreases the probability that a naturally dispersing marmot will encounter a colony; therefore, small population size may force marmots to travel longer dispersal distances than in the past.

Low Rate of Reproduction

Although wild Vancouver Island Marmots breed at rates similar to other species of alpine-dwelling marmots (i.e., age of first reproduction, between-litter intervals, litter size, and sex ratio of offspring) (Bryant 2005), they have a low lifetime reproductive output relative to many other rodents. Females occasionally reproduce as 2-year olds but most do not reproduce until they are 3–4 years old (Bryant and Janz 1996; Bryant 2005). The average age of first reproduction for female Vancouver Island Marmots is 3.6 years old (Bryant 2005), whereas the oldest reported female in the wild was 10 years old, although they have lived to at least 14 years old in captivity (COSEWIC 2008). Only 45.4% of females that wean a litter will wean one in the following year; 39.3% will skip one breeding season between litters, and 14.3% will skip two breeding seasons between litters (Bryant 2005). The average weaned litter size is 3.4 pups.

Lack of Suitable Habitat within Dispersing Proximity to Active Colonies

Although sufficient habitat appears to be available, the distribution of this habitat relative to dispersal distance may make some of it inaccessible to Vancouver Island Marmots dispersing from currently active colonies. Natural habitat patches that are suitable for marmots occur relatively infrequently within the broader landscape. The lack of locations with the essential habitat features within dispersing proximity of active colonies can limit the extent and number of locations at which colonies can exist (Bryant and Janz 1996). Suitable habitat may have been more extensive in the past, which would have increased the probability of a dispersing marmot encountering another colony. 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 1 000–2 000 years ago may have created larger and more widespread open meadow parkland. Archeological and paleontological discoveries at locations 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).

4 THREATS

Threats are defined as the proximate activities or processes that have caused, are causing, or may cause in the future the destruction, degradation, and/or impairment of the entity being assessed (population, species, community, or ecosystem) in the area of interest (global, national, or subnational) (adapted from Salafsky *et al.* 2008). For purposes of a threat assessment, only present and future threats are considered.[3]

For the most part, threats are related to human activities, but they can also be natural. The impact of human activity may be direct (e.g., destruction of habitat) or indirect (e.g., introduction of invasive species). Effects of natural phenomena (e.g., fire, flooding) may be especially important when the species is concentrated in one location or has few occurrences, which may be a result of human activity (Master *et al.* 2012). As such, natural phenomena are included in the definition of a threat, though they should be considered cautiously. These stochastic events should only be considered a threat if a species or habitat is damaged from other threats and has lost its ability to recover. In such cases, the effect on the population would be disproportionately large compared to the effect experienced historically (Salafsky *et al.* 2008).

[3] Past threats may be recorded but are not used in the calculation of threat impact. Effects of past threats (if not continuing) are taken into consideration when determining long-term and/or short-term trend factors (Master *et al.* 2012).

4.1 Threat Assessment

The threat classification below is based on the IUCN–CMP (World Conservation Union–Conservation Measures Partnership) unified threats classification system and is consistent with methods used by the B.C. CDC. For a detailed description of the threat classification system, see the Open Standards website (Open Standards 2014). Threats may be observed, inferred, or projected to occur in the near term. Threats are characterized here in terms of scope, severity, and timing. Threat "impact" is calculated from scope and severity. For information on how the values are assigned, see Master *et al.* (2012) and table footnotes for details. Threats for the Vancouver Island Marmot were assessed for the entire province (Table 3). Section 4.2 provides a description of the threats included in this table.

Table 3. Threat classification table for the Vancouver Island Marmot in British Columbia.

Threat #[a]	Threat description	Impact[b]	Scope[c]	Severity[d]	Timing[e]	Population(s) or location(s)
4	Transportation & service corridors	Negligible	Small	Negligible	Moderate	Mount Washington
4.1	Roads & railroads	Negligible	Small	Negligible	Moderate	Mount Washington
5	Biological resource use	Unknown	Small	Unknown	Moderate	All
5.3	Logging & wood harvesting	Unknown	Small	Unknown	Moderate	All
7	Natural system modifications	Medium	Large	Moderate	High	All
7.1	Fire & fire suppression	Unknown	Small	Unknown	Moderate	All
7.2	Dams & water management/use	Low	Restricted	Slight	High	Mount Washington
7.3	Other ecosystem modifications	Medium	Large	Moderate	Moderate	All
8	Invasive & other problematic species, genes & diseases	High–Medium	Pervasive	Serious–Slight	High	All
8.1	Invasive non-native/alien species/diseases	Unknown	Unknown	Unknown	Moderate	All
8.2	Problematic native species/diseases	High–Medium	Pervasive	Serious–Slight	High	All
8.3	Introduced genetic material	Negligible	Negligible	Unknown	Moderate	All
8.4	Problematic species/diseases of unknown origin	Unknown	Unknown	Unknown	Moderate	All
8.5	Viral/prion-induced diseases	Unknown	Unknown	Unknown	Moderate	All
8.6	Diseases of unknown cause	Unknown	Unknown	Unknown	Moderate	All
10	Geological events	Unknown	Pervasive	Unknown	Unknown	All
10.2	Earthquakes/tsunamis	Unknown	Pervasive	Unknown	Unknown	All
10.3	Avalanches/landslides	Negligible	Pervasive	Negligible	Moderate	All

Threat #[a]	Threat description	Impact[b]	Scope[c]	Severity[d]	Timing[e]	Population(s) or location(s)
11	Climate change & severe weather	Low	Restricted–Large	Slight	High	All
11.1	Habitat shifting & alteration	Low	Restricted–Large	Slight	High	All
11.2	Droughts	Unknown	Pervasive	Unknown	Moderate	All
11.3	Temperature extremes	Unknown	Pervasive	Unknown	Moderate	All
11.4	Storms & flooding	Unknown	Small	Unknown	Moderate	All

[a] Threat numbers are provided for Level 1 threats (i.e., whole numbers) and Level 2 threats (i.e., numbers with decimals).
[b] **Impact** – The degree to which a species is observed, inferred, or suspected to be directly or indirectly threatened in the area of interest. The impact of each threat is based on severity and scope rating and considers only present and future threats. Threat impact reflects a reduction of a species population. The median rate of population reduction for each combination of scope and severity corresponds to the following classes of threat impact: Very High (75%), High (40%), Medium (15%), and Low (3%). Unknown: used when impact cannot be determined (e.g., if values for either scope or severity are unknown); Not Calculated: impact not calculated as threat is outside the assessment time (e.g., timing is insignificant/negligible [past threat] or low [possible threat in long term]); Negligible: when scope or severity is negligible; Not a Threat: when severity is scored as neutral or potential benefit.
[c] **Scope** – Proportion of the species that can reasonably be expected to be affected by the threat within 10 years. Usually measured as a proportion of the species' population in the area of interest. (Pervasive = 71–100%; Large = 31–70%; Restricted = 11–30%; Small = 1–10%; Negligible < 1%).
[d] **Severity** – Within the scope, the level of damage to the species from the threat that can reasonably be expected to be affected by the threat within a 10-year or three-generation time frame. For this species, a 10-year time frame was used. Severity is usually measured as the degree of reduction of the species' population. (Extreme = 71–100%; Serious = 31–70%; Moderate = 11–30%; Slight = 1–10%; Negligible < 1%; Neutral or Potential Benefit ≥ 0%).
[e] **Timing** – High = continuing; Moderate = only in the future (could happen in the short term [< 10 years or three generations]) or now suspended (could come back in the short term); Low = only in the future (could happen in the long term) or now suspended (could come back in the long term); Insignificant/Negligible = only in the past and unlikely to return, or no direct effect but limiting.

4.2 Description of Threats

The overall province-wide Threat Impact for Vancouver Island Marmots is Medium–High.[4] The overall threat considers the cumulative impacts of multiple threats. Primary threats include native predators (*8.2 Problematic native species*), ecosystem modification (*7.3 Other ecosystem modification*) arising from post-logging forest succession (*5.3 Logging and wood harvesting*) and, longer term, predicted habitat loss associated with climate change (*11.1 Habitat shifting and alteration*) (Table 3). Details are discussed below under the Threat Level 1 headings.

4.2.1 Threats with Impact

Threat 4. Transportation & service corridors (Negligible impact)

4.1 Roads & railroads (Negligible impact)
In general, major transportation and service corridors are not associated with the alpine and subalpine habitats in which marmots live. Some two-lane paved roads lead to the Mount Washington Alpine Resort and resource roads (i.e., roads to access logging and mining sites) also occur throughout Vancouver Island.

No known instances of marmots killed by vehicles on roads have occurred to date. At Mount Washington, supplemental food has been used to draw marmots away from roads in the spring (Jackson *et al.* 2015), and signage is in place to warn drivers that marmots may be near the road. On resource roads, logging truck drivers are educated on where marmots live near roads. Vancouver Island Marmot field crews use the resource roads, and by calling in their locations on the road remind other drivers that marmots are in the area.

Marmots may encounter roadways during the dispersal process, and indeed the propensity of Vancouver Island Marmots to use resource roads for traveling has been documented (Bryant 1998; Jackson, pers. comm., 2016). The relatively low density of roads associated with marmot habitat, low volume of vehicles on resource roads, and small proportion of marmots that disperse makes the threat Negligible (Table 3). In ground-dwelling sciurids (including *Marmota*), dispersers are usually young males (Holekamp 1984; Armitage 2014), and this trend appears to hold true for Vancouver Island Marmots (Bryant 1996; Jackson and Doyle 2013; Jackson 2014). The death of subadult males will affect population numbers less than the death of a female, although a minor genetic consequence could occur. Genetic consequences could be mitigated through occasional translocation of individuals (Jackson *et al.* 2015).

Roads may also have an indirect negative affect on Vancouver Island Marmots as their main terrestrial predators, Cougars and Grey Wolves, have a propensity to use resource roads. See *8.2 Problematic native species* for a consideration of the threats posed by predators.

[4] The overall threat impact was calculated following Master *et al.* (2012) using the number of Level 1 Threats assigned to this species where timing = High or Moderate, which included 1 High – Low, 1 Medium, 1 Low, 3 Unknown, and 2 Not a Threat (Table 3). The overall threat impact considers the cumulative impacts of multiple threats.

Threat 5. Biological resource use (Unknown impact)

5.3 Logging & wood harvesting (Unknown impact)

Logging and wood harvesting threats to marmots can be divided into two categories: (1) the immediate effects of tree removal (discussed here); and (2) the longer-term ecosystem modification associated with natural succession after logging (*7.3 Ecosystem modification*), including the creation of early seral high-elevation cutblocks that provide temporary habitat for marmots, but that are also attractive summer forage for ungulates, the major prey species of Cougars and Grey Wolves (Threat 8.2).

In the past, marmots have established colonies (survived and reproduced) in recently logged cutblocks at high elevations due to the similarities between these areas and the subalpine meadows in which the marmots evolved. It is not known whether the marmots that colonize cutblocks were drawn from nearby natural habitat, or whether the cutblocks intercepted dispersing marmots, which would have otherwise traveled a longer distance to find natural habitat. Thus, these human-created habitats may have allowed the population to increase temporarily (positive effect) but, in the longer term, the ephemeral cutblock habitats appear to have been population sinks. Continuing tree and shrub removal may be a useful tool to maintain these habitats for ongoing use by marmots. As threat severity is scored over a 10-year time frame for this species, any longer-term negative effects of post-logging succession are discussed under *7.3 Ecosystem modification.*

Because Vancouver Island Marmot hibernacula are often associated with tree root systems within forested areas (Jackson, pers. comm., 2016), and the success of hibernation is influenced by the microclimatic conditions above and below ground (including characteristics of snow layer and associated impacts on thermoregulation), altering biophysical structures within the vicinity of an established hibernaculum (including local tree removal) can reasonably be projected to have a negative effect on the individuals that hibernate there. The extent of this effect is unknown (e.g., whether it causes them to die over winter, move to another area, or not be affected); however, Vancouver Island Marmots can also successfully hibernate in areas not associated with trees, so it is unknown what, if any, benefit hibernating in forested areas may convey.

In addition, trees associated with hibernacula at high elevations (most populations besides those on Mount Washington) are small and, therefore, less likely to be logged than lower-elevation forests available for logging. The land on Mount Washington (in the Strathcona region) is privately owned, and marmots have successfully hibernated on this forested land for over a decade.

Threat 7. Natural system modifications (Medium impact)

7.1 Fire & fire suppression (Unknown impact)

Historical intervals between major fires likely ranged from less than 300 years in the southeastern part of Vancouver Island to 700–3000 years in the western and central regions of Vancouver Island (Lertzman *et al.* 1998; Brown and Hebda 2003; Vancouver Island Marmot Recovery Team 2008). The degree to which fire is important in creating and maintaining suitable habitat for marmots is Unknown (Vancouver Island Marmot Recovery Team 2008), but it may be locally important to some areas (Milko 1984). Therefore, the degree to which fire suppression is a threat is also Unknown.

7.2 Dams & water management/use (Low impact)
Buttle Lake, where water levels increased by 8.5 m in 1958 related to the construction of the Strathcona Dam, may serve as a barrier to marmot dispersal. Although it has been on the landscape for almost 60 years, it is considered an ongoing threat (Low) because its location affects dispersal among colonies. Vancouver Island Marmots have recently been documented to disperse around the lake's western end (Jackson, pers. comm., 2016), indicating that it likely increases the distance some marmots in the area must travel during dispersal.

A water reservoir is planned for the Mount Washington Alpine Resort (Pendergast, pers. comm., 2016), an area in which some marmots in the Strathcona metapopulation live. With sufficient funding and selective timing, any marmots that would be directly affected through the flooding of burrows could be moved, potentially reducing the current threat level from Low to Negligible. In the past, two marmots drowned in a reservoir because the lining material was slippery and the marmots could not climb out (Pendergast, pers. comm., 2016). Any new reservoir will be designed and constructed to ensure marmots (and other animals) could escape if they entered it, and the reservoir could also be fenced above and below ground to prevent animals from entering.

7.3 Other ecosystem modifications (Medium impact)
Natural forest succession occurring in cutblocks after logging poses a threat to Vancouver Island Marmots. As mentioned above (*5.3 Logging and wood harvesting*), marmots have established colonies in recently logged, high-elevation cutblocks because these areas can mimic subalpine habitat during early succession; however, the cutblocks become unsuitable marmot habitat as forest succession occurs, individuals do not immigrate to the area, and survival is lower relative to natural habitat (Bryant 1996, 1998). The lower survival is thought to arise because terrestrial predators follow ungulate prey attracted to the high quantity and quality of forage associated with cutblocks and, while in the cutblock, these predators will also depredate marmots. Colonies in cutblocks are extirpated 5–19 years after establishment (median 10 years; Vancouver Island Marmot Team 2008).

Threat 8. Invasive & other problematic species, genes & diseases (High–Low impact)

8.1 Invasive non-native/alien species/ diseases (Unknown impact)
No alien plant species currently occur in the biogeoclimatic zones in which marmots are found (B.C. CDC 2016). In addition, alpine areas are cold most of the year, and are associated with high snowfall, high winds, a short growing season, and frost that can occur at any time of the year (Pojar and MacKinnon 2013). These areas are therefore unsuitable habitat for many alien plant species.

Non-native pathogen introduction is a significant concern, but the threat of a non-native disease is Unknown. An infectious organism that causes high mortality will have a large negative effect in a local area, with extirpation likely for an infected colony. Diseases that cause morbidity but low mortality are likely to become endemic in the colony and eventually in the population (McAdie, pers. comm., 2016). The full spectrum of specific diseases that may constitute a threat in the Vancouver Island Marmot program are unknown, so disease risk is managed rather than the specific diseases, with emphasis on minimizing the potential for introduced pathogens.

Non-native diseases could enter the marmot population in numerous ways, but this threat has not been quantified. Potential sources of non-native disease include other species of rodents (e.g., Yellow-bellied Marmots) accidently transported to Vancouver Island via vehicles and goods (*see 8.3 Introduced genetic material*), dogs that accompany humans into marmot habitat, or humans recreating in and around marmot colonies.

Non-native diseases could also enter the Vancouver Island Marmot wild population via the release of captive-born marmots. Captive marmots are held are multispecies facilities in which they may encounter other mammal (including rodent) species (McAdie, pers. comm., 2016). Marmots for release are transported from these zoo facilities to Vancouver Island via commercial airliners where they may encounter other mammal species in cargo holds. Disease risk is minimized in the captive population by conditions of permanent quarantine, regular health examinations, and complete post-mortems according to specific protocols. The disease risk associated with release of captive-born marmots is minimized through quarantine at the Tony Barrett Mount Washington Marmot Recovery Centre on Vancouver Island and health checks before release (McAdie, pers. comm., 2016).

8.2 Problematic native species/diseases (High–Medium impact)

Predation by native species (Cougars, Grey Wolves, and Golden Eagles) is the most immediate, direct threat to Vancouver Island Marmot populations. Both roads and logging can indirectly increase predation risk by facilitating the movement of predators into higher-elevation marmot habitat (see *4.1 Roads & railroads* and *5.3 Logging and wood harvesting*). Once in marmot habitat, these predators will opportunistically predate Vancouver Island Marmots if encountered.

Predation is the predominant cause of mortality among Vancouver Island Marmots, accounting for a minimum of 53%, and probably up to 83%, of marmot deaths (Jackson *et al.* 2015). The decline in the marmot population during the 1980s and 1990s (Bryant and Page 2005) was associated with high numbers of Golden Eagles (McAdie, pers. comm., 2016) and logging at high elevation (Lindsay, pers. comm., 2016).

Predator presence and density in marmot habitat is not related to marmot numbers but to the abundance and location of primary prey such as Black-tailed Deer and Roosevelt Elk. Therefore, even at low marmot densities, potential predators will remain abundant and may limit marmot population numbers or cause local extirpations.

Mechanisms to mitigate the effects of predation include augmenting the population with captive-bred or wild-born marmots, shepherding and protecting marmot colonies, and managing predators and habitat to reduce the risk of predators (i.e., maintaining a safe travel matrix by avoiding roads and logging near marmot habitat and in the travel matrix through which marmots are likely to disperse). Thus, predation by native species currently remains a High–Medium threat to the marmot population. The threat may be a slightly reduced in areas of high human use because Cougars, a main marmot predator (Jackson and Doyle 2013, Jackson 2014), may avoid these areas (Morrison *et al.* 2014).

8.3 Introduced genetic material (Negligible impact)

On at least six recorded occasions, Yellow-bellied Marmots have accidentally reached Vancouver Island via transport in vehicles and goods (McAdie, pers. comm., 2016). If these marmots encountered Vancouver Island Marmots, the two species are not very closely related and are unlikely to hybridize (Steppan *et al.* 1999, 2011). Similarly, a very low probability exists that Vancouver Island Marmots would encounter a Hoary Marmot, given their non-overlapping distributions and the further isolation afforded by their island location; however, given their closer phylogenetic relationship (Kruckenhauser *et al.* 1999; Steppan *et al.* 1999), hybridization may be possible if they had the opportunity to mate. Indeed, mitochondrial DNA analysis indicates ongoing, intermittent gene flow occurred between these two species over their evolutionary history (Kerhoulas *et al.* 2015).

8.4–8.6 Diseases of unknown origin, viral/prion diseases, diseases of unknown cause (Unknown impact)

The full spectrum of specific diseases that could constitute a threat in the Vancouver Island Marmot program is unknown (see *8.1 Invasive non-native/alien diseases*). Therefore, risk is managed for diseases in general rather than specific diseases. A priority of management is minimizing the potential for introduction of pathogens, particularly within the captive-bred population.

Threat 10. Geological events (Unknown impact)

10.2 Earthquakes/tsunamis (Unknown impact)

Vancouver Island Marmots live in a seismically active area (Seemann *et al.* 2011). Although an earthquake could conceivably occur over the next 10 years, the probability of a significant[5] event is less than 10% (Seemann *et al.* 2011). If one occurred, its impact on marmots is Unknown. Earthquake activity in New Zealand has recently caused the loss of up to 25% of the breeding population of a threatened seabird, which nests in similarly steep terrain (BirdGuides 2016), but given the more widespread spatial distribution of Vancouver Island Marmots, the impact would probably be much less than observed in this seabird population.

10.3 Avalanches/landslides (Negligible impact)

Marmots live at high elevation on steep mountains in areas of high avalanche activity (Nagorsen 2005). Although some marmots caught in avalanches could suffer negative effects, avalanches also have the positive effect of removing trees and thereby improving marmot habitat (Nagorsen 2005). If climate change leads to decreased avalanche frequency because of variations in precipitation and temperature, then marmots would be negatively affected because natural succession would result in tree establishment (see *7.3 Ecosystem modification*). Low confidence surrounds our ability to predict the effect of climate change on avalanches (Field *et al.* 2012); however, given the small area of marmot habitat associated with avalanche activity, any negative effect could be mitigated through logistically feasible management activities such as selective tree clearing in avalanche chutes (Jackson 2014).

[5] "Significant" refers to earthquakes with a Modified Mercalli Intensity level of VII, which can cause structural damage.

Threat 11. Climate change & severe weather (Low impact)
In the long term, climate change poses a potentially significant risk to the Vancouver Island Marmot as it is a high-elevation species and its available habitat is predicted to decrease (Thelin 2016). Davis (2005) suggested that marmots are generally more susceptible to the effects of climate change than other mammal species, and Armitage (2014) concluded that marmots with a narrow distribution, including Vancouver Island Marmots, are more at risk than other mammals. The impact of climate change on Vancouver Island Marmots over the 10-year time frame of this threat assessment is less clear and currently assessed as Low, although some effects on habitat, such as tree ingress, have already been observed.

11.1 Habitat shifting & alteration (Low impact)
Some existing Vancouver Island Marmot colony areas have experienced tree ingress over the past few decades (Laroque 1998; Pendergast, pers. comm., 2016), but this has not been observed in other current and historical colonies (Vancouver Island Marmot Recovery Team 2008). More tree cover will negatively affect the marmot population if it is associated with a decreased survival rate related to a rise in predation risk or less marmot forage (see *7.3 Ecosystem modification*).

Nevertheless, the negative effects of tree ingress have been mitigated through tree removal (Jackson 2014), and such activities are financially and logistically feasible for many marmot sites. However, climate change is expected to reduce the amount of suitable habitat for marmots, negatively affecting the species over the long term (Thelin 2016) and limiting the spatial and temporal scale at which mitigation measures are feasible. A robust northern metapopulation (i.e., Strathcona region) can help buffer against this threat.

11.2 Droughts (Unknown impact)
Late summer drought has decreased overwinter survival of Yellow-bellied Marmots and their reproduction in the following year and, therefore, may be a limiting factor in some years for this species (Armitage 1991, 2014). A similar effect may occur in Vancouver Island Marmots. Following a summer drought in 2015, overwinter survival and reproduction for marmots was lower than average in the Strathcona region (Jackson, unpubl. data); however, data analysis is required to determine whether other factors might explain this observation. Therefore, the potential severity and impact of drought is currently Unknown. Winter drought may reduce snowpack which, in turn, may affect the metabolic cost of hibernation, overwinter survival, and reproduction in the subsequent active season.

11.3 Temperature extremes (Unknown impact)
Because most marmot species become inactive during the hottest time of the day, high temperatures may reduce foraging times (Heard 1997; Armitage 2014). This negative impact may be minimized if a spectrum of habitat is available or if movement to another slope is possible. Temperature extremes may also reduce snowpack persistence and affect whether winter precipitation falls as snow or rain, both of which may affect the metabolic cost of hibernation, overwinter survival, and reproduction in the subsequent active season. Currently, it is impossible to predict the severity of future temperature extremes or the proportion of marmot populations that may be affected by them.

11.4 Storms & flooding (Unknown impact)
Natural flooding of Columbian Ground Squirrel hibernacula has been reported (Young 1990) and flooding has resulted in the death of hibernating Hoary Marmots (Gillis, pers. comm., 2016). Although anecdotal evidence suggests that spring flooding of hibernacula can cause mortality of Vancouver Island Marmots (Pendergast, pers. comm., 2016), such mortality appears rare. Occasional local flooding seems to affect only a few individuals in some years; however, the severity of this threat is Unknown. Extreme snow years that result in late spring melt may negatively affect survival and reproduction, but the extent of this impact and the degree to which frequency of extreme snow years will change is Unknown.

4.2.2 Other Threats Considered

Threat classifications currently assessed as "Not a Threat," to Vancouver Island Marmots, are discussed below under the applicable Threat Level 1 headings.

Threat 1. Residential & commercial development (Not a Threat)

1.3 Tourism & recreation (Not a Threat)
Expansion of the alpine ski-run networks may occur at the Mount Washington Alpine Resort within the next few years. Even if trail creation results in short-term negative impacts (e.g., noise and soil disturbance related to construction, or temporary inaccessibility of some marmot travel routes or areas during construction), the net impact may benefit the Strathcona metapopulation. Marmots use the open areas created by the alpine ski runs extensively for foraging, burrowing, and hibernating (Jackson, pers. comm., 2017). The newly cleared ski runs, if maintained, provide additional habitat for marmots (Dearden and Hall 1983).

Threat 5. Biological resource use (Not a Threat)

5.1 Hunting & collecting terrestrial animals (Not a Threat)
Vancouver Island Marmots are collected from the wild to augment the captive-breeding population. Anecdotal reports suggest that marmots were killed for recreation (McAdie, pers. comm., 2016), before their endangered status was publicized. More recently, an unverified report was made of a marmot in the Nanaimo Lakes metapopulation being shot and killed (Pendergast, pers. comm., 2016).

Vancouver Island Marmots will be collected alive over the next 10 years when augmentation of the captive-breeding population is required for demographic or genetic reasons. Such collections are done in a way that minimizes the demographic impact on wild metapopulations (e.g., collection of solitary marmots, marmots from colonies located in ephemeral cutblock habitat, or young marmots not yet of reproductive age). The collections also have a positive effect on populations as captive-born marmots are then released back into the wild. Approximately eight marmots have been returned to the wild population for every marmot that was collected for the captive-breeding program.

Threat 6. Human intrusions & disturbance (Not a Threat)

Human activities (e.g., work or recreation) occurring near Vancouver Island Marmot colonies may benefit the species as Cougars and Grey Wolves generally avoid areas of high human use

(Morrison *et al.* 2014). Overall, human intrusions and disturbance are considered Not a Threat at this time.

5 RECOVERY GOAL AND OBJECTIVES

5.1 Recovery (Population and Distribution) Goal

The recovery (population and distribution) goal is to maintain or increase the abundance of Vancouver Island Marmots in at least two geographically separated metapopulations within the species' historic range, and to ensure connectivity within each of these areas.

The recovery goal will be met when, in the absence of population augmentation using captive-bred individuals, the metapopulation in each of the two areas (and therefore the species overall) has a greater than 90% probability of persistence over 100 years.[6]

5.2 Rationale for the Recovery (Population and Distribution) Goal

The Vancouver Island Marmot has a naturally restricted distribution, being endemic to subalpine meadows on central Vancouver Island. Colonies were likely more connected historically; genetic results suggest that some colonies, such as those at Mount Washington in the Strathcona metapopulation, had been isolated for several generations (Kruckenhauser *et al.* 2009). The earliest estimated population size (in the 1970s) was approximately 100–150 individuals, although this estimate was extrapolated from incomplete data (Bryant and Janz 1996). The number of individuals possibly increased during the 1980s, owing to colonization of new cutblocks; however, given the uncertainty of the initial population estimates, it is also possible that any apparent increase was related to a redistribution of marmots. Regardless, starting in the mid-1980s, the population declined steeply because of increased predation.

Vancouver Island Marmots have a very small population size. To maintain and grow this population, natural recruitment is currently supplemented through the reintroduction of captive-bred marmots and the translocation of wild-born marmots. Among other considerations, the small population size led to its assessment as Endangered[7] in Canada, based on the criteria used by COSEWIC. Nevertheless, even if the historical (1970s and 1980s) distribution and abundance of this species could be achieved, the species would still be considered a Species at Risk in Canada.

The historical condition of many small, interconnected colonies throughout the species' range on Vancouver Island cannot be restored, owing to irreversible habitat change in some areas of their historic distribution in the lower-elevation matrix through which marmots would have to disperse. A previous recovery strategy (Vancouver Island Marmot Recovery Team 2008)

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[6] Probability of persistence will be determined through population viability analyses models, with data and results verified by multiple independent experts.

[7] Vancouver Island Marmot is COSEWIC-assessed as Endangered based on the Criteria A2a; C2a(i); D1: see COSEWIC quantitative criteria and guidelines for the status assessment of wildlife species.

identified a goal of maintaining three metapopulations; however, because of natural dispersal between two of those metapopulations, Forbidden Plateau and Western Strathcona are now considered one metapopulation, referred to here as “Strathcona.” The current recovery goal is therefore considered appropriate to ensure the species’ persistence in Canada by incorporating elements of resilience and redundancy. The two regions currently the focus of recovery efforts, Nanaimo Lakes and Strathcona (Figure 2; Table 1), are where the species naturally persisted. Establishing colonies at extralimital sites where high-elevation habitat is predicted to be less affected by climate change may be beneficial.

Although short-term interventions will be needed to maintain or increase the number of individuals in the two metapopulations, the ultimate goal is to ensure that metapopulations are self-sustaining (i.e., naturally stable or increasing). Population viability analyses are required to set specific targets for self-sustaining populations. Targets will ensure each metapopulation has a less than 10% probability of extinction over 100 years, which is the threshold that separates the designations of “Threatened” and “Special Concern” in Canada for COSEWIC’s quantitative analysis criterion. Because the Vancouver Island Marmot historically exhibited a metapopulation structure (i.e., spatially discrete subpopulations linked by dispersal), the target is for each metapopulation to contain at least seven subpopulations (mountains), each of which is (on average) stable or increasing.[8]

Even after the recovery goal is achieved (Jackson *et al.* 2015), occasional intervention (translocation of individuals between the two metapopulations) will be needed to maintain genetic diversity; however, although very beneficial, translocations will not be required for metapopulation persistence on a 100-year time scale (Jackson *et al.* 2015).

5.3 Recovery Objectives

The following are the recovery objectives for the Vancouver Island Marmot:

1. Increase the number of individuals through augmentation and, if possible, by increasing survival rates and reproductive rates in the wild.
2. Maximize opportunities for successful dispersion between colonies.
3. Maintain a large and genetically diverse captive-breeding population that can produce adequate numbers of release candidates to support population recovery.
4. Prioritize the maintenance of genetic variability in the global population until recovery goals are met.
5. Reduce knowledge gaps surrounding: (a) natural levels of variability in survival and reproductive rates in the wild; (b) factors (natural and management) that determine key demographic rates; and (c) the best method to monitor population size and key demographic rates long term.
6. Develop and implement a plan for reducing intensive management as populations recover.

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[8] Stable, increasing, or decreasing will be determined based on a geometric average of the annual intrinsic population growth rate over a 10-year time frame.

7. Develop and implement a sound strategy to ensure sufficient resources are available to support recovery efforts until recovery goals are met.

6 APPROACHES TO MEET OBJECTIVES

6.1 Actions Already Completed or Underway

The following actions have been categorized by the action groups of the B.C. Conservation Framework (B.C. Ministry of Environment 2009). Status of the action group for this species is given in parentheses.

Compile Status Report (complete)

- COSEWIC report completed (Munro 1978; Bryant 1997; COSEWIC 2000, 2008). Update scheduled for 2017–2018.

Send to COSEWIC (complete)

- Vancouver Island Marmot assessed as Endangered in 1978 (Munro 1978). Status re-examined and confirmed Endangered in 2000 and 2008 (COSEWIC 2000, 2008). Re-assessment due 2018.

Planning (update in progress)

- National Recovery Plan completed (Janz *et al.* 1994)
- National Recovery Plan updated (Janz *et al.* 2000)
- B.C. Recovery Plan (Vancouver Island Marmot Recovery Team 2008)
- B.C. Recovery Plan updated (this document, 2017).
- Vancouver Island Marmot Population and Habitat Viability Assessment Workshop (Jackson *et al.* 2015)
- Establishment of a non-profit registered charitable organization, the Marmot Recovery Foundation, both to raise funds and to administer the day-to-day recovery efforts (established 1998). This foundation has created a resourcing partnership that involves forestry companies, an alpine resort, various levels of government, and the public. Resources contributed by the partners include both financial and in-kind.

Habitat Protection and Private Land Stewardship (in progress)

- This species is found in Strathcona, Clayoquot Plateau, and Schoen Lake provincial parks, which are protected through the provisions of British Columbia's *Park Act* (Province of British Columbia 1996a).
- This species is found in the Haley Lake Ecological Reserve (888 ha), which is protected from industrial resource extraction through provisions in British Columbia's *Ecological Reserves Act* (Province of British Columbia 1996b). Part of the land (93 ha) for this reserve was donated by Island Timberlands for this purpose in 1986; Island Timberlands provided additional land (517 ha) for the reserve in 2000.
- The Green Mountain Wildlife Management Area (300 ha) was created to protect Vancouver Island Marmot habitat under provisions of British Columbia's *Wildlife Act* (Province of British Columbia 1982). This land was donated by TimberWest for this purpose in 1991.

- Vancouver Island Marmots are managed as Identified Wildlife in the province (B.C. Ministry of Environment 2001), which affords them some protection under British Columbia's *Forest and Range Practices Act* (Province of British Columbia 2002).
- Vancouver Island Marmots are listed under Schedule E (endangered species; Designation and Exemption Regulation, B.C. Reg. 168/90) of the provincial *Wildlife Act* (Province of British Columbia 1982), which affords some habitat protection.
- Marmot habitat on Crown lands leased to, and private lands belonging to, Island Timberlands, TimberWest, Western Forest Products Inc., and the Mount Washington Alpine Resorts has been managed in active consultation with the Marmot Recovery Foundation. These partnerships have been effective to date in maintaining and improving habitat features important for marmots on these lands. Formalizing these partnerships with written agreements that commit private landowners to stewardship of marmot habitat on their lands would be a beneficial action. Written agreements could take numerous forms, including Section 11 Stewardship Agreements, as described in the *Species at Risk Act* (Government of Canada 2002).

Habitat Restoration and Private Land Stewardship (completed and in progress)

- Removing trees that establish in subalpine meadows to improve habitat by decreasing hunting cover for predators and maintaining open meadow habitat has occurred at three sites in Nanaimo Lakes region (on Gemini [2006], Green [2013–2016], and Moriarty [2016] Mountains) (Jackson 2014; Jackson, pers. comm., 2016).
- Island Timberlands, TimberWest, Western Forest Products Inc., and the Mount Washington Alpine Resort: currently, maintain access for recovery work, and alter or delay land use to accommodate habitat protection for marmots; and, when warranted, report marmot sightings on their managed lands, and facilitate translocation of marmots.

Species and Population Management (completed and in progress)

Captive breeding (in progress)

- The Vancouver Island Marmot captive-breeding program began in 1997 and has been supported by up to four facilities. Fifty-five marmots (24 females) were brought into captive facilities between 1997 and 2004, and an additional 6 marmots (4 females) were brought into the program in 2016. The number of marmots in captivity at the start of fall hibernation in 1997 and 2008 ranged from 6 to 177, respectively (Jackson *et al.* 2015; McAdie, pers. comm., 2016). Since 2000, 579 pups, of which 45% were females, have been weaned in the captive population. In 2008, owing largely to financial considerations, the size of the captive population was reduced and consolidated. As of November 2016, the Calgary and Toronto zoos now support 43 marmots. Appendix 1 contains additional details about the captive-breeding program.
- Genetic diversity within the captive population is managed through a studbook that is continually updated and maintained in the Single Population Analysis and Records Keeping System (SPARKS) format (Jackson *et al.* 2015).
- Research to facilitate captive breeding of Vancouver Island Marmots is currently under way. Research includes sperm preservation and ovulation facilitation, artificial insemination and contraception (Jackson *et al.* 2015; Jackson, pers. comm., 2016; McAdie, pers. comm., 2016). Research has already been completed on monitoring ovulation and pregnancy using

progesterone metabolites found in feces (Keeley *et al.* 2012) and examining the roles of stress hormones and other factors limiting breeding in captivity (Casimir *et al.* 2007).
- Experimental research has been used to verify that captive-born marmots can still recognize predators (Blumstein 2006). This research is currently being repeated and expanded to replicate results obtained from 2002 to 2004 (Lloyd, pers. comm., 2016).

Population augmentation and increasing distribution of colonies (in progress)
- Release of captive-born, and translocation of wild-born, marmots has been used to increase both the number and the distribution of marmots.
- Releases of captive-bred marmots began in 2003. From 2003 to 2016, 490 captive marmots were released to either historical or suitable marmot habitat on Vancouver Island (range: 4–85 animals were released per year; Jackson *et al.* 2015, McAdie, pers. comm., 2016). See Appendix 1 for additional details.
- Translocations of wild-born marmots began in 1996. From 1996 to 2016, wild marmots have been moved to augment colonies, to re-establish or establish colonies, or because they dispersed or lived in areas where they were unlikely to encounter other marmots. From 1997 to 2011, translocations were done opportunistically (i.e., when an isolated colony had only one marmot, it was moved). In 1996, and since 2013, translocations have been pre-planned.
- An objective in the 2008 recovery strategy was to “Maximize wild breeding potential by providing solitary wild females with captive-bred potential mates when necessary” (Vancouver Island Marmot Recovery Team 2008). This is an ongoing initiative.
- Marmots have been released or translocated to 31 colonies or areas within the historical range of Vancouver Island Marmots, of which only four were extant in 2003. Some of these were naturally colonized by dispersers before augmentation. Seventy-one percent of the augmented colonies were occupied by marmots in 2016. Attempts have been made to establish extralimital colonies at an additional six mountains through releases. One of these colonies, and possibly a second, are currently extant (Jackson, pers. comm., 2016).

Demographic monitoring and inventory (in progress)
- To monitor survival, animal movements, and reproduction, marmots are individually marked in the following ways.
  - Before release, all captive-born marmots are ear-tagged with two individually numbered tags, and receive VHF radio transmitter implants.
  - Translocated wild-born marmots are ear-tagged with two individually numbered tags, and most receive VHF radio transmitter implants. Marmots are only released without a transmitter or ear-tags when the veterinarian was unavailable to do the procedure (Jackson, pers. comm., 2016).
  - Each summer, as many untagged wild marmots as possible are live-captured and ear-tagged with two individually numbered tags. They also receive VHF radio transmitter implants, unless a veterinarian is not available or it is determined that the risk of the procedure is too great because of the time of year, or the age or condition of the animal (Jackson, pers. comm., 2016; McAdie, pers. comm., 2016). To date, 897 surgeries have been done to implant transmitters in Vancouver Island Marmots. While three known mortalities (0.3%) have directly resulted from the handling associated with transmitter implant or the transmitter, in each case learnings were documented to help prevent future surgery mortalities (McAdie, pers. comm., 2017).

  - Tagged marmots with failed VHF radio transmitters are also live-captured, any missing ear-tags replaced, and most individuals receive a new VHF radio transmitter implant.
  - All transmitters record a pulse rate that can be correlated with body temperature. This information is used to determine whether an individual is alive during the active season, and whether they are active or hibernating in the spring and fall.
  - On average, approximately100 marmots are monitored using radio transmitters each year.
- Marmots are monitored throughout the active season using ground-based and aerial telemetry.
- Flights to listen for telemetered marmots are conducted each spring and fall to determine the fate (dead or inactive, alive) of marmots. These data are used to calculate overwinter and active season survival. If possible, the remains of dead marmots are recovered to determine the cause of mortality.
- A marmot inventory is conducted each summer by visually locating marmots at known colonies. The number of ear-tagged marmots and those without ear-tags are determined and, when possible, individual marmots are identified using their VHF radio transmitter frequency. This allows a yearly determination of the minimum number of marmots alive at each colony. Age class (pup, yearling, adult) and sex, if it can be determined or is known, is also recorded.
- Wildlife cameras are used at some colonies to determine presence of marmots, verify pups and yearlings are present and, when possible, determine the minimum number of marmots present in the area.
- Reproduction is monitored by visually locating and counting pups and, if possible, pups are assigned as the offspring of specific females based on behavior and location.

Management to increase wild population growth rate (completed and in progress)

- Since 2011, marmots living near the Mount Washington Alpine Resort have received supplemental food in the form of leaf-eater biscuits (Mazuri Exotic Animal Feed) to prevent their attraction to vegetation along the lower-elevation roadways in the spring. Supplemental food has also been provided to marmots at 1–9 colonies in the early spring to increase the number of pups weaned (Jackson *et al.* 2015; Jackson, pers. comm., 2016).
- In the past, the following management activities were used to increase the active season survival rate of marmots.
  - Fencing to exclude predators.
  - Hazing of terrestrial predators using trained dogs.
  - Monitoring of predators that live close to marmot colonies using radio-collars.
  - Shepherding of captive-born marmots following release. Shepherding involved people staying at the release point for several days or weeks (up to 3 months) after release to deter predators from the area (last done in 2011).
  - Lethal control: the B.C. Ministry of Water, Land and Air Protection killed six Golden Eagles in 2003–2004 to reduce predation on marmots.
  - Translocation of predators: three Golden Eagles were live-captured and released in areas of the province not inhabited by Vancouver Island Marmots. This was last done in 2008.
- Regulated hunting and trapping seasons for Cougars and Grey Wolves reduces the number of predators in some areas of the marmot distribution.

Evaluation of management techniques (completed and in progress)

- Analyses were conducted to identify the factors affecting site fidelity and survival of captive-born marmots (Aaltonen *et al.* 2009; Jackson 2012; Jackson *et al.* 2016).
- In March 2015, a population and habitat viability assessment workshop was held and a population and habitat viability analysis done based on the best information available (Jackson *et al.*, 2015). The workshop was organized by the Calgary Zoo, the Marmot Recovery Foundation, the IUCN–SSC Reintroduction Specialist Group, and the IUCN–SSC Conservation Breeding Specialist Group.
- Captive-born marmots have a lower survival rate than wild-born marmots during their first year post-release (Aaltonen *et al.* 2009; Jackson *et al.* 2016). An ongoing experiment, started in 2011, is determining whether it is beneficial to release captive-bred marmots to Mount Washington and then translocate the survivors to their ultimate destination in the Strathcona metapopulation the following year (Jackson 2014). The study is also evaluating whether wild-born marmots survive better (i.e., demonstrate fewer release effects) in their first year than captive-bred animals and, therefore, are a better or equivalent source for augmentation. This is a project with the Calgary Zoo's Centre for Conservation Research.
- An analysis of health data from captive and wild marmots is under way as part of veterinarian Malcolm McAdie's MSc thesis; his intent is to determine what constitutes a "healthy" marmot population (see http://karllarsen.sites.tru.ca/current-students/malcolm-mcadie/).
- Annual reporting to the Marmot Recovery Foundation includes an analysis of management techniques and recommendations (Jackson and Doyle 2013; Jackson 2014).

Population genetics

- When required to maintain genetic diversity in the captive program, wild marmots are brought into the captive population (started in 2016).
- Hair, blood, or tissue samples are taken from all wild marmots that are captured and handled. At some later date, these samples will be used to examine changes in genetic diversity in the wild population over time.
- Establishment and support (through augmentation) of marmot colonies that can act as "stepping stones" to facilitate gene flow.

6.2 Recovery Action Table

Table 4. Recovery actions for the Vancouver Island Marmot. Actions are organized by Conservation Framework action group followed by priority.

Objective	Conservation Framework action group	Actions to meet objectives	Threat[a] or concern addressed	Priority[b]
3	Compile Status Report	Update COSEWIC status report with current population and colony sizes, population distribution, demographic rates, colony-specific reproductive success, dispersal frequency and distances, and results from the population and habitat viability analysis.	Knowledge gap	Necessary
6	Planning	Develop guidelines for the demographic conditions under which specific management actions will be initiated/stopped for each metapopulation, including criteria for when management activities can be reduced to just monitoring (allowing natural variation in survival and reproduction to be quantified and used in population viability analysis).	Limiting factor; Threats 5.1, 8.4	Essential
1, 2, 3, 4, 5, 7	Planning	Identify current resources, future needs, priorities, capacity and funding gaps, and develop a sound strategy to ensure sufficient resources are available to support recovery efforts until recovery goals are met.	Knowledge gap; All	Essential
3, 6, 7	Planning	Develop a long-term plan that integrates recovery requirements for captive-born marmot releases with captive population management. The plan should ensure the Captive Breeding Program has the capacity to adequately support recovery objectives. If needed, create additional capacity by securing new partners, or reinstituting the Tony Barrett Mount Washington Marmot Recovery Centre for captive breeding. In addition, the plan should address both how the captive population will be managed when recovery goals are approached but a captive population is still desirable to serve as a "safety net," and how the captive population will be downsized when appropriate.	5.1	Necessary
3	Private Land Stewardship	Support and maintain the relationships and commitments of zoo partners, governments, industry partners, and public.	1.1, 1.3, 5.3, 6.1, 6.3, 7.2	Essential
3	Private Land Stewardship	Formalize land partnership stewardship agreements with owners of private and leased lands on which marmots live.	1.1, 1.3, 5.3, 6.1, 6.3, 7.2	Beneficial
1	Habitat Restoration	Remove tree ingress at extant marmot colonies to maintain habitat and increase predator detection by marmots.	7.3, 8.2, 11.1	Beneficial
1, 2	Species and Population Management	Provide solitary wild marmots with wild or captive-born mates.	Limiting factor	Essential

Objective	Conservation Framework action group	Actions to meet objectives	Threat[a] or concern addressed	Priority[b]
1	Species and Population Management	On an annual basis, monitor marmot survival, reproduction, and population size using telemetry and other population-monitoring techniques.	Knowledge gaps	Essential
1	Species and Population Management	Manage predation risk to increase survival in areas where predation is causing population declines.	8.2	Essential
5	Species and Population Management	Fully analyze all marmot, predator, experimental management, and environmental data available to statistically identify correlates of survival and reproduction and determine whether a threshold metapopulation size exists above which predation is no longer a threat.	8.2; Knowledge gap	Essential
3, 4	Species and Population Management	Maintain the studbook for the captive-breeding population.	Limiting factor	Essential
3, 4	Species and Population Management	Provide wild-born marmots of the appropriate age, sex, and source to the captive population, when required, to offset genetic and demographic attrition.	5.1; Limiting factor	Essential
3	Species and Population Management	Maintain the captive population in at least two locations (i.e., Canada's Accredited Zoos and Aquariums or equivalent accredited facilities); work with existing facilities (Calgary and Toronto zoos) to collaboratively maintain a healthy captive population and breed marmots for release.	5.1	Essential
3	Species and Population Management	Maintain the captive population in permanent quarantine.	8.1, 8.2, 8.4, 8.5, 8.6	Essential
1	Species and Population Management	Develop and implement a plan to manage marmot colonies that become established in cut blocks.	7.3	Necessary
1, 5	Species and Population Management	Determine, achieve, and maintain the carrying capacity and optimal colony size and composition at the Mount Washington site, so that marmots from this site can be used to augment other colonies in a way that does not jeopardize the source colony.	5.1; Knowledge gap	Necessary
1, 5	Species and Population Management	Use adaptive management to determine a release protocol that maximizes the survival of captive-born marmots after release.	Knowledge gap	Necessary
2, 5	Species and Population Management	Determine the natural distance, frequency, and barriers for marmot dispersal.	4.1, 7.2, 7.3, 8.2, 11.1; Knowledge gap	Necessary
1, 2, 4	Species and Population Management	Establish colonies that can link extant colonies through dispersal and increase natural colonization of new locations by marmots born *in situ* at existing colonies by working to support reproduction.	7.2	Necessary

Objective	Conservation Framework action group	Actions to meet objectives	Threat[a] or concern addressed	Priority[b]
5	Species and Population Management	Use previously collected field data to develop the most effective methodology for monitoring marmot metapopulations at different stages of recovery and once recovery goals are met.	Knowledge gap	Necessary
1	Species and Population Management	Unless it is shown to be ineffective, provide supplemental feed to wild marmots, where feasible, to increase reproduction and survival at Mount Washington and draw marmots away from roads.	4.1	Beneficial
4	Species and Population Management	To prevent loss of genetic diversity, translocate individuals between metapopulations at a rate deemed necessary through a population viability analysis.	Limiting factor	Beneficial
4, 5	Species and Population Management	Determine the current level of genetic variability in the wild population by using tissue and hair samples collected when wild-born marmots are live-captured.	Knowledge gap	Beneficial
6	Species and Population Management	Develop, implement, and publicize a standardized marmot reporting system for marmots sighted by the public.	Knowledge gap	Beneficial

[a] Threat numbers according to the IUCN–CMP classification (see Table 3 for details).
[b] Essential (urgent and important, needs to start immediately); Necessary (important but not urgent, action can start in 2–5 years); or Beneficial (action is beneficial and could start at any time that was feasible).

6.3 Narrative to Support Recovery Action Table

Approximately 70% of the actions listed in Table 4 are variations on actions identified during a Vancouver Island Marmot Population and Habitat Viability Assessment Workshop held in 2015. The workshop was attended by more than 40 participants from timber companies, government agencies, non-government organizations, captive-breeding facilities, and academia (Jackson *et al.* 2015). Thus, the Recovery Action Table (Table 4) has benefited from input from a broad range of perspectives.

Thus far, recovery planning and action for the Vancouver Island Marmot has focused on increasing the population size, and this focus will continue even though metapopulations are recovering. The transition from intensive to reduced management, and eventually to just monitoring, must be carefully planned. Failure to do so could result in a premature ending of some key management actions and an inability to detect or respond to a change in marmot abundance. The upcoming 2018 COSEWIC status report and assessment will better inform the prioritization of management actions.

The population viability analysis identified the maintenance of genetic diversity and increasing population size as key factors in determining the probability of extinction over the next 100 years (Jackson *et al.* 2015). Thus, actions related to achieving these objectives have been flagged as high priority.

7 SPECIES SURVIVAL AND RECOVERY HABITAT

Survival/recovery habitat is defined as the habitat that is necessary for the survival or recovery of the species. This is the area that the species naturally occurs or depends on directly or indirectly to carry out its life-cycle processes or formerly occurred on and has the potential to be reintroduced.

7.1 Biophysical Description of the Species' Survival/Recovery Habitat

A description of the known biophysical features and their attributes of the species' habitat that are required to support its life-cycle processes (functions) are provided in Section 3.3. Vancouver Island Marmots require habitat for burrowing, hibernating, foraging, raising and weaning pups, and dispersing. Addressing the knowledge gaps identified in the Recovery Action Table (Table 4) may add understanding of the species' habitat needs.

7.2 Spatial Description of the Species' Survival/Recovery Habitat

The area of survival/recovery habitat required for a species is guided by the amount of habitat needed to meet the recovery goal. Although no fine-scale habitat maps are included with this document, it is recommended that the locations of survival/recovery habitat be described on the landscape to help mitigate habitat threats and to facilitate the actions for meeting the recovery (population and distribution) goals.

8 MEASURING PROGRESS

The following performance indicators provide a way to define and measure progress toward achieving the recovery (population and distribution) goal. Performance measures are listed below for each recovery objective.

- Vancouver Island Marmot abundance is maintained or increased in at least two geographically separated areas within the species' historic range in British Columbia.
- Habitat connectivity is maintained or increased within each of the two geographically separated areas in British Columbia.
- The metapopulation in each area and the species overall have a greater than 90% probability of persistence over 100 years.

Measurables for Objective 1

- An increase in the number of wild Vancouver Island Marmots (relative to 2016) by 2020.
- By 2025, at least two metapopulations in which, on average, annual reproductive rates are equal to or exceed mortality rates (i.e., average annual intrinsic population growth rate 0 or higher) over a 10-year time frame.

Measurable for Objective 2

- By 2022, assess the opportunities at each colony for emigrating marmots to encounter another colony.

Measurables for Objective 3

- Annual reports from the Vancouver Island Marmot Recovery Team to the Captive Breeding Group that include the projected number of marmots that they would like to have available for release during each of the next 3 years.
- Annual reports from the Captive Breeding Group to Vancouver Island Marmot Recovery Team that include: projections of the number, age, and sex of release candidates for the next year; the percent of the original genetic diversity of the captive population that is still represented in the captive population; and a projection for how much of this diversity can be maintained in the captive population for the next 5 and 10 years, if the captive population was to remain the current size and no new individuals were brought into the population from the wild.

Measurables for Objective 4

- Report to the Captive Breeding Group from the Studbook Keeper on the percent of variation retained in the captive population every year.
- Publication of a study on the change in genetic variability of Vancouver Island Marmots in a peer-reviewed journal by 2025.

Measurable for Objective 5

- Completion of reports that include results of demographic analyses, starting in 2019.

Measurable for Objective 6

- Management Plan approved by the Vancouver Island Marmot Recovery Team by 2019.

Measurable for Objective 7

- Resource assessment and strategic plan for implementation is developed and approved by the Vancouver Island Marmot Recovery Team and Marmot Recovery Foundation annually starting in 2018.

9 EFFECTS ON OTHER SPECIES

The implementation of this Vancouver Island Marmot recovery plan should not have any negative effects on any other species. Although currently not planned, if lethal predator management was again conducted to protect Vancouver Island Marmots, it would only target individual predators known to depredate marmots. Therefore, while affecting local predators, this activity would have minimal population-level impacts for the predator species' overall population. Extensive consultation would occur between the Vancouver Island Marmot Recovery Team and the applicable provincial ministries before any such action. Both Cougars and Grey Wolves, currently the main predators of Vancouver Island Marmots, have open hunting and trapping seasons, and are not species at risk.

Implementation of this recovery strategy may have positive effects on other species. By increasing the number of Vancouver Island Marmots on the landscape, species that use marmot burrows (see Section 3.4) may benefit.

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APPENDIX A. Overview of Captive-breeding Program

The Vancouver Island Marmot captive-breeding program was initiated in 1997 in response to a severe decline of marmots on Vancouver Island, B.C. In subsequent years, the program was well supported by up to four captive facilities and was essential in increasing the number of marmots in the wild through reintroduction efforts. When the decision was made to initiate the program, approximately 70 marmots existed in the wild (McAdie 2004; COSEWIC 2008) and the Vancouver Island Marmot Recovery Team considered that, in the absence of a captive-breeding program, it was unlikely the species could avoid extinction.

Fifty-five marmots (~44% female) were brought into captive facilities between 1997 and 2004. Selection of marmots for the captive population was done in a way to minimize the demographic impact on the free-living population; captures focused on individuals living in declining colonies in forestry cutblocks (55% of captures), solitary individuals, juveniles, and genetically important individuals. No adult females were removed from alpine or subalpine colonies, and only one adult male was removed from an alpine colony (McAdie 2004).

The number of Vancouver Island Marmots in captivity at the start of fall hibernation has ranged from 6 in 1997 to 177 in 2008 (Figure A1.1). In response to financial and other considerations, the program was downsized between 2008 and 2015. As of November 2016, 43 marmots were housed in two facilities, including six that were captured in 2016 from wild metapopulations to offset demographic and genetic attrition in the captive population. Summer releases of captive-bred marmots began in 2003. From 2003 to 2016, 490 captive marmots were released to either historic or suitable marmot habitat on Vancouver Island (range: 4–85 animals were released per year; Figure A1.2) (Jackson *et al.* 2015; McAdie unpubl. data).

Marmots in the captive-breeding population are currently held at two facilities, the Calgary Zoo and the Toronto Zoo. In the past, captive marmots were also kept and bred at two additional locations - the privately owned Mountain View Conservation and Breeding Centre in Langley, BC (2000–2013) and the Tony Barrett Mount Washington Marmot Recovery Centre on Vancouver Island (2001–2012). The Vancouver Island Marmots from these two facilities were released to the wild or moved to the Calgary or Toronto zoos. The decision to phase out two of the breeding facilities was based solely on fiscal considerations; recovery efforts would have benefited had the facilities remained open.

Because of this downsizing, too few marmots were available for the population to maintain its genetic viability in isolation (Jackson *et al.* 2015). Therefore, in September 2016, an additional six wild-born marmots (four female; five young of the year and one yearling) were brought into the captive population.

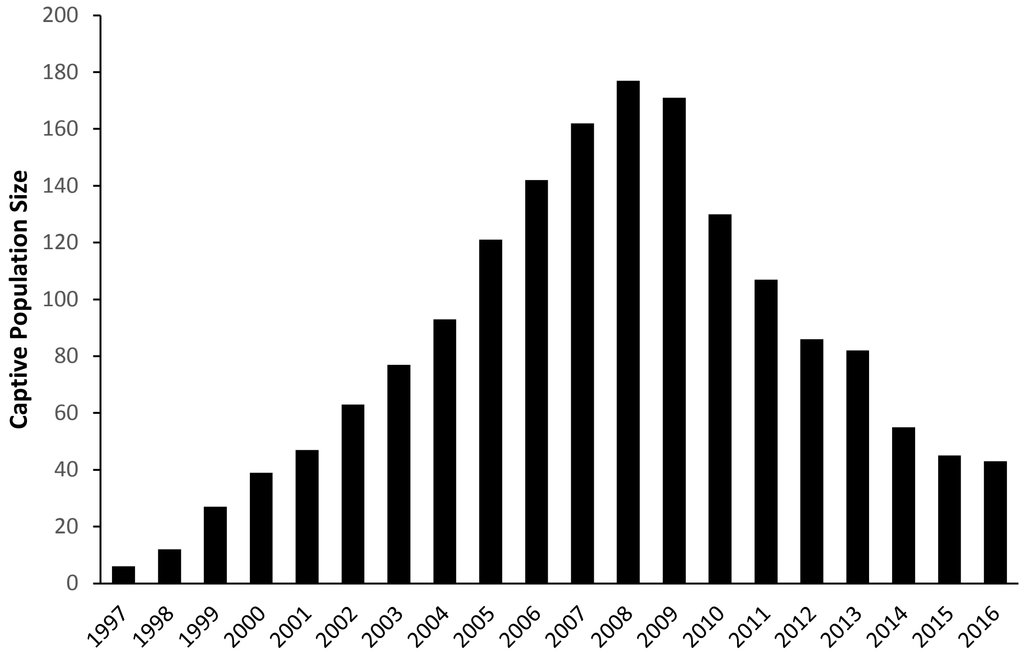

Figure A-1. Number of individuals in the captive population of Vancouver Island Marmots.

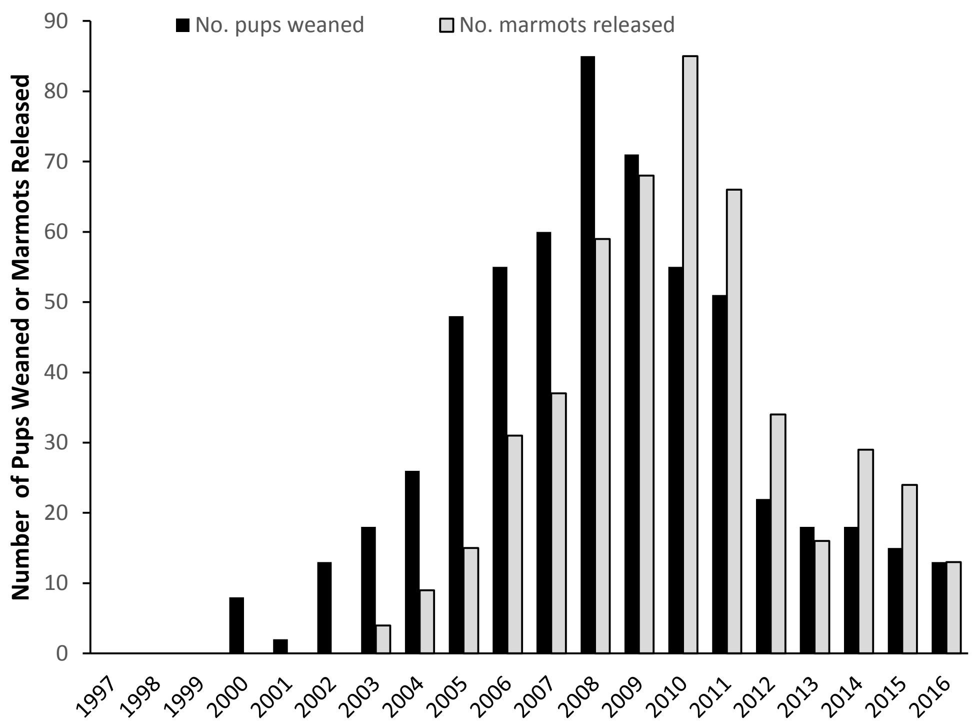

Figure A-2. Numbers of captive-born pups weaned and captive-born marmots released, 1997–2016.