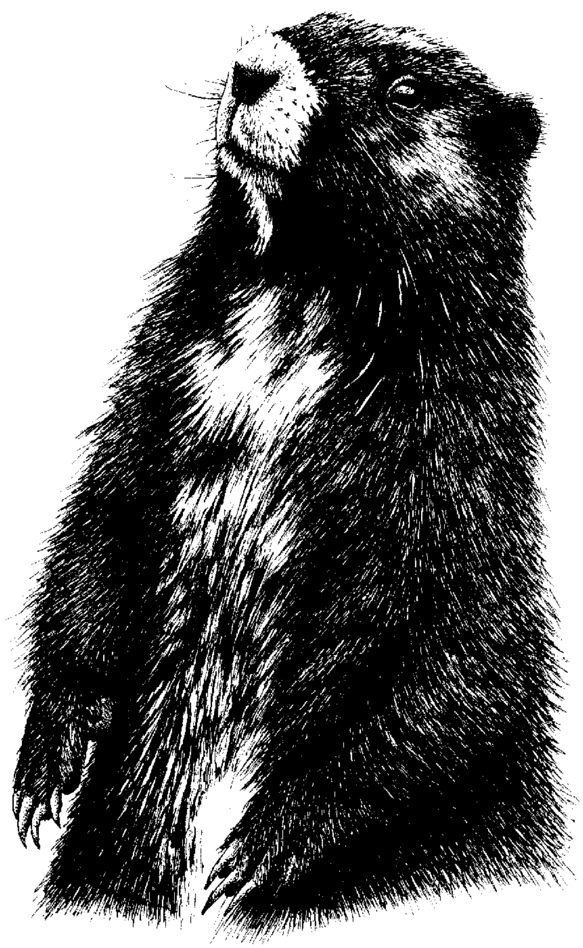
RENEW Report No. 19 **May 2000**

National Recovery Plan
for the

VANCOUVER ISLAND MARMOT

(Marmota vancouverensis)

2000 update



Recovery of Nationally Endangered Wildlife

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VANCOUVER ISLAND MARMOT

(Marmota vancouverensis)

2000 update

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on behalf of the

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The first author is the chair of the recovery team. Other members of the team at the time of preparation of this report include the starred authors, plus John Carnio of the Toronto Zoo

Approved: ______________________ Doug Dryden,
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Date: ______________________

Disclaimer

This updated recovery plan has been submitted to RENEW by the Vancouver Island Marmot Recovery Team to define recovery actions necessary to protect and recover the species. It does not necessarily represent the views of the individuals involved in the plan's formulation or the official positions of the organizations with which the individual team members are associated. The goals, objectives, and recovery actions identified in the plan are based on the best existing knowledge and subject to modifications resulting from changed objectives and new findings. We recognize that implementation of the plan will be subject to appropriations, priorities, and budgetary constraints imposed by participating jurisdictions and organizations.

Acknowledgements

The Vancouver Island Marmot Recovery Plan is a reflection of data, attitudes, and considered opinions provided by all members of the recovery team and others associated with the project. The updated plan benefited from independent scientific review by Dr. Ken Armitage and four anonymous reviewers.

Funding for implementation of the first five-year recovery-planning phase (1993–98) came from many sources. Major contributors included Forest Renewal B.C., Habitat Conservation Trust Fund, B.C. Ministry of Environment, Lands and Parks, World Wildlife Fund (Canada), Forest Alliance of B.C., TimberWest Ltd., and Macmillan Bloedel Ltd. As well, a large number of individuals and non-government organizations donated to the recovery project. We are very grateful for their support.

Levels of endangerment

Definitions of terms used by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (new wording in 2000)

EXTINCT species no longer exist.
EXIRPATED species no longer exist in the wild in Canada, but they occur elsewhere.
ENDANGERED species are facing imminent extinction or extirpation.
THREATENED species are likely to become endangered if limiting factors are not reversed.
SPECIAL CONCERN (formerly "vulnerable") species are of special concern because of characteristics that make them particularly sensitive to human activities or natural events.

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Summary of updated recovery plan

The purpose of this document is to reassess the goals, objectives, and tasks of the initial (1994) National Recovery Plan for the Vancouver Island Marmot and provide an overview of changes needed to achieve downlisting of *Marmota vancouverensis* from endangered status.

The original recovery goal of 400–600 marmots dispersed in three metapopulations on Vancouver Island has not changed and remains justifiable on geographic, habitat, genetic, and demographic grounds.

New data have clarified past and present marmot distribution and abundance. Inventory techniques are now properly developed, and the population status of this animal is well known compared with that of most other species at risk in British Columbia.

Within the “core” metapopulation south of Alberni Inlet, populations have declined by approximately 60% in the last decade. Marmots disappeared from the western Strathcona metapopulation within the last several decades, and the Forbidden Plateau metapopulation is now represented only by small colonies on Mount Washington. The entire population of the species was estimated at fewer than 100 individuals in 1998, of which >50% live in recently logged habitats. The spatial structure of colonies has changed in response to logging of high-elevation (>700 m) forests. Additional colonies will probably continue to be formed and found, but it is unlikely that significant populations remain undiscovered.

It is difficult to determine why marmots disappeared from areas north of Alberni Inlet, because so few historical (1900 to present) population data exist. Contributing factors may include weather, predation, disease, hunting by humans, changing climate, and reduced landscape connectivity. Empirical evidence for any of these processes is weak. Apart from concluding that postglacial forest succession has generally reduced the amount of potential marmot habitat, we know only that disappearances occurred relatively recently.

South of Alberni Inlet, forestry has produced dramatic effects on populations. Survival of marmots is lower in clearcuts, and logging has apparently inhibited dispersal movements by providing “easy” alternative places in which to settle. The most important result of forestry was to concentrate the population, thereby increasing the risk of mortality from other factors.

Wolves, cougars, and golden eagles prey upon marmots. Radiotelemetry indicates that predation has played an important role at some colonies. The significance of parasites and infectious disease remains unclear, although mortality has been associated with some parasitic and bacterial infections. Survival data are consistent with a hypothesis of localized mortality factors such as disease or hunting patterns by individual predators. Mark–recapture work suggests that most mortality occurs during winter hibernation, particularly in clearcuts. Weather plays a role but explains only a small amount of the variation in survival rates. There is no evidence to suggest that reproductive rates have declined. Survival rates have declined, and the frequency of high-mortality episodes has increased.

Most research objectives contained in the 1994 recovery plan have been met, although population objectives have not. Population distribution, trends, and ecology are now reasonably well understood. Health issues constitute the most important unanswered research questions. Progress has been made towards characterizing potential reintroduction habitats, although more work is required. With a handful of exceptions, additional habitat protection or habitat manipulation is not required. Experience on Vancouver Island and elsewhere supports the belief that reintroduction presents a realistic management tool. Substantial progress has been made towards increased public awareness, funding, and political support.

Changes to the 1994 recovery plan

Much of the initial plan was focused on activities designed to determine population trends and answer basic ecological questions. Many relevant questions are now answered. The challenge now is to raise necessary financial support and implement the plan.

The updated plan is based on four premises.

1. It is doubtful that significant new populations will be found north of Alberni Inlet, although that possibility exists.
2. South of Alberni Inlet, it appears unlikely that marmot populations will suddenly rebound of their own accord.
3. Another population expansion in the Nanaimo Lakes metapopulation, such as occurred during the early 1980s, would probably not result in increased geographic distribution (although it would give the Recovery Team additional options).
4. Captive breeding combined with reintroductions presents the best hope of increasing populations within a reasonable period of time.

At least seven of the world's 14 marmot species (*M. bobac*, *M. baibacina*, *M. menzbieri*, *M. marmota*, *M. monax*, *M. flaviventris*, *M. broweri*) have been successfully reared in captivity. Reintroductions using both captive-reared and wild-captured marmots have been successful, although some individual releases failed.

Experience from western Europe suggests that repeated reintroductions based on annual releases of ~20 individuals will work. The mathematics of marmot reproductive biology indicate that this will require maintenance of 40–80 marmots in captivity for 5–15 years.

Recovery: the next five years

The next five years will require that the Recovery Team invest heavily in several broad areas.

A. Population restoration
1. Captive breeding
    a. Zoo-based programs
    b. Vancouver Island facility

2. Reintroductions
    a. Experimental reintroductions
    b. Operational reintroductions

3. Planning
    a. Captive-breeding plan
    b. Reintroduction plan
    c. Contingency plan

B. Monitoring and research
1. Population monitoring
    a. Nonintensive population counts
    b. Intensive mark–recapture
    c. Radiotelemetry

2. Research
    a. Disease, parasites, and health
    b. Habitat
    c. Nutrition
    d. Behaviour
    e. Genetics

C. Habitat protection and manipulation
1. Protection
    a. Haley Lake Ecological Reserve
    b. Other habitats

2. Manipulation
    a. Clearcut habitats
    b. Natural meadows
    c. Predator–prey management

D. Fundraising and communications
1. Fundraising
    a. Prime funders
    b. Secondary funders

2. Communications
    a. Communications plan

E. Management issues
1. Project management
    a. Vancouver Island Marmot Recovery Team
    b. Marmot Recovery Foundation
    c. Friends of the Vancouver Island Marmot

Just as the future of *M. vancouverensis* is precarious by virtue of small numbers and confined distribution, eventual success of recovery efforts will be limited by money and personnel. Recovery is probably ecologically feasible but will require substantial financial, political, and scientific investments, together with a revised organizational structure.

Section I
Introduction/species background/status evaluation

1. Introduction

Much new information has become available since publication of the original five-year recovery plan for the Vancouver Island marmot (Janz et al. 1994). Some components of that plan have been completed, progress has been made on others, and some remain unfulfilled. In addition, research has raised new issues that require incorporation into the plan.

The purpose of this document is to:

1. Summarize the “state of the science” and identify new issues of relevance to planned marmot recovery efforts.
2. Review the original recovery targets and task strategies and identify those that have been accomplished, those that require additional work, and those that remain valid in light of current information.
3. Provide a framework within which to implement the next phase of recovery efforts.

Marmota vancouverensis is a typical “alpine” marmot in most regards. It is highly social and displays complex behaviour (Heard 1977). Females require three or four years to achieve sexual maturity, rarely reproduce in consecutive years, and exhibit low lifelong reproductive performance (Bryant 1996*a*). Marmots provide a good example of metapopulation dynamics, with the entire population apparently consisting of small colonies that occasionally suffer local extinction and recolonization (Bryant and Janz 1996). Dispersal is a fundamental aspect of population ecology.

An updated status report was prepared in 1996 (Bryant 1997), and in 1997, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) reaffirmed the status of *M. vancouverensis* as endangered nationally.

2. Evaluation of the current status of the Vancouver Island marmot

A. Factors influencing vulnerability and contributing to status

1. Population considerations

a. Population status and distribution

Recent years have seen greatly increased understanding of population status and distribution (Bryant and Janz 1996).

It is unlikely that large colonies remain undiscovered. Most potential marmot habitats were ground-searched in recent years, with most areas receiving multiple visits (Bryant 1995). Particular efforts were devoted to historic marmot locations within Strathcona Provincial Park and adjacent areas.

Important results were obtained from ear-tagging and radiotelemetry at intensively studied colonies. Resightings of marked animals at these colonies (where population size was known with some precision) allowed Bryant and Janz (1996) to estimate the success of population counts at other colonies. Results suggest that >9 repeated visits are needed to obtain accurate population sizes, but 2–4 counts would result in detection of 65–75% of the adults actually present.

Inventory efforts after 1992 benefited from greatly increased funding levels, consistency of personnel, development of a computerized database, and improved mapping technology (geographic information system [GIS] and global positioning system [GPS]). In recent years, most colonies received more than three visits per year. This, combined with highly experienced inventory crews, presumably resulted in improved population estimates (Appendix 1).

b. Changes in distribution

The overall geographic distribution has not changed in recent years, although it did over a period spanning decades (Figure 1).

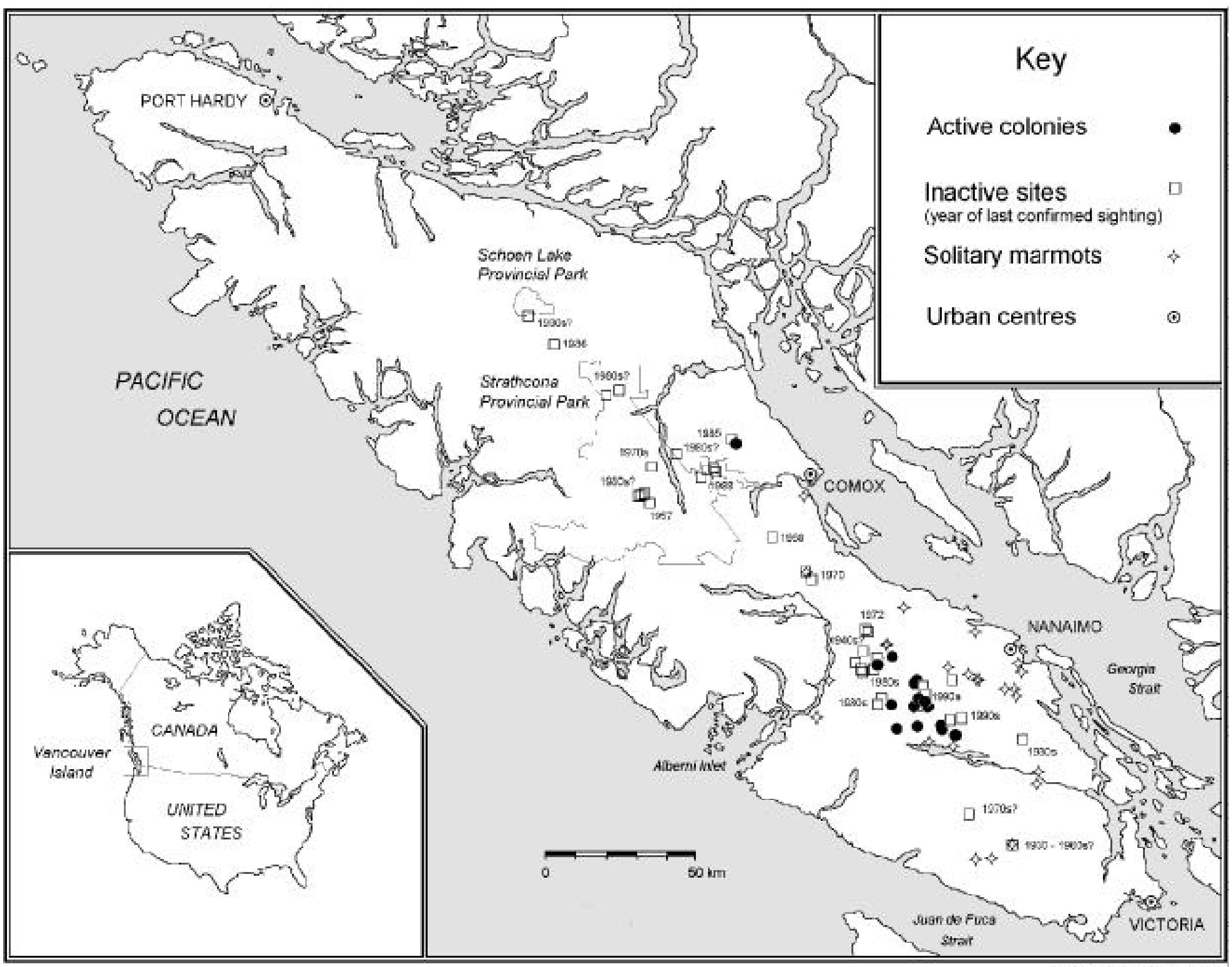
With the exception of Mount Washington, all known active colonies are located within five adjacent watersheds on south-central Vancouver Island (the Nanaimo, Cowichan, Chemainus, Nitinat, and Cameron river drainages). The current population remains extremely localized, with 90% of the population found within 150 km^2.

Despite increased survey effort, only two new colonies were discovered during the 1990s. Both were in clearcut habitats (Mount Franklin and Sherk Lake) and represent actual colonization events. In addition, new natural habitat patches were discovered on several mountains, including Mount Washington, although it remains unconfirmed that these represent reproductive colonies.

c. Changes in abundance

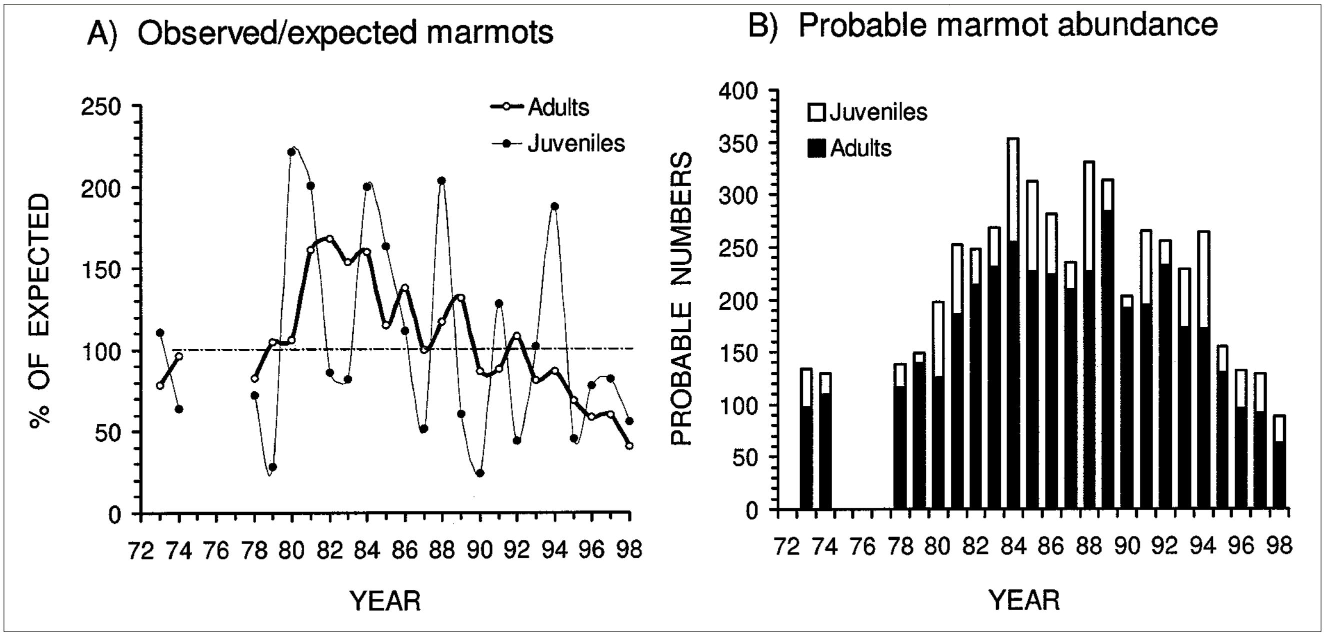
Bryant and Janz (1996) used long-term abundance data to estimate "expected" marmot numbers at individual colonies. They showed population trends by comparing annual ratios of observed and expected numbers (Figure 2). The approach was straightforward. If marmot numbers were stable, annual counts should produce similar

Figure 1
Historical (1900 to present) and current distribution of Vancouver Island marmots



Map by Andrew A. Bryant Services

Figure 2
Marmot population trends, 1972–1998. Observed:expected ratios (A) were based on maximum counts/long-term averages for each site, using only those sites counted in any year. Probable marmot numbers (B) were estimated by applying a correction factor based on count effort, by excluding clearcut habitats for years prior to colonization, and by excluding years in which fewer than four sites were counted. From Bryant (1998).



observed:expected ratios across years. This was not the case. Numbers of adults were consistently above average from 1981 to 1986 and near or below average from 1990 to 1995. Bryant (1996*b*) expanded on this approach by applying a correction factor based on count intensity and numbers of habitats occupied, thus providing an estimate of probable population sizes.

There are problems with this approach, principally caused by different count effort across years. Counts made prior to 1980 and from 1987 to 1991 were based on limited data, and estimated abundance from this period is therefore more tenuous. Despite this, data are internally consistent and corroborated by counts at intensively studied colonies (Bryant 1996*b*), together with records of colonizations and extinctions (Bryant and Janz 1996).

From a peak of 300–350 animals during the mid-1980s, marmots apparently began to decline in the late 1980s to the present total of fewer than 100 animals. This was accompanied by a structural change. In recent years, more than 50% of the world's *M. vancouverensis* inhabited regenerating clearcuts (Figure 3).

d. Genetic variation

Early electrophoretic results suggested levels of polymorphisms and heterozygosity comparable to those of other marmot species (Bryant 1990). Note that the current genetic effective population size (N_e) would be close to 20–25 animals if previously established methods (Janz et al. 1994) were repeated.

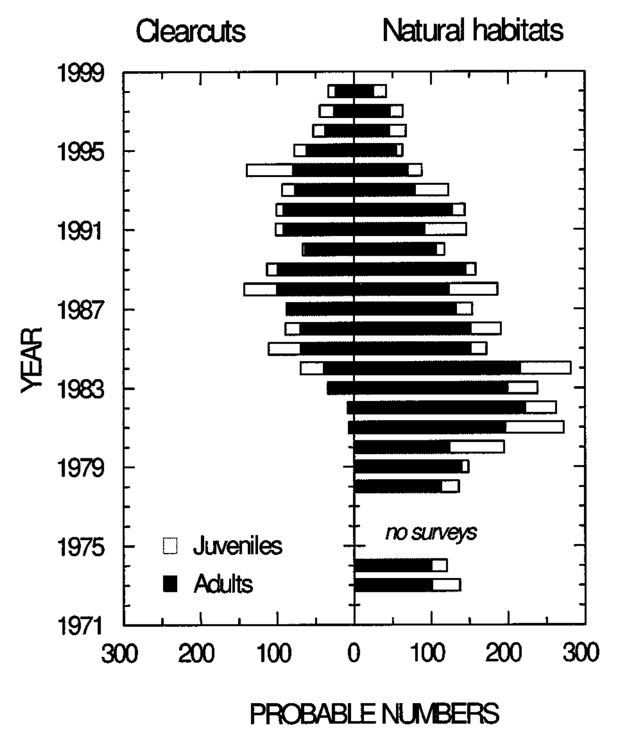
A recent DNA-based phylogeny suggests that *M. vancouverensis* is more closely related to *M. caligata* than to *M. olympus* (Steppan et al. in press). Additional DNA work in progress should provide new information about paternity and social assemblages (L. Kruckenhauser, Institute for Medical Biology, Vienna, pers. commun.).

2. *Environmental considerations*

In 1990, the Green Mountain Critical Wildlife Management Area was created (300 ha). The Haley Lake Ecological Reserve was expanded from 98 to 127 ha in 1992 and then to 376 ha in 1998.

A survey of potential marmot habitat on southern Vancouver Island was undertaken in 1994–95 prior to an experimental reintroduction (Demarchi et al. 1996).

Figure 3
Probable marmot abundance in natural habitats and clearcuts, 1972–1998. Probable numbers were estimated by applying a correction factor to observed:expected ratios, with the correction factor based on count effort. Data exclude clearcut habitats for years prior to their colonization, years in which fewer than four colonies were counted, and Mount Washington data. The 1998 Nanaimo Lakes metapopulation probably contained fewer than 100 animals, of which ~50% were found in clearcuts. Adult marmot abundance in the two habitat types was not correlated (Pearson $R = -0.431$, $n = 17$ years). Data from Bryant (1998).



Criteria for selecting release sites included 1) historic occupancy, 2) high relative abundance of known food plant species, 3) deep colluvial soils associated with marmot hibernation, and 4) boulders associated with marmot thermoregulation and "lookout" sites. Of eight potential release sites examined, all met the minimum criteria, but only one site was rated as "high" potential. Limited information is also available concerning potential reintroduction locations within Strathcona Provincial Park (Bryant 1993).

a. Tree invasion of subalpine meadows

The mountains of western North America are characterized by moving tree lines over the past 10 000 years in response to climatic conditions (Rochefort et al. 1994). During the early Holocene, tree lines may have extended as much as 60–130 m higher than at present. This trend presumably had a large impact upon habitat availability.

Marmot population dynamics may also be influenced by naturally occurring vegetation changes over historical periods (i.e., 1900 to present). Within the past 100 years, a warmer and drier climate has resulted in another tree invasion of subalpine meadows in most of the western mountains, including the Cascades, Olympics, and southern Coast mountains. It is not yet clear if this is a long-term trend or a minor fluctuation.

In 1995–96, the Recovery Team supported dendrochronological (tree ring) research at historic and extant marmot colonies. At least two sites (Gemini Peak and Green Mountain) have experienced tree invasions over a period spanning a few decades (Laroque 1998).

The evidence, however, is equivocal. In Strathcona Provincial Park, where marmots apparently disappeared some 10–30 years ago, most trees above 1000-m elevation are more than 800 years old. There is little evidence of recent tree invasion despite close overlap of tree ring sites with marmot records (e.g., Cruikshank Canyon, Circlet Lake, Greig Ridge, Philips Ridge; C.P. Laroque, University of Victoria, pers. commun.).

The role of fire in creating or maintaining marmot habitat is also unclear. Milko (1984) speculated that a recent fire on Gemini Peak created open meadow habitat throughout the nearby ridge system, but tree ring analyses do not support this idea (Laroque 1998). Apparently, different regions of Vancouver Island experienced very different fire histories. Intervals between major fires were relatively short (<300 years) on southeastern Vancouver Island but substantially larger (700–3000 years) in western and central regions (C.P. Laroque, pers. commun.; Lertzman et al. 1998).

Natural tree invasion may be important for at least two colonies in subalpine meadows. Conversely, it does not appear to explain recent marmot disappearances from areas north of Alberni Inlet.

b. Forestry

Bryant (1990, 1996*a*, 1996*b*) suggested that logging of forests above 700 m has caused detrimental population effects by a) producing low-quality "sink" habitat, b) reducing the likelihood of long-distance dispersal, and c) increasing local marmot density, therefore making marmots more vulnerable to disease or predators. Evidence for this is compelling, but the impact of forestry is not uniform throughout Vancouver Island.

Limited forestry activities took place near historic marmot locations north of Alberni Inlet, although some parts of Strathcona Provincial Park were logged, particularly in the Ash and Drinkwater drainages (Hyntka 1990). Extensive logging also occurred between the north end of Strathcona Provincial Park and Schoen Lake Park, as well as in the vicinity of historic marmot locations in the Beaufort Range.

South of Alberni Inlet (i.e., the extant marmot metapopulation), most areas are owned by forest companies (a result of the Esquimalt and Nanaimo Railway Land Grant of 1883). These lands constitute some of the most intensively harvested forests on Vancouver Island, with most (>60%) of the original mature forests removed during a 25-year period (Bryant 1998).

The demographic results of a marmot's choice to live in a clearcut include a 5–10% annual reduction in survival rates (Figure 4). The result is reduced lifelong reproductive performance compared with counterparts in natural habitats, despite similar reproductive rates (Bryant 1996*b*). Colonies in clearcuts may therefore act as population "sinks" (Pulliam 1988) that "consume" more dispersing marmots than they produce (Bryant 1997).

Forestry produced other effects as well. Bryant and Janz (1996) noted that most colonization events were within 1 km of existing natural habitats, a trend that they suggested represents "short-circuiting" of normal (pre-logging) dispersal movements due to the presence of nearby alternative places to settle (i.e., adjacent clearcuts).

Using GIS, Bryant (1998) tested this by randomly selecting clearcuts of appropriate age and elevation for "virtual colonization," given a likely maximum dispersal distance of 15 km (an estimate based on historical records of marmots at low elevations). He then compared the spatial isolation of the virtual and actual colonization events, with results that lend support to the "short-circuiting" hypothesis (Appendix 2a).

A similar procedure was used to test the effect of isolation on survival (Appendix 2b). This analysis used "apparent" survival rates (survival plus immigration minus emigration) for both adults and juveniles, together with an "isolation index" based on the median distance of that colony to other colonies. Results supported the prediction that peripheral colonies receive fewer immigrants. Apparent adult survival was lower at peripheral colonies than at "core" colonies, but juvenile survival was similar (an expected result if juveniles do not disperse).

South of Alberni Inlet, logging created areas of potential habitat that were available as early as the late 1960s. A small fraction (<1%) of clearcuts were eventually colonized in the 1980s, although it is impossible to confirm that no colonizations occurred prior to this date.

It appears that the essential effect of forestry is to provide relatively low quality habitat (in which survival is depressed), inhibit dispersal movements or "rescue effects" at peripheral colonies (by greatly altering habitat availability), and profoundly alter the spatial structure of the metapopulation. The latter is probably the most important effect, as it concentrates the population, making it more susceptible to factors such as predators, disease, and other random events (Bryant 1998).

c. Other landscape effects

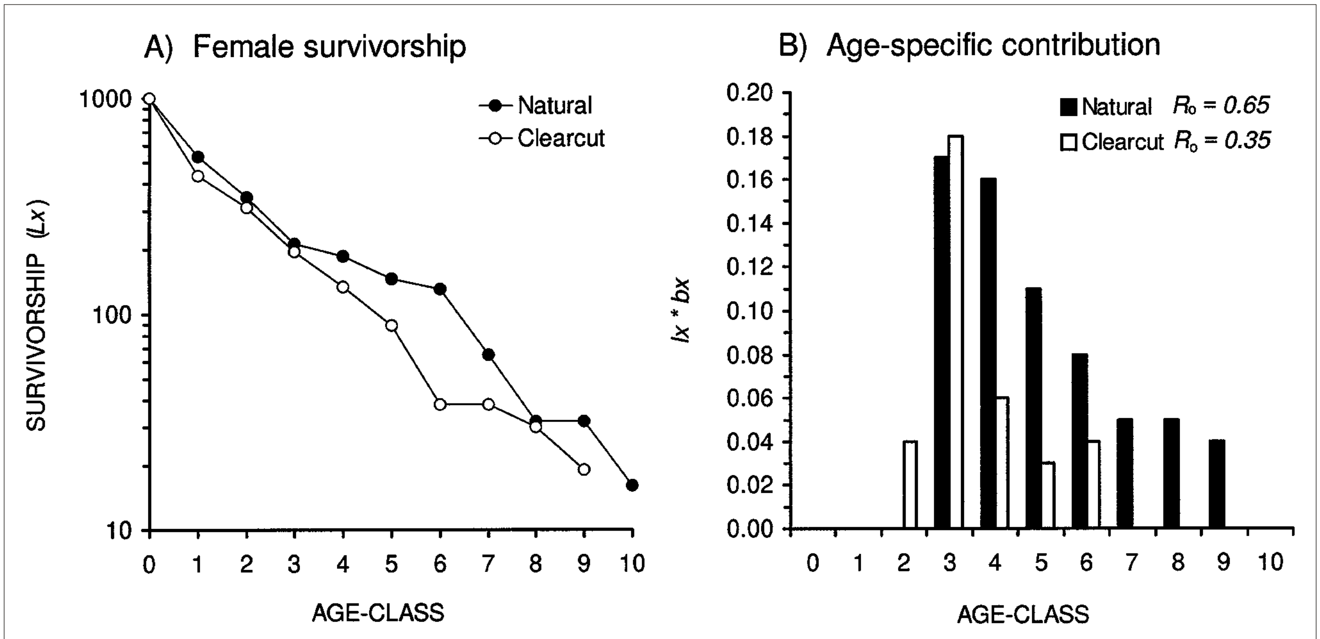
Road construction is another possible landscape factor. South of Alberni Inlet, the last several decades have seen greatly increased road density in the area of current marmot distribution (from 1.0 linear km of roads/km² in 1972 to 2.5 linear km/km² in 1996). By facilitating easy movement, it is possible that roads increase the frequency of predator–prey interactions (e.g., Simberloff et al. 1992).

Loss of marmots from Strathcona Provincial Park is curious, as neither logging nor tree invasion appears to explain it. One possible factor may relate to construction of Strathcona Dam at the north end of Buttle Lake. This dam, completed in 1957, raised the water level by 9 m and increased the area of the lake substantially (it inundated nearly 90% of the lake's tributary stream spawning areas; Hyntka 1990). This may have influenced marmot dispersal or metapopulation dynamics.

d. Predator–prey dynamics

Recoveries of tooth-marked radio transmitters show that terrestrial predators such as cougars and wolves are important causes of marmot mortality. Golden Eagle *Aquila chrysaetos* predation may also be important, particularly for juvenile marmots (Bryant 1996*a*).

Figure 4
Effect of habitat on demographics. Female survivorship (A) is lower in clearcut habitats. The result is reduced lifetime reproductive contribution (B). Data are from tagged females monitored from 1987 through 1998 (n = 34 in natural habitats and n = 51 in clearcuts). From Bryant (1998).



Wolf and cougar abundance data (sightings by deer hunters in an area of ~500 km², an area much larger than that occupied by marmots) have not been tested for reliability but currently comprise the only long-term measure of terrestrial predator abundance on Vancouver Island (Bryant 1998).

Cougar and wolf abundance were poor predictors of marmot abundance or survival (Appendix 3). This was not unexpected; "hunter sighting indices" show great annual variability and may not reflect actual predator abundance. Numbers of cougars and wolves removed from the population also had no apparent effect, despite the numbers being substantial in some years (e.g., 20 cougars and nine wolves removed in 1989, at approximately the time that marmot colonies began to decline).

Predator population sizes may be less relevant than hunting patterns of individuals. For example, Bryant (1998) reported cougar tracks leading from one hibernaculum in a clearcut to another in a nearby natural meadow on the first day of emergence (21 April) in 1995 and again in 1997. The idea that predators may benefit from increased marmot population density and easier travel along logging roads is difficult to test but appears reasonable (Simberloff et al. 1992).

Annual deer abundance estimated from systematic night counts (Harestad and Jones 1981) showed no significant effect upon marmot survival but was positively associated with marmot abundance in natural habitats but not in clearcuts (Bryant et al. in press *a*). Drastic reduction in deer numbers within the last decade (Appendix 3; current population is about 40% of normal) raises the possibility that predators may be "switching" efforts to marmots (e.g., Bergerud 1983).

Marmots disappear more frequently from clearcuts. One idea is that forest regeneration in clearcut habitats provides additional cover for stalking predators such as cougars. Regression analysis supports this hypothesis, with survival being negatively associated with increasing clearcut age (Appendix 4). However, data do not support the idea that predation is exclusively responsible for increased mortality in clearcuts. It is equally possible that forest regeneration alters the quality or quantity of other resources (food, shelter, or the ability to meet a mate).

The timing of last observation of tagged marmots was not evenly distributed throughout the active summer season, as one would predict if mortality is equally likely at any time (Appendix 5). In clearcuts, the probability of last observation was skewed towards late summer, suggesting that some marmots die in winter hibernation. In natural habitats, the probability of last observation of adults was more evenly distributed throughout the season.

Predators have an undeniable impact on particular marmots and colonies. This is probably exacerbated by the increased concentration of marmots in a small geographic area. Reduced abundance of prey such as deer probably encourages predation on marmots. Data from Northwest Bay showed high cougar numbers despite large reduction in deer populations (D. Doyle, B.C. Ministry of Environment, Lands and Parks [MELP], pers. commun.). Finally, observations of tracks suggest that predators may benefit from increased ability of predators and prey to move easily along roads.

e. Weather

Weather has been implicated in regulating other marmots, but evidence for weather regulation of *M. vancouverensis* is relatively weak (Bryant 1998). Logistic regression of weather variables against marmot survival and birth rates revealed some significant relationships but explained only a moderate amount of variation in these rates (Appendix 6).

Survival was positively associated with snowpack depth in the subsequent winter, but negatively associated with snowpack in the previous spring. Barash (1973) found that survival of *M. olympus* was positively associated with increasing snow depth. Arnold's (1990*a*, 1990*b*, 1992) work on *M. marmota* suggested a possible physiological explanation for this — i.e., the physiological necessity for a thermally stable environment in which to hibernate. Recent work on *M. marmota* lends credence to the snowpack survival hypothesis (Farand et al. in press).

Negative association between survival and snowpack in the previous spring may reflect the length of the growing season. Van Vuren and Armitage (1991) suggested that the timing of snowmelt, and not the depth of snowpack, may be critical in determining marmot survival.

Recent physiological studies provide important clues about the possible influence of weather on marmot survival during winter. Thorp et al. (1994) conducted a laboratory study in which *M. flaviventris* were fed diets containing high or low compositions of essential polyunsaturated fatty acids. The result was that marmots supplied with a diet deficient in essential fatty acids showed identical weight gains during summer, but exhibited higher spontaneous arousal rates, shortened bouts of deep hibernation, and higher overall metabolic expenditures. That this could lead to increased winter mortality is clear (Arnold 1993). It seems reasonable to suggest that between-site soil characteristics and annual weather variation could influence both the availability and chemical composition of plants eaten by marmots (Kuramoto and Bliss 1970; Sinclair et al. 1982).

f. Disease and parasites

The impact of disease and parasites on marmots remains poorly understood but may be very important. Four of six animals relocated from different colonies to a vacant historic location in 1996 died, possibly from a bacterial infection during hibernation (Bryant et al. in press *b*). In addition, chorioptic mange was diagnosed in two animals from Mount Washington (H. Schwantje, MELP, pers. commun.). Both conditions clearly demonstrate the potential implications of infectious diseases for small colonies, especially given that marmot survival rates apparently declined in recent years (Figure 5).

Whether epizootic or low levels of chronic infectious diseases or parasites are responsible for recent *M. vancouverensis* population trends or even the disappearance from areas north or south of Alberni Inlet remains unknown. The loss of apparently healthy colonies from places such as North Hooper (1982–83) and Gemini Peak (1986–87), combined with observed population crashes at places like Haley Lake and Butler Peak, suggests episodic mortality events that are congruent with a hypothesis of disease outbreak (Bryant 1998). Such events underscore the inherent dangers of a small population and confined distribution.

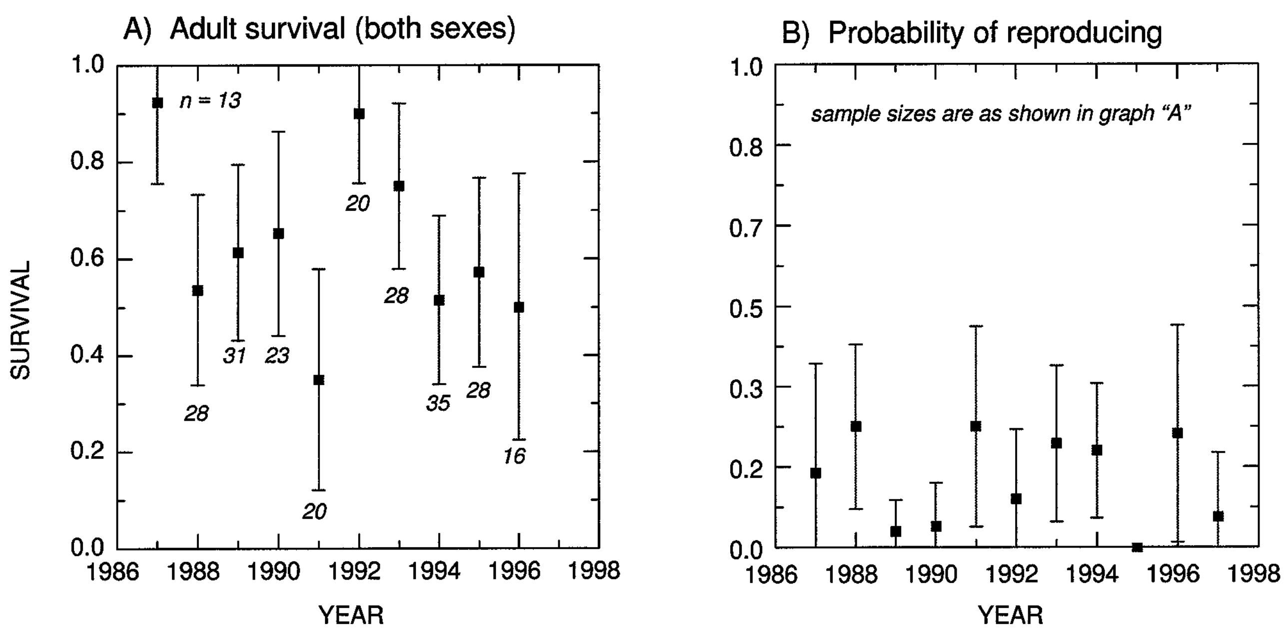
Limited baseline data currently exist for normal *M. vancouverensis* health parameters. Health investigations began in 1998 and were designed to develop assessment protocols and to collect animal and environmental samples for potential pathogen identification (N. deWith, University of Saskatchewan, pers. commun.).

B. Role in the ecosystem and interactions with humans

1. Ecological considerations

Vancouver Island marmots cannot be considered a "keystone" species in an ecosystem context. They provide prey for predators and act as habitat for parasites, at least one of which (*Diandrya vancouverensis*; Mace and Shepard 1981) lives only on Vancouver Island marmots and must also be considered endangered.

Figure 5
Marmot survival and birth rates over time. Data are mean annual rates and 95% confidence limits based on 88 tagged adults and 242 marmot-years of observation through 1997. Survivorship has been relatively low since 1994 (A). Birth rates (B) remained fairly constant over time but showed great annual variation. From Bryant (1998).



2. Sociopolitical considerations

Marmota vancouverensis is one of only five endemic mammal species in Canada (Wilson and Reeder 1993). Including taxonomic species, subspecies, and populations, it is one of only six endemic mammal "species" in Canada considered by COSEWIC to be endangered nationally.

a. Public appeal

Vancouver Island marmots and the Recovery Project enjoy widespread popular support. Well over 500 people have “adopted” a marmot, and the Internet Web site (www.islandnet.com/marmot) has been well received.

b. Utilitarian value

There is currently no utilitarian value for Vancouver Island marmots. High potential exists to incorporate public viewing and education opportunities within the context of recovery efforts.

c. Legal considerations

Marmota vancouverensis is legally protected and listed as endangered under the *B.C. Wildlife Act* (1980) and regulations (Munro et al. 1985). It is listed as endangered by COSEWIC, by the U.S. *Endangered Species Act* (*Federal Register*, 23 January 1984), and by the International Union for the Conservation of Nature and Natural Resources (IUCN; Groombridge and Mace 1994).

Most colonies occur on privately owned lands held by MacMillan Bloedel Limited, TimberWest Limited, and Mount Washington Ski Corporation. These lands were originally part of the *Esquimalt and Nanaimo Railway Land Grant Act* of 1883.

Two marmot habitats are legally protected under the *Ecological Reserves Act* (Haley Lake Ecological Reserve, 376 ha) or the *Wildlife Act* (Green Mountain Critical Wildlife Management Area, 300 ha).

C. Recovery potential

1. Review of major threats

a. Forestry

Forestry activities are unlikely to pose significant new threats north of Alberni Inlet, with the possible exception of the immediate Mount Washington area. Much nearby historical habitat is contained within Strathcona Provincial Park and therefore fully protected (Hyntka 1990).

South of Alberni Inlet, GIS measurements of the Nanaimo Lakes metapopulation region show the results of intensive forestry activities over the past 40 years on private forestlands (Bryant et al. in press *a*). Forest harvest rates decreased dramatically in recent years. This trend will continue because of limited remaining old-growth forests, but much of the harvest will occur at higher elevations.

More than half of the world's *M. vancouverensis* now live in clearcut habitats that will become unsuitable as forest succession occurs. Within the next 20–30 years, most areas will be unusable by marmots, and the second rotation of forest harvest, especially above 700 m elevation, will not occur for perhaps 60–80 years after that, unless market demands or technology dictates otherwise.

b. Predation

Predation will probably continue to be an important cause of mortality as long as the population remains small and concentrated. Low deer numbers suggest that changing predator hunting patterns (e.g., Bergerud 1983) could pose real problems for marmots, particularly if logging roads tend to channel both predator and prey. Predator numbers will eventually adjust to deer abundance, but data from Northwest Bay suggest that the lag time for this to occur could be a decade or more (D. Doyle, MELP, pers. commun.).

c. Disease, parasites, and health

Changing recovery emphasis towards captive breeding and translocation of animals requires consideration of the health risks involved. Translocated animals may carry organisms that present new risks (Cunningham 1996):

- An exotic pathogen could be introduced to a new geographic region.
- Release of infected animals could intensify preexisting disease conditions.
- Translocated animals may have no immunity to organisms present at the release site.

Present data are insufficient to make management recommendations regarding reintroductions. The captive breeding program will play a critical role in developing such guidelines. We know that *M. vancouverensis* is susceptible to some diseases and parasites. Determining normal health parameters and testing procedures for selected pathogens is therefore a high priority.

d. Random events

Because of small colony sizes, Vancouver Island marmots are extremely vulnerable to random events. "Immigration–emigration stochasticity" consists of chance births and deaths that influence individual subpopulations, and "regional stochasticity" consists of environmental factors acting on a number of subpopulations simultaneously. Both processes probably play a critical role in regulating numbers of *M. vancouverensis* (Bryant and Janz 1996).

With some mountains containing only one or two family groups, the fate of individuals (predation, overwinter mortality, dispersal, successful immigration) can cause important population effects. Local extinctions, lack of reproduction, and immigration "rescue effects" (Brown and Kodric-Brown 1977) have been apparently caused by immigration or disappearance of single males (Bryant 1996*b*). The small geographic range makes *M. vancouverensis* susceptible to "regional stochasticity" that can cause high mortality among adjacent colonies (e.g., 36% survival of juveniles during winter of 1994–95; Bryant 1998).

e. Source of releasable animals

Marmot reintroductions have been successful in parts of western Europe and Russia (Ramousse et al. 1992). Reintroductions using animals transplanted from the wild usually have a better chance of establishing self-sustaining populations (Griffith et al. 1989). Unfortunately, the current population of *M. vancouverensis* is too small to allow this approach.

Reintroductions using captive-reared marmots have also achieved success (Dimitriev et al. 1992). Techniques associated with breeding marmots in captivity are well developed (Rymalov and Maximov 1992; Tokarsky 1996; Rumiantsev and Rymalov 1998).

If demographic rates of captive *M. vancouverensis* are similar to those in the wild (0.9–1.2 births per adult female per year), then approximately 20–25 adult females would be required to produce a similar number of juveniles annually. Males, juveniles, and yearlings would add to this number. Assuming equal sex ratio of juveniles and excellent (80%) survival rates, this would yield 20 releasable yearlings annually, which is probably a reasonable minimum required to achieve success (Ramousse et al. 1992).

f. Changes in climate and vegetation

It is impossible to predict future effects of climate and vegetation change. However, Rochefort et al. (1994) concluded that if global warming models are valid, then tree invasion will increase, with tree lines reaching elevations similar to those of the early Holocene. Tree establishment 60–130 m above the present tree lines on Vancouver Island could have a major impact on marmot habitat. Changes in snow and rainfall patterns could also have important impacts.

g. Loss of genetic variation

Current population distribution suggests little possibility of genetic exchange among some colonies. It is impossible to determine the eventual susceptibility of *M. vancouverensis* to deleterious genetic loads (inbreeding depression), but, in any event, the solution is identical: quickly increase their distribution and abundance.

In order to maintain genetic variation in captivity, efforts will begin with a minimum of 20 unrelated individuals. Pairings will be managed and appropriate breeding records will be kept to maximize the genetic contribution of each individual.

h. Catastrophe

Small population size and confined distribution make *M. vancouverensis* highly vulnerable to catastrophic events. Even one or two years of low survival or failed reproduction could place the Recovery Team in the unenviable position of being forced to remove all or most marmots from the wild to ensure their survival, as occurred with black-footed ferrets *Mustela nigripes* and Micronesian Kingfishers *Todirhamphus cinnamominus*. Essential contingency planning is under way.

2. Current habitat protection efforts

In 1999, the Haley Lake Ecological Reserve was expanded as part of Goal II of the Protected Areas Strategy. The expansion was significant, from 127 ha to 376 ha. Negotiations continue to add to this protected area. The goal is to protect a total of 762 ha. Private landowners are playing an increasingly important role in management issues, such as road deactivation, vegetation management, and other activities.

3. Degree of habitat protection required

With the exception of the Haley Lake Ecological Reserve expansion, no additional protected areas are required in the near future (i.e., the five-year scope of this recovery plan).

Most extant colonies occur on private lands and are not easily accessible (Janz et al. 1994). Levels of human disturbance are negligible at most colonies. Intensively studied colonies that experienced high visitation showed no measurable reduction in birth or survival rates compared with other colonies (Bryant 1997).

Some colonies may experience increased visitation in the future as *M. vancouverensis* becomes more widely known. Habitat management issues will continue to occur at particular colonies (e.g., Mount Washington), which will require landowner cooperation.

Ultimately, while recovery efforts must necessarily be focused on population maintenance and restoration in the short term, long-term viability of this species can be assured only by ensuring that populations (reintroduced or otherwise) do not suffer from the same kinds of deleterious effects currently influencing the extant metapopulation.

For example, following future reintroductions, particularly south of Alberni Inlet, the present human-induced alterations of the landscape connectivity must be modified. Wildlife managers and the forest companies will have to work together to find an appropriate method of harvesting the second-rotation, higher-elevation forests in order to avoid re-creating the low-quality “sink” habitat that appears to be playing a significant role in the decline of the marmot populations today.

Section II
Recovery

1. Recovery goal and objectives

The 1994 recovery plan established a population target of 400–600 marmots, dispersed in three discrete areas of Vancouver Island (Janz et al. 1994). This population objective was based on the probable historic distribution of marmots, probable barriers to dispersal, and the idea that sufficient natural habitat exists on Vancouver Island to support three metapopulations of 150–200 animals each.

The population target was also based on the need to maintain genetic variation and the idea that metapopulations of this size would be sufficient to maintain an "effective size" (N_e) of close to 50, a level thought to minimize the danger of inbreeding depression (e.g., Lande 1988). Finally, the population objective was based upon the simple desire to maximize the geographic distribution of Vancouver Island marmots and therefore reduce the possibility that random events or weather patterns could simultaneously influence the entire population.

The population objectives listed in the 1994 recovery plan (400–600 marmots in three metapopulations) are still realistic. Limited habitat assessment work supports the original distribution target of three metapopulations in the 1) Nanaimo Lakes region, 2) western Strathcona region, and 3) Forbidden Plateau region, but the latter area will probably remain a relatively minor objective (there appears to be more potential release habitat to the west and north of Buttle Lake; Bryant 1993). Similarly, the Nanaimo Lakes metapopulation will probably continue to provide the major population reservoir, provided recent population declines can be reversed.

We reiterate that the current "eggs in one basket" distribution is intrinsically dangerous. Extinction from random events such as weather, predation, and disease is no longer just a theoretical possibility, as the severe winter of 1994–95 clearly showed.

2. Strategies

Seven strategies were designed to meet the recovery goal and objectives outlined in the 1994 recovery plan. These were:

A. Monitor known populations (to determine population trends, survival of marked animals, and model population dynamics).
B. Determine habitat characteristics and map habitat availability (to determine hibernacula characteristics, map potential habitats, and therefore determine what recovery would mean in a geographic and population sense).
C. Inventory for undiscovered colonies and habitats (to verify that marmots have or have not disappeared from parts of their historic range through surveys of historic sites and high-capability habitats).
D. Investigate dispersal (to understand how frequently marmots move from one colony to another and whether such movements are influenced by human activity).
E. Protect and manage important subalpine and logged habitats (to ensure protection of keystone colonies by incorporating important habitats into integrated management processes, identifying important habitats for long-term protection, and evaluating the effectiveness of habitat management activities).
F. Conduct intensive population management if warranted (including the development of a translocation plan, a pilot translocation, and operational translocations if necessary).
G. Develop public support through education, participation, and fundraising activities (to facilitate implementation of the recovery plan).

Two of the seven strategies are essentially completed (C: inventory for colonies and habitats, and D: dispersal study). Three strategies (A: population monitoring, E: habitat management, and G: develop public support through education, participation, and fundraising activities) have received much attention but represent ongoing commitments. The two remaining strategies (B: habitat mapping, and F: reintroductions) have seen progress, but more work is required (Bryant 1993; Demarchi et al. 1996).

3. Revisions to the 1994 recovery plan

The revised plan is based on four premises:

1. It is doubtful that significant new populations will be found north of Alberni Inlet, although this possibility exists.
2. South of Alberni Inlet, it appears unlikely that marmot populations will suddenly rebound of their own accord.
3. Another population expansion in the Nanaimo Lakes metapopulation, such as occurred during the early 1980s, would probably not result in increased geographic distribution (although it would give the Recovery Team transplant options that do not currently exist).
4. Captive breeding combined with reintroductions appears to present the best hope of increasing populations within a reasonable period of time.

At least seven of the world's 14 marmot species (*M. bobac*, *M. baibacina*, *M. menzbieri*, *M. marmota*, *M. monax*, *M. flaviventris*, *M. broweri*) have been successfully reared in captivity (Rymalov 1996; Rumiantsev and Rymalov 1998; K.B. Armitage, University of Kansas, pers. commun.). Reintroductions using both captive-reared and wild-captured marmots have been resoundingly successful, although some individual releases failed (Dimitriev et al. 1992; Ramousse et al. 1992).

The scale of required recovery activities dictates a shift in emphasis. Much of the 1994 recovery plan was focused on research and population monitoring. Many of the relevant questions are now answered, and the challenge now is to incorporate the results into an "operational" management plan and gather the political, corporate, and public support necessary to implement it.

4. Revised stepdown outline

The next five years will require that the Recovery Team invest heavily in several broad areas.

A. Population restoration

1) Captive breeding
- *a) Zoo-based programs*
- *b) Vancouver Island facility*

2) Reintroductions
- *a) Experimental reintroductions*
- *b) Operational reintroductions*

3) Planning
- *a) Captive breeding plan*
- *b) Reintroduction plan*
- *c) Contingency plan*

B. Monitoring and research

1) Population monitoring
- *a) Nonintensive population counts*
- *b) Intensive mark–recapture*
- *c) Radiotelemetry*

2) Research
- *a) Disease, parasites, and health*
- *b) Habitat*
- *c) Nutrition*
- *d) Behaviour*
- *e) Genetics*

C. Habitat protection and manipulation

1) Protection
- *a) Haley Lake Ecological Reserve*
- *b) Other habitats*

2) Manipulation
- *a) Clearcut habitats*
- *b) Natural meadows*
- *c) Predator–prey management*

D. Fundraising and communications

1) Fundraising
- *a) Prime funders*
- *b) Secondary funders*

2) Communications
- *a) Communications plan*

E. Management issues

1) Project management
- *a) Vancouver Island Marmot Recovery Team*
- *b) Marmot Recovery Foundation*
- *c) Friends of the Vancouver Island Marmot*

5. Narrative

The current "eggs in one basket" distribution is dangerous. Few animals exist for reintroductions or other management activities. If recent survival trends continue, the Recovery Team will be forced to consider last-minute rescue options in the near future.

It is unlikely that wild populations will suddenly rebound of their own accord. Captive breeding and reintroduction present the only chance of increasing populations within a reasonable period of time and minimizing the risk of extinction.

A. Population restoration

1. Captive breeding

We recommend a two-pronged approach, including a) establishment of a pilot captive breeding program with animals at more than one zoological institution, each with a demonstrated history of successful work with endangered species, and b) establishment of an operational breeding facility on Vancouver Island in an area of appropriate elevation and climatic conditions.

a. Zoo-based programs

The first phase involves zoo-based pilot programs in which small numbers of animals are reared under quarantine conditions and research initiatives are pursued in facilities equipped with the necessary veterinary and scientific expertise.

Zoo-based programs will secure against the risk of catastrophe and provide a long-term reservoir of genetic material. Zoo-based programs will also permit development of appropriate husbandry techniques. Consideration will be given to employing intensive genetic management tools such as *in vitro* fertilization, cross-fostering, and long-term gamete cryopreservation.

Six animals were transferred to the Toronto Zoo in 1997 to initiate the zoo-based program. This population was expanded in 1998, and a second captive population was established at the Calgary Zoo.

b. Vancouver Island facility

The second phase of the breeding program will be guided by experience gained from zoo-based programs. The overall approach will be to maintain larger numbers of animals in conditions resembling potential release habitats on Vancouver Island.

Marmot reintroductions elsewhere suggest that moderate numbers (~20 per year) of releasable animals are required to ensure a reasonable chance of success (Ramousse et al. 1992). The mathematics of marmot reproductive biology indicate that this will require maintenance of 40–80 marmots in captivity. A dedicated breeding facility is required to produce such numbers of releasable animals on an annual basis. The timing of reintroductions is impossible to estimate, but they will likely occur over a period of 5–15 years.

The most logical location for the facility is on Mount Washington. The site experiences environmental conditions similar to those at sites where marmots will be released and could provide marmots with pre-release exposure to natural sights, sounds, and foods. Mount Washington also provides year-round access and necessary utilities such as water and power.

Apart from simplifying the logistics of reintroduction, Mount Washington is already a summer destination for tourists. The opportunity exists to enhance public awareness of Vancouver Island marmots through adjacent interpretive projects.

Detailed planning for the Mount Washington breeding facility is under way. External experts (from zoos and academia) have been consulted to assist in design of the facility and to develop the necessary husbandry protocols. The plan is to be operational by late 2000.

Plans call for a phased approach to construction. The initial housing module will accommodate 20–80 marmots (14 pens), and a second module will be added later as requirements dictate. Experience gained from zoos and from the initial module will guide design of the second.

2. Reintroductions

Marmot reintroductions involving three species (*M. marmota*, *M. bobac*, and *M. baibacina*) have achieved notable success in a list of countries that includes Russia, Austria, Switzerland, Poland, Romania, France, and Spain (e.g., Dimitriev et al. 1992; Ramousse et al. 1992; Preleuthner et al. 1995).

The 1996 *M. vancouverensis* reintroduction provided some positive lessons, although it ultimately failed to reestablish marmots at that site. We learned to move animals and social groups, and we learned that individuals from different family groups will habituate to one another. That four of the six released animals remained on the release site, excavated old marmot burrows, and hibernated communally should be strong cause for optimism (Bryant et al. in press *b*).

a. Experimental reintroductions

Experimental reintroductions (i.e., those based on wild-captured animals) are no longer feasible, given current population size.

b. Operational reintroductions

Reintroductions have sometimes been successful after release of small numbers of animals (e.g., release of 18 animals in the Pyrenees in the early 1960s led to a population numbering several hundred today; Nebel and Franc 1992). However, a repeated theme from participants at the Third International Marmot Congress involved the need to release substantial numbers of animals repeatedly. The French experience, which is the most completely documented, typically involved release of 12–20 animals per year over a period of 3–5 years (Ramousse et al. 1992). Reintroductions on such a scale will likely not occur before the year 2003, given likely reproductive rates in captivity.

3. Planning

a. Captive breeding plan

The scale of planned captive breeding efforts dictates that husbandry protocols be formalized in a breeding plan. This plan will focus on methods of basic care, accommodation, hibernation, behaviour, group composition, genetics, nutrition, and health. Special attention will be devoted to the role that nutrition and hibernation play in marmot development and reproduction, and to the possibility that reproduction could be enhanced above that observed in wild populations.

b. Reintroduction plan

A formal reintroduction plan is not yet possible. Additional work is needed to identify and prioritize suitable reintroduction habitats and to determine how best to condition animals to the wild. The reintroduction plan must also consider behavioural issues, disease and predation risks, and future landscape changes.

c. Contingency plan

The vulnerability of *M. vancouverensis* to single catastrophic events cannot be overstated. Planning is under way to identify scenarios and options should populations crash in the wild. Arrangements to house marmots on short notice have already been made with several zoos and other institutions.

B. Monitoring and research

1. Population monitoring

a. Nonintensive population counts

Previous uncertainty over population size and distribution has been greatly clarified over the past few years. Although a few colonies probably remain undiscovered, it is unlikely that large numbers of marmots exist outside of the central Vancouver Island core area of distribution. Inventory efforts will continue, with emphasis on monitoring known colonies and assisting with research and management activities. New information on potential marmot colonies will continue to be investigated as a high priority.

b. Intensive mark–recapture

Ear-tagging is the only cost-effective means of distinguishing surviving animals and immigrants (Bryant 1998). Tagging also provides a benchmark against which to assess population counts (Bryant and Janz 1996) and test hypotheses about mortality factors, behaviour (Blumstein et al. in prep.), genetics, growth rates, or similar age- or sex-specific questions. Established mark–recapture protocols will be continued at a subset of colonies.

c. Radiotelemetry

Work over the last several years at the Sherk Lake and Mount Washington colonies revealed surprisingly high immigration rates, suggesting the possibility of nearby undiscovered colonies. In particular, two males on Mount Washington showed large weekly foraging movements compared with other marmot species (Barash 1989). This also permitted discovery of a previously unknown meadow (M. deLaronde, MELP, pers. commun.).

Radiotelemetry work using surgically implanted transmitters will continue, with the objective of discovering causes of mortality and gathering new data on dispersal and home range size. Results may have a profound bearing on the Recovery Team’s ability to identify suitable reintroduction habitats.

2. Research

a. Disease, parasites, and health

The loss of four transplanted animals in 1996 underlined the need for additional investigation of the health status of marmots. In 1998, the Recovery Team initiated a health study. This study included a review of literature and disease risks together with laboratory tests for *Yersinia* spp. and other diseases. Marmot health monitoring and environmental sampling protocols were also developed. Results are in preparation (N. deWith, University of Saskatchewan, pers. commun.).

b. Habitat

The question of why marmots no longer inhabit some areas is of fundamental importance. If climatic changes have altered historic habitats, efforts to reestablish colonies will fail, and there may be little that managers can do to enhance marmot populations. If, on the other hand, the problem is human-caused alteration of landscape connectivity, then transplants may be a simple means of population enhancement (e.g., Ramousse et al. 1992), and prospects for eventual recovery of the species are probably excellent.

North of Alberni Inlet, factors that played a role in the disappearance of the marmot from areas such as Strathcona Provincial Park are unknown. It is important to emphasize that factors that caused local extinction may still be playing a role there today. It is equally possible that local extinction occurred because of episodes of high mortality combined with inability to recolonize. More biophysical inventory and research are needed to assess habitat suitability in Strathcona Provincial Park, Schoen Lake Park, and elsewhere. A graduate student has initiated a habitat modelling project using data obtained from remote sensing. The habitat model will incorporate biophysical (vegetation, soils, aspect, snowmelt) and metapopulation (spatial structure, landscape conditions) considerations (J. Lewis, University of Calgary, pers. commun.). Dendrochronological and fire history work may shed further light on recent climatic trends and should be supported; ultimately, however, the only way in which to determine current habitat suitability will likely be through monitoring of reintroduced animals.

Maintaining marmots on southern Vancouver Island will require that those factors currently causing declines be eliminated. In the long term, it will be essential that we determine and adopt appropriate logging practices that would allow future harvest of the second-rotation, higher-elevation forests and yet not alter the landscape connectivity between adjacent marmot colonies.

c. Nutrition

Nutritional factors remain poorly understood but are potentially very important (e.g., Thorp et al. 1994). Research on nutritional conditions in captivity has begun at the Toronto Zoo. Baseline data will be compared with those obtained from the wild using a combination of scat analysis and direct measurement of nutritional characteristics of food plants. The focus of the research will be to evaluate possible differences among natural and clearcut marmot habitats and the role of nutrition in hibernation physiology and reproduction.

d. Behaviour

It is critical that animals reared in captivity display normal behaviour patterns (Griffith et al. 1989; Snyder et al. 1994). Conversely, captivity offers the potential for experiments not possible in the wild. For example, mating behaviour, estrous cycles, and the importance of communal hibernation are not clearly understood for *M. vancouverensis*. Captive animals will be maintained so as to maximize the research potential.

e. Genetics

Additional sampling and analytical work will be conducted to ensure maintenance of genetic diversity in captivity and characterize natural patterns of variation. Collection of hair and blood will continue as new animals are captured. Paternity analyses using existing samples are currently under way (L. Kruckenhauser, Institute for Medical Biology, Vienna, pers. commun.). Maximizing genetic variation in the captive population will require maintenance of a studbook and calculation of genetic effective population size (N_e).

C. Habitat protection and manipulation

1. Protection

a. Haley Lake Ecological Reserve

Efforts to expand the existing Haley Lake Ecological Reserve will be pursued in order to maintain the integrity of the bowl environment and associated lake-forest Eocene. The area is the archetype Vancouver Island marmot habitat and deserves a more appropriate buffer zone. However, efforts to increase the size of the reserve must be undertaken with the firm knowledge that it would have little positive benefit for marmots as a whole.

b. Other habitats

No other protected areas are recommended at this time.

2. Manipulation

a. Clearcut habitats

No widespread habitat manipulation is recommended at this time. Efforts to remove vegetation from clearcuts to enhance them for marmots must be carefully weighed on a site-specific basis. The same rationale applies to attempts to create additional marmot “condominiums” on logging roads scheduled for deactivation. While such activities might reduce predation, they might have no effect on mortality caused by poor nutrition, disease, or other factors and might simply encourage additional animals to colonize suboptimal habitat.

This is not to say that animals in clearcuts are unimportant. In some cases, clearcut colonies will provide critical genetic material for the captive population. Clearcut colonies that expand quickly might provide additional opportunities for reintroductions using wild-captured animals.

b. Natural meadows

For particular natural sites where evidence suggests that tree invasion is creating a problem (e.g., Gemini Peak), vegetation management may be an appropriate management tool and will be used. We recognize that it will be difficult to test the efficacy of such experiments, given current low population sizes.

c. Predator–prey management

Vancouver Island marmots have not suddenly been exposed to a new predator (e.g., Vitousek 1988). *Marmota vancouverensis* has evolved in the presence of wolves, cougars, and eagles, it exhibits a variety of typical antipredator strategies that reduce predation risk, and indeed it appears to be no less vigilant than other marmots (Blumstein et al. in prep.).

Available data show no clear association between marmot survival rates and predator abundance (Bryant 1998). However, we know that abundance of major prey (deer) has declined, and there is evidence of increasing wolf and cougar numbers since 1990. The significance of predation does not necessarily require increasing predator numbers. Changes in the landscape due to forestry may increase hunting opportunities by predators. These changes have concentrated marmots, reduced deer winter ranges, and created a network of roads that may channel both predators and prey along travel corridors (Simberloff et al. 1992).

Individual predators could exert a profound effect on marmot colonies, particularly when numbers of major prey (deer) and minor prey (marmots) are low. Efforts to increase human harvest of predators and restrict harvest of prey by manipulation of hunting and trapping seasons may help to restore a more balanced predator:prey ratio and reduce predation pressure on marmots. Individual predators will be removed if evidence reveals that they are targeting specific colonies.

D. Fundraising and communications

The Recovery Project faces increasing financial challenges as the scale of recovery efforts changes from that of a research project to that of an implemented recovery project. Five-year projected costs of $3.75 million require development of substantial new fundraising capabilities, and communications are at the heart of these.

1. Fundraising

For revenues, a complex partnership involving government, business, and public support must be structured. The $1.5 million target for revenues to be raised publicly will require a sophisticated fundraising campaign.

a. Prime funders

A syndicate of government ministries and forest companies must be negotiated to provide full five-year funding as the financial safety net. We believe that it would be irresponsible to begin large-scale captive breeding without securing a minimum five-year funding commitment. The extent of prime funder payments towards revenue requirement will depend on the success of complementary public fundraising efforts.

b. Secondary funders

Potential success of public fundraising cannot be presumed. Market feasibility must be determined by professional testing. Soliciting contributions from targeted and general public audiences can be done in a variety of ways. A project with negligible public profile cannot expect to successfully attract public gifts until it has established a positive public profile at a threshold level. Significant marketing research must be conducted in years 1 and 2.

The popular “adoption” program will be continued, but the increasing scale of the program requires redesign of materials, process, and donor “fulfilment” practices.

2. Communications

Communications plans and fundraising plans are interdependent. Communications objectives are to provide primary funders with appropriate recognition and raise public awareness of Vancouver Island marmots in support of direct-response public fundraising.

a. Communications plan

A communications plan will be developed following assessment of baseline test results (focus groups, telephone surveys, and test mailings) and perceived feasibility of public funds solicitation. The potential of communications vehicles such as posters, brochures, fact sheets, and radio, TV, and print media will be assessed in light of communication objectives determined through market research.

E. Management issues

As the project is implemented, proper handling of management and administrative matters becomes as critical to success as good science. Effective management and sound financial stewardship are essential to maintaining the support of funding partners and organizations.

The roles and responsibilities of committees and organizations responsible for recovery efforts need to be adjusted to reflect a growing public profile, increasing funds to manage, complex activities to coordinate, and the deadlines and deliverables expected by funding organizations and partners. This new operating environment will demand more clearly defined roles, responsibilities, and accountabilities among the various organizations involved. Professionally planned and executed budgets and a refined accounting and financial management reporting system will also be required to properly implement the plan.

1. Project management

a. Vancouver Island Marmot Recovery Team

The Recovery Team is the scientific committee established under RENEW (Recovery of Nationally Endangered Wildlife) and MELP (B.C. Ministry of Environment, Lands and Parks). The latter agency has legal authority for management of *M. vancouverensis* under the *Wildlife Act*. Under the chairmanship of MELP, the Recovery Team will continue to be responsible for developing and updating the recovery plan, advising other bodies on the implications of various actions on marmot recovery, and reviewing all documents associated with marmot recovery.

The Recovery Team is not a legal entity and therefore lacks the ability to enter into contracts and financial transactions with other organizations. To date, the Recovery Team has essentially functioned as a board of directors that governed the overall direction of recovery actions, while remaining largely divorced from day-to-day management decisions. These, in turn, were largely handled within respective member agencies and organizations.

The growing scale of recovery activities has forced realization that this structure is no longer adequate. Accordingly, many of these responsibilities will be transferred to the newly established Marmot Recovery Foundation. This body will essentially serve as the “implementation arm” of the Recovery Team.

This organizational structure recognizes the Recovery Team as the fundamental authority behind the project. The Recovery Team will continue to be responsible for providing annual operational plans and research priorities. Direct connection will be retained between the Marmot Recovery Foundation and the Recovery Team by having some members that serve on both organizations.

Recent additions to the Recovery Team reflect an increase in public profile, workload, and need for specialized biological expertise (e.g., disease and captive breeding). Further work is required in structuring the Recovery Team to include working groups and/or subcommittees with explicit responsibilities and reporting structures. In particular, the Recovery Team will engage external scientific advisors to help develop and evaluate research proposals and to provide independent peer review of results.

b. Marmot Recovery Foundation

The Marmot Recovery Foundation has been established and incorporated under the *British Columbia Society Act* to produce an entity responsible for coordinating and administering recovery actions for the Vancouver Island marmot (Appendix 7).

The purpose of this Foundation is to fund, facilitate, promote, and carry out activities necessary to assist and enhance the survival of this species. As a registered charity, it can receive donations of funds and property and invest and distribute these assets as appropriate. The Foundation can enter into contracts, hire employees, purchase or lease property, and incur debt as necessary for its purposes. Directors of the Foundation are selected for the strengths and skills required in a charitable organization (e.g., administration, fundraising, communications, politics, finance, and law).

Eventually, two permanent positions will report directly to the Marmot Recovery Foundation. The Project Manager will be responsible for overseeing implementation of the recovery plan, developing and implementing operational plans and budgets, and being responsible for day-to-day management decisions. The Chief Scientist will be responsible for developing and implementing research projects, maintaining appropriate data standards, evaluating the scientific basis of proposed recovery actions, and communicating results to the Recovery Team, the scientific community, and the public.

The Marmot Recovery Foundation will provide the strong financial stewardship and efficient project management essential to wring the best value out of contributors' funds and to meet participants' expectations for fiscal accountability. Activities and funds currently being handled by various members of the Recovery Team will be consolidated under the Marmot Recovery Foundation's financial system.

c. Friends of the Vancouver Island Marmot

The Friends of the Vancouver Island Marmot or "blue-ribbon committee" is an organization appointed by, and reporting to, the B.C. Minister of Environment, Lands and Parks. Its role is to assist the Recovery Team and the Marmot Recovery Foundation in promoting public awareness and fundraising activities. Members are selected based on their high public profile, communications skills, and interest in conservation issues.

Section III
Implementation schedule

Type	Activity	1998	1999	2000	2001	2002
A) Population restoration						
Captive breeding						
A1a	Zoo-based programs	expansion	expansion	expansion	maintain	maintain
A1b	Vancouver Island facility	planning	planning	construct	operational	
Reintroductions						
A2a	Experimental reintroductions	none	none	none	none	?
A2b	Operational reintroductions	none	none	none	planning	operational?
Planning						
A3a	Captive breeding plan		completed			
A3b	Reintroduction plan		begins	in prep.	completed	
A3c	Contingency plan		completed			
B) Monitoring and research						
Population monitoring						
B1a	Nonintensive population counts	ongoing	ongoing	ongoing	ongoing	ongoing
B1b	Intensive mark–recapture	ongoing	ongoing	ongoing	ongoing	ongoing
B1c	Radiotelemetry	ongoing	ongoing	?	?	?
Research						
B2a	Disease, parasites, and health	begins	ongoing	ongoing	?	?
B2b	Habitat	?	begins	ongoing	completion	?
B2c	Nutrition	?	begins	ongoing	completion	?
B2d	Behaviour	?		begins	ongoing	completion
B2e	Genetics	?	begins	ongoing	completion	
C) Habitat protection and manipulation						
Protection						
C1a	Haley Lake Ecological Reserve	ongoing	ongoing	ongoing	ongoing	ongoing
C1b	Other habitats	ongoing	ongoing	ongoing	ongoing	ongoing
Manipulation						
C2a	Clearcut habitats	none	none	none	none	none
C2b	Natural meadows	planning	?	?	?	?
C2c	Predator–prey management	?	?	?	?	?
D) Fundraising and communications						
Fundraising						
D1a	Prime funders	ongoing	ongoing	ongoing	ongoing	ongoing
D1b	Secondary funders	ongoing	ongoing	ongoing	ongoing	ongoing
Communications						
D2a	Communications plan	planning	ongoing	ongoing	ongoing	ongoing
E) Management issues						
Project management						
E1a	Vancouver Island Marmot Recovery Team	planning	ongoing	ongoing	ongoing	ongoing
E1b	Marmot Recovery Foundation	planning	ongoing	ongoing	ongoing	ongoing
E1c	Friends of the Vancouver Island Marmot	planning	ongoing	?	?	?

Section IV
Literature cited

Arnold, W. 1990*a*. The evolution of marmot sociality: I. Why disperse late? *Behavioral Ecology and Sociobiology* 27: 229–237.

Arnold, W. 1990*b*. The evolution of marmot sociality: II. Costs and benefits of joint hibernation. *Behavioral Ecology and Sociobiology* 27: 239–246.

Arnold, W. 1992. Social evolution and obligatory group hibernation in marmots. Pages 41–54 *in* B. Bassano, P. Durio, U. Gallo Orsi, and E. Macchi (Editors): *Proceedings, International Symposium on Alpine Marmot and Genus Marmota*. University of Turin (Turin, Italy). 268 pp.

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

Barash, D.P. 1973. The social biology of the Olympic marmot. *Animal Behavior Monographs* 6: 171–245.

Barash, D.P. 1989. *Marmots: social behavior and ecology*. Stanford University Press (Stanford, CA). 360 pp.

Bergerud, A.T. 1983. Prey switching in a simple ecosystem. *Scientific American* 249: 130–141.

Blumstein, D.T., J.C. Daniel, and A.A. Bryant. In prep. Antipredator behavior of Vancouver Island marmots: using congeners to evaluate abilities of a critically endangered mammal. Manuscript.

Brown, J.H. and A. Kodric-Brown. 1977. Turnover rates in insular biogeography: effect of immigration on extinction. *Ecology* 58: 445–449.

Bryant, A.A. 1990. Genetic variability and minimum viable populations in the Vancouver Island marmot (*Marmota vancouverensis*). M.E.Des. thesis, University of Calgary (Calgary, AB). 101 pp.

Bryant, A.A. 1993. Locations of potential Vancouver Island marmot habitats within Strathcona Provincial Park. Unpublished report to B.C. Parks (Parksville, BC). 7 pp. and 6 maps.

Bryant, A.A. 1995. Unsuccessful searches for Vancouver Island marmots, 1972–1994. Unpublished report to the Vancouver Island Marmot Recovery Team (Nanaimo, BC). 8 pp.

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

Bryant, A.A. 1996*b*. Demography of Vancouver Island marmots (*Marmota vancouverensis*) in natural and clearcut environments. Pages 157–168 *in* M. LeBerre, R. Ramousse, and L. Le Guelte (Editors): *Biodiversity in marmots*. International Marmot Network (Moscow-Lyon). 276 pp.

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

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

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

Bryant, A.A., D.W. Janz, M.C. deLaronde, and D.D. Doyle. In press (*a*). Recent Vancouver Island marmot (*Marmota vancouverensis*) population changes. *Proceedings, Third Congress on Genus Marmota* (Cheboksary, Russia, 25–30 August 1997).

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

Cunningham, A.A. 1996. Disease risks of wildlife translocations. *Conservation Biology* 10: 349–353.

Demarchi, D.A., L. Bonner, L. Lacelle, S. Moss, and B. von Sacken. 1996. Biophysical analysis of Vancouver Island marmot habitat. Unpublished report to B.C. Ministry of Environment, Lands and Parks (Victoria, BC). 21 pp.

Dimitriev, A.V., M.N. Leontieva, I.B. Abrakhina, M.A. Barmin, A.Yu. Isaev, V.A. Kuvshinov, V.G. Marphin, Z.N. Plechova, and R.I. Shiyan. 1992. Modern state and prospects of reacclimatization of the bobac (*Marmota bobac* Müll) in the Volga region. Pages 27–44 *in* V.Yu. Rumiantsev (Editor): *Actual problems of marmots investigation*. Russian Academy of Science (Moscow).

Farand, E., D. Allaine, and J. Coulon. In press. Survival of the alpine marmot (*Marmota marmota*): a capture–recapture study of the population from La Saussiere, France. *Proceedings, Third Congress on Genus Marmota* (Cheboksary, Russia, 25–30 August 1997).

Griffith, B., J.M. Scott, J.W. Carpenter, and C. Reed. 1989. Translocation as a species conservation tool: status and strategy. *Science* 245: 477–480.

Groombridge, B. and G. Mace. 1994. *The 1994 list of threatened animals.* International Union for the Conservation of Nature and Natural Resources (Gland, Switzerland). 286 pp.

Harestad, A.S. and G.W. Jones. 1981. Use of night counts for censusing black-tailed deer on Vancouver Island. Pages 83–96 *in* F.L Miller, A. Gunn, and S.R. Hieb (Editors): *Symposium on census and inventory methods for populations and habitats*. University of Idaho (Moscow, ID). 220 pp.

Heard, D.C. 1977. The behaviour of Vancouver Island marmots (*Marmota vancouverensis*). M.Sc. thesis, University of British Columbia (Vancouver, BC). 129 pp.

Hyntka, J. 1990. Strathcona Park master plan background report. Unpublished report to B.C. Parks (Victoria, BC). 186 pp.

Janz, D., C. Blumensaat, N.K. Dawe, B. Harper, S. Leigh-Spencer, W. Munro, and D. Nagorsen. 1994. National recovery plan for the Vancouver Island marmot. Report No. 10. Recovery of Nationally Endangered Wildlife Committee (Ottawa, ON). 32 pp.

Kuramoto, R.T. and L.C. Bliss. 1970. Ecology of subalpine meadows in the Olympic Mountains, Washington. *Ecological Monographs* 40: 317–347.

Lande, R. 1988. Genetics and demography in biological conservation. *Science* 241: 1455–1460.

Laroque, C.P. 1998. Tree invasion in subalpine Vancouver Island marmot meadows. Unpublished report to the B.C. Environmental Research Scholarship Committee (Victoria, BC). 36 pp.

Lertzman, K., D. Gavin, D. Hallett, L. Brubaker, D. Lepfosky, and R. Mathewes. 1998. Long-term fire histories and the dynamics of wet coastal forests. Pages 93–94 *in* J.A. Trofmyow and A. MacKinnon (Editors): *Structure, processes and diversity in successional forests of coastal British Columbia.* Canadian Forest Service (Victoria, BC). 151 pp.

Mace, T.F. and C.D. Shepard. 1981. Helminths of a Vancouver Island marmot *Marmota vancouverensis*, with a description of *Diandrya vancouverensis* sp. Nov. (Cestoda: Anoplocephalidae). *Canadian Journal of Zoology* 59: 790–792.

Milko, R.J. 1984. Vegetation and foraging ecology of the Vancouver Island marmot (*Marmota vancouverensis*). M.Sc. thesis, University of Victoria (Victoria, BC). 127 pp.

Munro, W.T., D.W. Janz, V. Heinsalu, and G.W. Smith. 1985. The Vancouver Island marmot: status and management plan. B.C. Ministry of Environment Wildlife Bulletin B-39 (Victoria, BC). 24 pp.

Nebel, D. and R. Franc. 1992. Introduction of the marmot (*Marmota marmota*) into the Mont-Vallier nature reserve and the history of its subsequent colonisation, 1961–1991. Pages 253–256 *in* B. Bassano, P. Durio, U. Gallo Orsi, and E. Macchi (Editors): *Proceedings, International Symposium on Alpine Marmot and Genus Marmota*. University of Turin (Turin, Italy). 268 pp.

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

Pulliam, H.R. 1988. Sources, sinks and population regulation. *American Naturalist* 132: 652–661.

Ramousse, R., J.P. Martinet, and M. Le Berre. 1992. Twenty years of re-introduction policy of alpine marmots from the national park of La Vanoise. Pages 171–177 *in* B. Bassano, P. Durio, U. Gallo Orsi, and E. Macchi (Editors): *Proceedings, International Symposium on Alpine Marmot and Genus Marmota*. University of Turin (Turin, Italy). 268 pp.

Rochefort, R.M., R.L. Little, A. Woodward, and D.L. Peterson. 1994. Changes in the tree-line distribution in western North America: a review of climatic and other factors. *The Holocene* 4: 89–100.

Rumiantsev, V.Yu. and I.V. Rymalov. 1998. Captive breeding of marmots in the former Soviet Union. Unpublished report to the Vancouver Island Marmot Recovery Team (Nanaimo, BC). 20 pp.

Rymalov, I.V. 1996. Hibernation and breeding of *Marmota bobac*. Pages 203–208 *in* M. LeBerre, R. Ramousse, and L. Le Guelte (Editors): *Biodiversity in marmots*. International Marmot Network (Moscow-Lyon). 276 pp.

Rymalov, I.V. and A.Y. Maximov. 1992. Hibernation of marmots in captivity. Pages 63–66 *in* B. Bassano, P. Durio, U. Gallo Orsi, and E. Macchi (Editors): *Proceedings, International Symposium on Alpine Marmot and Genus Marmota*. University of Turin (Turin, Italy). 268 pp.

Simberloff, D., J.A. Farr, J. Cox, and D.W. Mehlman. 1992. Movement corridors: conservation bargains or poor investments? *Conservation Biology* 6: 493–504.

Sinclair, A.R.E., C.J. Krebs, and J.N.M. Smith. 1982. Diet quality and food limitation in herbivores: the case of the snowshoe hare. *Canadian Journal of Zoology* 60: 889–897.

Snyder, N.F.R., S.E. Koenig, J. Koschmann, H.A. Snyder, and T.B. Johnson. 1994. Thick-billed parrot releases in Arizona. *Condor* 96: 845–862.

Steppan, S.J., M.R. Akhverdyan, E.A. Lyapunova, D.G. Fraser, N.N. Vorontsov, R.S. Hoffmann, and M.J. Braun. In press. Molecular phylogeny of the marmots (Rodentia: Sciuridae): Tests of evolutionary and biogeographic hypotheses. *Systematic Biology*.

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

Tokarsky, V.A. 1996. Biology, behaviour and breeding black-capped marmots (*Marmota camtschatica* Pall.) in captivity. Pages 257–260 *in* M. LeBerre, R. Ramousse, and L. Le Guelte (Editors): *Biodiversity in marmots*. International Marmot Network (Moscow-Lyon). 276 pp.

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

Vitousek, P.M. 1988. Diversity and biological invasions of oceanic islands. Pages 181–189 *in* E.O. Wilson (Editor): *Biodiversity*. National Academy Press (Washington, DC). 521 pp.

Wilson, D.E. and D.M. Reeder. 1993. *Mammal species of the world: a taxonomic and geographic reference*. Smithsonian Institution Press (Washington, DC). 1206 pp.

Section V
Appendices

Appendix 1
Survey effort and probable count success at known marmot colonies, 1972–1998

Year	Number of colonies counted	Total number of counts	Number of juvenile counts*	Number of adults seen	Number of juveniles seen	Effective counts per colony	Probable success rate
1972	2	4	4	13	0	2.0	0.66
1973	6	11	9	18	8	1.8	0.64
1974	7	19	12	35	7	2.7	0.71
1975	1	1	1	5	8	1.0	0.54
1976	3	3	2	11	0	1.0	0.54
1977	2	3	3	12	0	1.5	0.61
1978	4	5	5	19	7	1.3	0.58
1979	14	20	4	51	2	1.4	0.60
1980	18	41	35	63	41	2.3	0.68
1981	19	50	27	105	34	2.6	0.71
1982	30	99	58	148	24	3.3	0.75
1983	30	80	47	140	23	2.7	0.71
1984	37	101	73	167	68	2.7	0.71
1985	25	38	14	108	31	1.5	0.61
1986	34	113	73	150	40	3.3	0.75
1987	17	35	15	57	5	1.2	0.57
1988	16	47	22	69	36	1.6	0.62
1989	15	41	17	97	13	1.1	0.55
1990	9	18	18	48	5	1.0	0.54
1991	7	24	21	38	18	1.3	0.59
1992	18	64	51	90	11	1.5	0.61
1993	32	126	84	86	34	1.6	0.62
1994	32	130	81	97	64	2.1	0.67
1995	41	162	75	86	19	2.5	0.70
1996	41	234	117	72	31	4.1	0.78
1997	36	242	109	71	11	4.2	0.79
1998	40	227	109	50	21	3.9	0.78
mean	20.8	74.4	41.9			2.1	0.7
SD	13.8	73.7	37.9			1.0	0.1

* Denotes counts made after 1 July, when juveniles first emerge.

Appendix 2a
Nearest colony-neighbour distances for marmot colonizations and random sites. Distances for actual colonizations were measured to the nearest occupied colony in natural subalpine habitat known to be extant at that time. Random clearcuts were selected of appropriate age (0–15 years) and elevation (>700 m) to represent colonization events if all locations were equally accessible by marmots.

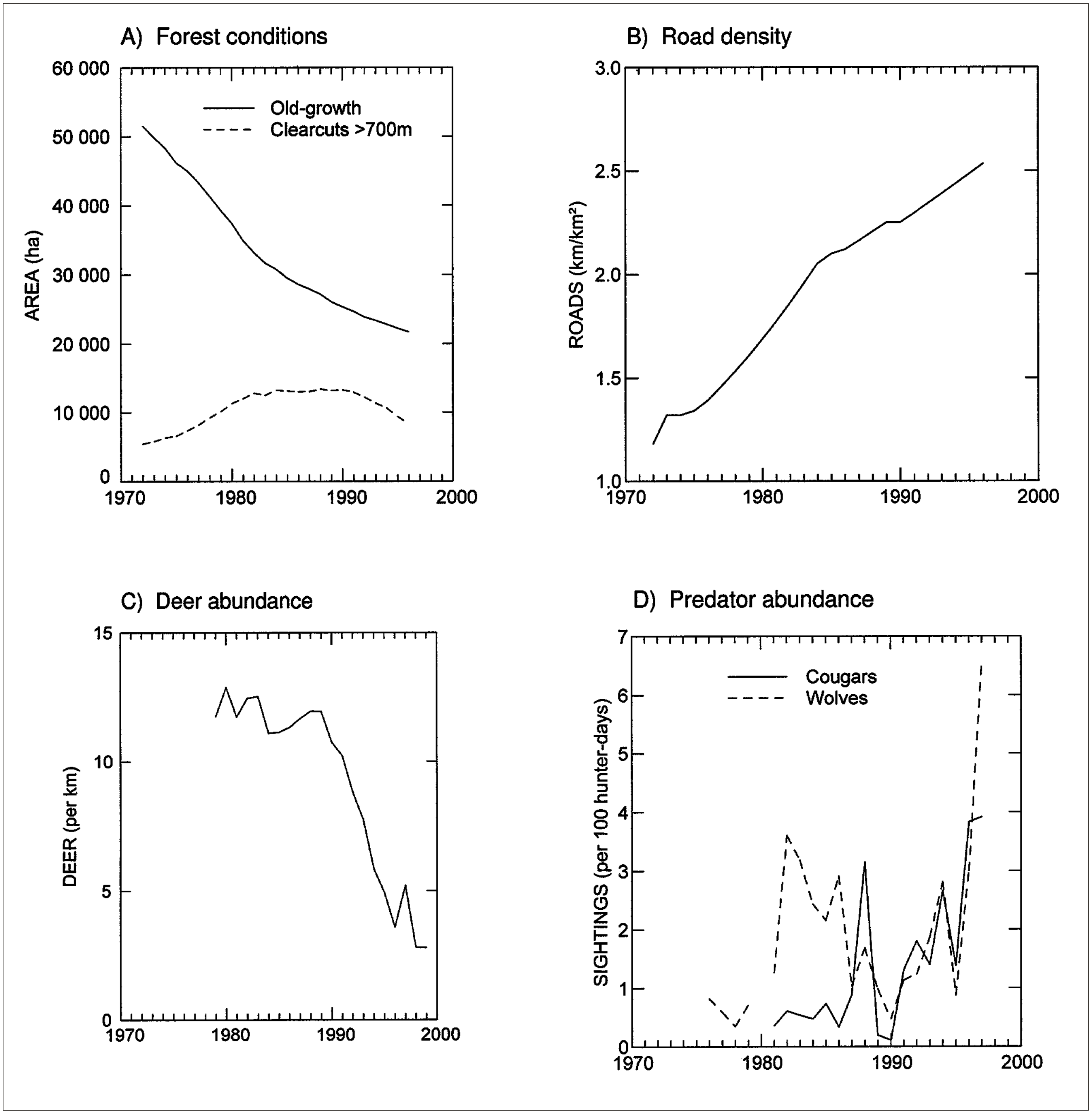
	N	Mean nearest-colony distance (km)	SD	*t*	df	*P* value
Actual colonizations	10	1.40	1.46	–5.29	35	<0.001
Virtual colonizations	30	5.47	3.37			

Appendix 2b
Effect of increasing isolation on apparent marmot survival. Logistic regression indicated that "apparent" adult survival was negatively associated with increased isolation, but juvenile survival was not. This supports the hypothesis that peripheral colonies receive fewer immigrants.

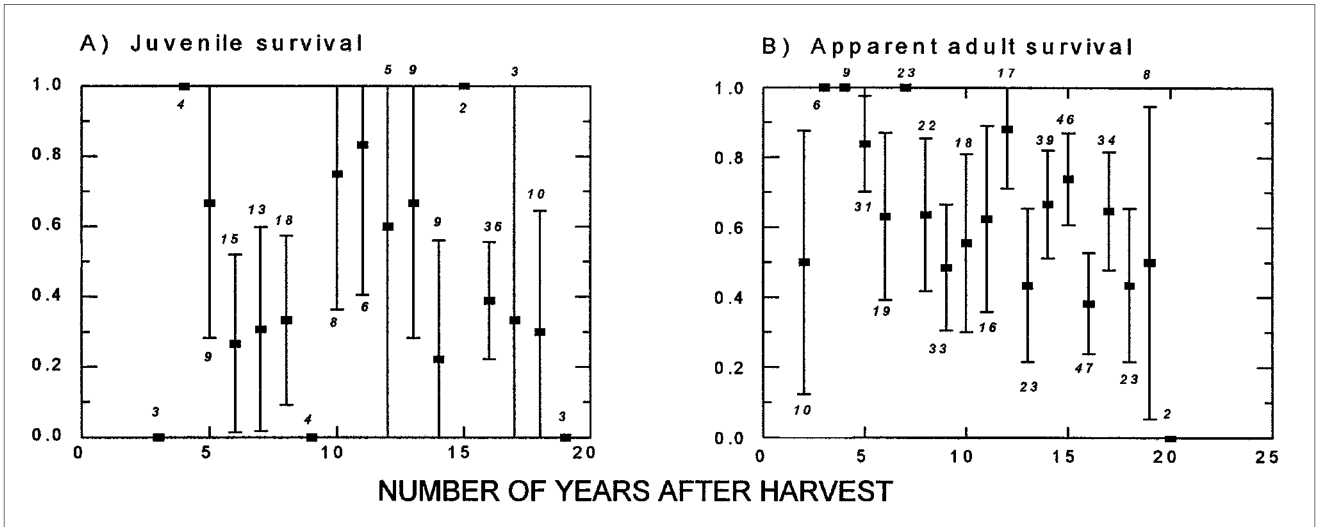
	Effect of isolation on survival				
	N	Odds ratio	Coefficient	Rho^2	*P* value
Adult survival + net immigration	1144	0.960	–0.041	0.070	0.002
Juvenile survival	334	1.018	0.018	0.009	0.483

Appendix 3

Temporal trends in landscape conditions and predator–prey abundance. Data are A) hectares of old-growth forest and potential clearcut marmot habitats (clearcuts above 700 m in elevation and 0–15 years old), B) road density (in linear km of road per km²), C) deer abundance (numbers per km), and D) wolves and cougars seen by hunters (numbers per 100 deer hunter-days). Updated from Bryant (1998).



Appendix 4a
Effect of increasing clearcut age on marmot survival. Data are mean and 95% confidence survival estimates based on consecutive annual counts of juveniles (A) and ear-tagged adults (B). From Bryant (1998).



Appendix 4b
Logistic regression of survival against age of regenerating clearcuts. Results indicate a significant effect for adults but not for juveniles. For adults, the magnitude of the effect was small (i.e., an odds ratio close to 1.0) but highly significant. From Bryant (1998).

	Effect of clearcut age on survival				
	N	Odds ratio	Coefficient	*Rho*^{2}	*P* value
All juveniles (tagged and untagged)	157	0.978	–0.022	0.002	0.532
Nonintensive adult survival (counts)	284	0.910	–0.094	0.035	0.000
Tagged adults (intensively studied)	121	0.911	–0.093	0.025	0.002

Appendix 5
Timing of last observation of ear-tagged marmots. Data are from 97 tagged adults and yearlings that disappeared for at least one active season. Last observation was not independent of habitat type (χ^2 = 12.3 with 4 df, $P < 0.025$). Adult disappearances in clearcuts appear to be more concentrated in late summer, suggesting winter mortality. From Bryant (1998).

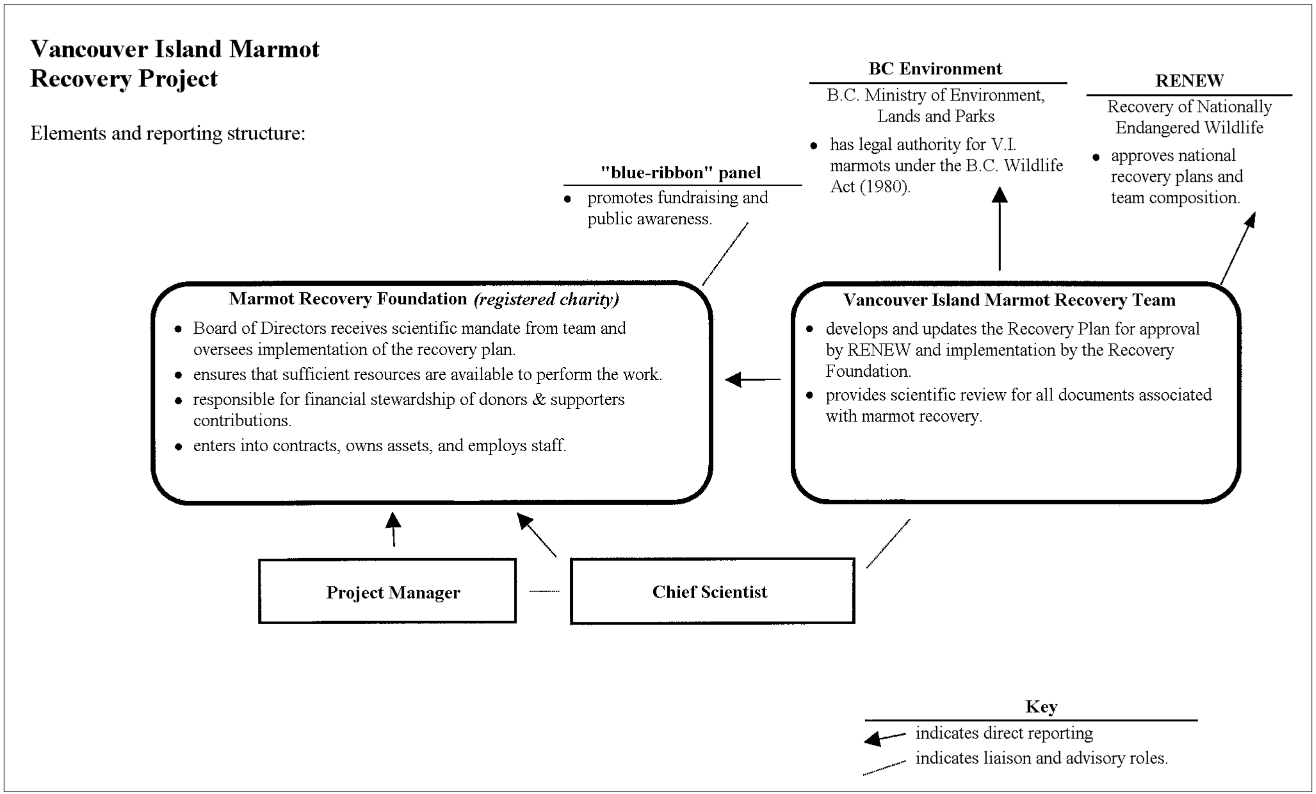
Habitat type	May	June	July	August	September	Totals
Natural colonies	12	9	2	9	14	46
Clearcut colonies	7	4	10	19	11	51
Totals	19	13	12	28	25	

Appendix 6
Effect of weather variables on marmot survival in natural and clearcut habitats. All logistic regressions were highly significant but explained only small amounts of the overall variation in survival (McFadden's *Rho* statistic <0.2).*

Test variable	Key to variables	Odds ratio	Coefficient	*P* value	*Rho*^{2} statistic	Overall *P* value
Natural colonies						
Juveniles (n = 162 records)					0.118	<0.001
MAYTEMP	May–June average temperature	2.280	0.824	0.037		
MAYDAYS	May–June days with rainfall	1.443	0.367	0.000		
SUMDAYS	July–August days with rainfall	1.683	0.521	0.021		
SNOEARLY	December–February snowpack	0.956	–0.045	0.003		
SNOWJUN1	June snowpack (next spring)	0.992	–0.008	0.011		
SNOWJUN	June snowpack (current year)	1.026	0.026	0.057		
Adults (n = 638 records)					0.038	<0.001
ASPECT	Aspect (exposed)	1.666	0.510	0.075		
MAYTEMP	May–June average temperature	1.374	0.318	0.000		
MAYRAIN	May–June cumulative rainfall	0.462	–0.772	0.002		
MAYDAYS	May–June days with >5 mm rainfall	1.337	0.290	0.000		
SNOEARLY	December–February snowpack	0.993	–0.007	0.003		
SNOWJUN1	May–June snowpack (next spring)	1.002	0.002	0.069		
SNOWJUN	May–June average snowpack	1.006	0.006	0.004		
Clearcut colonies						
Juveniles (n = 142 records)					0.056	0.029
MAYDAYS	May–June days with >5 mm of rainfall	1.301	0.263	0.037		
SUMRAIN	July–August rainfall	9.268	2.227	0.032		
SUMDAYS	July–August days with >5 mm of rainfall	0.516	–0.662	0.059		
SNOEARLY	December–February snowpack	0.987	–0.013	0.080		
Adults (n = 388 records)					0.055	<0.001
MAYTEMP	May–June average temperature	1.211	0.191	0.034		
MAYRAIN	May–June cumulative rainfall	0.260	–1.020	0.002		
MAYDAYS	May–June days with rainfall	1.232	0.209	0.006		
SUMRAIN	July–August cumulative rainfall	0.325	–1.123	0.001		
SUMDAY	July–August days with >5 mm of rainfall	1.422	0.352	0.005		
SNOEARLY	December–February snowpack	1.004	0.004	0.086		

* The regression model statement was Survival = Elevation + Aspect + Mayrain + Maydays + Maytemp + Sumrain + Sumtemp + Sumdays + Snowjun + Snowjun1 + Snoearly.

Appendix 7
Recommended Vancouver Island Marmot Recovery Project structure



Previous RENEW Reports

1. Canadian Whooping Crane Recovery Plan — December 1987
2. *Anatum* Peregrine Falcon Recovery Plan — October 1988
3. National Recovery Plan for the Baird's Sparrow — April 1993
4. National Recovery Plan for the Roseate Tern — June 1993
5. National Recovery Plan for the Greater Prairie-Chicken — October 1993
6. National Recovery Plan for the Whooping Crane — January 1994
7. National Recovery Plan for the Loggerhead Shrike — March 1994
8. National Recovery Plan for the Marbled Murrelet — May 1994
9. National Recovery Plan for the Gaspésie Caribou — November 1994
10. National Recovery Plan for the Vancouver Island Marmot — December 1994
11. National Recovery Plan for the Ferruginous Hawk — December 1994
12. National Recovery Plan for the Harlequin Duck in Eastern North America — March 1995
13. National Recovery Plan for the Burrowing Owl — April 1995
14. National Recovery Plan for the Newfoundland Marten — August 1995
15. National Recovery Plan for the Swift Fox — April 1996
16. National Recovery Plan for the Blanchard's Cricket Frog — March 1997
17. National Recovery Plan for the Henslow's Sparrow — August 1997
18. National Recovery Plan for Blandings Turtle (*Emydoidea blandingii*) Nova Scotia population — January 1999

Recovery of Nationally Endangered Wildlife

In 1988, the Wildlife Ministers' Council of Canada endorsed a new strategy to rescue wildlife species at risk of extinction and to prevent other species from becoming at risk. Called RENEW (the acronym for Recovery of Nationally Endangered Wildlife), the strategy brings together all agencies, organizations, and interested individuals to work as a team for the recovery of wildlife at risk. RENEW focuses on those species or populations that have been designated as extirpated, endangered, or threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The responsible jurisdictions establish a National Recovery Team of experts for each species to produce a recovery plan, which then becomes the basis for a recovery program carried out by the responsible governments in cooperation with universities, non-government organizations, businesses, and private citizens.

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