RENEW Report No. 10 December 1994

NATIONAL RECOVERY
PLAN FOR THE

VANCOUVER ISLAND MARMOT

Recovery of Nationally Endangered Wildlife

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NATIONAL RECOVERY
PLAN FOR THE

VANCOUVER ISLAND MARMOT

Prepared by the
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For the

Recovery of Nationally Endangered Wildlife Committee

Approved D Gaskett

Date: 1994 12 19

Disclaimer

This recovery plan has been prepared for submission to RENEW by the Vancouver Island Marmot Recovery Team, in consultation with others, to define recovery actions that are deemed necessary to protect and recover the species. It does not necessarily represent the views of the individual team members 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. Earlier drafts benefitted from critical review by C.W. (Bud) Smith, Joe Bryant and Chris Shank. The initial compilation and drafting of the plan was done by A.A. Bryant under a contract with the Wildlife Branch of the British Columbia Ministry of Environment. We are indebted to all those who collected data on Marmota vancouverensis, especially A.A. Bryant and G.W. Smith, or who otherwise provided the scientific guidelines upon which to base this recovery plan. The Vancouver Island Marmot Public Liaison Committee provided a small public forum where, over the years, several team members were exposed to lively debate, which influenced their approach to marmot management.

Citation for this recovery plan is as follows:

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

Correspondence about RENEW should be sent to Recovery of Nationally Endangered Wildlife. Ottawa, Ontario K1A 0H3

RENEW gratefully acknowledges the help of the Canadian Wildlife Service in the production of this report and of the Canadian Wildlife Federation in its printing, distribution, and cover illustration.
Copies of this publication may be obtained from the Canadian Wildlife Federation, 2740 Queensview Drive, Ottawa, Ontario K2B 1A2
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Également disponible en francais sous le titre *Plan national de rétablissement de la marmotte de l'ile de Vancouver.*

Catalogue no. CW69-11/9-1994E
ISBN 0-662-20960-5

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Recovery plan summary

The Vancouver Island marmot *Marmota vancouverensis* is the only endemic mammal species in Canada that has been listed as "endangered" either by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) or by any provincial or territorial government Surveys suggest one metapopulation of 200-300 individuals concentrated in the Nanaimo-Cowichan Lake region. Data on historical distribution and abundance are limited, but marmots have apparently disappeared from some parts of Vancouver Island. Causes are unknown.

In 1938 a Recovery Team was established to prepare an action plan that, when implemented, would result in populations of sufficient size and distribution to remove the Vancouver Island marmot from the endangered list. Population objectives are based on the need to prevent inbreeding, maintain long-term genetic variability, and reduce the vulnerability of marmot colonies to extinction through random environmental events. Annual monitoring of existing populations and a complete inventory of habitat and marmot populations throughout Vancouver Island are the most pressing needs.

The team recommends a total population objective of 400-600 marmots dispersed in three metapopulations on Vancouver Island. Although the existing population appears to be genetically viable, the recovery team considers that downlisting of the species from "endangered" to "threatened" should not occur until a population of 300-400 animals is established in two metapopulations.

Seven strategies are required to meet the recovery goal and objectives. These are as follows:

A. Monitor known populations.
B. Determine habitat requirements and map habitat.
C. Search for undiscovered colonies and habitats.
D. Investigate dispersal characteristics.
E. Protect and manage important subalpine and logged habitats.
F. Conduct intensive population management if warranted.
G. Develop public support through education, public participation, and fund-raising activities.

The Wildlife Branch, British Columbia Ministry of Environment, Lands and Parks (BCMELP), is the lead agency responsible for implementing the overall plan. Other agencies and organizations, including B.C. Parks (a branch of BCMELP), the Royal B.C. Museum, the Canadian Wildlife Service of Environment Canada, and various nongovernment organizations, including universities, private industry, and outdoor groups, will also participate in recovery efforts.

Funding and scheduling requirements for the various activities associated with the strategies are identified. The projected cost of implementing this five-year plan is about $530,000. Activities will be reviewed and adjusted annually by the recovery team, pending results of each year's work. The plan will be reviewed in detail every five years.

Section I

Introduction/species' background/status evaluation

1. Introduction

The Vancouver Island marmot *Marmota vancouverensis* is the rarest and among the least studied of the six marmot species found in North America. This gregarious and lively rodent lives in the mountainous regions of Vancouver Island. Its closest North American relatives in the squirrel family are the Olympic marmot *M. olympus* of the Olympic Peninsula, and the more widespread hoary marmot *M. caligata*. About the size of a large house cat, an adult marmot is 65-70 cm from nose to tip of bushy tail. Weights of marmots show tremendous seasonal variation. Adults average only 2.5 kg when they emerge from hibernation, but are 5 kg or more by September. Most of this gain is fat, which sustains them during hibernation.

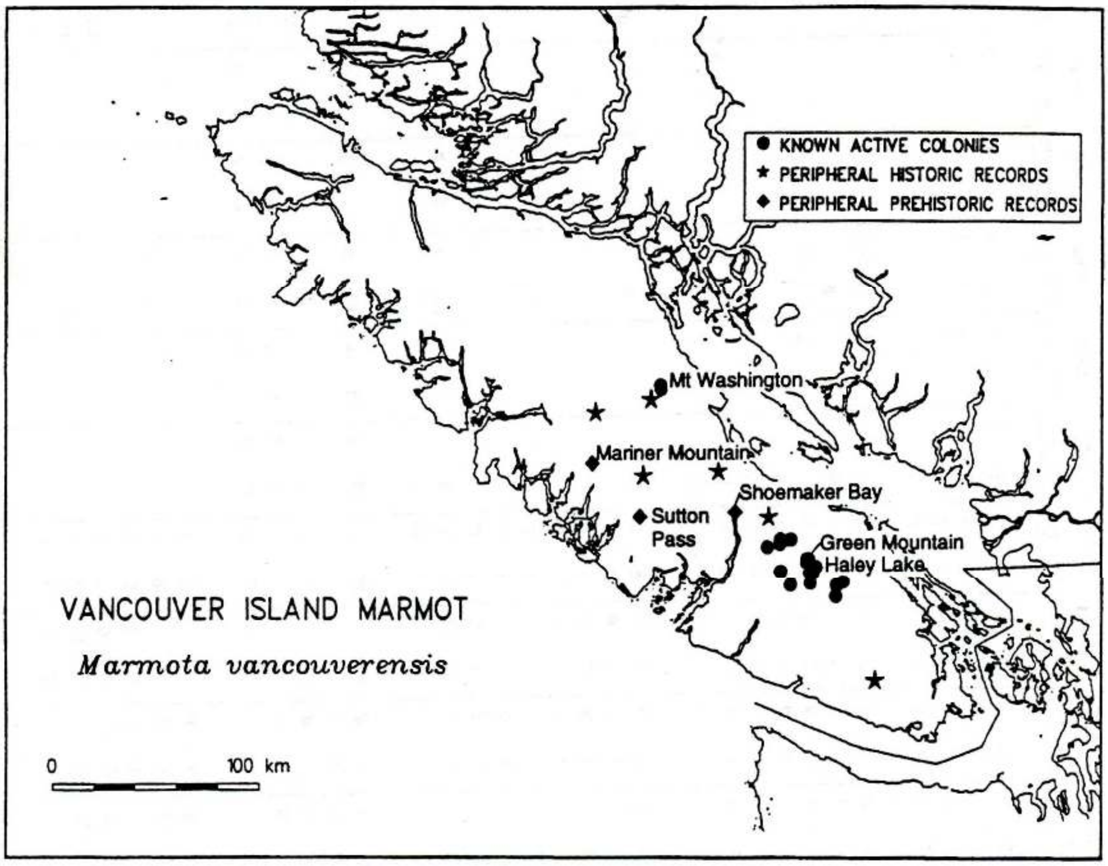
The most striking external feature of the Vancouver Island marmot, and what distinguishes it from its grizzled, light-brown mainland cousins, is its dark chocolate-brown coat. Patches of white on the nose, chin, forehead, and chest contrast sharply with the rest of the body. White hair on the underside can vary from a distinct white streak to a diffuse pattern. As the moult progresses during summer, the marmots take on a mottled appearance, with patches of old faded and new dark fur. Young of the year have a dark, almost black, woolly coat.

The Vancouver Island marmot was listed as "endangered" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in1979, and in 1980 it was legally designated as "endangered" by the Province of British Columbia (Munro et al. 1985). Reasons for this designation relate to the late-1970s population estimate of 50-100 animals, minimal data concerning historical abundance and distribution, and the unknown influence of human activities on marmot colonies. A review of surveys (Munro et al. 1985) suggested a population within the survey areas of approximately200-300 individuals. Most known colonies are confined to the Nanaimo Lakes, Nanaimo River and Cowichan Lake watersheds (Fig. 1). However, we stress the lack of a complete inventory of all potential marmot habitat on Vancouver Island.

Before the early 1970s, little was known about the distribution or biology of the Vancouver Island marmot (Janz 1982). Swarth (1911, 1912) described it as locally abundant near Douglas Peak but did not encounter it elsewhere on Vancouver Island. K. Racey collected eight specimens from the Haley Lake Bowl in 1931 (Munro et al. 1985). Carl (1943) described a colony from Mount Washington and reported a single animal on Mount Strata. Rausch and Rausch (1971) collected an adult female from Mount Washington for karyotype analysis. Members of the Nanaimo Fish and Game Protective Association inspired the first attempt to inventory marmot colonies (Finkelstein and Darling1973) and the establishment of an unofficial "marmot reserve" surrounding Haley Lake and Bell Creek (Janz 1982). Heard (1977) conducted the first field investigations of the Vancouver Island marmot. His M.Sc. research was designed to test hypotheses of a socio-biological nature. However, he also compiled significant ecological, behavioural and population data that established the basis for future investigations. His work also did much to enhance interest in Vancouver Island marmots, and the late 1970s saw much effort directed towards defining their status. Carson (1978) compiled records of historical distribution, and members of various conservation groups established a public-interest group now known as the Vancouver Island Marmot Public Liaison Committee.

Beginning in 1979, surveys were conducted at known or suspected marmot colonies by either affiliates of the above group or the British Columbia Ministry of Environment, Lands and Parks. The Canadian Wildlife Service (CWS) of Environment Canada sponsored a survey in 1981(Fry 1981). Initial surveys suggested a small population (~100 animals) and confined distribution. In 1984, Milko (1984) completed his botanical thesis of the Haley Lake Bowl; he later collaborated with CWS in a

Figure 1
Distribution of known Vancouver Island marmot colonies, and historic and prehistoric records (from Nagorsen, in press).



study of food habits of the Vancouver Island marmot at that site (Martell and Milko 1986).

In 1987, a portion of the Haley Lake Bowl was designated as an Ecological Reserve for marmots, and Bryant (1990) began his master's research on genetic variability and viable population size. In 1991 the Ecological Reserve was further expanded to include the Bell Creek colony, and a portion of Green Mountain was legally designated a Critical Wildlife Management Area. In August 1988, the Wildlife Branch, BCMELP, took the lead in establishing the Vancouver Island Marmot Recovery Team. The team has been charged with designing recovery efforts for the Vancouver Island marmot.

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

A. Factors influencing vulnerability and contributing to status

1. Biological considerations

a. Population status and current distribution

In 1979, BCMELP began sponsoring systematic searches for marmots. Early surveys were conducted by the Vancouver Island Marmot Preservation Committee, initiated by the Federation of British Columbia Naturalists (Routledge and Merilees 1980; Routledge 1981, 1982). Surveys from 1982 to 1986 were done by B.C. Environment (Smith 1982, 1983, 1985; Smith et al. 1984; Fry et al. 1986). One survey was carried out by CWS [Fry 1981). A synopsis of the results is included as Table 1; survey objectives and methods varied, and data are not strictly comparable from year to year.

Table 1

Vancouver Island marmot survey results, 1979-1993. Counts for adults (ad.) and young-of-the-year (*yoy*). Blanks indicate no survey and 0 indicates site surveyed but no marmots observed. See text for sources.

		1979		1980		1981		1982		1983		1984		1985		1986		1987		1988		1989		1990		1991		1992		1993	
Site #	Site	Ad.	yoy	Ad.	yoy	Ad.	yoy	Ad.	yoy	Ad.	yoy	Ad.	yoy	Ad.	yoy	Ad.	yoy	Ad.	yoy	Ad.	yoy	Ad.	yoy	Ad.	yoy	Ad.	yoy	Ad.	yoy	Ad.	yoy
	Green Mountain																														
1	Top of ski hill	3		4	6	15	6	5	3	9	4	5	0	2	0	8	1	5	3	6	6	5	0	4	0	5	4	3	3	3	3
2	SE talus slope					4		2	0	3		3	0	1	0	2	0	0	0	2	0	0	0	1	0			0		0	0
3	NW Ridge					8		7	0	3	0	5	0	3	2	1	4														
4	West Green (east)					3		6	0	3	0	2	0	1		3	0													0	0
5	West Green (west)					8		0	0	2	0	1	0																	0	0
6	South slope					4	2	2	1	6	0	3	0	1		2	0														
7	Road D15					2	1	0	0	0	0	0		2				0				0									
8	Elk Meadow									1	0	2	4	2		3	0	3		0	0									0	0
9	Road D west											2	3	1		0	0	0												0	
10	Road D east													3	0	3	2	0				3	0							0	
11	Road K44A					1	0	1	0	10	0	6	5	5	0	5	4	8		3		5				5	0	2		7	0
12	Heart Lake basin													2																	
	Gemini Peak																														
13	S. facing meadow					14	5	15	0	16	0	8	3	7	0	10	2	1				4	0					0	0	0	0
14	2nd divide south									4	0	4	0	3	0	2	0													0	0
15	**Westerholm Basin**			2	0	9	2	7	0	9		13	3	7		5	0														
16	Meadow #1							2	2	2		3	0	1		1	0													0	0
17	Meadow #2							2	0	2		0	0			0	0													0	0
18	**Bell Creek North**							6	0			2	0			0	0														
19	Road G2C							2	0	1		1	4	3		1	0	1												0	0
20	Road D13E											8	7	10	12	9	2	9		6	1	2	1	3	2					6	2
21	Road W4													2	0	1	0	3		6	1									0	0
	Haley Lake																														
22	Bowl	9	0	14	4	16		15	4	16	7	16	6	10		17	6	16	2	13	12	17	0	12	3	11	9	11	0	9	10
23	East of parking area									1	0	2																			
24	**Bell Creek**	7	0	2	0	9		9	0	9	1	12	4	12		7	3	6				7						12	3	9	3
25	Vaughan Rd. (top)									1	0	2	0					2	0	0	0	0	0	0	0	0	0	0	0	0	0
26	Vaughan Rd. (bottom)											1	0	1		7	3	9	0	11	6	5	4	4	0	2	0	2	0	6	5
	Butler Peak																														
27	West face					6	3	8	0			9	4			5	2														
28	East alder slide					1	0	1	0	3	0	3	3			6	6					5	0								
29	Above Road V7							2	0			3	0	1	0	2	0														
30	Road K43e1c							2	0	5	0	7	0	2	0	2	0					5						10	0	6	0
31	Road K43e									9	0	8	4	9	11	17	4					23						11	0	10	1
32	Road K43f											4	2	4	2	3	0					0						4	0	2	0
	Mt. Buttle																														
33	Top meadow									2	1	5	2	5	2	3	0													0	0
34	South pocket							3	0																					1	0
35	Road NM 50																													0	0

(cont'd)

Table 1 *(cont'd)*

Vancouver Island marmot survey results, 1979-1993. Counts for adults (ad.) and young-of-the-year (*yoy*). Blanks indicate no survey and 0 indicates site surveyed but no marmots observed. See text for sources.

		1979		1980		1981		1982		1983		1984		1985		1986		1987		1988		1989		1990		1991		1992		1993	
Site #	*Site*	Ad.	*yoy*	Ad.	*yoy*	Ad.	*yoy*	Ad.	*yoy*	Ad.	*yoy*	Ad.	*yoy*	Ad.	*yoy*	Ad.	*yoy*	Ad.	*yoy*	Ad.	*yoy*	Ad.	*yoy*	Ad.	*yoy*	Ad.	*yoy*	Ad.	*yoy*	Ad.	*yoy*
	Mt. Whymper																														
36	South Basin							**11**	*0*	**4**	*2*	**9**	*0*	**0**		**3**	*1*													**1**	*0*
37	West Basin									**3**	*0*	**0**	*0*			**1**	*0*													**0**	*0*
38	Pat Lake basin													**6**	*2*	**7**	*0*			**15**	*7*	**14**	*4*	**10**	*0*	**9**	*3*	**8**	*5*	**10**	*4*
	Mt. Landalt																														
39	Top east meadow											**2**	*0*			**2**	*0*											**2**	*0*		
40	F19 Sherk Lake																											**3**	*0*	**4**	*0*
	Heather Mtn.																														
41	S. alder basin							**0**	*0*	**4**	*1*	**4**	*3*			**4**	*0*			**0**								**5**	*0*	**2**	
	Mt. Hooper																														
42	SW Basin			**2**	*2*	**3**		**2**	*3*	**4**	*0*	**1**	*4*																	**0**	*0*
43	SE side							**3**	*0*			**2**	*0*																		
44	West Shaw Creek			**1**	*3*																										
45	**Hooper North**							**4**	*3*	**0**	*0*	**1**	*0*																	**0**	*0*
	P. Mountain																														
46	South basin			**2**	*3*	**1**	*0*	**3**	*0*	**5**		**5**	*0*			**2**	*0*	**1**		**0**	*0*									**0**	*0*
47	North basin			**1**	*0*	**3**		**4**	*0*	**1**	*0*	**3**	*4*			**2**	*0*	**1**		**0**	*0*									**0**	*0*
48	W. facing meadow							**1**		**1**		**3**	*2*			**1**	*0*	**1**		**0**	*0*									**3**	*0*
49	NW ridge									**2**						**3**	*0*	**2**		**2**	*0*									**0**	*0*
	Mt. Moriarty																														
50	SW aspect											**2**	*0*															**3**	*0*	**0**	*0*
51	NE aspect									**1**	*0*	**0**	*0*							**2**	*0*							**2**	*0*	**2**	*1*
	Mt. Franklin																														
52	S. of summit																							**7**	*0*			**10**	*0*	**5**	*3*
	Mt. Washington																														
53	W. basin+ski-runs			**2**	*0*			**0**	*0*	**0**	*0*	**0**	*0*			**1**	*0*	**0**	*0*	**0**	*0*	**0**		**0**	*0*	**2**	*2*	**1**	*0*	**0**	
54	Minesite											**3**	*1*	**2**	*0*	**0**	*0*	**0**	*0*	**0**	*0*	**0**						**0**			
	Big Ugly																														
55	SE face															**2**	*0*													**1**	*0*
56	N avalanche run																													**0**	*0*
	Column totals	**19**	*0*	**30**	*18*	**107**	*19*	**125**	*16*	**142**	*16*	**175**	*68*	**108**	*31*	**153**	*40*	**68**	*5*	**66**	*33*	**95**	*9*	**41**	*5*	**34**	*18*	**89**	*11*	**87**	*32*
	Total Marmots	**19**		**48**		**126**		**141**		**158**		**243**		**139**		**193**		**73**		**99**		**104**		**46**		**52**		**100**		**119**	

Note: The above date reflect Munro et al's (1985) review of inventory data, in which data were bases on the summary statistics given in each report.

Surveys in 1982 and 1983 were designed to inventory habitats used by marmots and not to count individuals (Munro et al. 1985). Because colonies were sometimes surveyed before the emergence of young-of-the-year, reproductive rates are not comparable between colonies. In 1984 and 1986, surveys were more intensive and involved repeated visits to colonies; they provide a better estimate of total numbers. The 1984 effort resulted in a minimum count of 234 individuals, including 68 young, at 42 colonies or potential colonies (Munro et al. 1985). Fry et al. (1986) found 188 marmots including 40 young in 1986, but several areas surveyed in 1984 were not included in this survey. No methodical surveys were conducted from 1987 to 1992, although Bryant (1990) monitored numbers at Haley Lake and Green Mountain, and searched unsuccessfully for marmots at historical sites such as Douglas Peak, Mount Strata, and Mount Jutland. BCMELP periodically monitored a number of other sites during the course of other duties.

Surveys indicate a metapopulation of 200-300 individuals concentrated in the Nanaimo-Cowichan Lake area, with a total population estimate of fewer than 500 animals.

b. *Past distribution*

Our knowledge of the past status of the Vancouver Island Marmot is incomplete. Figure 1 shows the distribution of all records.

Swarth (1912) discovered Vancouver Island marmots in 1910 in the basins, meadows, and ridges around Douglas Peak and Mount McQuillan, where he described them as "fairly abundant" and "vigilant and unapproachable." That his party could collect 11 adults over the course of two weeks suggests a sizable population in the region (indeed, he mentions others that escaped into their burrows "in every instance" after being shot with hard-point bullets). Swarth's work is also intriguing for what he did not find; for he ascended Mount Arrowsmith and explored the mountains north of Great Central Lake without finding additional marmots. A. Peake collected an adult female from Mount Buttle in 1929. K. Racey collected eight adult specimens from the Haley Lake Bowl in 1931 (Nagorsen 1988). In 1938, I.M. Cowan reported burrows and marmots on the northeast face of Mount Arrowsmith (Munro et al. 1985). A small colony on Mount Washington and a single animal on Mount Strata were reported in 1942 by Carl (1943). Other reports from Strathcona Park include marmot jawbones of indeterminate age from Drinkwater Creek in 1940 and the Golden Hinde in 1976 and fresh burrows and scats near the summit of Mount Jutland in 1983 and 1988. Two old burrows and a "trial burrow" were found just west of the south end of Buttle Lake by Wildlife Branch personnel in 1982, but no fresh evidence of use was observed in a brief inventory (Heinsalu and Smith 1982). A survey in 1992 by B.C. Parks found two old burrows on Greig Ridge, five old burrows near Big Den Mountain, and one old burrow on Adrian Peak.

Carl (1944) described marmots from the head of Shaw Creek and Jordan Meadows, which is the most southern record for this species. A 1930 specimen in the Royal British Columbia Museum (RBCM), which was labelled "Jordan River", may in fact be from Jordan Meadows. In 1982, W. Hazeldine donated a skull to the RBCM that was found on Mount Joan, in the Beaufort Range, on or about 1970 (Nagorsen 1988). Prehistoric marmot bones (700-2500 years before present) have been found at three sites (Fig. 1): Shoemaker Bay (Calvert and Crockford 1983), Sutton Pass (Nagorsen 1989), and Mariner Mountain in 1992. Living marmots are not known from any of these sites, although marmot whistles were reported near the Sutton Pass site in 1988 (on Nahmint Mountain; G.W. Smith, pers. commun.).

On the strength of museum specimens, sight records and interviews, Carson (1978) suggested a historical distribution of some 25 colonies throughout Vancouver Island. Some of the records are uncertain and may have been based on solitary (dispersing) individuals. Carson's work, and the prehistoric findings, suggest a more widespread historical distribution of the Vancouver Island marmot, however, there is no evidence that this marmot was ever "abundant" on Vancouver Island.

c. *Incidence of disease or pests*

Ectoparasites identified from the Vancouver Island marmot include the flea *Thrassis spenceri spenceri* and an unidentified tick *(Ixodes* spp.). Endoparasites include the nematode *Bayliascaris laevis* and cestodes *Diandrya composita* and *D. vancouverensis*, the latter recorded only from Vancouver Island marmots (Nagorsen 1987).

d. *Commercial or subsistence use*

The presence of tool markings on marmots' bones found at archaeological sites indicate native peoples once used the Vancouver Island marmot for food and skins (Nagorsen 1989). Many reports of early explorers on Vancouver island also refer to the use of marmot skins by native people.

2. Habitat considerations

a. Overview of habitat requirements

The best Vancouver Island marmot habitats, like those in the Green Mountain - Haley Lake area west of Nanaimo (Heard 1977; Milko 1984), are on steep slopes (35-90 percent) in subalpine areas, between the 1000- and 1460-m elevations. These hardy animals prefer sites where lush herbaceous growth provides abundant summer food, and tree cover doesn't hinder their ability to see one another or detect predators. The best habitats face southeast to west (Bryant 1991a), which promotes early spring snowmelt; have pockets of deep soil suitable for hibernacula and burrows; contain scattered boulders or rock ledges used for loafing and lookouts; and are situated below steep, rock bluffs that shed snow. Snow avalanches and snow creep are believed to be the major processes that maintain these meadow habitats, which are of quite limited extent on Vancouver Island. Occasional wildfires may also create some subalpine openings used by marmots.

Marmots are highly dependent upon the *Anaphalis-Aster* wildflower community, which provides a diversity of food sources and soil conditions suitable for burrows. Grasses are important in the diet in spring and although the availability of grass increases over the summer, the marmots switch to forbs. Preferred forbs in summer are lupines, peavine, paintbrush, meadowrue, cow parsnip, and woolly sunflower. Milko (1984) speculated that encroachment by *Pteridium ferns* and trees limit marmot habitat. and that natural successional processes are the most likely explanation for the scarcity of this marmot.

Nonetheless, the Vancouver Island marmot can survive in many habitat types. The Mount Washington colony, which has existed since at least the early 1940s, occupies an environment quite different from that of the Haley Lake Bowl (Fry et al. 1986). The dominant vegetation consists of scattered alpine fir *Abies lasiocarpa* and mountain hemlock *Tsuga mertensiana* interspersed with juniper *Juniperus communis* and blueberries (*Vaccinium* spp.). Marmots on the northwest ridge of "P" Mountain live on steep cliffs and talus slides interspersed with thick forest; colonies on Mount Heather and in Westerholm basin live amidst willow (*Salix* spp.). and alder *Alnus* spp. thickets and rock slides.

Marmots have been observed in a variety of disturbed habitats. Heinsalu and Smith (1982) first recorded marmots in logged-over habitat, and Smith et al. (1984) documented successful reproduction in that environment. By 1984 at least 56 marmots had been found in logging-slash environments at five discrete locations. Marmots also occur in openings created by ski-run developments (on Mt. Washington and Green Mountain) and in mine tailings on the north slopes of Mount Washington. Sightings of marmots at low elevations (<50!) m), such as a vegetable garden at Coombs, on the beach at Union Bay, near the airport at Cassidy, under a horse stable at Cedar, and in a backyard at Franklin River, likely represent dispersing animals. Both the Coombs and Cassidy marmots hibernated successfully at these low elevations.

The broad range of habitat types used by Vancouver Island marmots precludes a simple estimate of the total habitat available for the species and makes inventory difficult.

b. Status of critical habitat

Milko (1984) suggested that natural reduction in marmot habitat since the Pleistocene is the most likely explanation for the current rarity of Vancouver Island marmot; he cites Franklin et al. (1971) and Kuramoto and Bliss (1970) in support of his interpretation that historical declines in the species were concurrent with a period of pronounced climatic change and forest succession. Milko's hypothesis is probably correct. Subalpine meadows such as those above Haley Lake are much less numerous on Vancouver Island than they were immediately following the Fraser Glaciation, but that does not satisfactorily explain the apparent recent loss of colonies from Douglas Peak or the Strathcona Park region. What appears to be suitable habitat remains at those sites, considering the variable nature of the habitats used by the species elsewhere (Smith et al. 1984; Bryant 1990), but it is unclear what constitutes critical habitat for this species.

B. The Vancouver Island marmot's role in the ecosystem and interactions with humans

1. Ecological considerations

a. Ecological role

The Vancouver Island marmot is a herbivorous rodent of rocky subalpine meadows on Vancouver Island. Although it is a known prey item for Golden Eagle *Aquila chrysaetas*, cougar *Felis concolor vancouverensis*, and gray wolf *Canis lupus*, it is only available seasonally for five months, and its numbers are probably not large enough to sustain any predator population.

b. Taxonomic position

The Vancouver Island marmot was described in 1911 based on 11 specimens shot in 1910 near Douglas Peak in west-central Vancouver Island (Swarth 1911, 1912). The species is endemic to Vancouver Island and is the only species of the genus Marmota that occurs there. The Vancouver Island marmot differs from the closely-related hoary marmot and Olympic marmot in morphologic (Hoffman et al. 1979; Nagorsen'1987), karyotypic (Rausch and Rausch 1971), and behavioural (Heard 1977) traits. It is a "good species" in the sense that it is reproductively isolated from all other marmot species, although no one has tested interbreeding with mainland populations of *M. caligata* or other species.

2. Socio-political considerations

a. Public appeal or existence value

Until the 1970s, little was known about Vancouver Island marmots. Interest in the species had increased dramatically, and a public-interest group known as the Vancouver Island Marmot Public Liaison Committee was formed in 1978. Public interest in endangered species is high.

b. Utilitarian value

Although the Vancouver Island marmot has no present consumptive value, it is very valuable in nonconsumptive uses such as photography and viewing and in the context of environmental education. Marmots are readily observable at known colony sites and one of the easiest endangered species to photograph in the wild.

c. Legal considerations

The Vancouver Island marmot has been designated an endangered species in British Columbia, and is protected from harassment and disturbance under the British Columbia Wildlife Act.

d. Proportion of breeding population in Canada

The entire population of this species is endemic to Canada, as Vancouver Island marmots are found only on Vancouver Island.

C. Recovery potential of the Vancouver Island marmot

1. Review of major causes of threat and likelihood of continued threat

a. Human harassment

Logging, mining, and ski-hill development could create problems associated with human visitation and harassment, mostly by providing easy access to marmot colonies. Possible deleterious effects include trampling of vegetation, snow compaction, disturbance by wildlife photographers, shooting, all-terrain vehicles, and vandalism (Dearden 1983). Munro et al. (1985) cited two cases of marmots being shot and recommended that dogs be used to determine presence of animals only, not reproductive success, due to possible harassment. Most colonies are protected by inaccessibility and through a lack of specific information as to their location. In addition, the South Nanaimo River watershed is closed to the public during all but three weeks of the period when marmots are active.

There is no evidence that these human harassment factors have had a significant effect on any marmot colony. Marmot research is not thought to have a negative impact on the population. Bryant (1990, 1992) has handled over 159 marmots and has only one capture-related mortality. Observations by various individuals suggest that the Vancouver Island marmot is very tolerant of human presence (Heard 1977; Munro et al. 1985; Bryant 1990). Heinsalu and Smith (1983) described marmots living amidst the noise and dust of log-yarding activities. Indeed, the tolerance of Vancouver Island marmots to humans has resulted in it being one of the most photographed endangered species in Canada.

b. Habitat changes

During the 1970s and early 1980:, there was considerable public concern that populations of Vancouver Island marmots suffered from habitat changes associated with logging or the development of alpine ski operations (Dearden 1983; Munro et al. 1985). There is no evidence to substantiate such contentions; indeed, marmots apparently have benefitted by the creation of more foraging habitat, at least in the short term (Munro et al. 1985; Bryant 1992). However, other effects of logging, particularly on marmot dispersal, are unknown. D. Heard and I. McTaggart-Cowan (cited in Munro et al. 1985) speculated that removal of forest cover would enhance dispersal and recolonization of mountain sites. Bryant (1990) suggests that the reverse is true: i.e., that the creation of new logged habitats at the base of colony at a distant mountain. Survivorship data for ear-tagged marmots (Bryant, unpubl.) also indicates that overwinter survival in these lower elevation hibernacula in logged areas may be lower. Unfortunately, insufficient data are currently available to determine the long-term impact of logging on Vancouver Island marmot populations.

2. *Current habitat protection efforts*

B.C. Environment (a branch of BCMELP) has entered into several successful landowner agreements with forest companies owning marmot sites. One of these agreements evolved into a 93-ha Haley Lake Ecological Reserve, established in 1987 on private land donated by MacMillan-Bloedel. This reserve was further expanded by 27 ha of private land donated by Fletcher-Challenge in 1991. In addition, a 300-ha Critical Wildlife Management Area was established on Crown land on Green Mountain in 1991.

3. *Degree of habitat management required*

There is no evidence of short-term negative impact by logging, ski-hill development, or human harassment. However, because long-term effects are not clear, the management of these impacts, and other potential impacts, such as mining, is a high priority through ongoing habitat protection and management activities of B.C. Environment. Research is required on the influence of land-use changes on marmot populations to better guide land-use decisions and habitat management initiatives.

4. *Biological considerations affecting recovery*

a. *Recruitment rate*

Female Vancouver Island marmots may produce young at three years of-age, but most do not until four years-of-age (Bryant, unpubl.). There are few data available on the frequency of breeding in individuals. The interval between litters may be one, two, or three years; other marmot species commonly produce litters every two years. Hoary and Olympic marmots first breed in their third year and typically produce young in alternate years (Barash 1974; Holmes 1979; Wasser and Barash 1983), although individuals may skip one or more consecutive years (Holmes 1984). Heard (1977) speculated that Vancouver Island marmot: should similarly breed in alternate years. On occasion, Vancouver Island marmots have produced litters in consecutive years, both in captivity (Dyer 1982) and in the wild (Bryant 1990), but some females have not reproduced even after two or three years (Bryant, unpubl.). Average litter size between 1987 and 1992 was 3.16 (Bryant. unpubl., n= 19). A litter of 3 is by far the most common, with one litter of 5, two litters of 4, and one litter of 2 also observed.

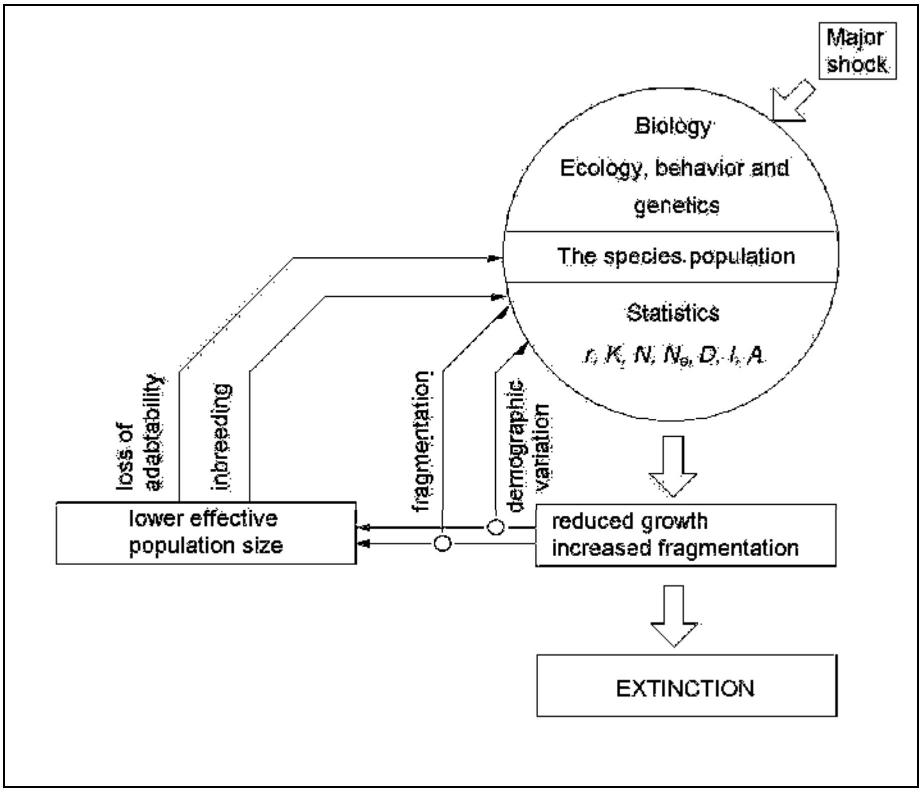
b. *Population viability analysis*

What is the minimum population required to ensure the long-term survival of Vancouver Island marmots? In theory, for every population there is a threshold size above which the risk of extinction falls below an established level of probability (i.e., it becomes an "acceptable" risk: Shaffer 1981). The problem is to identify what population size and distribution would provide a strong probability of survival despite random demographic, genetic, or environmental events over time. Fortunately, there are a few scientific guidelines on how to do this.

Existing methods are based on the need to minimize inbreeding (Reed et al. 1986), maintain long-term genetic adaptability (Franklin 1980), and account for random environmental or demographic events (Burgman et al. 1988). General rules-of-thumb have been suggested, such as the need to maintain an effective population size (*Ne*) of 50 to prevent inbreeding depression and an *Ne*; of 500 to prevent the long-term erosion of genetic variability and adaptability (Frankel and Soulé 1981). "Effective" population size is the "size of an idealized population that would have the same amount of inbreeding or random genetic drift as the population under consideration" (Kimura and Crow 1963; see Appendix 1). The number of animals required to maintain a given *Ne* is generally much higher than that value, depending upon the biology of the species in question (Reed et al. 1986). Calculation of "minimum viable population" (MVP) size on genetic grounds alone is attractive. However, the multiplicity of factors involved in most extinctions suggests that an MVP calculated to counter a single threat (e.g., inbreeding) will be inadequate.

A useful tool for wildlife managers is population viability analysis (PVA). The idea is to combine various extinction threats into a single model (Fig. 2). Managers can then identify primary threats to a population as well as feedback loops that can further reduce viability. In Gilpin's model, the species in question is described as the sum of various population parameters. External "shocks" have the effect of changing these population statistics and may lead directly to extinction. In addition, changes in these parameters can set up

Figure 2
Model for population viability analysis. In this model, the species is described as the sum of population parameters (intrinsic growth rate r, habitat carrying capacity *K*, population size *N*, genetic effective population size *Ne*, distribution or fragmentation index *D*, inbreeding coefficient *I*, and measure of genetic adaptability *A*). Environmental shocks may influence these parameters and fragment or reduce the size of populations. This may lead directly to extinction or establish feedback loops that further reduce population viability. Adapted from Gilpin (1987).



feedback loops or "extinction vortices" that can further influence the status of the animal (Gilpin and Soulé 1986). For example, persecution of the black-footed ferret *Mustela nigripes* and its prey led to reduced ferret population size and created a situation where the species became much more vulnerable to a single natural event, such as disease (Clark 1987).

The primary value of the PVA model is that each feedback loop is amenable to empirical analysis. Techniques such as electrophoresis can be used to estimate levels of genetic variability, and comparison with other taxa can lead to informed decisions concerning the danger of inbreeding depression or long-term loss of adaptability (Wayne et al. 1986). Standard population techniques can be used to estimate other parameters, and computer simulations can be used with those data to predict the effects of random environmental or demographic events (Burgman et al. 1988). Note that PVA analyses are complicated by species that have subpopulations separated in space ("metapopulations": Gilpin 1987). For metapopulations that are genetically isolated from one another, a separate PVA may be required for each (as in the case of the Yellowstone population of grizzly bears *Ursus arctos*).

The PVA model, like all such models, is designed as a tool for thinkers and not as a crutch for the lazy. It is imperfect, particularly when applied to "real-world" examples where often population parameters are estimated instead of precisely known. It is an exercise in risk assessment and, like all risk assessments, it is impossible to know whether the proverbial 100-year flood will come tomorrow or 87 years hence. Despite this, PVA provides a coherent model for the design of recovery plans.

c. *Stochastic causes of extinction*

Random demographic or environmental effects have likely influenced the number and distribution of the Vancouver Island marmot, particularly given the small and disjunct nature of many colonies. Data from Bryant (1990), Milko (1984), and Heard (1977) illustrate the variable reproductive success at the Haley Lake Colony. Smith (1982) reported a dramatic increase in population size at the Green Mountain colony from the 1950s to the early 1980s, and Bryant (1990) describes a similar change at Pat Lake. Mount Hooper North (Heinsalu and Smith 1983), Mount Washington, and "P" Mountain colonies may have declined within the past few years (Bryant 1990).

Population fluctuations may be related to yearly weather patterns, although no researcher has demonstrated a statistical association. Smith (1982) attributed increased marmot numbers and distribution during the late 1970s to a period of mild winters. Annual differences in reproductive success have been attributed to variation in winter snow depth and timing of spring snowmelt (Milko 1984). Similar trends exist in other marmots (e.g., *M. flaviventris*; Armitage and Downhower 1974) and certainly the subalpine regions of Vancouver Island exhibit highly variable weather conditions. Page (1987) posits an 18-year cycle in Vancouver Island snowfall patterns, with decades of comparatively mild winters followed by periods of more extreme winters. Such a pattern could have enormous implications for the survival of marmot colonies, particularly small colonies at sites with marginal hibernacula or food resources. Bryant (1993b) attempted to simulate stochastic factors with computer models of Vancouver Island marmot colonies. Although his population data are incomplete, results fit the general rule that small colonies are more vulnerable to stochastic extinction than larger ones.

Because random demographic or environmental processes cannot be controlled by wildlife managers, the only recourse is to try to maintain populations sufficiently large to withstand those effects, and close enough together to promote recolonization if local extinctions occur. In effect, the objective must not be to protect every small colony of marmots from random effects; rather. it must be to manage larger populations that are resilient to such processes.

d. *Inbreeding depression*

Inbreeding leads to the loss of genetic variability and the expression of deleterious recessive alleles, a phenomenon known as inbreeding depression. Inbreeding depression has occurred in a wide range of mammal species (Wayne et al. 1986) and may involve reduced reproductive success (Wildt et al. 1987), increased juvenile mortality (Ralls et al. 1988), or susceptibility to disease (O'Brien et al. 1985). Alternately, inbreeding can "purge" populations of deleterious genetic traits, and some highly inbred captive populations have survived for many generations (white lab rats being the classic example). In most natural populations, strong behavioural traits such as dispersal of juveniles tend to prevent close inbreeding (Rails et al. 1986). Inbreeding depression is therefore most common in zoo populations, where such behavioural traits cannot operate (Wayne et al. 1986).

Recent studies suggest that inbreeding may be a major problem in wild populations that are small or increasingly fragmented by the effects of human activity (e.g., Shaffer 1981; Gilpin and Soulé 1986). For example, Chesser (1983) found that inbreeding and genetic drift created genetic differences between colonies of black-tailed prairie dogs *Cynornys ludovicianus* that were extreme given the short geographic distances between colonies. He suggested that poisoning and habitat changes altered normal dispersal patterns to the point where inbreeding could be aggravated. In contrast, close inbreeding is unknown in yellow-bellied marmots *M. flaviventris* (Schwartz and Armitage 1980). Evidently, rates of dispersal between marmot colonies, together with behavioural traits, prevent inbreeding depression in that species.

There is currently no evidence for inbreeding depression in Vancouver Island marmots. Bryant (1990) found levels of genetic variability in Vancouver Island marmots comparable to those found in yellow-bellied marmots and woodchucks. He did find genetic differences between colonies in the Nanaimo Lakes - Nanaimo River watersheds. Whether this indicates inbreeding or recent colony isolation is not yet clear: samples from additional colonies are needed. In particular, Bryant (1990) was unable to find or sample any animals from Mount Washington. Theory dictates that a small isolated colony of marmots, such as that thought to have existed on Mount Washington since the 1940s, must be inbred by definition. That colony could provide important data concerning "normal" levels of genetic variability and inbreeding in the species.

Several formulae are available to estimate the effective genetic size (*Ne*) of a population (e.g., Lande and Barraclough 1987; Reed et al. 1986; LaCava and Hughes 1984; Lemkuhl 1984; Ryman et al. 1981; and Hill 1972). These formulae were applied to the Vancouver Island marmot using demographic data derived from-either fieldwork or from a population simulation model (Bryant 1993b, 1990, and unpublished data). The purpose was to estimate the effective population size (*Ne*) of the known population, and to determine what total population size (*N*) would be necessary to keep inbreeding rates below 1% (which translates to an effective population size of 50). Assuming that the known population is neither increasing nor decreasing, that no polygamy occurs, that all marmot colonies are connected by dispersal of successful immigrants, and using field-data or simulation-derived demographic parameters, the formulae produced *Ne* estimates in the range of 20-30 animals for the known population (Appendix ll. Estimated *Ne/N* ratios were in the range of 0.08 to 0.11, suggesting that 470-574 animals are required to maintain an effective population of 50. This is more than twice the known population. If the population fluctuates in size, if dispersal rates are not uniform among colonies, or if relatively few males breed with many females, *Ne* size will be reduced still further (Lande and Barraclough 1987). Conversely, if our inventory data underestimated the actual number of breeding individuals, or if adult survival rates are higher than estimated from mark-recapture data, *Ne* size would be increased. Because empirical data suggest that Vancouver Island marmots can disperse long distances, and genetic data show surprisingly high levels of variability, and because the evolutionary history of Vancouver Island marmots may have purged deleterious genes through a succession of genetic bottlenecks, we reason that inbreeding depression is not of immediate concern, and the known population is at least in the order of magnitude necessary to prevent drastic loss of genetic information.

Population objective #1 (see Section II) is based on this assumption. However, environmental stochasticity, long-term loss of adaptability and population fragmentation are also important factors to consider in the design of the recovery plan.

e. Long-term adaptability

Whereas inbreeding depression has measurable effects upon reproductive success or other population parameters, the long-term loss of genetic variability may confer evolutionary disadvantages that do not become apparent for generations (Frankel and Soulé 1981). Few empirical data exist that suggest how much genetic variability is enough. That places wildlife managers in a difficult situation, particularly if no information is available concerning "normal" levels of genetic variability in a particular species. Franklin (1980) argued that an effective population *Ne* of 500 would balance the conflicting forces of mutation and genetic drift and would be sufficient to preserve genetic variability over the long term. Substitution into the estimated *Ne/N* ratio suggests that this would necessitate the maintenance of 4500-5740 marmots. This is not a valid recovery objective. First, it is unlikely that existing natural habitats on Vancouver Island could ever support such a large population. Second, the *Ne* = 500 rule-of-thumb assumes a single effective population and does not consider the complex relationships between genetic structure and metapopulation structure (Gilpin 1991). Finally, Franklin assumed a political policy of "benign neglect", with survival of wildlife populations and natural environments exclusively dependent upon natural processes. This ignores the possibility that wildlife managers might undertake activities such as translocation to ensure adequate genetic "mixing." Bryant's (1990) data suggest that the Vancouver Island marmot is in no immediate danger of becoming genetically monotypic or less evolutionarily fit than other mammal species. The establishment of three metapopulations, each large enough to avoid inbreeding depression or extinction through random demographic or environmental events, is judged to be a reasonable way of maintaining long-term adaptability, as it will permit genetic mixing among them, if and when that is found to be necessary.

f. Fragmentation and metapopulation theory

Vancouver Island marmot ecology appears to be a classic example of metapopulation theory, with the entire population consisting of small colonies in geographically isolated patches of habitat that are periodically extirpated and recolonized (Gilpin 1987). With the possible exception of the Mount Washington colony, no known small subpopulation of Vancouver Island marmot apparently survived for any length of time without being connected (through dispersal) to other colonies. Indeed, there is no theoretical basis for assuming that such a colony could survive for long, given what is known about stochastic environmental and genetic effects.

Given that view, the scanty historical evidence suggests that during the early-to-mid 1900s there may have been three metapopulations on Vancouver Island: one centred around the Douglas Peak type locality, one in the Nanaimo and Cowichan watersheds, and another in the Strathcona Park/Forbidden Plateau region. Current inventory data, although admittedly incomplete, suggest that the Douglas Peak and Forbidden Plateau metapopulations are greatly reduced and may be near extinction. The Nanaimo - Cowichan Lake metapopulation is relatively stable.

No data are available to relate colony dynamics with land-use changes. If future expansion of logging-slash marmot colonies occurs at the expense of more peripheral colonies, wildlife managers will be faced with a growing "eggs in one basket" scenario. Even if that does not occur, the recovery team is concerned about the present geographical distribution of marmot colonies. Given the small total known population of the Vancouver Island marmot, prudent management should include the dispersal of risk through re-establishment of metapopulations in additional regions.

Finally, every effort must be made to ensure that colonies within a metapopulation are connected through natural dispersal or translocations. Fragmentation of the existing population would increase the probability of extinction through random genetic or environmental events.

5. Competing species/predators

The only conceivable competitors would be other herbivores such as black-tailed deer *Odocoileus hemionus columbianus*, Roosevelt elk *Cervus elaphus roosevelti*, and voles (*Microtus* spp.), although significant interaction with these species is considered unlikely.

There is a long list of potential predators of the Vancouver Island marmot, including cougar, wolverine *Gulo gulo vancouverensis*, gray wolf, black bear *Ursus americanus vancouveri*, Golden Eagle, Bald Eagle *Haliaeetus leucocephalus*, Red-tailed Hawk *Buteo jamaicensis*, Northern Goshawk *Accipiter gentilis langi* and humans. Heard (1977) described one instance of probable predation by cougar. He and others report attacks or attempted attacks by Golden Eagles (Heard 1977; Fry et al. 1986). There is speculation that an increase in numbers of hawks and Golden Eagles due to increased prey availability, notably the introduced eastern cottontail rabbit *Sylvilagus floridanus*, could result in increased predation pressure on marmots (Merilees 1980). Nagorsen (pers. commun.) reports finding marmot fur in a wolf scat. Munro et al. (1985) reported two cases where marmots were shot by vandals. The presence of marmot bones in a 1500-year-old archaeological site at Port Albemi (Calvert and Crockford 1983), 2500-year-old tool-marked bones in a cave at Sutton Pass (Nagorsen 1989), and 680-1060-year-old tool-marked bones in a cave on Mariner Mountain is evidence that native peoples hunted marmots for food or robes or both.

Circumstantial evidence suggests that predation is a factor with potentially important ramifications upon small isolated colonies. The presence of 13 partial skeletons in the Sutton Pass cave, and 70-80 partial skeletons in the Mariner Mountain cave suggest human predation may have been a major factor explaining the lack of known colonies in these two areas. Similarly, few marmots have been found at Douglas Peak since Swarth's scientific collecting in 1910. Halpin (1987) found that shooting of several adult males in a colony of black-tailed prairie dogs was followed by profound population effects. Young animals continued to disperse and did not replace the lost adults; the population was thus left with a dearth of breeding males and declined.

Section II

Recovery

1. Recovery goal and objectives

The goal of the recovery plan is to remove the Vancouver Island marmot from the endangered species lists. Population objectives are designed to ensure the long-term survival of the species despite natural catastrophes, inbreeding, and habitat changes. The Vancouver Island Marmot Recovery Team and appropriate jurisdictional authorities (primarily BCMELP) are responsible for implementing the plan. The recovery team and the recovery plan are integral components of the Recovery of Nationally Endangered Wildlife in Canada (RENEW) initiative.

Objective #1: Maintain the existing Nanaimo - Cowichan Lake metapopulation at not fewer than 200 animals within the currently known distribution of the species. Species status remains "endangered."

Objective #2: When a second stable or increasing metapopulation of between 100 and 200 animals is discovered or established by translocation, ask COSEWIC to consider downlisting the Vancouver Island marmot from "endangered" to "threatened." Total population of marmots would be 300-400.

Objective #3: When a third stable or increasing metapopulation of between 100 and 200 animals is discovered or established by translocation, ask COSEWIC to consider downlisting the Vancouver Island marmot from "threatened" to "vulnerable." Total population of marmots would be 400-600.

The feasibility of achieving objectives #2 and#3 will be determined within the timeframe of this 5-year plan, depending on the results of animal and habitat inventory.

Metapopulations are defined as a set of local colonies or subpopulations (Gilpin 1987). Metapopulations should be large enough to prevent inbreeding depression and maintain genetic variability over time, and large enough to buffer the effects of demographic or environmental stochasticity. A metapopulation should consist of approximately 100-200 marmots (young-of-year excluded), depending on the degree of natural or human-induced genetic interchange. Each metapopulation should consist of at least six subpopulations or colonies, among which natural dispersal and recolonization will occur.

2. Strategies

General strategies required to achieve the recovery goal and objectives include:

A. Monitor known populations.
B. Determine habitat requirements and map habitat.
C. Inventory for undiscovered colonies and habitats.
D. Investigate dispersal characteristics.
E. Protect and manage important subalpine and logged habitats.
F. Conduct intensive population management if warranted.
G. Develop public support through education, participation, and fund-raising activities.

3. Stepdown outline

A. Monitor known populations.

1. Determine population trends.
   a. Establish procedures for standardized surveys.
   b. Conduct standardized surveys.
   c. Monitor reproductive status.
2. Determine survival of marked animals.

3. Model population dynamics to estimate minimum viable population size.

B. Determine habitat requirements and map habitat.

1. Determine hibernacula characteristics.
2. Conduct biophysical habitat mapping.

C. Inventory-for undiscovered colonies and habitats.

1. Survey historic sites and unconfirmed sightings.
2. Survey high capability habitats for presence of marmots.

D. Investigate dispersal characteristics.

1. Determine dispersal rates of marked animals.
2. Determine age and sex classes of dispersing marmots.
3. Determine effects of dispersal on colony establishment and persistence.
4. Determine influence of land-use activities on dispersal characteristics.

E. Protect and manage important subalpine and logged habitats.

1. Maintain protection of habitat through the existing referral system.
2. Incorporate important habitats into integrated management processes.
3. Identify important habitats for long-term protection.
4. Evaluate effectiveness of habitat management activities.

F Conduct intensive population management if warranted.

1. Develop translocation plan.
   a. Map candidate sites.
   b. Develop protocol and procedures for translocation.
2. Carry out pilot translocation.
3. Carry out operational translocations if necessary.

G. Develop public support through education, participation, and fund-raising activities.

1. Maintain the public liaison committee.
2. Promote reports of marmots.
3. Increase public awareness and participation.
4. Support fund-raising activities with promotional materials.

4. Narrative

A. Monitor known populations.

A.1. Determine population trends.

Standard surveys are required to provide an early warning of declining populations. Populations of the Vancouver Island marmot have increased in the Nanaimo Lakes - Nanaimo River watersheds since the early 1970s (Munro et al. 1985). Much of this increase has occurred in logging-slash environments near Haley Lake, Pat Lake, and Butler Peak. Reproductive rates suggest healthy populations at these sites. However, this is not the case at some historical colonies. The Mount Washington colony survives at a very low population level, and no colonies are known from the Forbidden Plateau/Strathcona Park region. The "P" Mountain colony appears to be at a low ebb, and few recent records of marmots exist for the region surrounding the type locality at Douglas Peak (Bryant 1990).

A.1.a. Establish procedures for standardized surveys.

It is difficult to compare information from historic inventory counts from known colonies because of different methodologies used over the years. Previous methodologies will be reviewed and evaluated to determine a standard set of procedures for conducting marmot surveys. These procedures can then be used by both government and nongovemment personnel conducting marmot surveys to create a database of population estimates that is comparable over time to determine trends.

A.1.b. Conduct standardized surveys.

The existing animal inventory database on the Haley Lake, Green Mountain, Butler Peak, Mt. Whymper, and associated "slash" colonies will be maintained and expanded consistent with the procedures for conducting marmot surveys. This is a very high priority task, because it will provide the first indication of any downward population trend that threatens the existence of the known population of marmots.

A.1.c. Monitor reproductive status.

Newborn marmots first emerge from their burrows in late June or early July (Heard 1977). Nagorsen (1987) estimated a gestation period of 28-33 days, but that is speculative as there are no data concerning mating behaviour or duration of nursing. Litter sizes and reproductive rates are highly variable, as shown by data from the Haley Lake Bowl colony. Heard (1977) reported a mean litter size of 3.0 (n = 2) in 1973 but observed no reproduction whatsoever in 1974. Milko (1934) reported 11 young-of-the-year and calculated a mean litter size of 2.7 in 1982. Bryant (1992) observed mean litter sizes of 3.16 (n = 19).

Historic information on reproductive rates are not comparable among known colonies because of different methodologies used over the years. Use of standard procedures for conducting marmot surveys will allow comparison of average litter size and breeding intervals among known colonies.

A.2. Determine survival of marked animals.

This task involves searching for previously marked animals and marking additional animals with ear-tags. It is a critical component of monitoring survivorship and reproductive status of existing populations.

A.3. Model population dynamics to estimate minimum viable population size.

Modelling will be used to identify components of marmot population dynamics that have important ramifications on species survival. Modelling will allow confirmation and calibration of vital rates used in estimates of effective population size. Population sensitivity to random environmental fluctuations will also be modelled. based on empirical information gathered in field surveys. Initial modelling attempts have been conducted (Bryant 1993b).

B. Determine habitat requirements and map habitat

The broad range of habitat types used by the Vancouver Island marmot precludes a simple estimate of the total habitat available for the species, making inventory difficult. Although there is apparently considerable natural habitat available for the Vancouver Island marmot on Vancouver Island, there has been no systematic investigation of hibernacula requirements and the associated biophysical features that constitute good overwintering habitat. Neither has there been extensive mapping of existing and potential marmot habitat throughout its prehistoric, historic and current range.

B. 1. Determine hibernacula characteristics.

Vancouver Island marmots hibernate from early October to May (Nagorsen 1987). The physiological toll exacted by hibernation is likely a significant cause of mortality, particularly for young marmots. Adults lose over half their body weight by the time they emerge from hibernation.

Data for *M. flaviventris* reveal that young-of-the-year survivorship averages about 50% but varies dramatically with site and year; rates as low as 7% or as high as 80% have been recorded (Armitage and Downhower 1974). Similar mortality rates occur in populations of hoary and Olympic marmots (Barash 1973; Holmes 1979). On Vancouver Island, Bryant (1990) found in one case that only one of five infants survived their first winter. More recent data from ear-tagged individuals (Bryant unpubl.) indicate that 50% (9 of 18) survived their first winter. The availability of suitable hibernacula is likely the most important determinant of overwintering mortality, although snow depth and consequent food availability are also critical (Armitage and Downhower 1974).

Survival of radio-marked animals in known hibernacula (see task D.1] will help to determine the importance of hibernacula characteristics on overwinter survival. Temperature-sensitive radio-transmitters and temperature probes will be used to determine me thermal dynamics of both overwintering marmots and the hibernacula they are using. Biophysical characteristics of all known hibernacula will be determined as part of the biophysical habitat mapping program.

B.2. Conduct biophysical habitat mapping.

Biophysical habitat mapping of current and potential marmot habitat will be used to direct search efforts for undiscovered colonies, plan habitat protection activities, and plan possible translocation programs. The mapping task will involve compiling all existing information on habitat requirements of the Vancouver Island marmot and related species, biophysical sampling of the habitat at known colonies and representative sites throughout the potential range of marmots, and air-photo and satellite imagery interpretation to derive the final map polygons.

A detailed 150,000 scale biophysical map of all existing and potential marmot habitat on Vancouver Island (above 700 m elevation) will be produced.

C. Inventory for undiscovered colonies and habitats.

Caution must be used in interpreting the historical and current information on distribution and abundance of marmots. Large portions of Vancouver Island have never been searched for marmots, and other sites have been only cursorily surveyed. That, together with the wide variety of habitats used and the reclusive nature of the species, makes it likely that other colonies remain to be discovered. Discovery of new colonies could modify die nature of recovery efforts, notably concerning the need for translocations.

C. 1. Survey historic sites and unconfirmed sightings.

Additional surveys are required to determine present marmot population status throughout Vancouver Island. Unconfirmed sightings that exist for areas in northern and western Vancouver Island (G.W. Smith. pers. commun.) will be investigated. Particular attention will be given to historical sites in the Douglas Peak and Forbidden Plateau regions

C.2. Survey high capability habitats for the presence of manners.

Biogeoclimatic and ecoregion mapping is available for Vancouver Island at 1:250 000 scale. These maps will be used to plan searches for undiscovered colonies. Biophysical habitat mapping of potential marmot habitat will also be used to direct search efforts as information becomes available (see task B.2).

D. Investigate dispersal characteristics.

The nature and frequency of dispersal in young Vancouver Island marmots is not understood, and data for other marmots are conflicting. According to Barash (1973), *M. olympus* normally disperses at 2 years of age, and the probability of dispersal is greater in large colonies. Holmes (1979) determined that 2-year-old *M. caligata* in Alaska dispersed only if their family group produced a new litter. In *M. flaviventris*, Brody and Armitage (1985) documented dispersal of yearlings, especially males, regardless of population status. Dispersal occurred even when adult males and females or both had been experimentally removed from the colony, suggesting that adult-yearling interactions were not the proximate factors in causing dispersal.

Population simulation results indicate that the number of immigrants entering a colony has a major influence on population trends (Bryant 1993b). Colonies that do not receive immigrants will likely become extinct relatively quickly.

D.1. Determine dispersal rates of marked animals.

This task involves a 3-year Ph.D. program to surgically implant radio transmitters in approximately 40 marmots of various sex and age classes. This technique was chosen for a number of reasons. Radio-marking was considered essential to answer the conflicting hypotheses on the impact of clearcut logging, because of the need to document the movements and survival of known individuals among the population of dispersing marmots. Other radio-marking techniques (e.g., collars or ear-tags) were considered but were found to be unfeasible due to burrowing behaviour, the physical nature of the marmot, or unreliable transmitter technology.

The use of surgically-implanted transmitters has proven to be both safe and effective in extensive application on yellow-bellied marmots in Colorado. Of 300 surgeries on 183 animals, there was only one post-surgical mortality that may have been related to the surgery (Van Vuren 1989). The animal care protocol developed in the Colorado studies was witnessed on site, by both the primary researcher on this project and the veterinarian in charge of all Vancouver Island marmot surgeries. The animal care protocol used on this project, although based on the Colorado work, has been extensively modified to ensure the utmost in safe and humane animal care. Colorado researchers found that transmitters generally lasted fewer than 15 months (D. Van Vuren, pers. commun.). Therefore, researchers in B.C. will replace implanted transmitters annually and will remove them at the end of the study (in year 4).

Radio-marked animals will be intensively located at least weekly, and often daily, to determine the onset of dispersal activity and the survival and behaviour of dispersing marmots in different habitats. Telemetry is the only way in which causes of mortality (e.g., predation, overwintering mortality) can be ascertained. The team also believes that use of radio-telemetry will minimize any possible observer-impact, because animals can be located from distances of up to 1 km. Heard (1977) and Bryant (1990) concluded that daily visits to study colonies did not influence marmot behaviour, survival, or reproductive success. Animals quickly habituated to the observer's presence. Apart from the impact of surgeries, use of telemetry will presumably be less intrusive than intensive mark-recapture observations. The possibility of establishing computerized remote monitoring stations was considered and rejected by the team. Apart from the expense, marmot transmitters have a relatively weak signal strength and a narrow directional beam which preclude use of fixed receiving stations. This is a fundamental limitation imposed by the physics of an encased antenna and the need to keep transmitter packages as small as possible (35 g). Finally, addition of a human observer will facilitate correlation of telemetry data with empirical observations of marmot behaviour and body temperature. Preliminary work in 1992 and 1993 resulted in 19 animals with implanted transmitters. Survival of implanted marmots has been 100% to date. One mortality occurred in 1992 that was due to overheating during transport prior to surgery. All future surgeries will be performed at the capture site rather than moving the animals to a fixed surgical site. Results to date indicate that body temperatures in *M. vancouverensis* may vary by up to 4°C in the course of an hour, that body temperature changes are correlated with behaviour, and that thermal characteristics may explain some observed patterns of habitat selection (A. Bryant. pers. commun.).

D.2. Determine age and sex classes of dispersing marmots.

This task will be accomplished by locating radio-marked animals and observing and identifying ear-tagged animals (see tasks A.2 and D.1).

D.3. Determine effects of dispersal on colony establishment and persistence.

Preliminary information from the population modelling exercise (Appendix 1) indicates that periodic immigration has to occur for colonies to persist. The magnitude of immigration and emigration that occurs within individual colonies is unknown. Locations of radio-marked individuals and opportunistic sightings of ear-tagged individuals will be used to refine input to population models.

D.4. Determine influence of land-use activities on dispersal characteristics.

The conflicting hypotheses of Cowan and Heard (Munro et al. 1985) and Bryant (1990) require testing, as dispersal is central to understanding why, when, and how marmots establish new colonies or augment existing ones. Monitoring the survival of radio-marked marmots in logged and unlogged habitats will determine whether habitats created by logging have a positive or negative impact on populations of marmots. If logged habitats prove to be valuable to maintaining marmot populations, then plans to maintain early seral stages through silviculture techniques may be required. In addition to monitoring survival of marked animals, the use of transmitters will also provide the opportunity to determine causes of mortality (e.g., predation, overwinter kill.)

E. Protect and manage important subalpine and logged habitats.

Many marmot colonies occur on private forest land; however, most sites are not likely to be threatened by timber extraction due to difficult access and poor timber quality. Tourism, recreation development, and mining may cause conflict at some existing or potential marmot colonies.

E. 1. Maintain protection of habitat through the existing referral system.

The BCMELP referral system was initiated in the early 1970s. Any development proposal on Crown land is referred to the Habitat Protection Section of BCMELP for evaluation and recommendations to minimize and mitigate adverse impacts on fish and wildlife resources. The requirements of Vancouver Island marmots are considered when development proposals are received that occur in marmot habitat. This is an on-going routine activity of the ministry.

E.2. Incorporate important habitats into land-use planning initiatives.

A number of integrated management processes that involve potential protection and management of marmot habitat are currently underway. The Protected Areas Strategy, Coastal Biodiversity Guidelines, and the Forest Practices Code are examples of initiative that offer opportunities to incorporate the habitat requirements of Vancouver Island marmots into the overall land-use planning framework. Endangered species, including the Vancouver Island marmot, will receive special emphasis in these programs.

E.3. Identify important habitats for long-tem protection.

Long-term protection of marmot habitat can be achieved by acquisition of private land, administrative transfer of Crown land, and through landowner agreements. Given the history of successful landowner agreements with companies owning marmot sites and the high cost of land, the outright purchase of marmot habitat is feasible only on an opportunistic basis, and is not a high priority for existing land acquisition programs. Securing tenure on important Crown lands by administrative transfer is a higher priority. The highest priority for protection of marmot habitat is through long-term landowner agreements, especially on potential translocation sites on private land. High priority sites for long-term protection will be identified by biophysical habitat inventory and animal inventory.

E.4. Evaluate the effectiveness of habitat management activities.

The effectiveness of the various habitat protection and management systems and initiatives will be determined by monitoring and auditing referral recommendations and the degree to which marmot requirements are incorporated into land-use plans. This will be the responsibility of Wildlife and Habitat Management staff of B.C. Environment. Priorities for habitat securement may increase if these other habitat management efforts are determined to be less than fully effective.

F. Conduct intensive population management if warranted.

Potential intensive population management activities include captive breeding and translocation of individuals to establish new colonies in vacant habitat. There are insufficient grounds to support the establishment of a captive breeding colony. The financial costs of captive breeding are high, and although a captive colony could provide benefits with regard to public education and research, the money would be more profitably spent on other components of the plan. Translocation may be the most effective means of achieving recovery objectives and downlisting the species, if surveys for undiscovered colonies do not find significant numbers of marmots.

F.1. Develop translocation plan.

Downlisting the Vancouver Island marmot involves finding or establishing second and third populations of marmots that are geographically isolated from the centre of distribution of the existing population. If inventory of potential colonies reveals the presence of suitable unfilled habitat, then the first step in a successful translocation program is to refine techniques for safely and effectively translocating marmots to new areas.

The translocation plan will be used to determine the need for, implementation of, and evaluation of any translocation activities. if surveys for undiscovered colonies do not meet objective #2 within two years, then the translocation plan will be implemented.

F.1.a. Map candidate sites.

Translocation sites will be developed based on habitat and hibernacula characteristics of existing colonies, and the presence of vacant high capability habitats based on biophysical mapping.

F.1.b. Develop protocol and procedures for translocation.

Because many translocation programs are unsuccessful, this task is of particular importance to ensure a reasonable probability of success. Information on other transplant programs in similar habitats or with similar species will be gathered from published and unpublished sources. The best time of year, the required number of individuals and their sex and age, and the degree of preparation required at reintroduction sites to re-establish marmot colonies are currently unknown. For these reasons, the timing, scale, and methods involved in re-introduction are important components of the translocation plan. The translocation plan will include animal care protocols to ensure that marmots are not unduly stressed.

F.2. Carry out pilot translocation.

A prototype reintroduction, involving the translocation of one or two families to one site, will provide much needed information regarding specific techniques. One or two marmots would be radio-marked in order to monitor movement and survival of translocated animals. Information gathered from monitoring the pilot translocation would be used to modify the translocation plan.

F.3. Carry out operational translocations if necessary.

Depending on the results of searches for other colonies, biophysical habitat mapping, and the pilot translocation program, an operational translocation program may be required to reach the total population objective of 400-600 animals. This task is designed to establish two distinct metapopulations genetically isolated from the existing colonies in the core area to meet objective #2. Each metapopulation of approximately 100-200 marmots would consist of at least six subpopulations or colonies, distributed in such a way that natural dispersal and recolonization can occur. One or two marmots from each translocated colony would be radio-marked in order to monitor movement and survival of translocated animals.

G. Develop public support through education, participation, and fund-raising activities.

Recovery efforts are best supported by an informed and supportive public. Support for marmot conservation efforts is high among the informed public, but more of the general public should be made aware of the existence and plight of this endangered species.

G. 1. Maintain the public liaison committee.

The Vancouver Island Marmot Public Liaison Committee, comprising members of government, nongovernment organizations, and the general public, is an effective forum through which many issues are addressed. The liaison committee will be used to channel volunteer labour and funds from nongovernment organizations into recovery efforts. The liaison committee recently established a small working group to develop a communication strategy that is to include fund-raising activities.

G.2. Promote reports of marmots.

Reporting of marmot sightings by members of the public can be encouraged by posting signs and posters; signs are already in place on the access roads to the Nanaimo Lakes and River watersheds, and a poster for general distribution has been produced (Appendix 2). Additional signs are needed near Forbidden Plateau in Strathcona Provincial Park, at the entrance to Mount Arrowsmith Regional Park, on the Port Alberni/Bamfield road just outside the Port Alberni city limits, and on the Island Highway near Woss. Posters requesting marmot information will be placed in government offices on Vancouver Island.

G.3. Increase public awareness and participation.

B.C. Environment will continue existing efforts to promote public awareness and appreciation of marmots. Marmot "fact-sheets" will be updated. Media representatives will be supplied with accurate information to promote marmots and marmot recovery efforts.

Reid et al. (1988) determined that 84% of British Columbians are interested in endangered species. Possible development of one marmot colony for public viewing will have two beneficial results. First, a public able to see marmots would be more prone to support the costs of recovery efforts. Second, by planning ahead, managers can control and confine impacts to one site.

G.4. Support fund-raising activities with promotional materials.

Funding required to implement this plan should come from a variety of sources: government, industry, academic, and private. To encourage contributions, The Nature Trust of B.C. has established an interest-bearing Vancouver Island Marmot Recovery Account. All donations will be acknowledged with tax receipts, and money collected will go directly to work on marmots. Disbursements from this fund and all work done as a result will be under the direction of the Vancouver Island Marmot Recovery Team. Donations may be made to The Nature Trust of British Columbia, 808-100 Park Royal South, West Vancouver, B.C. WT 1A2, and should be identified as being for the "marmot account."

Section III

Implementation schedule

The implementation schedule (Table 2) lists recovery actions outlined in the recovery plan and identifies their priorities, time frame, costs, and the agencies responsible for carrying them out. Priorities for these actions are defined as follows:

Priority 1: An action that must be taken to prevent extinction or prevent the species from declining irreversibly in the foreseeable future.

Priority 2: An action that must be taken to prevent a significant decline in species population or habitat quality, or some other significant negative impact short of extinction.

Priority 3: All other actions necessary to provide for full recovery (or status improvement) of the species.

Table 2
Implementation schedule for the Vancouver Island marmot Recovery Plan

Action	Recovery plan no.[1]	Priority	Responsibility[2] Lead	Responsibility[2] Co-op	Target date	Est. cost $K(PMs)[3] 93/94	94/95	95/96	96/97	97/98
A. Background studies and research										
1. Monitor known populations	A.1	1	BCE	NGO	Ongoing	15(6)	15(6)	15(6)	15(6)	15(6)
2. Determine habitat requirements and map habitat	B.1,2	2	BCE	UVIC	1995	10	10	10	0	0
3. Inventory potential colonies and habitats	C 1,2	2	BCE	BCP, CWS, RBCM	1995	45(16)	45(16)	45(16)	0	0
4. Investigate survival and dispersal characteristics of marked animals	A.2,3 D.1-4	2	BCE	UVIC	1995	58(12)	62(12)	43(12)	0	0
B. Management										
1. Manage and protect habitat	E.1-4	1	BCE	BCP	Ongoing	Part of routine BCE activities				
2. Develop translocation plan	F.1	2	BCE		1994	0	4(2)	0	0	0
3. Carry out pilot translocation if necessary	F.2	2	BCE		1995/96	0	0	20(6)	15(4)	0
4. Carry out operational translocation if necessary	F.3	2	BCE		1997	0	0	0	0	40(10)
C. Monitoring and evaluation										
1. Monitor, evaluate, revise all activities of the plan	All	2	BCE	All	Annual	Part of routine recovery team activities				
D. Administration and public relations										
1. Public liaison committee	G.1	1	BCE	NGO	Ongoing	No funding required				
2. Promote public awareness and participation	G.2,3	3	BCE	NGO	Ongoing	Part of BCE activities				
3. Fund-raising activities	G.4	1	BCE	NGO	Ongoing	Administered by The Nature Trust of B.C.				

[1] Refers to "Stepdown outline."
[2] BCE = B.C. Environment; BCP = B.C. Parks; CWS = Canadian Wildlife Service; NGO = nongovernment organizations; RBCM = Royal British Columbia Museum; UVIC = University of Victoria.
[3] Numbers in parentheses are person-months included in the budget, *exclusive* of permanent agency staff time.

Section IV

Literature Cited

Armitage, K.B., and .J.F. Downhower. 1974. Demography of yellow-bellied marmot populations. Ecology 55:1233-1245.

Barash, D.P. 1973. The social biology of the Olympic marmot. Animal Behavior Monogr. 6:171-245.

Barash, D.P. 1974. Social behavior of the hoary marmot. Animal Behavior 22:256-261.

Brody, A.K., and K.B. Armitage. 1985. The effects of adult removal on dispersal of yearling yellow-bellied marmots. Can. J. Zool. 63:2560-2564.

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

Bryant, A.A. 1992. Demography of Vancouver Island marmots (*Marmota vancouverensis*): year-end report for 1991. Unpub. rep. prepared for the Vancouver Island Marmot Recovery Team. Andrew A. Bryant Services, Nanaimo, B.C. 28 pp.

Bryant, A.A. 1993a. A review of inventory data for Vancouver Island Marmots. Unpubl. rep. for the Vancouver Island Marmot Recovery Team. Nanaimo, B.C. 26 pp.

Bryant. A.A. 1993b. A stochastic population simulation model, and estimates of effective population size *Ne*, for Vancouver Island Marmots. Unpubl. rep. for the Vancouver Island Marmot Recovery Team. Nanaimo, B.C. 22 pp.

Burgman, M.A., H.R. Akcakaya, and S.S. Loew. 1988. The use of extinction models for species conservation. Biol. Conserv. 43:9-25.

Calvert, G., and S. Crockford. 1983. Analysis of faunal remains from the Shoemaker Bay site. Pages 174-219 *in* A.D. MacMillan and D.E. St. Claire (eds.). Alberni prehistory: archaeological and ethnographic investigations on western Vancouver Island. Theytus Books, Nanaimo, B.C

Carl, G.C. 1943. The natural history of the Forbidden Plateau area, Vancouver Island, British Columbia. Pages 18-40 *in* Report of the B.C. Provincial Museum for 1943. Victoria, B.C. 78 pp.

Carl, G.C. 1944. The Vancouver Island marmot. Victoria Nat. 1:77-78.

Carson, T. 1978. The Vancouver Island marmot, an endangered species in Canada. Unpubl. rep. 24 pp.

Chesser, R.K. 1983. Genetic variability within and among populations of the black-tailed prairie dog. Evolution 37:320-331.

Clark, T.W. 1987. Black-footed ferret recovery: a progress report. Conserv. Biol. 1:8-13.

Dearden, P.E. 1983. Non-consumptive recreation pressures and the case of the Vancouver Island marmot. Environ. Conserv. 10:63-66.-

Dyer, 0. 1982. Behaviour of captive Vancouver Island marmots at the Okanagan Game Farm. Unpubl. rep. B.C. Ministry of Environment, Fish and Wildlife Branch, Penticton. 57 pp.

Finkelstein, M., and B. Darling. 1973. Marmot survey, 1973. Unpubl. rep. B.C. Ministry of Environment, Fish and Wildlife Branch, Nanaimo. 51 pp.

Frankel, 0.1-1., and M.E. Soulé. 1981. Conservation and evolution. Cambridge Univ. Press, Cambridge, U.K. 327 pp.

Franklin, LA. 1980. Evolutionary change in small populations. Pages 135-150 in Conservation biology: an ecological-evolutionary perspective. Sinauer Associates, Sunderland, Mass. 393 pp.

Franklin. J.F., W.H. Moir, G.W. Douglas, and C. Wiberg. 1971. Invasion of subalpine meadows by trees in the Cascade Range, Washington and Oregon. Arct. Alpine Res. 3:215-224.

Fry, K.S. 1981." Vancouver Island marmots: field investigations. Unpubl. rep. Canadian Wildlife Service, Ottawa. 27 pp.

Fry, K.S., LA. Morgan, and G.W. Smith. 1986. Vancouver Island marmot inventory, 1986. Unpubl. rep. B.C. Ministry of Environment, Fish and Wildlife Branch, Nanaimo. 68 pp.

Gilpin, M.E. 1987. Spatial structure and population vulnerability. Pages 125- 140 in M.E. Soule (ed.), Viable populations for conservation. Cambridge Univ. Press, New York. 189 pp.

Gilpin, M.E. 1991. The genetic effective size of a metapopulation. Biol. J. Linnean Soc. 42:165-175.

Gilpin, M.E., and M.E. Soulé. 1986. Minimum viable populations: processes of species extinction. Pages 19-35 in M.E. Soulé (ed.), Conservation biology: the science of scarcity and diversity. Sinaur Associates, Sunderland, Mass. 584 pp.

Halpin, Z.T. 1987. Natal dispersal and the formation of new social groups in a newly established town of black-tailed prairie dogs (*Cynomys ludovicianus*). Pages 104-188 in B.D. Chepko-Sade and Z.T. Halpin (eds.), Mammalian dispersal patterns: the effects of social structure on population genetics. Univ. of Chicago Press, Chicago. 342 pp.

Harris, R.B., and F.W. Allendorf. 1989. Genetically effective population size of large mammals: an assessment of indicators. Conserv. Biol. 3:181-191.

Hartl, D.L. 1981. A primer of population genetics. Sinauer Associates, Sunderland, Mass. 191 pp.

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

Heinsalu, V., and G.W. Smith. 1982. Vancouver - Island marmot survey, 1982. Unpubl. rep. B.C. Ministry of Environment, Fish and Wildlife Branch, Nanaimo. 34 pp.

Heinsalu, V., and C.W. Smith. 1983. Vancouver Island marmot inventory 1983. Unpubl. rep. B.C Ministry of Environment, Fish and Wildlife Branch, Nanaimo. 34 pp.

Hill, W.G. 1972. Effective population size of populations with overlapping generations. Theoretical Pop. Biol. 3:278-289.

Hoffman, R.S., LW. Koeppl, and C.F. Nadler. 1979. The relationships of the amphiberingian marmots (Mammalia: sciuridae). Occas. Pap. Museum Natural History, University of Kansas, Lawrence. 56 pp.

Holmes, W.G. 1979. Social behavior and foraging strategies of hoary marmots (*Marmota caligata*) in Alaska. Ph.D. Thesis, Univ. of Washington, Seattle. 130 pp.

Holmes, W.G. 1984. The ecological basis of monogamy in Alaskan hoary marmots. Pages 250-274 in J.0. Murie and G.R. Michener (eds.), The biology of ground dwelling squirrels. Univ. of Nebraska Press, Lincoln. 459 pp.

Janz, D.W. 1982. Management of an endangered species: the Vancouver Island marmot. Pages 310-318 in Association of Zoological and Parks and Aquariums Regional Conference Proceedings.

Kimura, M., and J.F. Crow. 1963. The measurement of effective population numbers. Evolution 17:279-288.

Kuramoto, R.T., and L.C. Bliss. 1970. Ecology of subalpine meadows in the Olympic Mountains, Washington. Ecol. Monogr. 40:31?-347.

LaCava, J., and J. Hughes. 1984. Determining minimum viable population levels. Wildl. Soc. Bull. 12:370-376.

Lande, R., and G.F. Barraclough. 1987. Effective population size, genetic variation and their use in population management Pages 87-123 in Soulé, M.E. (ed.), Viable populations for conservation. Cambridge Univ. Press, Cambridge, U.K.

Lemkuhl, J.F. 1984. Determining size and dispersion of minimum viable populations for land management planning and species conservation. Environ. Manage. 8:187-176.

Martell, A..M., and RJ. Milko. 1986. Seasonal diets of Vancouver Island marmots. Can. Field-Nat. 100:241-245.

Merilees, W. 1980. Vancouver Island fauna best left alone. B.C. Nat. 18 (2,3):19-20.

Milko, RJ. 1984. Vegetation and foraging ecology of the Vancouver Island marmot (*Marmota vancouverensis*). M.Sc. Thesis, Univ. of Victoria, Victoria, B.C. 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 Environ. Wildl. Bull. B-39, Victoria. 24 pp.

Nagorsen, D.W. 1987. *Marmota vancouverensis*. Mammalian Species 270:1-5.

Nagorsen, D.W. 1988. A summary of museum specimens for the Vancouver Island marmot. Unpubl. rep. Royal B.C. Museum, Victoria. 5 pp.

Nagorsen, D.W. 1989. Marmot bones in caves on Clayoquot Plateau. Can. Caver 21:39-40.

Nagorsen, D.W. In press. Endangered mammals in British Columbia. In L.E. Harding and EA. McCullum. Biodiversity in British Columbia: our changing environment. Environment Canada, Pacific and Yukon Region, Vancouver, B.C.

O'Brien, SJ., M.E. Roelke, L. Marker, A. Newman, C.A. Winkler, D. Meltzer, l... Colly, J.F. Evermann, M. Bush, and D.E. Wildt. 1985. Genetic basis for species vulnerability in the cheetah *Acinonyx jubatus*. Science 227:1428-1434.

Page, R. 1987. Re: 18-year cycles in Vancouver Island snowfall. Unpubl. memorandum, B.C. Ministry of Lands and Forests (Jan. 13, 1987). 6 pp.

Ralls, K., .J.D Ballou, and A. Templeton. 1988. Estimates of lethal equivalents and the cost of inbreeding in mammals. Conserv. Biol. 2:185-193.

Ralls, K., P.H. Harvey, and A.M. Lyles. 1986. Inbreeding in natural populations of birds and mammals. Pages 35-56 in M.E. Soulé (ed.], Conservation biology: the science of scarcity and diversity. Sinauer Associates, Sunderland, Mass. 534 pp.

Rausch, R.L, and V.R. Rausch. 1971. The somatic chromosomes of some North American marmots. Extrait de Mammalia 35:85-101.

Reed, l.M., P.D. Doerr, and J.R. Walters. 1986. Determining minimum population sizes for birds and mammals. Wildl. Soc. Bull. 14:255-261.

Reid, R., M. Stone, and F. Rothman. 1988. Report on the British Columbia survey of non-hunting and other wildlife activities for 1983. Ministry of Environment, Victoria 182 pp.

Routledge, J.D. 1981. The Vancouver Island marmot survey, 1980. Vancouver Island Marmot Preservation Committee. Unpubl. rep. no. 2. 9 pp.

Routledge, J.D. 1982. The Vancouver Island marmot survey, 1981. Vancouver Island Marmot Preservation Committee. Unpubl. rep. no. 3. 12 pp.

Routledge, J.D., and W.J. Merilees. 1980. The Vancouver Island marmot survey, 1979. Vancouver Island Marmot Preservation Committee. Unpubl. rep. no. 1. 10 pp.

Ryman, N., R. Baccus, C. Reuterwell, and M.H. Smith. 1981. Effective population size, generation interval, and potential loss of genetic variability in game species under different hunting regimes. Oikos 36:257-266.

Shaffer, M.L. 1981. Minimum population sizes for species conservation. Bioscience 31:131-134.

Schwartz, 0.A, and K.B. Armitage. 1980. Genetic variation in social mammals: the marmot model. Science 207:665-667.

Schwartz, 0.A, and K.B. Armitage. 1981. Social substructure and dispersion of genetic variation in the yellow-bellied marmot (*Marmota flaviventris*). Pages 139-159 in M.H. Smith and J. Joule (eds.), Mammalian population genetics. Univ. of Georgia Press, Athens.

Smith, G.W. 1982. Vancouver Island marmot, present status, 1981. Unpubl. rep. B.C. Ministry of Environment, Fish and Wildlife Branch, Nanaimo. 19 pp.

Smith, G.W. 1983. Vancouver Island marmot: present status. Unpubl. rep. B.C. Ministry of Environment, Fish and Wildlife Branch, Nanaimo. 12 pp.

Smith, G.W. 1985. Vancouver Island marmot inventory, 1985. Unpubl. rep. B.C. Ministry of Environment, Fish and Wildlife Branch, Nanaimo. 15 pp.

Smith, G.W., K. Sturmanis, and B. Mason. 1984. Vancouver Island marmot inventory, 1984. Unpubl. rep. B.C. Ministry of Environment, Fish and Wildlife Branch, Nanaimo. 10 pp.

Swarth, H.S. 1911. Two new species of marmots from northwestern America. Univ. of California Publ. Zool. 7: 201-204.

Swarth, I-LS. 1912. Report on a collection of birds and mammals from Vancouver Island. Univ. of California Publ. Zool. 10: 1-124.

Van Vuren, D. 1989. Effects of intraperitoneal transmitter implants on Yellow-bellied Marmots. J. Wildl. Manage. 53:320-323.

Wasser, S.K., and D.P. Barash. 1983. Reproductive suppression among female mammals; implications for biomedicine and sexual selection theory. Quarterly Rev. Biol. 58:513-538.

Wayne, R.K., L. Forman, L K. Newman, J. M. Simonson. and SJ. O'Brien. 1986. Genetic monitors of zoo populations: morphological and electrophoretic assays. Zoo Biol. 5:215-232.

Wildt. D.E., M. Bush, K.L. Goodrowe, C. Packer, A.E. Pusey, J.L. Brown, P. Joslin, and SJ. O'Brien. 1987. Reproductive and genetic consequences of founding isolated lion populations. Nature 329:328-331.

Appendix 1

Estimating effective population size *Ne* (from Bryant 1993b)

The concept of effective population size (*Ne*) is important to understanding population genetics. The term has been defined as "the size of an idealized population that would have the same amount of inbreeding or random gene frequency drift as the population under consideration" (Kimura and Crow 1963). The concept is important because genetic variation is lost through genetic drift and inbreeding at a rate proportional to *Ne* and not the census population size *N* (Hartl 1981). This occurs because most populations fail to meet the genetic ideals of random mating, monogamy, equal survivorship of sexes, uniform reproduction by all individuals, and non-overlapping generations. For this reason *Ne* is generally a fraction of the total census population *N*.

Effective population size of the known Vancouver Island marmot metapopulation was calculated using seven published methods (Reed et al. 1986; Reed et al. 1986 with the adjustment contained in Harris and Allendorf 1989; Hill 1972; LaCava and Hughes 1984: Lande and Barraclough 1987; Lemkuhl 1984; and Ryman et al. 1981). Our estimates of *Ne* assume a stable population size, panmictic breeding among all animals, and monogamy.

Population and demographic parameters used in the calculations were as follows:

	Ne	*Ne/N* ratio	*N* to achieve *Ne*=50
Hill (1972)	22.04	0.0942	530.78
Ryman et al (1981)	20.49	0.0876	570.63
Lande and Barraclough (1987)	21.37	0.0913	547.64
Reed et al. (1986 modified)	26.01	0.1111	450.05
Reed et al. (1986)*	52.65	0.2250	222.22
Lemkuhl (1984)*	3.72	0.0159	3144.65
LaCava and Hughes (1984)	233.79	0.9991	50.04

* The Lemkuhl and LaCava and Hughes (1984) formulae have been discredited by Harris and Allendorf (1989) and are no longer in general use. The same authors found that the unadjusted Reed el. al. (1986) formula typically overestimated *Ne* by up to 60%; however, when the formula is adjusted for variation in production of young, the formula produces reasonably accurate values.

1. Number of males and females that breed annually is equal (no polygamy) and invariant (no population fluctuations). Assuming that 68 infants are produced annually (Munro et al. 1985), division by litter size (3.16; n=19, Bryant unpublished) yields *F*=22 reproductive females and *M*=22 reproductive males annually.

2. Average age of parents was generated from simulation results and male and female parents were assumed to have equal average ages (*L*=6.8).

3. Mean number of male progeny from breeding males, males from females, females from males, and females from females. These rates were calculated by creating a simulated cohort of 100 3-year-old animals, applying observed survivorship rates to a maximum age of 15 years, and applying observed sex ratio and fecundity rates to surviving animals. Variance in reproductive rates were calculated directly from these data (*mm*=0.26, *mf*=0.33, *fm*=0.26, *ff*=0.33). Hill's model also requires an estimate of covariance terms; these were also generated from the artificial 100-animal cohort (*Covmm*,*mf*=0.2525, *Covfm*,*ff*=0.2525).

4. Annual recruitment of breeding-age females was assumed to be equal to the average number of young (68) divided by sex-ratio (1:1) multiplied by the survival rate to reproductive age (0.146). *N*=4.9 females annually.

5. Heritability of fertility. No empirical data are available. I assumed there was a very weak correlation between litter size and the probability of progeny themselves producing large litters (*h*=0.01). In Ryman et al.'s (1981) model, strong heritability of fertility has a dramatic influence on *Ne*, as reproductive success is "family-biased"

and the actual number of animals contributing to the next generation comes from only a few lineages. This variable is not used in other formula.

6. Mean and variance of individual lifetime production of young. These rates were calculated by creating a simulated cohort of 100 reproductive-age (3-year-old animals), applying observed survivorship rates to a maximum age of 15 years, and applying observed sex ratio and fecundity rates to surviving animals. Mean and variance in lifetime reproductive rates were calculated directly from these data (for males, k=2.72, 0-10.27, and for females, k=2.72, v=10.27).

7. Mean and variance of individual lifetime production of offspring who themselves survive to reproductive age and produce young. Although similar to #7, Ka and Va parameters are based only on that fraction of progeny that themselves survive long enough to reproduce. Mean and variance in lifetime reproductive rates were calculated directly from the 100-animal artificial cohort (Ka=0.19, Va=0.26).

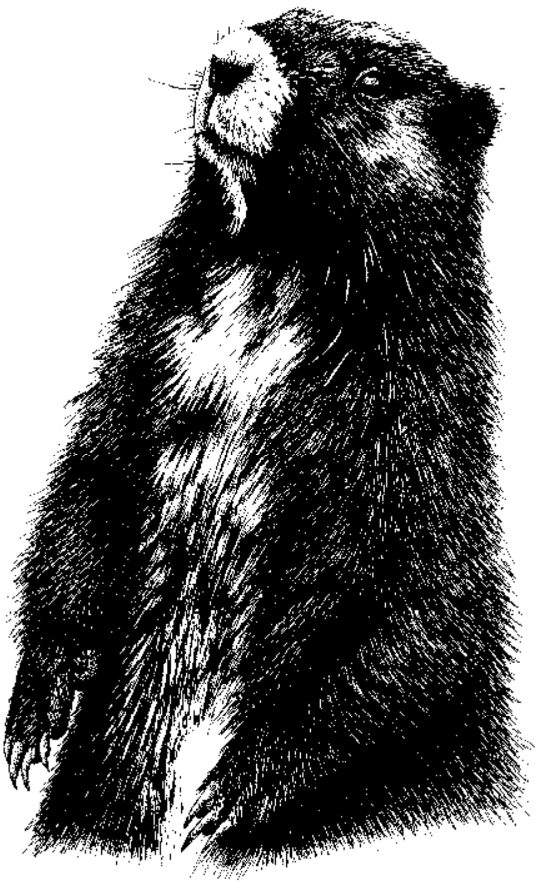
8. Probabilities of males and females surviving to reproductive age were taken from simulation results (for males, lm=0.222, and for females, lf=0.146).

9. Total population size N=234. This value was taken from the 1984 survey, the year of most intensive inventory effort (Munro et al. 1985). It likely underestimates the total population size.

10. Ratio of adult males/total adult population size was based on field data (m/N=0.48). 11. Mean generation length was generated from simulation results (L=6.29).

Appendix 2

Public information poster



HELP!

We need help to protect the endangered Vancouver Island Marmot.

Vancouver Island Marmots live only on Vancouver Island. The known population numbers fewer than 300 individuals, making it one of the world's rarest mammals.

Marmots are most abundant in sub-alpine meadows that provide good soil for burrowing, plentiful grasses and flowers to eat, and suitable rocks for lookout spots. They also inhabit steep cliffs, rock slides, logged areas and other man-made habitats.

We need your help to find marmot colonies!

Undiscovered colonies almost certainly exist near Strathcona Provincial Park; we are particularly interested in all marmot sightings made in areas *north* or *west* of Port Alberni.

If you see marmots in this area, please write or telephone:

Vancouver Island Marmot Recovery Team
Wildlife Management Section
Ministry of Environment, Lands and Parks
2569 Kenworth Road
Nanaimo, B.C. V9T 4P7
☎ Telephone 751-3100

Previous publications

Canadian Whooping Crane Recovery Plan		December 1987
Anatum Peregrine Falcon Recovery Plan		October 1988
RENEW Report No. 3	*National Recovery Plan for the Baird's Sparrow*	April 1993
RENEW Report No. 4	*National Recovery Plan for the Roseate Tern*	June 1993
RENEW Report No. 5	*National Recovery Plan for the Greater Prairie-Chicken*	October 1993
RENEW Report No. 6	*National Recovery Plan for the Whooping Crane*	January 1994
RENEW Report No. 7	*National Recovery Plan for the Loggerhead Shrike*	March 1994
RENEW Report No. 8	*National Recovery Plan for the Marbled Murrelet*	May 1994
RENEW Report No. 9	*National Recovery Plan for the Gaspésie caribou*	November 1994

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 of terrestrial mammals, birds, reptiles, and amphibians that have been designated as extirpated, endangered, or threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The RENEW strategy is implemented by a committee of the same name composed of the directors of provincial, territorial. and federal government wildlife agencies plus the heads of the three major national wildlife organizations (Canadian Nature Federation, Canadian Wildlife Federation and World Wildlife Fund [Canada]). The RENEW committee establishes a "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, businesses, and private citizens.

Renew gratefully acknowledges the assistance of the Canadian Wildlife Service in producing this report and the Canadian Wildlife Federation in printing and distributing it and creating the cover artwork. The Canadian Wildlife Service is part of Environment Canada and the Canadian Wildlife Federation is a national nonprofit conservation organization.

Environment Canada	Environnement Canada
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