Vancouver Island Marmot - Buttle Lake Supplementation and Monitoring 2016

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Vancouver Island Marmot on Castlecrag Mtn, Strathcona Provincial Park.
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Fish and Wildlife Compensation Program

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EXECUTIVE SUMMARY

The Vancouver Island Marmot (*Marmota vancouverensis*, Swarth 1911) is endemic to Vancouver Island, in British Columbia, Canada, but was extirpated from historical habitat in Strathcona Provincial Park by the mid-1990's. Over the past decade, the Marmot Recovery Foundation (MRF) has worked under the guidance of the Vancouver Island Marmot Recovery Team to re-establish a wild population in the region. Initially, reintroductions of captive-bred marmots were intended to create two metapopulations that would be geographically distinct and genetically isolated from one another by the presence of Buttle Lake. However, successful releases at the south end of Buttle Lake established some connectivity between these two small populations, which are now being managed as a single metapopulation. This report describes the methods and results from the 2016 field season, during which MRF addressed three categories of actions described in the Campbell River Watershed Species of Interest Action Plan: Species-Based Actions, Monitoring and Evaluation, and Research and Information Acquisition (Fish and Wildlife Compensation Program 2011).

MRF installed six supplemental feeders at Mt. Washington and two in Strathcona Provincial Park, in order to improve maternal condition and increase the likelihood of reproduction. During live-trapping sessions at Mt. Washington, 18 wild-born marmots were implanted with radiotelemetry. MRF also live-trapped at two colonies in Strathcona Provincial Park, which resulted in the radiotelemetry implant of three additional marmots. In total, 17 marmots were released into Strathcona to support seven existing colonies, and an additional nine marmots were released on Mt. Washington for pre-conditioning. Throughout the active season, MRF used radiotelemetry to monitor the survival of >70 telemetered marmots. There was poor survival in Strathcona between 2015 and 2016, and mortality rates were high for established marmots as well as new releases. Remote cameras captured footage of weaned pups at three of five monitored colonies, and field crew observed two litters and five pups on Mt. Washington. MRF tracked the location of dispersing marmots, and most confirmed dispersals occurred between release sites and existing colonies on nearby mountains. MRF estimates that there are currently 70-100 marmots living in nine colonies in the Strathcona region. There is an ongoing research collaboration to analyze survival data from recent releases in Strathcona (2012-16). Analyses will explore whether there are differences in survival probability as a function of release type, and will help managers to identify the release candidates that are most likely to survive in the region over the short- and long-term.

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1. INTRODUCTION

The Vancouver Island Marmot (*Marmota vancouverensis*) is a large ground squirrel, and one of only five mammals endemic to Canada (Nagorsen 2004). This species of marmot is native to Vancouver Island, where it lives in subalpine and alpine meadows and talus slides at 1050-1400m in elevation (Bryant and Janz 1996). Paleoecological evidence suggests that marmot were widespread on Vancouver Island 8000 years ago, but as glaciers retreated at the end of the last Ice Age, marmot habitat in open heather ecosystems was forced upward to present day elevations (Hebda et al. 2004).

Marmots are the largest true hibernators (Armitage 1999), and the Vancouver Island Marmot hibernates for seven months of each year. During the five-month active season (May through September), Vancouver Island Marmots forage on a wide variety of plant species (Martell and Milko 1986; Heard 1977) in order to recover ~30% body mass that they lose each hibernation (Bryant and McAdie 2003). Similar to other marmot species, the Vancouver Island Marmot is slow to reach reproductive maturity, and typically starts breeding at age 3-4, weaning litters of 3-4 pups every other year (Bryant 2005). Researchers have termed this behaviour "reproductive skipping", and attributed it to the harshness of conditions in marmot habitat, and the extreme demands of a long hibernation (Armitage 1999). In the wild, Vancouver Island Marmots can live to be approximately 10 years of age. Predation is the main cause of mortality for wild-born marmots (Jackson et al. 2016; Jackson et al. 2015; Aaltonen et al. 2009; Bryant and Page 2005).

Vancouver Island Marmots are semi-fossorial, and their role is that of an "ecosystem engineer" (Vancouver Island Marmot Recovery Team, in prep.). There are no other large mammals that modify this habitat through excavation, and Vancouver Island Marmots also contribute to ecosystem function through foraging and defecation activities. Field crew have documented the use of Vancouver Island Marmot burrows by insects and moths (Vancouver Island Marmot Recovery Team 2008), and as refuges by Western Toads (*Anaxyrus boreas*, COSEWIC Special Concern 2012; Marmot Recovery Foundation, MRF, unpublished data), and garter snakes (*Thamnophis spp*.; MRF, unpublished data). Remote cameras have recorded sooty grouse using excavated piles of soil as sources for dust baths and digestive grit. Literature on the ecological contribution by conspecifics suggests that Vancouver Island Marmots likely also play a unique and valuable role in ecosystem health; however, research on this species has focused almost entirely on gaining information to support their recovery from near-extinction, and so their specific ecological contributions has not yet been quantified.

Though recognized as an Endangered Species in 1979, observers recognized a rapid decline in the species in the mid-1990s. By 1997, the southern population of Vancouver Island Marmots was in rapid decline and the northern population was represented by a single, isolated colony on Mount Washington (Bryant 1998). Recent population declines have been attributed primarily to predation (Aaltonen et al.

2009; Bryant and Page 2005; Bryant 2000). The reason for population decline in Strathcona Provincial Park remains unclear, but was probably related to a combination of pressures from predation, weather, disease, landscape-level change, and colony isolation (Janz et al. 1994). The development of hydroelectric facilities near Strathcona Provincial Park is known to have adversely impacted several species of fish and wildlife and their habitat in the region (Fish and Wildlife Compensation Program 2011). For the Vancouver Island Marmot, the impoundment of the Upper Campbell Reservoir and Buttle Lake may have impeded marmot dispersal between colonies by interrupting landscape connectivity (Janz et al. 2000). Prior to 2007, the last marmots reported in Strathcona Park were solitary individuals seen on Mount Albert Edward in 1992, and at the Westmin mine site in 1995 (MRF, unpublished data).

In 1997, a captive-breeding program was established in order to protect the species from extinction and provide marmots for release back to the wild. The following year, the Marmot Recovery Foundation was created in order to fund recovery efforts. Three main recovery documents have been published for the species (Janz et al. 1994, 2000; Vancouver Island Marmot Recovery Team 2008), and each describes a recovery goal of three geographically distinct metapopulations that are stable or growing and composed of 150-200 marmots. An updated provincial-level Recovery Plan is currently undergoing managerial review (Vancouver Island Marmot Recovery Team in prep.), and a national Recovery Strategy is also in progress. Releases have been carried out since 2003 to increase the wild population and expand the geographic distribution of extant colonies. Initial reintroduction efforts focused on the southern core of historic habitat near the Nanaimo Lakes region. In 2007, in order to expand the species' distribution, the Marmot Recovery Foundation began to release captive-bred marmots in historic habitat to the east and west sides of Buttle Lake in Strathcona Provincial Park (see Figure 1 for current distribution). This goal supported the existing Recovery Strategy and aligned with management objectives for the region by improving the status of a priority species of interest in the Campbell River system (Fish and Wildlife Compensation Program 2011).

Reintroducing captive-bred marmots to Strathcona Provincial Park has proven more difficult than reintroductions on south Vancouver Island. A number of differences in the condition of the southern and Strathcona regions help explain the additional challenges. Colonies in Strathcona had been extinct for more than a decade by the time reintroductions began. Marmots released in Strathcona would have had to re-establish entire networks of escape burrows and hibernacula at each new release site, whereas marmots in Nanaimo Lakes would have had to expend less energy to restore historic habitat. Furthermore, the Nanaimo Lakes population included three extant colonies that continued to provide additional reproductive support for population recovery at the same time that colonies were being re-established through augmentation. In contrast, when MRF began to release marmots in Strathcona in 2007, Mt. Washington was the only colony in the region. Although this colony included several adult

marmots, reproduction was extremely poor, and managers suspected that this was a consequence of a decade or two of genetic isolation and inbreeding. Therefore, the Mt. Washington colony was unable to contribute to the re-establishment of a marmot population in Strathcona during the first few years of releases.

In 2011, MRF began to explore alternate methods that could help to accelerate population growth in the Strathcona region while continuing with population augmentation. These methods addressed three categories of actions promoted in the Campbell River Watershed Species of Interest Action Plan (Fish and Wildlife Compensation Program 2011), and included (1) the use of spring supplemental feeding as a stimulant for maternal condition and reproductive success, (2) evaluation of wild-born marmots as a superior source of marmots for translocation to Strathcona Provincial Park, and (3) evaluation of fitness gained by pre-conditioning captive-bred marmots for one year in the wild colony at Mt. Washington.

Although Vancouver Island Marmots have been re-introduced to Strathcona Provincial Park, and the current distribution of nine colonies extends around the south end of Buttle Lake, the population remains fragile and unstable. Small populations face inflated risk of extirpation from predation and stochastic events, and the risk of extirpation was certainly a concern for several marmot colonies in Strathcona in 2016. These were challenges from which a larger population could more easily recover. Modelling at the 2015 IUCN Population and Habitat Viability workshop indicate that the region can support a population that is self-sustaining, but that significant recovery work needs to be completed before that

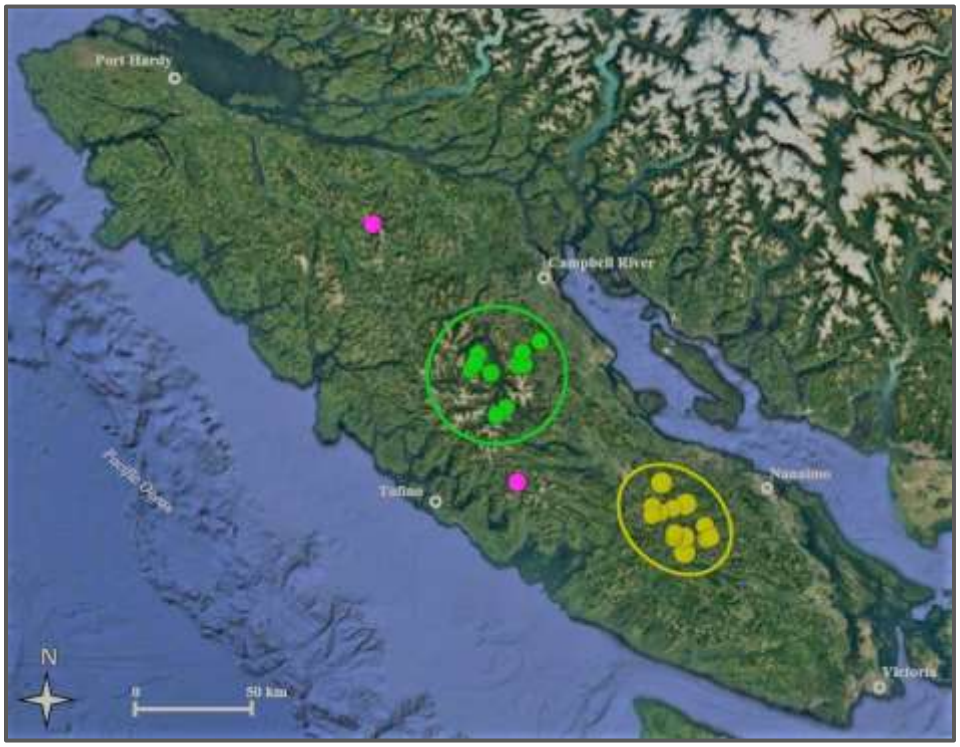

Figure 1. Current distribution of the Vancouver Island Marmot, with populations re-established in Strathcona Provincial Park (green oval) and Nanaimo Lakes (yellow oval).

goal can be achieved (Jackson et al. 2015). The 2016 field season was the sixth year of supplemental feeding at Mt. Washington and in Strathcona Provincial Park, and the fifth year in which wild-born and pre-conditioned marmots were released into Strathcona and monitored for survival. This report describes the methods and results for 2016.

2. GOALS AND OBJECTIVES

Project objectives addressed three broad categories of actions described in the Campbell River Watershed Species of Interest Action Plan (Fish and Wildlife Compensation Program 2011):

1. *Species-Based Actions*
   - Supplemental spring feeding: install feeders at insular emergence holes on Mt. Washington and select sites in the Buttle Lake area.
   - Translocation trials: translocate marmots to support existing fledgling colonies in both the Forbidden Plateau and Western Strathcona regions.
2. *Research and Information Acquisition*
   - Monitor dispersal movements of marmots.
   - When possible, locate hibernacula to aid future monitoring.
3. *Monitoring and Evaluation*
   - Assess overwinter survival by pre-conditioned marmots at Mt. Washington.
   - Assess overwinter survival by marmots released or translocated to the Buttle Lake area in the 2012-15.
   - At Mt. Washington, capture and implant yearlings and replace expired transmitters in older marmots.
   - Verify reproduction and survival by previously released or translocated breeding-aged females and their offspring.
   - Monitor active season survival by marmots released in the Buttle Lake area in 2012-2016.
   - Ongoing collection of field data to monitor marmot demographics and to answer research questions.

While completing these actions, the Marmot Recovery Foundation continued to explore new ways to engage the local community in collaborative efforts to recover the Vancouver Island Marmot.

3. STUDY AREA

Each release site (Figure 2) reflects typical Vancouver Island Marmot habitat, consisting of wet sedge meadows in combination with talus boulder complexes in the alpine tundra (ATc) and subalpine zones

(MHmm2), between 900 metres and 1400 metres in elevation (Bryant 1998). Supplemental feeding and release sites for 2016 were located within the historically occupied range of the Vancouver Island Marmot (see Janz et al. 1994, 2000; Vancouver Island Marmot Recovery Team 2008), and included the following:

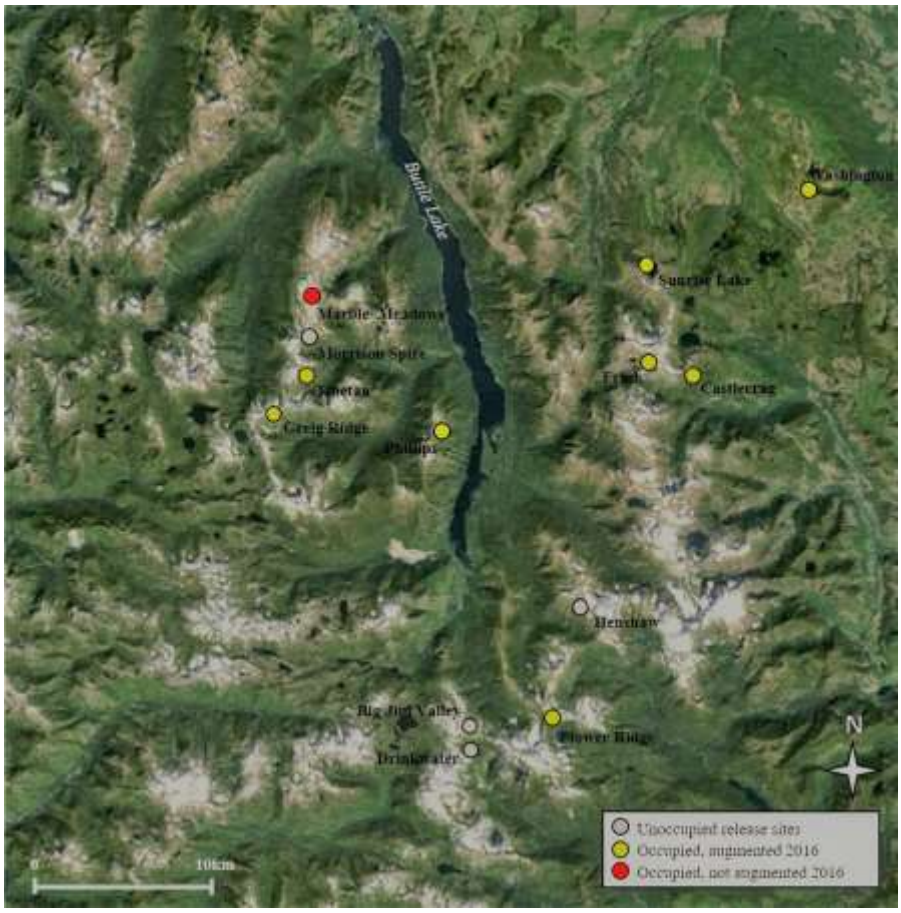

Figure 2. Study area and release sites for the Vancouver Island Marmot in Strathcona Provincial Park (2016).

(i) Castlecrag (Forbidden Plateau, UTM: 10U 327898mE 5509715mN) is located at the south end of Forbidden Plateau, near the headwaters of the Cruickshank River. It sits beside Mt. Frink, across from George V, and in close proximity to the colonies at Albert Edward and Sunrise Lake. It is characterized by a large expanse of lush meadows and talus slides on the southern face of the mountain, as well as significant cliffs and talus bowls on the east and north sides of the hill. The variety of terrain makes it ideal habitat for marmots.

(ii) Frink (Forbidden Plateau, UTM 10U 325310mE 5503720mN) shares a ridge system with Castlecrag to the east, Albert Edward to the west, George V to the south, and Sunrise Lake to the

north. The south side of Mt. Frink features talus bands, cliffs and meadow patches. It was colonized by marmots in 2014.

(iii) Sunrise Lake (Forbidden Pleateau, UTM: 10U 315875mE 5483088mN) is located on the north side of Jutland Mountain near the headwaters of Oyster River and Piggott Creek. Sunrise sits northwest of Castlecrag and southwest of Mount Washington. Initially, this site was selected because of its historical relevance - it was one of the last known locations for marmot sightings in Strathcona (1981, MRF, unpublished data).

(iv) Greig Ridge (Western Strathcona, UTM: 10U 305628mE 5502021mN) is located approximately 11km west of Buttle Lake, within the Phillips Creek drainage that flows into the west side of Buttle Lake. Greig Ridge runs east-west and is connected to the Mt. Phillips colony via Phillips Ridge that wraps south and then east, and to release sites at Tibetan, Morrison Spire and Col, and Marble Meadows via a ridge running to the north. Greig Ridge includes over six kilometres of alpine/subalpine habitat and features the largest subalpine complex with high marmot habitat suitability in the Buttle Lake area. This site was initially selected for reintroductions because of existing burrows (circa 1980).

(v) Marble Meadows (Western Strathcona, UTM 10U 307763mE 5508601mN) is located 7km west of central Buttle Lake, south of Mount McBride, and at the north end of the ridge connecting to Morrison Spire, Tibetan, and Greig Ridge. The habitat, which is east-facing and gently sloped, consists of an alpine heather bowl with a mixture of large boulder piles and limestone rock formations. This location was colonized by marmots in 2013.

(vi) Phillips (Western Strathcona, UTM: 10U 313840mE 5500530mN) rises steeply from the west shore of Buttle Lake. Mt. Phillips connects to Greig Ridge via a 17km long ridge system that wraps south, west, north and then east around the Phillips Creek drainage; as the crow flies, the Greig Ridge colony is only 5km away. Mt. Phillips is furnished with cliffs, meadow and abundant talus, and is a known dispersal destination. It was colonized by marmots in 2014.

(vii) Tibetan (UTM: 10U 306568mE 5503614mN) is the first peak on the connecting north-south ridgeline from Greig Ridge past Morrison Spire and Marble Meadows to Mt. McBride. This site features a mixed boulder and talus slope, with many options for refuge, and was colonized by marmots in 2008.

4. METHODS

4.1 Supplemental spring feeding

MRF installed feeders at Mt. Washington in the springs of 2011-2016, with the idea that providing early, high-quality supplemental food would promote maternal condition and successful weaning in this colony, and that this would make available wild-born candidates for translocation into Strathcona Provincial Park. Feeders were constructed from PVC pipe and filled with Mazuri® leaf-eater biscuits. There were six feeders installed at Mt. Washington in 2016. Feeders were installed close to emergence burrows, although we avoided deployment of feeders at bear-prone locations on the periphery of the ski hill. Feeders were re-filled twice a week from the date of installation (early May 2016) until mid-June 2016. MRF also installed larger feeders at two colonies (Marble Meadows, Tibetan) in Strathcona Provincial Park in the hope that it would increase the likelihood of successful reproduction (Table 1). Feeders at those sites were accessible only by helicopter, and were not refilled after the initial installation.

Table 1. Locations of spring supplemental feeders (2011-16)

Colony	2011	2012	2013	2014	2015	2016
Castlecrag	0	1	1	1	0	0
Frink	0	0	0	0	1	0
Greig Ridge	0	1	0	0	0	0
Henshaw	0	1	0	0	0	0
Marble Mdws	0	0	0	1	1	1
Phillips	0	0	0	0	1	0
Sunrise	0	1	1	1	0	0
Tibetan	0	1	1	1	1	1
Washington	7	12	12	10	6	6

4.2. Population augmentation

4.2.1. Release candidate selection

In 2016, all captive-bred candidates to be released for pre-conditioning on Mt. Washington were yearlings. Release candidates for Strathcona included *wild-born marmots* (born on Mt. Washington), *pre-conditioned marmots* (released from captivity onto Mt. Washington in 2015 and recaptured for translocation in 2016), and *same-season marmots* (brought to Vancouver Island in the year of their release and released directly from captivity with no wild experience). All release candidates for Strathcona were one or two years of age; the older resident and pre-conditioned marmots on Mt. Washington were not considered eligible for translocation. For the sake of simplicity, all sites where marmots were released into the wild from a trap will be referred to as “release sites” and all marmots are

described as being "released" regardless of whether they were released from captivity or translocated from the wild colony on Mt. Washington.

4.2.2. Release site preparation

There was moderate snowfall in the winter of 2015-16 (Figure 3) but by late June, much of the snow had melted and there was plenty of available forage. Release burrows on Mt. Washington were selected based on occupancy and habitat use by existing residents, in order to give newly released marmots the space to explore without risking adverse social pressure from older marmots. Marmots bred in captivity are not given access to traditional burrows; instead, they hide, hibernate, and raise their young in plywood "nest boxes" that have been filled with straw bedding and have exit holes at either end. To facilitate the release of captive-bred marmots on Mt. Washington, field crew provided nest boxes and bedding at release burrows.

Release sites in Strathcona Provincial Park were selected to provide access to successful hibernacula, connectivity to nearby active colonies for marmots that dispersed, and to address the need for augmentation in existing colonies themselves. Some marmots were released directly into unoccupied hibernacula at previously occupied sublocations; however, at colonies where successful hibernacula were occupied, most release sites were located a few hundred meters away. Wild-born marmots are not accustomed to using nest boxes, and pre-conditioned marmots had adjusted to using traditional burrows in their year on Mt. Washington, so these marmots were released into nearby burrows or refuges and not into the same nest boxes as facility marmots. Because MRF anticipated that most release sites would receive only one or two captive-bred marmots, no plywood nest boxes were installed at release sites in Strathcona.

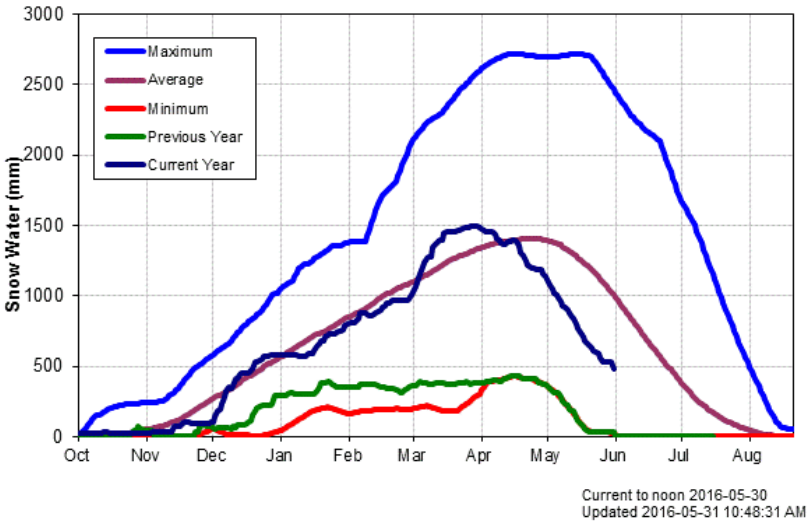

Figure 3. Snow water accumulation (2015-16) at the Wolf River snow station in Strathcona Provincial Park, BC (FLNRO 2016).

4.2.3 Release Protocols

Same-season release candidates were transported from the Calgary or Toronto Zoos to the Tony Barrett Mount Washington Marmot Recovery Centre (TBMWMRC) in late April. There they were examined by the Project Veterinarian and cared for in quarantine for a minimum of 30 days. After the quarantine ended in late May, the Project Veterinarian examined, ear tagged (National Band and Tag Co. Newport, KY USA) and implanted same-season and wild-born marmots with VHF radio transmitters (Holohil Systems Ltd. Ontario, Canada). Pre-conditioned marmots did not require surgery because they had been implanted prior to their release on Mt. Washington in 2015. In order to avoid additional stress following the invasive nature of the surgeries, newly implanted wild-born marmots were not kept in captivity, but were released back to the burrows from which they had been captured. Implanted marmots of any origin were given a minimum of two weeks of convalescence to allow for adequate healing before they were released on Mt. Washington or in Strathcona. Mt. Washington yearlings that were captured and implanted in the second trapping session (trapping for translocation) were released back into the wild for potential translocation in 2017.

The TBMWMRC functioned as a temporary holding facility for wild-born and pre-conditioned marmots that had been recaptured prior to their translocation into Strathcona After being recaptured, most wild-born and pre-conditioned marmots were kept in captivity for a short period of time, usually 1-3 days. This was necessary to enable a final examination by the veterinarian and to allow time to partition marmots into release groups that were balanced by sex and age. Please see Appendix A for a timeline of activities on Mt. Washington and in Strathcona Provincial Park.

4.3 Monitoring

4.3.1. Radiotelemetry

MRF used radiotelemetry to monitor marmots on Mt. Washington and in Strathcona Provincial Park throughout the field season. Telemetry receivers included the R1000 (Communications Specialist, Inc. CA, USA), Lotek SRX 400® and SRX 1000® (Lotek Wireless Inc. ONT. CA.). For antennas, field crew used the 3-element Yagi from Wildlife Materials (Wildlife Materials Inc. IL, USA). Mt. Washington received frequent ground-visits by field crew, particularly in May through July. During these visits, crew split up and hiked or drove 4x4 trucks on maintenance roads, stopping to search for marmot signals in popular marmot areas or at good vantage points. In contrast, MRF relied on helicopter-based telemetry to collect most survival data for marmots in Strathcona Provincial Park, because the terrain is too steep and rugged for easy or efficient ground-based data collection. MRF flew multiple flights and at variable altitudes in an attempt to detect missing marmots, and focused on detecting the greatest number of signals possible to better inform our estimates of marmot survival.

Implanted transmitters emit different pulse rates based on the transmitter temperature, which is ultimately determined by the body temperature of the marmot itself. MRF defined a marmot as being on "active" pulse if the pulse rate averaged >28 beats per minute. Marmots with an active pulse were considered to be alive. Because bare transmitters exposed to the sun have been known to heat to an active pulse rate when they should really indicate mortality, ground- and helicopter-based telemetry was conducted in the morning before temperatures became warm enough to create this effect. When there was an average pulse rate of ≤28 beats per minute, MRF considered the marmot to be on "mortality" pulse. Hibernating marmots cycle through periods of cooling and re-warming, and in a cool or "torpor" phase, their transmitter can pulse at the same rate as a mortality. Therefore, the assessment as alive or dead for a marmot with a mortality pulse rate was largely a function of the time of year. Whenever possible, the field crew attempted to recover transmitters of marmots detected on mortality pulse to infer the cause of death.

In addition to the surgical implants of radiotelemetry transmitters in marmots on Mt. Washington, MRF conducted trapping-for-implant sessions at the Tibetan and Castlecrag colonies in Strathcona Provincial Park. The Project Veterinarian examined, ear tagged (National Band and Tag Co. Newport, KY USA) and implanted captured marmots with VHF radio transmitters (Holohil Systems Ltd. Ontario, Canada). Newly implanted marmots were released back into or near the burrows from which they had been captured, and were monitored using radiotelemetry for the duration of the trip and active season.

4.3.2. Remote cameras

MRF used motion-triggered remote cameras (Primos Hunting©, Flora, MS, US; Stealth Cam© Grand Prairie, TX, US; Bushnell© Kansas City, MO, US) to record marmot use of spring supplemental feeders, and to monitor the presence of marmots at select locations. Remote cameras were attached to feeders, trees, or to metal stakes hammered into the ground. Cameras were stocked with 32GB memory cards and AA lithium batteries. Field crew programmed the cameras to record daytime and nighttime video of 30-40 seconds in length, with a mandated 30 minutes of inactivity between triggers. Cameras were maintained and batteries and memory cards changed every 2-6 weeks from the time of install until removal. Supplemental feeder cameras were active in May and June; hibernacula cameras were installed in June and removed in the first half of September.

Camera footage was reviewed throughout the active season and into the fall. Initial reviews removed any videos triggered by wind, weather, insects, and deer that did not include auditory captures of marmots. Videos containing visual or auditory captures of marmots were reviewed, saved and labeled. Reviewers watching the videos took screen captures when footage revealed a marmot with unique or semi-unique features that could help reviewers to identify it as individual. Reviewers typically looked to assess the

age and relative size of the marmot, the presence, partial presence, or absence of ear-tags, patterns of faded fur, and any injuries or disfigurements that were visible in the footage. The dorsal surface is known to show the most unique patterns of new and faded fur, and ideally, screen captures from a single video would have led to individual screen captures of the left ear, right ear, and a large portion of the dorsal surface. Realistically, however, many videos showed only one or two of the identifying features at a time, and it required several videos for reviewers to get screen-captures to describe all identifying features of one individual (see Appendix B for an example). Because marmots continue to molt over the course of the active season, comparisons of individuals were considered valid only when the videos were recorded within one month of one another. Videos that recorded predators or endangered, rare or data-deficient species were saved and shared with the appropriate organizations.

4.4 Statistical analysis

There is an active and ongoing collaboration between researchers at MRF, Calgary Zoo's Centre for Conservation Research, the USGS Patuxent Wildlife Research Center, and the USGS Washington Cooperative Fish and Wildlife Research Unit. Researchers are using multi-event mark-recapture-recovery models to evaluate apparent survival of marmots following release. Analyses will explore whether there are differences in probability of surviving to various ages as a function of the release type (captive-bred and released directly to Strathcona, captive bred and pre-conditioned at Mt Washington prior to release at Strathcona, and wild-born). MRF has collected and prepared the project data and shared it with researchers, and there are no outstanding funding needs for this project. These analyses are still in progress at the time of this report; therefore, a detailed description of methods and results is not yet available. The academic goal of this collaboration is to publish the results of this study in a journal in 2017. The conservation goal is to improve release success in the Strathcona region by helping managers identify the release candidates that are most likely to survive over the short- and long-term.

4.5. Population counts

Regional population counts from 2007-2016 were based on a combination of radiotelemetry detections and visual observation In 2016, the "low count" included telemetered marmots, aged ≤10 years, that were detected alive in 2016 and not detected on mortality signal, as well as untelemetered marmots that were observed and/or heard calling over the duration of the field season (Appendix C). The "high count" included those marmots in the "low count" as well as telemetered marmots aged ≤10 years that were not detected in 2016 but that were detected alive in 2014-2015. The high count also included untelemetered marmots that were believed to be unique individuals, but could have been duplicate sightings of an individual in the low count. Marmots with telemetry batteries that were due to fail were not included in the high or low count. A key assumption behind this method is that the number of marmots without telemetry that died undetected after their initial observation would be balanced by the

number of untelemetered marmots that were never observed in the first place, or that were incorrectly assumed to be individuals already counted.

5. RESULTS AND OUTCOMES

5.1 Supplemental spring feeding

During May, field crew located 11 emerged hibernacula on Mt. Washington and installed feeders at six of them. Based on the habitat use by marmots at that colony, it is likely that feeders were accessible to 5-10 breeding pairs, four pre-conditioned marmots that had recently emerged from their first wild hibernation, and 8-12 wild-born yearlings. One feeder was removed in mid-May when camera footage revealed that a bear had passed through the site and inspected the empty feeder. The other five feeders were refilled 6-10 times between May and mid-June, at which point they were removed.

In Strathcona Provincial Park, feeder installation was impeded by poor weather and fog that prevented aerial emergence checks and access to three colonies (Castlecrag, Frink and Henshaw). Emergence holes were visible at four of six colonies surveyed (Greig, Marble Meadows, Sunrise, Tibetan) and MRF installed feeders at two colonies (Marble Meadows and Tibetan). The Marble Meadows feeder benefited a breeding pair and at least 3-6 offspring, and the Tibetan feeder benefited 2-4 untelemetered adults and one untelemetered yearling. No emergence holes were sighted at Mt. Phillips or at Flower Ridge, but the telemetry had failed for resident marmots at those sites, and so the search for emergence holes relied solely on visual observation.

5.2. Population augmentation

In total, 17 marmots were released at seven locations in Strathcona, including eight wild-born, five captive-bred and pre-conditioned, and four same-season marmots released with no wild experience (Table 2). Since releases of marmots with different experience began in 2012, MRF has released 53 wild-born marmots, 33 pre-conditioned marmots, and 47 captive-bred marmots with no wild experience into twelve locations in Strathcona Provincial Park.

Table 2. Distribution of release groups in Strathcona Provincial Park (2016).

Experience	Castlecrag	Flower	Frink	Greig	Phillips	Sunrise	Tibetan	Total
Wild-born	1	1	2	0	2	1	1	8
Pre-conditioned	1	2	0	2	0	0	0	5
No wild experience	0	0	2	0	0	1	1	4
Site totals	2	3	4	2	2	2	2	17

MRF released an additional nine captive-bred marmots on Mt. Washington. The first release of five yearlings (June 27) was planned for the purpose of pre-conditioning marmots for translocation in 2017. The second release of four yearlings (July 16) was unexpected, and the consequence of poor weather preventing a planned and time-sensitive release in another region. Those marmots were re-directed to Mt. Washington because of the ease of access for release and monitoring, and the potential for those marmots to be translocated elsewhere in 2017.

5.3. Monitoring

5.3.1. Radiotelemetry

Field crew spent 121 crew-days on Mt. Washington over the course of 34 site visits. They recorded >300 telemetry-based detections of 40 individuals, and made 52 observations of untagged individuals. Of the nine captive-bred yearlings released for pre-conditioning on Mt. Washington in 2016, field crew confirmed release site fidelity by six marmots. MRF believes that the other three yearlings dispersed from the ski hill. Field crew documented the start of hibernation for 16 telemetered marmots on Mt. Washington, including five pre-conditioning yearlings, and identified at least 13 hibernacula on the ski hill that were in use at the end of the field season. The three hibernacula that were in use by pre-conditioning yearlings were not previously known hibernacula. MRF shared a map of all hibernacula locations with staff at Mt. Washington Alpine Resort, in order to help with management activities.

Field crew spent 30 crew-days over 9 days of site visits to conduct ground-based inventory in Strathcona Provincial Park in 2016. MRF also conducted eight telemetry flights in Strathcona, and made >300 radiotelemetry detection attempts resulting in 160 positive detections for approximately 80 marmots. Trapping-for-implant sessions at Tibetan and Castlecrag resulted in the capture and implant of three marmots at Castlecrag. These marmots included a replacement transmitter for one captive-bred adult female that had survived at the site since her release in 2010, as well as two previously unknown wild-born adult males. In total, from 2012-2016, MRF has monitored 224 marmots in Strathcona Provincial Park and gathered over 800 records of survival data for these marmots.

5.3.2. Remote cameras

Remote cameras captured >350 videos of Vancouver Island Marmots at five colonies in Strathcona Provincial Park (Castlecrag, Flower Ridge, Marble Meadows, Sunrise, Tibetan). This footage resulted in the documentation of at least 16 untelemetered adults as well as identification of two pup litters and eight pups. See Appendix D for site-specific summaries.

5.4. Statistical analysis

The data have been shared with researchers at the Calgary Zoo's Centre for Conservation Research, the USGS Patuxent Wildlife Research Center, and the USGS Washington Cooperative Fish and Wildlife

Research Unit. Results will become available when the manuscript is published. Preliminary results will be made available to MRF prior to the 2017 field season, and will be used to guide upcoming releases.

5.5. Mortalities

In 2016, MRF detected 31 mortalities of marmots in the Strathcona region (excepting Mt. Washington). Twenty-one mortalities were confirmed early in the active season, and sixty-two percent (n=13) were for marmots that were in their first twelve month period in Strathcona. An additional ten mortalities were detected in July, August or September, and detections records confirm that nine of those mortalities occurred during the 2016 active season. Sixty percent of active-season mortalities (n=6) were detected for marmots that were in their first twelve months in Strathcona. MRF recovered just one transmitter from these mortalities, for a wild-born yearling male that dispersed from Mt. Washington in 2015 and was recovered in a culvert beside a cutblock, 4.5km NW of his last known location on Mt. Allan Brooks. Evidence in the form of broken bones and scattered hair suggested that this mortality may have been caused by predation, although much of the evidence may have been washed away in spring runoff through the culvert. On the date that the remains were recovered, field crew found wolf tracks ~100m from the transmitter.

In the winter of 2015-16, overwinter survival on Mt. Washington was estimated at 91% (95% CI = 0.60-1.00) for 11 wild-born and established marmots, and 71% (95% CI = 0.35-0.92) for seven newly-released captive-bred (Figure 4). Over the past five hibernation periods on Mt. Washington, overwinter survival was 18% lower for 57 captive-bred marmots ($\hat{p}$ = 0.74, 95% CI = 0.61-0.83) than for 83 wild-born or established marmots ($\hat{p}$ = 0.92, 95% CI = 0.83-0.96). In total, there were four marmot mortalities on Mt. Washington in 2016. Two older captive-bred marmots did not survive their first hibernation in the wild: the 5yo male emerged in late May and died above ground, and the 8yo female failed to emerge. One wild-born yearling female died

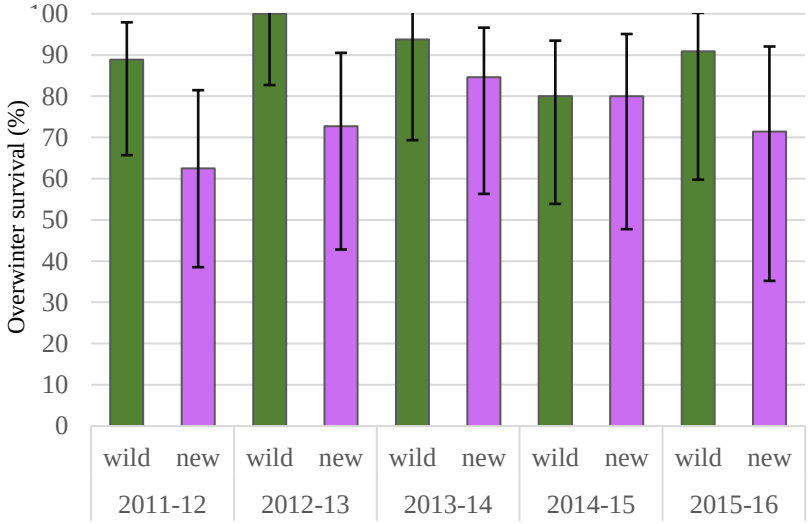

Figure 4. Overwinter survival by wild-born and established marmots ("wild") and newly-released captive-bred marmots in their first wild hibernation ("new").

between September 2015 and early June 2016, and was detected on slow signal throughout the 2016 field season. The transmitter and remains were never recovered, so there is some uncertainty as to her cause of death. Last, a new ly-released yearling male was detected on slow signal in early October 2016. The timing could have suggested hibernation, but the strength of the transmitter signal suggested that it was above rather than below ground. For the time being, MRF has assumed that it indicated a mortality, and field crew will monitor this signal in 2017 to confirm this assessment.

5.6. Dispersal

For a dispersal to be considered successful, a marmot must leave its release colony or natal colony and, after traveling some distance, join a colony at another location. By this definition, there are nine extant colonies that are connected to at least one other colony (Figure 5), and in 2016, there were four successful dispersals. Two marmots traveled from Frink to Castlecrag (2.5km), one marmot dispersed from Morrison Spire to the talus release site on Greig Ridge (4.5km), and one marmot dispersed from Henshaw to the colony on Flower Ridge (6km). MRF also documented three dispersals that were in

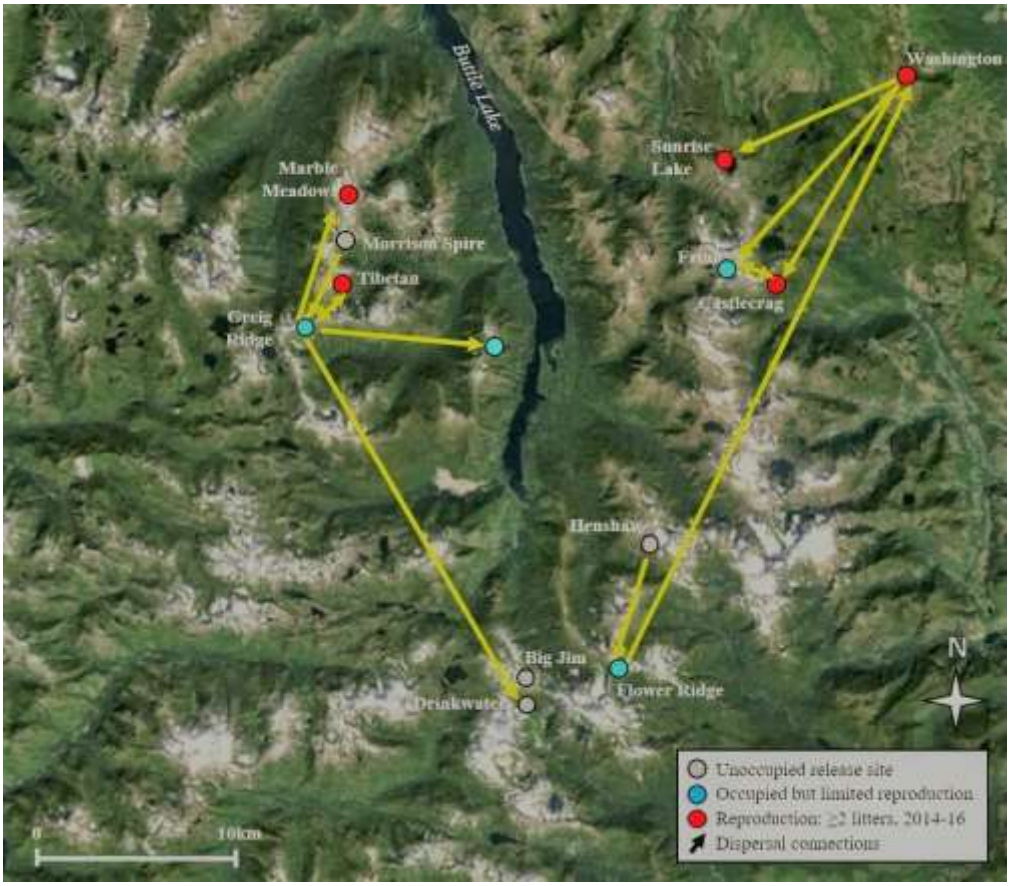

Figure 5. Colony connectivity: dispersal start and end locations in Strathcona Provincial Park (2012-16).

progress, in which marmots had dispersed from a colony and were detected alive within the landscape, but had not yet joined a new colony. Dispersals in progress included one marmot that dispersed from Tibetan and was last located on Limestone Cap, one marmot that dispersed from Mt. Washington and could not be tracked to a specific location, and a newly released male that dispersed from Sunrise to a cutblock near Blue Grouse Lake, 16km to the northeast. This marmot was sighted in November by a member of the public, and field crew following up on the report tracked the marmot to a shallow and poorly constructed hibernaculum. The project veterinarian determined that the marmot was extremely unlikely to survive hibernation if he remained at that location; therefore, he was recaptured and taken to Mt. Washington to hibernate in the TBMWMRC. There were at least two dispersals that resulted in mortalities, including a marmot that dispersed from Greig Ridge to Tibetan and another that dispersed from Mt. Washington to an unknown location in Forbidden Plateau.

5.7. Reproduction

There were two new litters and five pups observed on Mt. Washington in 2016 (Figure 6). Based on the current age structure of the residents in the colony, and making a conservative assumption that the females that bred in 2016 will not breed again in 2017, there could be seven females within the prime reproductive age range (3yo-8yo) in 2017.

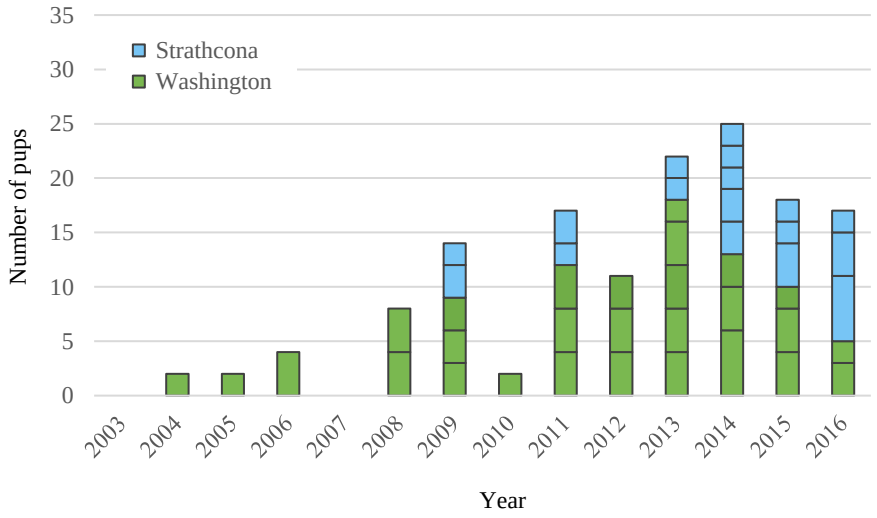

Figure 6. Weaned pups observed in the Strathcona region, subdivided into litters and grouped by location (Mt. Washington versus Strathcona Provincial Park). Because of challenges observing an entire litter simultaneously, this figure assumes a minimum litter size of two even if only a single pup was observed.

MRF also documented three litters and twelve pups in Strathcona Provincial Park in 2016. Two litters were recorded by remote camera footage (Marble Meadows, Sunrise) and the additional litter was observed by field crew while live-trapping marmots on Castlecrag. The litter at Marble Meadows

represented the third consecutive year of breeding by the resident female, and there were six pups in this litter.

In the past six years, females on Mt. Washington have weaned >22 litters and 70 pups. Counts of weaned pups on Mt. Washington consistently underestimate the number of pups and litters born by 20-70%. In 2016, field crew re-sighted twelve yearlings (171%) of the seven pups counted on Mt. Washington in 2015. Individual yearlings were also recorded in remote camera footage at Castlecrag (two pups counted in 2015) and Tibetan (no pups counted in 2015). No yearlings were recorded at Marble Meadows (four pups counted in 2015); however, the camera was flipped upside between installation and mid-June, and so limited footage was recorded during the time when yearlings would regularly have used the hibernaculum.

5.8. Population counts

At the end of the 2016 field season, MRF estimates that there were approximately 40-70 marmots at eight colonies in Strathcona Provincial Park (Figure 7; see Appendix E for specific colony counts). This are an additional ~30 marmots in the intensively managed colony on Mt. Washington.

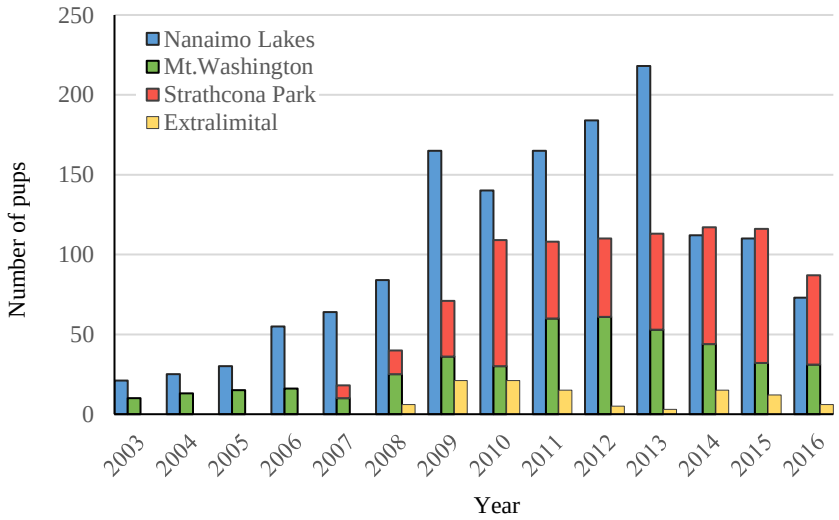

Figure 7. Population counts for the wild population of Vancouver Island marmots (2003-2016).

These numbers, and those provided in previous reports, do not differentiate between marmots that were born in the region or have become established at a colony and are likely to remain there for their lifetime, and newly-released or dispersing marmots that have not become established at a location and are less likely to have begun to contribute to population functionality. By considering only those marmots that are likely to be established within the landscape (so ignoring newly-released marmots and those that are likely to be translocated in 2017), there are ~28-50 established marmots at eight colonies in Strathcona Provincial Park. As a point for comparison, there were approximately 15-40 established marmots at five colonies in 2011.

5.9 Community Engagement

In 2016, MRF published 27 blog posts, >30 Facebook posts, and >350 tweets. This contributed to >22,000 unique website visitors, 300 new Facebook "likes", and 300 new followers on MRF's Twitter account. Please see Appendix F for a list of MRF's other media activities.

6. DISCUSSION

The 2016 active season was reasonably predictable in its spring and summer weather, and seasonal behaviour by marmots was also more predictable. Emergence timing in all wild populations ranged from mid-April to late May, and the first instances of torpor were recorded on September 14. This timing supported the traditional survival surveys in early June and early September, and there was none of the uncertainty that existed as a consequence of early emergence and torpor in 2014 and 2015. However, changes in hibernation timing is not unique to Vancouver Island Marmots, and may indicate a greater climatic pattern impacting the phenotype of sciurids rather than a few years with greater behavioural variability for this particular species.

A long-term study of yellow-bellied marmots (*M. flaviventris*) found that marmots in the Upper East River Valley of Colorado, USA, emerged 38 days earlier than 23 years previously (Inouye et al. 2000), and that earlier emergence and weaning of young led to larger body masses, declining adult mortality, and population increase (Ozgul et al. 2010). Conversely, climate change conditions associated with early springs led to entirely different responses in alpine marmots (*M. marmota*, French Alps*;* Tafani et al. 2013) and Columbian ground squirrels (*Urocitellus columbianus*, Rocky Mountains, Canada; Lane et al. 2012). Alpine marmots recorded a continuous decline in litter size as a consequence of thinner snow cover, and Columbian ground squirrels delayed their emergence dates in response to a later date of snowmelt and lower spring temperatures. There are not enough data yet to indicate whether climate change will help or hinder recovery efforts for the Vancouver Island Marmot. Whatever the impact, managers must expect some potential for long-term changes in the timing of seasonal behaviours of Vancouver Island Marmots, and understand that these will continue to add variability to results.

Unfortunately, 2016 was a season with exceptionally high mortality in the Strathcona region. At the end of the 2015 field season, MRF detected 15 marmots on slow signal in Strathcona, and there was some hope that perhaps these marmots were alive and hibernating (Jackson and Lester 2015). Aerial surveys in May and June 2016 detected slow signals for each of those marmots, and MRF decided to treat them as mortalities from the previous year. MRF also detected an additional 31 mortalities of marmots in the Strathcona region in 2016. The majority (68%) of these mortalities occurred between September 2015 and June 2016. The scale of these early-season mortalities led MRF to question

whether it might be worthwhile to conduct additional flights to pursue the recovery of the deceased marmots' transmitters.

In the best-case scenario for recovery flights, it was possible that the transmitters could have been tracked by field crew to hibernacula or to remains that could provide conclusive evidence for the cause of mortality. In particular, it would have been valuable to know how many mortalities of newly released wild-born or pre-conditioned marmots occurred as the result of hibernation-related mortality. In the worst-case scenario, the helicopter might not have been able to land near the transmitter, the field crew might not be able to safely access the remains because of challenging and hazardous terrain, the remains could have been underground or buried under spring snow, or crew could have recovered only a bare transmitter with no other sign nearby. After great consideration, MRF decided that the information gained from the recovery of any transmitters would be minimal relative to the cost and the low likelihood of gathering useful information. Based on the timing of the mortalities and the results seen in locations where transmitters are regularly recovered (Nanaimo Lakes region, and on Mt. Washington), MRF assumed that some mortalities detected in June were caused by hibernation-related mortality, and some by late fall or early spring predation. MRF believes that predation was almost certainly the cause for the mortalities that occurred between June 8 and September 13, 2016.

Population recovery efforts between 2003 and 2011 focused almost entirely on the release of captive-bred marmots into the wild. These marmots were born at one of four captive-breeding facilities, and were released directly from captivity into marmot habitat with no prior experience living in the wild. There is some evidence that the timing and duration of hibernation may differ for Vancouver Island Marmots in captivity relative to marmots in the wild. Marmots in captivity were found to immerge six weeks late and emerge five weeks early relative to marmots in the wild, and so hibernated for only two-thirds the length of marmots in the wild (Bryant and McAdie 2003). Moreover, newly-released captive-bred marmots record greater rates of first-winter overwinter mortality than resident wild-born marmots (2003-2010; Jackson et al. 2016). The question of whether this effect would also be evident in translocated wild-born marmots, or in captive-bred marmots translocated after surviving their first wild hibernation, was the basis for the releases conducted in Strathcona from 2012-16. MRF awaits the results of this study, which will help managers to select the future release candidates that are most likely to survive to contribute to population growth in this region. What this study was not designed to accomplish, however, was to identify the causes behind the differences in hibernation that exist, and explore how these differences impact post-release survival for captive-bred marmots.

Members of the genus *Marmota* have been maintained in captivity to study a variety of hibernation topics, such as age-related differences in body temperature (*M. flaviventris*; French 1990), reproductive performance under different hibernation regimes (*M. monax*; Concannon et al. 1989), latitudinal

influences on energetic costs (*M. monax*; Fenn et al. 2009), and weight cycles and energy balance (*M. marmota*; Kortner and Heldmaier 1995). Field studies of marmots have looked at changes in the morphology and function of the gastrointestinal tract (*M. marmota*; Hume et al. 2002), body temperature patterns (*M. broweri*; Lee et al. 2009). Several studies, both in captivity and in the field, examined the impact on hibernation of diet, particularly in the role of polyunsaturated fatty acids (Ruf and Arnold 2008; Bruns et al. 2000; Hill and Florant 1999; Thorp et al. 1994; Florant et al. 1993). Initially, however, there were no direct, quantitative comparisons of hibernation patterns for a single species in captivity and in the wild. Geiser et al. (2000) conducted a review of literature review for a number of hibernators and daily heterotherms and found data that suggested that torpor in the wild is more frequent, deeper, and longer than in captivity. This review included data from three species of hibernating rodents, which achieved less regular hibernation, shorter torpor bouts, and less seasonal bout duration changes (*Spermophilus richardsonii*), a shorter mean torpor bout duration (*S. columbianus*), and asynchronous periodic arousals in groups and a greater minimum body temperature relative to wild cohorts (*M. marmota*). Given the differences in overwinter survival between newly-released captive-bred Vancouver Island Marmots and resident wild-born marmots, and knowing that captive-bred marmots are a valuable and predictable resource for population recovery, MRF believes that this should be a priority research topic for the immediate future.

The Vancouver Island Marmot is managed through a process of adaptive management, by which a method is applied, results are monitored, data collected and analyzed, and original methods are adjusted to incorporate these results and in order to achieve greater rates of success. Wildlife projects often face difficult decisions about the best methods for sampling, and this is especially the case for endangered species that, by definition, may exist at extremely low numbers. The Vancouver Island Marmot is one such species, and there are additional challenges to monitoring marmots in the Strathcona region because of the remoteness of colonies, the expense of access, and the need to collect data for both telemetered and untelemetered individuals during short and infrequent visits. Radiotelemetry data for the Vancouver Island Marmot has facilitated the estimation of sex- and age-specific Kaplan-Meier survival, which were the basis for the Nanaimo Lakes population viability modeling conducted by the IUCN in 2015 (Jackson et al. 2015). Providing that radiotelemetry transmitters continue to be implanted in a subpopulation of marmots in the Strathcona region, similar survival estimates will also be possible for the Strathcona region in the future.

Draft recovery plans for the Vancouver Island Marmot (Vancouver Island Marmot Recovery Team, in prep.) suggest that future assessment of the marmot's recovery status will place a greater reliance on the use of population viability analysis (PVA). A PVA is a tool used to model the likelihood of an individual species going extinct within a certain number of years, based on its specific life history traits

and demographic trends. In addition to incorporating survival rates, models also include starting population size, age structure, sex ratio, and reproductive parameters such as age of first breeding, breeding frequency and litter size. For Vancouver Island Marmots, only some of these parameters can be estimated from telemetry data. The collection of data about other parameters will require observational surveys that can also account for untelemetered marmots.

MRF believes that the standardized use of remote cameras could greatly improve the estimates of demographic parameters for colonies in the Strathcona region. Remote cameras have been successfully used in Capture-Mark-Recapture studies to estimate abundance and density of several large and elusive predators, including snow leopards (*Uncia uncia*; Jackson et al. 2006), leopards and tigers (*Panthera pardus*, *Panthera tigris*; Wang and Macdonald 2009), puma (*Puma concolor*; Kelly et al. 2008), and bobcats (*Lynx rufus*; Heilbrun et al. 2006). In a study on grizzly bears (*Ursus arctos*; Fisher et al. 2014), remote cameras facilitated estimates of reproductive success and creation of occupancy models. Remote cameras have also been used to collect data about social species, such as the endangered Brush-Tailed Rock-Wallaby (*Petrogale penicillata*), a small marsupial that inhabits rock piles and cliffs of Australia in small, fragmented colonies (Gowen and Vernes 2014). For the Vancouver Island Marmot, remote cameras have already enabled the identification, aging and count of individuals, and the detection of reproduction. With a more intensive and standardized installation and analysis process, they will better confirm pup-to-yearling survival, and contribute to robust population viability analyses that will be the basis for recovery assessment in the future.

7. RECOMMENDATIONS

The Provincial Recovery Plan for the Vancouver Island Marmot is under revision (Vancouver Island Marmot Recovery Team, in prep.), and will become available in 2017. The purpose of the document is to identify the strategies and actions needed to recover Vancouver Island Marmot populations, and it will identify knowledge gaps and research needed to improve recovery and management. MRF anticipates that the updated plan will continue to emphasize the need for support for the metapopulation in the Strathcona region, which is not yet self-sustaining. MRF also expects that the report will place a greater reliance on the use of population viability analyses for a quantitative evaluation of metapopulation status. These objectives align with a key management objective of the Fish and Wildlife Compensation Program to “maintain or improve the status of species of interest in the Campbell River system,” (p.17, Fish and Wildlife Compensation Program 2011).

The Strathcona metapopulation is currently comprised of five colonies with established, resident marmots that have each demonstrated some persistence and recent potential for growth through reproduction: Castlecrag, Marble Meadows, Sunrise, Tibetan, and Mt. Washington. MRF recommends

that recovery activities for the region focus on supporting survival and reproduction in the region, and at these colonies in particular. In order to gain a greater confidence in reproduction at these colonies, MRF will invest additional time in searching for hibernacula in the spring, and will work towards designing a more standardized process for installing and maintaining remote camera traps so that their information can be used in population viability analyses. Finally, in order to improve the effective contribution made by newly released captive-bred marmots, MRF recommends the pursuit of research that may identify the causes for poor first-year hibernation survival, and particularly causes that could be mitigated by changes in management or release practices.

Regional priorities include:

(i) *Spring supplemental feeding* – Installation of 10-15 feeders on Mt. Washington and at select and reproductively valuable sites in Strathcona Provincial Park. For each feeder that is installed, MRF will also install a motion-detecting remote camera that will record feeder use by marmots and the presence of other species.

(ii) *Inventory* – A dedicated spring emergence flight to search for new emergence holes and hibernacula. Aerial surveys of each of the main colonies, as needed to direct camera installment, colony augmentation, and confirm survival at critical stages of the active season. MRF will also develop standardized protocols for remote camera installation, and will analyze video data collected by remote cameras in order to identify individuals, record evidence of pup litters, and establish a base count for the minimum-known-alive (MKA) at each colony.

(iii) *Colony augmentation* – The number of individuals available for release or translocation into the Strathcona region will depend upon augmentation needs across the entire wild population. MRF expects that the demand for augmentation will outstrip the supply of marmots available for release and/or translocation. As directed by the Recovery Team, marmots will be released to maximize the positive impact and likelihood of success at an individual, colony and population level. Selection of release sites and release candidates will occur in July, and will be guided by results from the ongoing statistical analyses.

(iv) *Trapping for implant*s – One week trapping and implanting radiotelemetry transmitters in untagged marmots in Strathcona Provincial Park. It remains a high priority to collect data on marmots that were born at fledgling colonies in order to evaluate their survival and track dispersal and site colonization.

(v) *Translocation of marmots in inappropriate locations* – MRF will respond to reports of dispersing marmots that are observed in inappropriate locations, and will translocate these individuals to nearby active colonies or bring them into the captive program.

(vi) *Population estimates* – A transition from telemetry- and observation-based hill-counts to methods for more statistically-robust population estimates that can include data from remote camera traps.

(vii) *Signage* – In consultation with BC Parks, the installation of educational signs at high-use trailheads in Strathcona Provincial Park.

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Appendices

Appendix A. Timeline for main activities in the Strathcona region (May to September 2016)

Category	Activities	May	June	July	August	September
Supplemental feeding	Feeders and remote cameras	Hibernacula located; feeders installed, maintained and removed; camera footage analyzed.	Feeders removed or left empty for camera support; camera footage analyzed.	-	-	-
Population augmentation	Wild-born marmots and pre-conditioned captive-bred marmots.	Marmots monitored in the wild colony on Mt. Washington.	Marmots monitored. Wild-born marmots trapped and implanted with radiotelemetry transmitters.	Marmots recaptured, examined by veterinarian. Release sites selected and prepared. Marmots translocated to Strathcon.	Aerial survey to monitor active season survival.	Aerial surveys to verify active season survival.
	Same-season captive-bred marmots released with no wild experience.	Marmots transported from captive-breeding facility in Calgary to TBMWMBC; 30 days spent in quarantine.	Marmots examined by veterinarian, implanted with radiotelemetry transmitters.	Release sites selected and prepared. Marmots examined by veterinarian, and released in Strathcona Provincial Park.	Ground surveys (when possible) to monitor active season survival.	Aerial surveys to verify active season survival. Ground surveys (when possible) to identify hibernacula, check plugs.
	Captive-bred marmots released on Mt. Washington for pre-conditioning.	Marmots transported from captive-breeding facility in Calgary to TBMWMBC; 30 days in quarantine.	Marmots examined by veterinarian, implanted with radiotelemetry transmitters, released on Mt. Washington.	Ground surveys to monitor active season survival.	Ground surveys to monitor active season survival.	Ground surveys to verify active season survival, identify hibernacula, check for plugs, detect torpor.
Monitoring	Radiotelemetry - Mt. Washington	Ground visits by field crew to identify successful hibernacula and install feeders and remote cameras.	Ground-based inventory. Untagged and/or untelemetered marmots trapped for telemetry implants.	Ground visits for telemetry- and observation-based inventory. Pup counts.	Ground visits for telemetry- and observation-based inventory. Pup counts.	Ground surveys to verify active season survival, identify hibernacula, check for plugs, detect torpor.
	Radiotelemetry - Strathcona	Emergence flight conducted to identify successful hibernacula and install feeders and remote cameras.	Aerial flight to estimate overwinter survival and install and maintain remote cameras.	Aerial based inventory and remote camera maintenance. Trapping-for-implant sessions for untagged and/or untelemetered marmots.	Aerial flight for telemetry-based inventory and remote camera maintenance.	Aerial flight for telemetry-based inventory, active season survival estimates cameras removed from sites.
	Remote cameras	Installed near feeders and/or emergence holes. Camera footage analyzed, with a focus on detecting yearlings.	Cameras moved from spring positions in deep snow to summer positions. Camera footage analyzed.	Camera maintenance. Camera footage analyzed, count of minimum number of pups and untagged adults.	Camera maintenance. Camera footage analyzed, count of minimum number of pups and untagged adults.	Cameras removed. Camera footage analyzed, count of minimum number of pups and untagged adults.

Appendix B. Sample analysis slide for remote camera footage.

Pup 1: Appeared late July. Darker, smaller, not seen regularly

Adult 1: Both ear tags. Blonde.

Adult 2: No ear tags, older, a little scraggly.

Adult 3: No ear tags. Old, scraggly, wet-looking, black-and-orange, no sign that ear tags lost. Recorded once.

Adult 4: No tags. Blonde rump, minor black patches above. Brown tail tip. Seen regularly. Same male captured and named Howard the following week?

Adult 5: Right ear tag only. Triangle notch in left ear. Following week captured Mia, no tags and two triangle notches. Mia?

Summary:

July pre-trapping:
5 adults
- 2 with tags
- 3 with no tags

1 pup (minimum)

July trapping inventory:
3 adults
- 1 with v-notched ears (tags lost)
- 1 2yo male new given ear tags.
- 1 2yoF that dispersed from Frink.

4 pups
Suspect additional, dominant male that not seen.
Video suggests additional 2-3 adults not observed.

Appendix C. Guidelines for making colony and population counts.

Category	Count category	Description
Known Telemetered Adults	Low	Tagged adults <10yo confirmed alive in 2016 by telemetry or ear tags and not detected as a mortality during the active season (June - September).
	High	Tagged adults <10yo not detected in 2016 but detected on-site since 2014 and since not confirmed as a mortality, count assumes still on site or in the landscape and just missed.
Known Telemetered Yearlings	Low	Tagged yearlings confirmed alive in 2016 by telemetry or ear tags and not detected as a mortality during the active season (June - September).
	High	Same as low count, because no marmots were telemetered as pups, and so all telemetered yearlings were confirmed alive at least once, on their implant date, in 2016.
Known Telemetered Pups	Low	Not applicable. No pups trapped and telemetered in 2016.
	High	Not applicable. No pups trapped and telemetered in 2016.
Observed Untelemetered Adults	Low	The minimum count of untagged adults observed on one day at different sites on a mountain.
	High	The maximum count of untagged adults at different sublocations on a hill that are unlikely to be the same individuals based on their sublocations.
Observed Untelemetered Yearlings	Low	The minimum count of untagged yearlings observed on one day at different sublocations on a mountain.
	High	The maximum count of untagged yearlings at different sites on a hill that are unlikely to be the same individuals based on their sublocations.
Observed Untelemetered Pups	Low	The minimum count of untagged pups observed on one day at different sublocations on a mountain.
	High	The maximum count of untagged pups that are unlikely to be the same individuals based on their sublocations or the adult marmots tending them.
Total	Low	The sum of all low counts, for a colony or population.
	High	The sum of all high counts, for a colony or population.

Appendix D. Site-specific summaries.

1. **Allan Brooks**: There was a yearling male that dispersed here from his natal colony at Mt. Washington in 2015. He was last detected at this location on XXX in September, and not detected again until XXX. His transmitter was recovered in a cutblock NW of Allan Brooks. MRF could not determine whether it was a fall or spring mortality, but assumed that predation was the cause.
2. **Castlecrag**: This was another successful year at Castlecrag, with overwinter survival confirmed for established breeding pairs at two sublocations, and active season survival confirmed at three sublocations.
    - Main meadow: A trapping-for-translocation session in late July resulted in the replacement of a telemetry transmitter in a new wild-born male and a captive-bred female. This female, Mia, had been living at the same location since her release in 2010. She produced at least three litters during this time, including a new litter in 2016. Remote cameras captured footage of at least 2-3 additional adults that were using this sublocation but were not observed by field crew. Field crew did confirm the dispersal of two marmots from Frink, and both were observed in the company of other marmots near this sublocation.
    - West shelf: Footage of the adult pair was recorded here consistently throughout the summer, and at least one of two pups from their first litter in 2015 was seen on camera. An additional untagged adult was recorded in August, after the trapping-for-implant session, but may have been one of the untagged adults also recorded at the main meadow sublocation.
    - Talus bowl: This sublocation was previously used by an adult female who hibernated successfully for at least two winters and then abandoned the site to find a male. Two marmots were released here in July to try to establish a third breeding pair for this colony. The female remained on site in late September. The male had moved around the corner, closer to the Main meadow sublocation.
3. **Flower:** This colony has at least two known sublocations. The resident breeding pair (established 2013) is believed to be onsite at the main meadow sublocation, although their telemetry has now failed. Remote camera installation issues limited the capture of useful identification footage, but enabled the identification of at least two adults. A pair of pre-conditioned marmots was released to a ridgetop sublocation to the north of the main meadow that had previously been successful but was empty by the end of 2015. Those two marmots were still alive and onsite at the end of the active season. There were two dispersals of male marmots from Henshaw to Flower Ridge (2015, 2016). One was detected as a mortality, but one was confirmed alive throughout the field season. His signal came from an area between the 2016 release site and the main meadow.
4. **Frink**: Very little is known about marmots' habitat use of this mountain, apart from a stretch of talus on the arm between Frink and George V, and a stepped meadow between the talus and Castlecrag's west shelf. Two marmots first colonized the talus site in 2014, and a captive-bred male that was recorded by video onsite has also been known to use habitat near the west shelf of Castlecrag. A breeding-aged pair of marmots that were documented on George V in 2015 appear to have moved to and hibernated on Frink at the end of that season, and they were joined in 2016 by a dispersing pre-conditioned marmot from Mt. Washington. The proximity of Frink and Castlecrag, and data about marmot movements between the two, suggests the potential for frequent interactions between colony residents. It would be extremely helpful for field crew to spend some time on the ground here to locate hibernacula, burrows, and basking rocks for future remote camera surveys.
5. **George V**: A pre-conditioned male from Washington dispersed here in 2015, and was joined by a wild-born adult female who dispersed from the talus bowl on Castlecrag. MRF anticipated that the marmots would hibernate at this location, but they were not detected here in September 2015, and were detected in the main meadow on Mt. Frink in May 2016. It is possible that this mountain does not have appropriate habitat for hibernation, and was abandoned for that reason.
6. **Greig**: There was one established pair on the north side of the ridge that had been resident since 2014, but the adult female did not survive into June 2016. A pre-conditioned pair was released to the main talus site that had supported marmots between 2007 and 2010. Those marmots were joined by a resident captive-bred male that had been released nearby in 2013, and a pre-conditioned adult female that had dispersed from her release site on Morrison in 2015.

7. **Henshaw**: There are no telemetered marmots believed to be onsite. The last-known marmot dispersed to Flower Ridge in 2016. This site was not ground-surveyed in 2016.
8. **Marble Meadows**: Overwinter and then active season survival were confirmed for the resident telemetered female, but the resident male at the site is not telemetered. Footage from previous years revealed that one of the residents had no ear tags; assuming that this is the male and that he is wild-born, he is most likely a survivor from litters at Greig Ridge (2009, 2011) or early litters at Tibetan (2009, 2011). In 2016, remote cameras captured footage of a litter of six pups, which is the third consecutive litter produced by the telemetered female since she colonized this site. Her telemetry will likely fail in 2017, which could make this a priority site for trapping-for-implants next summer.
9. **Morrison**: There are no telemetered marmots believed to be onsite. The last-known marmot dispersed to Greig Ridge in 2016. This site was not ground-surveyed in 2016.
10. **Phillips**: The telemetry failed for the resident adult female that colonized this site in 2014, and the other resident adult documented in 2015 had ear tags but no telemetry. Survival or occupancy by this pair could not be confirmed in 2016 because this site was not ground-surveyed nor surveyed by remote camera. Two marmots were released into the main talus bowl, and one was alive at the end of the active season.
11. **Sunrise**: Telemetry had failed for the resident adult female and the resident adult male was untagged and untelemetered, but an emergence hole was visible in the spring. In July, field crew released two marmots at this location; the yearling male dispersed and was recaptured in a cut block in November, and the female was missing for a while and then detected as a mortality in August. Field crew observed two pups during the release, and they were also recorded by remote camera.
12. **Tibetan**: This site has been active and successful since 2008, with litters documented (some retroactively) in 2009, 2011, 2013, 2014, and 2015. Footage in May and June revealed regular site use by a tagged adult with no telemetry and an untagged and untelemetered adult. A yearling was also recorded interacting with one of the adults. Videos captured near-daily footage from May 25-July 12, but only a single video between July 12 and 25, at which point field crew and the project veterinarian arrived on site to trap and implant the marmots. In the three days that the field team was on site, they did not observe or hear a single marmot, despite constant monitoring of the main talus slide and exploratory hikes to search for pocket habitat nearby. Two marmots were released at the site in July, and the male dispersed north along the ridge before going missing to the end of the active season. The female also dispersed, and was detected on mortality signal in September. The last video from the active season revealed a single marmot on August 23, 2016. That was the only video capture of a marmot in August or September. This site is a priority for ground surveys and/or remote camera installation in 2016.

Appendix E. Colony and population counts for the Strathcona region.

	Telemetered						Untelemetered							
	Adults		Yearlings		Pups		Adults		Yearlings		Pups		Total	
Mountain	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Albert Edward	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Allan Brooks	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Castlecrag	7	7	2	2	0	0	0	0	1	2	4	4	14	15
Celeste	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Drinkwater	0	2	0	0	0	0	0	0	0	0	0	0	0	2
Flower Ridge	4	6	1	1	0	0	0	0	0	0	0	0	5	7
Frink	4	4	2	2	0	0	0	0	0	0	0	0	6	6
George V	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Greig Ridge	6	9	0	0	0	0	0	0	0	0	0	0	6	9
Henshaw	0	2	0	0	0	0	0	0	0	0	0	0	0	2
Marble Meadows	1	2	0	0	0	0	0	1	0	1	3	6	4	10
Morrison Spire	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Phillips	1	1	1	1	0	0	0	0	0	0	0	0	2	2
Sunrise	0	3	1	1	0	0	1	1	0	0	2	2	4	7
Tibetan	1	3	0	0	0	0	0	1	0	1	0	0	1	5
Washington	13	14	11	11	0	0	2	2	0	0	5	5	31	32
	37 -	56	18 -	18	0 -	0	3 -	5	1 -	4	14 -	17	73 -	100

*Note: Hill counts were conducted prior to full analysis of remote camera data. Numbers in this table have not been adjusted.

Appendix F. Summary of media activity for the Marmot Recovery Foundation in 2016.

Date	Outlet	Media	Link
Jun 21, 2016	Times Colonist	Newspaper	http://www.timescolonist.com/news/local/researchers-fear-many-endangered-island-marmots-didn-t-survive-winter-1.2283226
Jun 21, 2016	CTV News	Broadcast TV	http://vancouverisland.ctvnews.ca/it-s-alarming-island-s-marmot-population-sees-big-drop-in-numbers-1.2957043
Jun 22	Castanet	Web only	http://www.castanet.net/news/BC/168925/Marmots-on-the-brink
Jun 21	CHEK	Broadcast TV	http://www.cheknews.ca/vancouver-island-marmots-fail-wake-hibernation-190550/
Jun 21	CBC	Radio/Web	http://www.cbc.ca/news/canada/british-columbia/vancouver-island-marmot-1.3646433
Jun 21	The Province	Newspaper	http://www.theprovince.com/technology/researchers+fear+many+endangered+vancouver+island+marmots/12000999/story.html
Jun 21	Vancouver Sun	Newspaper	http://vancouversun.com/news/local-news/researchers-fear-many-endangered-vancouver-island-marmots-didnt-survive-winter
Jun 21	Eagle News	Radio	Not Online
Jun 21	Global News	TV	http://globalnews.ca/news/2779640/over-30-endangered-b-c-marmots-die-over-winter/
Jun 24	Metro News	Newspaper	http://www.metronews.ca/news/toronto/2016/06/24/toronto-zoo-welcomes-nine-marmot-pups.html
Jun 27	CHEK News	TV	http://www.cheknews.ca/marmots-released-mount-washington-193014/
Jun 27	CTV News	TV	http://vancouverisland.ctvnews.ca/vancouver-island-marmots-released-into-the-wild-1.2964332
Jun 30	Comox Valley Record	Newspaper	http://www.comoxvalleyrecord.com/news/384893991.html
Jul 1	Toronto Sun	Newspaper	http://www.torontosun.com/2016/07/01/toronto-zoos-baby-marmots-to-help-save-the-species
Summer	Mt Washington Marmot	Magazine	http://www.rickgibson.ca/the-marmot/issues/summer-fall-2016/new-hope-marmots-on-mount-washington/
July 27	MetroNews	Newspaper	http://www.metronews.ca/news/calgary/2016/07/27/calgary-zoo-renews-population-of-rarest-canadian-mammal-.html
July 27	Calgary Herald	Newspaper	http://calgaryherald.com/news/local-news/calgary-zoo-welcomes-four-vancouver-island-marmots-to-be-released-into-the-wild
July 27	660 News	Radio	http://www.660news.com/2016/07/27/marmots-welcomed-into-calgary-zoo-13-others-released-into-the-wild/
July 28	Calgary Sun	Newspaper	http://www.calgarysun.com/2016/07/27/calgary-zoo-leading-marmot-recovery-charge

Appendix G. Photos from the 2016 field season.

Field crew: Jordan Cormack, Marina Gray, Joseph Chisholm, Michael Lester, Andrew Horsfield, Norberto Pancera, and Cheyney Jackson.

Field crew receive avalanche safety training from Mt. Washington staff.

Marmot tracks and emergence holes are highly visible from a helicopter in spring.

Field crew used radiotelemetry antennas and receivers to monitor survival of ~80 marmots in the Strathcona region.

Field crew used two snowmobiles to deliver biscuits for feeder refills on Mt. Washington.

Field crew hike back to the helicopter after installing a supplemental spring feeder and remote camera at a colony in Strathcona Provincial Park.

MRF conducted trapping sessions on Mt. Washington and two locations in Strathcona Provincial Park. In this photo, a curious yearling enters a trap (*Joseph Chisholm).*

When untagged marmots were captured, field crew secured the traps on packgrames and carried them to the project veterinarian for examination and a telemetry implant.

A wild-born resident male was captured, and a member of the field crew records data while the project veterinarian implants a transmitter. Radiotelemetry implants of untelemetered marmots increased the number of marmots whose survival and location was monitored *(Joseph Chisholm).*

Marmots are most often found in open meadows or talus slides, such as this talus bowl near Mt. Washington *(Joseph Chisholm).*

Some untagged marmots evaded capture efforts. This wild-born yearling on Castlecrag was photographed but not implanted (*Joseph Chisholm*).

Marmots make use of a variety of escape terrain. In this photo, a pup hides in a deep shelf within a rock face *(Joseph Chisholm).*

MRF released nine captive-bred marmots into the wild colony on Mt. Washington for pre-conditioning and eventual translocation *(Joseph Chisholm)*.

MRF released seventeen marmots to augment seven active colonies in Strathcona Provincial Park *(Joseph Chisholm)*.

Individual Vancouver Island marmots can often be identified through a combination of age, size, ear tag status, and patterns of faded fur, especially on their dorsal surface *(Joseph Chisholm)*.

MRF used remote camera footage to identify and count individuals and pup litters at remote locations in Strathcona Provincial Park.

Marmots are often observed carrying dried vegetation back to their burrows for use as bedding *(Joseph Chisholm)*.

Field crew observed two litters and five pups on Mt. Washington in 2016. Experience suggests that there were likely several that were not observed and will be first sighted as yearlings in 2017 *(Joseph Chisholm)*.