COSEWIC
Assessment and Update Status Report

on the

Vancouver Island Marmot
Marmota vancouverensis

in Canada

ENDANGERED
2000

COSEWIC
COMMITTEE ON THE STATUS OF
ENDANGERED WILDLIFE
IN CANADA

COSEPAC
COMITÉ SUR LA SITUATION DES
ESPÈCES EN PÉRIL
AU CANADA

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COSEWIC 2000. COSEWIC assessment and update status report on the Vancouver Island marmot *Marmota vancouverensis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 25 pp.

Bryant, A.A. 1997. Update COSEWIC status report on the Vancouver Island marmot *Marmota vancouverensis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-25 pp.

Previous report:
Munro, W.T. 1978. COSEWIC status report on the Vancouver Island marmot *Marmota vancouverensis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 12 pp.

Production note:
The 2000 COSEWIC assessment and update Status Report on the Vancouver Island marmot is based on the existing status report with an addendum.

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Également disponible en français sous le titre Rapport du COSEPAC sur la situation de la marmotte de l'île de Vancouver *(Marmota vancouverensis*) au Canada – Mise à jour

Cover illustration:
Vancouver Island Marmot — C. Douglas, from Natural History Notebook Series 4, No. 31. Canadian Museum of Nature, Ottawa, Ontario

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Catalogue No. CW69-14/109-200E-IN
ISBN 0-662-31877-3

Recycled paper

COSEWIC
Assessment Summary

Assessment Summary – May 2000

Common name
Vancouver Island marmot

Scientific name
Marmota vancouverensis

Status
Endangered

Reason for designation
A rare mammal endemic to Vancouver Island, reduced to less that 20 mature animals. The population has declined by at least 50% in the past 10 years.

Occurrence
British Columbia

Status history
Designated Endangered in April 1978. Status re-examined and confirmed Endangered in April 1997 and in May 2000. May 2000 assessment based on new quantitative criteria applied to information from the existing 1997 status report with an addendum.

COSEWIC
Executive Summary

Vancouver Island Marmot
Marmota vancouverensis

Description

The Vancouver Island marmot (*Marmota vancouverensis*), like other members of the genus, is fossorial, herbivorous and hibernates during winter. *M. vancouverensis* differs from other species in karyotype, skull characteristics, pelage and behaviour. It is similar to other alpine-dwelling marmots in its slow maturation, long life span, and complex social organization. *M. vancouverensis* persists despite a small and fragmented natural habitat base. It exhibits a “metapopulation” structure. The entire population consists of small colonies that occasionally form and become extinct.

Distribution

M. vancouverensis is endemic to Vancouver Island, British Columbia. The current population is concentrated within 5 adjacent watersheds on south-central Vancouver Island. Even within this area the population is extremely localized; >65% of marmots live on 4 mountains in the central 40 km^2 portion of their current range. Palaeontological and archaeological records indicate that *M. vancouverensis* enjoyed a broader distribution in the recent geological past. Historic records suggest that marmots disappeared from some areas quite recently (10-30 years ago).

Protection

M. vancouverensis is listed as endangered under the B.C. Wildlife Act (1980). It is also listed as endangered by the Committee on the Status of Endangered Wildlife in Canada, the U.S. Endangered Species Act and the International Union for the Conservation of Nature. Most colonies occur on privately owned lands. Two marmot habitats are legally protected (combined area of <400 ha).

Population size and trends

The current population contains 150-200 individuals. This represents a 50-60% decline in numbers during the past 10 years. Concomitant with this has been local extinction of several colonies during this period, including some which typically contained >10 adults.

Habitat

Vancouver Island marmots require three essential habitat features: 1) grasses and forbs to eat, 2) colluvial soil structure for construction of overnight and overwintering burrows, and 3) microclimatic conditions that permit summer foraging, thermo-regulation, and successful hibernation. Most marmots are found between 1000 and 1400 metres in elevation, and on south to west-facing slopes. Habitat scarcity is the fundamental reason for the rarity of *M. vancouverensis*.

Biology

M. vancouverensis is among the most social of marmots. They live in colonies which contain fewer than 5 adults on average. Females are capable of breeding at age 3, but most animals do not breed until age 4. Young marmots disperse at age 2 or later; dispersal is fundamental to maintaining metapopulation structure.

Limiting factors

The essential short-term problem is low adult and juvenile survival. Predators and unsuccessful hibernation are the principal causes of mortality. Both factors are exacerbated by the restricted range. Reproductive rates are apparently stable. There is no evidence of inbreeding depression or disease. Long-term problems probably include reduced long-distance dispersal (altered landscape connectivity caused by logging, together with reduced survival in logged habitats), and climatic/vegetation change (tree invasion of sub-alpine meadows). The question of why marmots no longer inhabit some areas is of fundamental importance. If climatic change is principally responsible, efforts to re-establish colonies will fail and there may be little that managers can do to enhance marmot populations. Alternatively, if human-caused alteration of landscape connectivity is the problem, then reintroductions should allow recovery of the species within a reasonable time period.

Special significance of the species

Marmota vancouverensis is one of only five endemic mammals in Canada. It is the only endemic mammal species which appears on the COSEWIC endangered list.

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COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) determines the national status of wild species, subspecies, varieties, and nationally significant populations that are considered to be at risk in Canada. Designations are made on all native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fish, lepidopterans, molluscs, vascular plants, lichens, and mosses.

COSEWIC MEMBERSHIP

COSEWIC comprises representatives from each provincial and territorial government wildlife agency, four federal agencies (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biosystematic Partnership), three nonjurisdictional members and the co-chairs of the species specialist groups. The committee meets to consider status reports on candidate species.

DEFINITIONS

Species	Any indigenous species, subspecies, variety, or geographically defined population of wild fauna and flora.
Extinct (X)	A species that no longer exists.
Extirpated (XT)	A species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A species facing imminent extirpation or extinction.
Threatened (T)	A species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A species of special concern because of characteristics that make it particularly sensitive to human activities or natural events.
Not at Risk (NAR)**	A species that has been evaluated and found to be not at risk.
Data Deficient (DD)***	A species for which there is insufficient scientific information to support status designation.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.
** Formerly described as "Not In Any Category", or "No Designation Required."
*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list.

Environment Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

Update
COSEWIC Status Report

on the

Vancouver Island Marmot
Marmota vancouverensis

in Canada

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1997

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INTRODUCTION

The Vancouver Island marmot (*M. vancouverensis*) is endemic to Vancouver Island, British Columbia (Nagorsen 1987). Like other members of the genus, *M. vancouverensis* is fossorial, herbivorous and hibernates during winter (Barash 1989). The species was described from specimens collected in 1910 (Swarth 1911, 1912). *M*. *vancouverensis* differs from other marmots in karyotype (Rausch and Rausch 1971), skull characteristics (Hoffmann *et al*. 1979), pelage (Nagorsen 1987) and behaviour (Heard 1977). In many respects it is a typical alpine-dwelling marmot, showing slow maturation, a relatively long life span, and a complex degree of social organization (Bryant 1996*a*). Perhaps the most interesting attribute of *M. vancouverensis* concerns its ability to persist despite a small and fragmented natural habitat base. Vancouver Island marmots exhibit a metapopulation structure, in which the entire population consists of small colonies that occasionally form and become extinct (Bryant 1990, Bryant and Janz 1996).

Much new information has become available since preparation of the original status report (Munro 1979). *M. vancouverensis* has been the subject of systematic population counts since 1979 (Bryant and Janz 1996), behavioural studies (Heard 1977), habitat and diet studies (Milko 1984, Martell and Milko 1986), and intensive mark-recapture, genetic and radio-telemetry work (Bryant 1990, 1996*a*, 1996*b*, in prep.). The life-history, distribution and demography of Vancouver Island marmots are now well known compared to some other marmot species (Bibikov 1996, Barash 1989).

Vancouver Island marmots are listed as endangered nationally (Munro 1979) and in the province of British Columbia (Munro *et al*. 1985). A formal Recovery Team was established in 1988, a draft recovery plan was prepared in 1990 (Bryant 1990), and the National Recovery Plan was published in 1994 (Janz *et al*. 1994).

DISTRIBUTION

Palaeontological and archaeological records

It is unknown when marmots first colonized Vancouver Island. Heard (1977) speculated that marmots crossed to Vancouver Island via land connections that existed during the Illinoian glacial period, approximately 100,000 years ago, and survived subsequent glacial maxima on nunataks and coastal refugia or both. Nagorsen (1987) suggested the possibility of a more recent colonization, after the retreat of the Cordilleran Wisconsin glaciation some 10,000 to 13,000 years ago. Available data do not exclude either hypothesis (see Hoffmann *et al*. 1979 and Nagorsen *et al*. 1996). A study of marmot phylogeny employing DNA analysis may shed further light on the evolutionary history of *M. vancouverensis* (M. Braun, Smithsonian Institution, personal communication).

Prehistoric marmot remains have been found at 8 locations, all well outside the present core area of distribution (Nagorsen *et al*. 1996, Calvert and Crockford 1983).

Three palaeontological finds have been made. The first (Pellucidar Cave, near Nimpkish Lake) was radio-carbon dated at 10,000 years before present. The second and third (caves at Weymer Creek, near Tahsis) consists of a partial upper incisor tooth, and a complete skeleton, respectively. The latter remains have not yet been dated (D. Nagorsen unpublished data).

Tool-marked bones at 4 high elevation archaeological sites and 1 low elevation midden provide indisputable evidence that marmots were present and hunted by aboriginal peoples. Radiocarbon dates from high elevation sites (range = 830-2630 years before present), numbers of individuals (range = 4-74 marmots), preponderance of marmot bones in samples (range = 85-100%), and presence of juvenile marmot remains present strong evidence that Vancouver Island marmots were the principal target species for late summer hunting expeditions by aboriginal peoples (Nagorsen *et al*. 1996). Cumulatively, the palaeontological and archaeological records indicate that *M. vancouverensis* enjoyed a broader distribution in the recent geological past than it has in historical times.

Historical distribution (1864-1989)

Several authors mapped location records for *M. vancouverensis* (Heard 1977, Nagorsen 1987, Bryant 1990, Janz *et al*. 1994, Bryant and Janz 1996). The most recent analysis was based on a systematic review of government files, photographs and museum records (Bryant and Janz 1996). These authors established a computerized records scheme which is updated as new information becomes available.

Based on their assessment of “reliable” and “unreliable” records, Bryant and Janz reported that between 1864 and 1971, marmots were recorded from a minimum of 28 sites on 25 mountains. In fact, most pre-1970 records are vague, and interpretation of whether sightings referred to reproductive colonies or solitary individuals is difficult. For example, one record mentioned “swarms of ground hogs” at the “head of Nitinat Valley” (<u>Victoria Times</u>, 7 September 1893), while another described a “brace” of marmots shot in the Beaufort Range (<u>Victoria</u> <u>Times</u>, 8 August 1922).

Naturalists and hunters interested in *M. vancouverensis* began counting marmots in 1972. The B.C. government began sponsoring annual population counts in 1979 (*Janz et al*. 1994). Bryant and Janz (1996) compiled results of these surveys, and estimated probable accuracy of counts. They reported that since 1972, marmots or fresh burrows were found at 47 sites on 15 mountains. Reproduction was observed at 34 sites on 14 mountains. Except for 2 sites, all colonies or potential colonies active since 1972 were located within the Nanaimo, Cowichan, Chemainus, Nitinat and Cameron River drainages on south-central Vancouver Island. The 2 exceptional colonies were both on Mount Washington, an area separated from other known colonies by at least 100 kilometres.

Current distribution (1990-1996)

Based on counts made from 1990 through 1996, Vancouver Island marmots are presently confined to 25 sites on 13 mountains (Figure 1). This does not reflect inadequate sampling effort. Most potential marmot habitats have been ground-searched in recent years, with many areas receiving multiple visits (A. Bryant unpublished data). Given public awareness of marmots, popularity of backcountry recreation, and recent discovery of old burrows and prehistoric bones in remote locations by untrained personnel, it is unlikely that significant new marmot populations remain undiscovered (Bryant and Janz 1996).

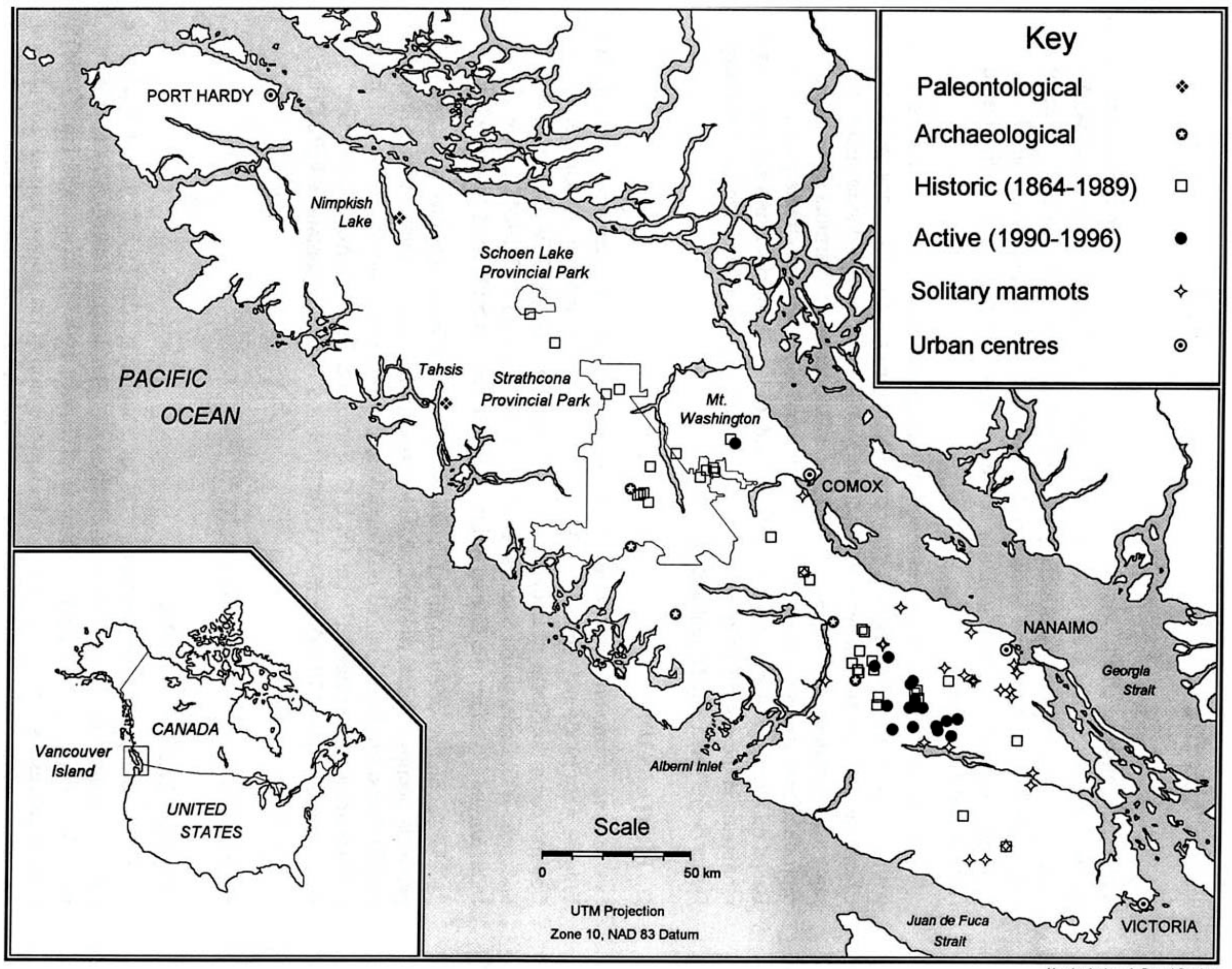

Figure 1. Location records of *M. vancouverensis.* See text for dates of palaeontological and archaeological records. Based on recent counts, the entire population is confined to 25 colonies on 13 mountains, virtually all found within 5 adjacent watersheds on south-central Vancouver Island. Updated from Bryant and Janz (1996).

Except for 2 small colonies on Mount Washington, all known active sites are located within 5 adjacent watersheds on south-central Vancouver Island (the Nanaimo, Cowichan, Chemainus, Nitinat and Cameron River drainages). Not all occupied sites appear to represent reproductive colonies. Of the 25 sites that contained marmots since 1990, reproduction was observed at 13 sites. The current population is extremely localized. Based on average colony sizes during this period, 67% of known animals are found on 4 mountains in the central 40 km^2 portion of their current range (the Green-Gemini-Haley-Butler "core" area; see Bryant and Janz 1996).

PROTECTION

Marmota vancouverensis is legally protected and listed as endangered under the B.C. Wildlife Act (1980) and regulations (Munro *et al*. 1985). It is listed as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC; Munro 1979), under the U.S. Endangered Species Act (Federal Register, Jan. 23, 1984), and by the International Union for the Conservation of Nature (Groombridge and Mace 1994).

Most colonies occur on privately-owned land. With few exceptions, all animals presently occupy habitats owned by MacMillan Bloedel Limited, TimberWest Limited, Pacific Forest Products Limited or Mount Washington Ski Corporation. Two marmot habitats are legally protected under the B.C. Ecological Reserves Act (Haley Lake Ecological Reserve; 127 ha) or the B.C. Wildlife Act (Green Mountain Wildlife Critical Habitat Area, 260 ha).

POPULATION SIZE AND TRENDS

Adequacy of census methods

Determining accurate population sizes for Vancouver Island marmots is difficult. On some days, given excellent weather and a known population of marked animals, it is possible to detect all individuals, or none at all (Bryant 1996*b*). Bryant and Janz (1996) used count results from colonies with a high proportion of ear-tagged animals to estimate probable accuracy of population counts, and the effect of count timing. Their results suggest that > 9 repeated visits are necessary to obtain accurate population data, but that 2 to 3 counts provide a reasonable index of marmot use (Figure 2).

Bryant and Janz (1996) concluded that for sites and years with single visits, observers probably counted 40-60% of the adults actually present, depending upon time of year. For most site-year combinations (2 or more visits in June and July), observers probably counted 66-78% of adults, and 75-89% of young present. Because of differences in coverage, visibility among sites, observer experience, and count intensity, they did not attempt to place confidence limits on these estimates.

Current population size and recent trends

By using long-term average or "expected" abundance from individual colonies, Bryant and Janz (1996) estimated annual ratios of observed-to-expected marmots, and were therefore able to elucidate trends. Their approach was straightforward. If marmot numbers were stable, annual counts should produce similar observed/expected ratios across years. This was not the case (Figure 3). Numbers of adults were consistently above average (134-147%) from 1981 to 1984, and near or below average (58-99%) from 1990 to 1995 (Bryant and Janz 1996). Bryant (1996*b*) expanded on this approach by applying a correction factor based on count intensity and numbers of habitats occupied, thus providing a first approximation of probable population sizes.

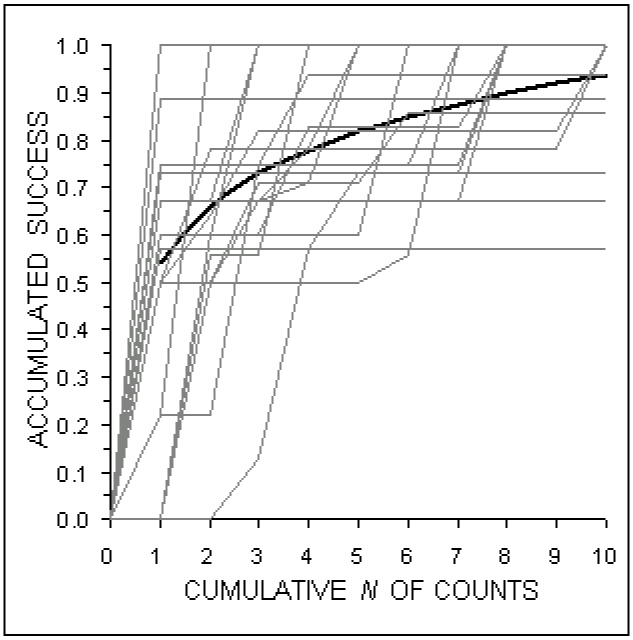

Figure 2. Probable accuracy of marmot counts. Transformed daily counts at colonies with known numbers of adults were randomly resampled to create 100 trials of 10 counts each (for clarity, results from only 25 trials are shown). The cumulative success curve (bold line) was fitted using linear regression (log-transformed x values, slope = 0.397 and constant = 0.540). On average, 2 counts resulted in detection of 66% of the adults actually present, but 9 counts were needed to account for >90%. From Bryant and Janz (1966).

There are problems with this approach, principally caused by differing count intensity and coverage from year to year. Counts made prior to 1980, and from 1987-1991, were based on visits to small numbers of colonies, and estimated abundance from this period is therefore more tenuous. Despite this, resulting data are internally consistent, and corroborated by counts at intensively studied colonies (Bryant 1996*b*) together with records of colonizations and extinctions (Bryant and Janz 1996).

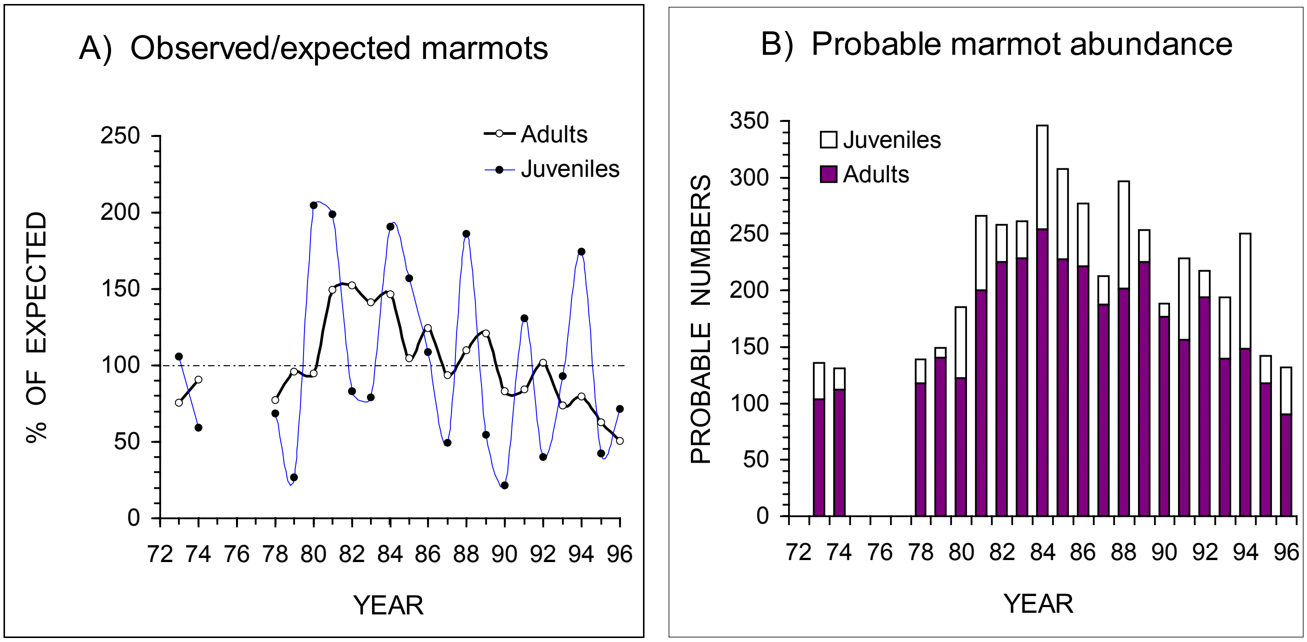

Figure 3. Marmot population trends, 1972-1996. Observed/expected ratios (A) were based on maximum counts/ long-term averages for each site, using only those sites counted in any year. Probable marmot numbers (B) were estimated by applying a correction factor based on count effort, by excluding clearcut habitats for years prior to colonization, and by excluding years in which fewer than 4 sites were counted. The current (1996) population probably contains close to 150 animals. Updated from Bryant (1996*b*).

Marmot numbers increased following 2 years of unusually high reproduction (in 1980 and 1981). The most obvious manifestation of this was colonization of clearcuts (first record in 1981, with 7 additional sites colonized between 1982 and 1985). In some cases, increases were dramatic. For example, the Butler Peak "west roads" site was logged during 1976-1980, apparently colonized by 2 marmots in 1982, and contained at least 28 adults by 1989. During the same period marmots expanded into an abandoned minesite near Mount Washington, and colonized ski-runs on Mount Washington and Green Mountain (Munro *et al*. 1985). Marmot numbers also increased in natural habitats during this period, and apparently colonized some small habitat patches in the central core area (Green Mountain Heart Lake Basin, Gemini meadows #1 and #2).

From a peak of perhaps 300-350 animals during the mid-1980s, marmots apparently began to decline in the late 1980s to the present total of close to 150 animals (Bryant and Janz 1996, Bryant in prep.). The spatial structure of marmot colonies also changed during that period (Figure 4).

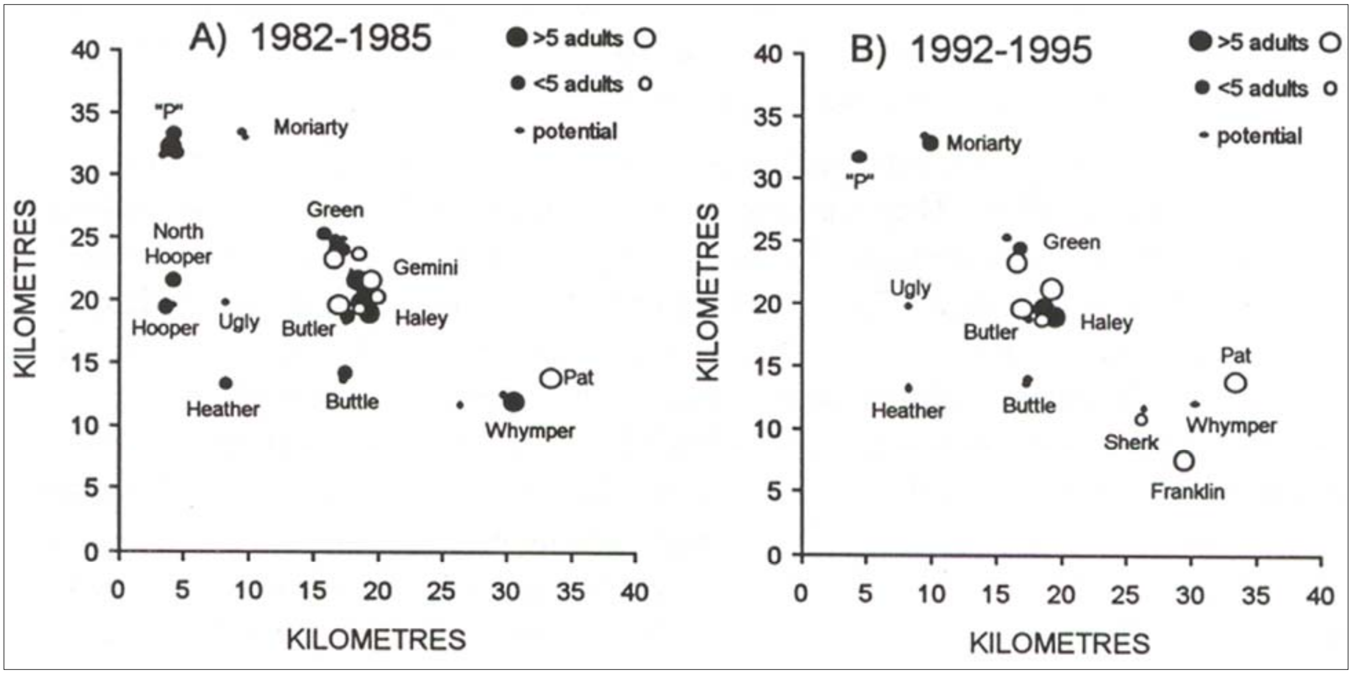

Figure 4. Metapopulation structure of Vancouver Island marmots, 1982-1985 and 1992-1995. Clearcut colonies (open circles) and non-reproductive sites (dots) are shown. Data reflect average adult numbers during each of the 4-year periods. Several sites occupied during the mid-1980s are now vacant. In contrast, only 2 new sites were colonized during the last decade. Mount Washington colonies are outside the range of this map. From Bryant (in prep.).

HABITAT

Vancouver Island marmots require three essential habitat features: 1) grasses and forbs to eat, 2) colluvial soil structure for construction of overnight and overwintering burrows, and 3) microclimatic conditions that permit summer foraging, thermo-regulation, and successful hibernation (Demarchi *et al*. 1996). Habitat scarcity is the fundamental reason for the rarity of *M. vancouverensis*. Bryant and Janz (1996) estimated that in the 40 km² core area of present distribution, there are only 16 patches of apparently suitable subalpine meadow habitat, totaling 34.5 hectares.

Vegetation and topography

Milko (1984) studied vegetation at several marmot colonies in natural subalpine meadows. He identified six major communities (*Phlox*-moss, *Anaphalis-Aster*, *Ribes-Heuchera, Pteridium aquilinum*, *Senecio-Veratrum* and *Vaccinium-Carex*) and concluded that “typical” habitats are maintained by avalanches or snow-creep. However, *M. vancouverensis* colonies have been confirmed from other habitat types as well. For example, Mount Washington habitat is dominated by scattered alpine fir *(Abies lasiocarpa)* and mountain hemlock *(Tsuga mertensiana)* interspersed with heather *(Juniperus communis)* and blueberries *(Vaccinium spp.)*. Marmots on the northwest ridge of "P" Mountain live on steep cliffs and talus slides; colonies on Mount Heather and

Westerholm Basin live amidst willow *(Salix)* thickets and rock slides. Marmots also inhabit clearcuts, openings created by ski-run development (Mt. Washingon and Green Mountain) and mine tailings (Mount Washington). Some natural meadows may be created by wildfires (Mount Whymper, Hooper North).

Bryant and Janz (1996) used average abundance (1972-1995) data to describe habitats used by marmots. They reported that most (81%) marmots were found between 1000 and 1400 metres in elevation. Colonies in logged habitats were generally lower (median = 990 metres, range = 730-1140) than natural sub-alpine meadows (median = 1240 metres, range = 1040-1450). Most marmots were found on south to west-facing slopes (74%). Most colonizations of clearcuts occurred within 10 years of logging (median = 8.5 years, range = 1-15) and within 1 km of natural colonies (median = 0.82 km, range = 0.4-4.5 km). Only a small fraction (<2%) of logged sites above 700 metres elevation was eventually colonized by marmots. Maximum occupancy at logged sites is unknown, but residence times of 15 years (20 years after logging) have been observed. Conversely, extinctions have been documented at 5 sites (median residence time = 7.0 years, range = 5-12 years; Bryant in prep.).

Food resources

Martell and Milko (1986) used fecal samples from 3 natural subalpine colonies to identify plants eaten by marmots (Table 1). They concluded that marmots depend on oatgrass (*Danthonia intermedia*) and sedges (*Carex spp.*) in early spring, and shift to forbs (especially *Lupinus latifolius* and *Eriophyllum lanatum*) in summer and fall. Spreading phlox (*Phlox diffusa*) is apparently an important food item in early summer. Similar work has not been conducted at other colonies; however, known food plants at low elevation clearcut sites include grasses, *Anaphalis margariticea*, *Fragaria* spp., *Epilobium angustifolium*, and *Lupinus latifolius* (A. Bryant unpublished data).

Hibernacula and other burrows

Vancouver Island marmots construct burrows in which to hibernate, bear young, hide from predators, and avoid environmental extremes. Burrows (including hibernacula) are commonly re-used in multiple years by the same individuals (Bryant 1990, 1996*a*). No data are available with which to describe the length, depth or geometry of burrows constructed by *M. vancouverensis*.

Escape burrows (used to avoid predators) may be a shallow excavation under a rock or tree root. Burrows used overnight or as birthing chambers are more elaborate, and often feature multiple entrances. As with escape burrows, they are typically constructed underneath a boulder or tree root system, which presumably offers supporting structure. Hibernacula are presumably deep enough that marmots can be underneath the frost layer, although this is unconfirmed. Work on alpine marmots (*M. marmota*) suggests that a critical feature of hibernacula may be its ability to maintain stable ambient temperatures close to 5°C (Arnold 1990, Arnold *et al*. 1991).

Table 1. Food items found in marmot fecal pellets from 3 subalpine colonies, 1981-1982 Data are $\bar{x}$ ± SD percentages of plant fragments found in samples of 25 pellets each. Arthropods (insects) probably entered the fecal material after it was deposited. A "*tr*" designation indicates presence of "trace" amounts. Adapted from Martell and Milko (1986).

		Month			
Class/species	***Common Name***	***May***	***June***	***August***	***September***
Moss		**1.20** ± 0.29	**0.20** ± 0.08	*tr*	**0.10** ± 0.07
Mycorrhiza		**0.50** ± 0.31	**3.20** ± 1.48	**0.20** ± 0.12	
Lichens		**0.40** ± 0.11	**0.40** ± 0.12	*tr*	*tr*
Cladonia spp.	Reindeer moss	**0.10** ± 0.10	**0.20** ± 0.08		
Ferns		**2.60** ± 0.95	**1.10** ± 0.45	**0.30** ± 0.16	**1.00** ± 0.33
Gymnosperms		**3.60** ± 1.38	**0.90** ± 0.28	**0.40** ± 0.21	**0.40** ± 0.15
Juniperus communis	Yellow cedar	**1.40** ± 0.58	**0.60** ± 0.20	**0.10** ± 0.14	**0.30** ± 0.11
Tsuga sp.	Hemlock	**2.20** ± 0.97	**0.20** ± 0.09	**0.20** ± 0.18	**0.10** ± 0.07
Graminoids		**56.40** ± 8.76	**24.10** ± 4.61	**3.70** ± 0.72	**2.70** ± 0.97
Danthonia intermedia	Oatgrass	**18.70** ± 6.97	**1.30** ± 0.28	**0.50** ± 0.12	**0.30** ± 0.13
Carex sp.	Sedge	**8.80** ± 1.05	**16.20** ± 3.02	**1.90** ± 0.47	**0.80** ± 0.30
" " "	Sedge (glume)	**26.90** ± 11.23	*tr*		
Festuca sp.	Fescue-grass	*tr*	*tr*		
Poa sp.	Bluegrass	**0.50** ± 0.18	**0.70** ± 0.15	**0.20** ± 0.12	*tr*
Luzula sp.	Woodrush	**1.10** ± 0.35	**5.40** ± 1.72	**1.00** ± 0.43	**1.40** ± 0.85
Forbs		**34.50** ± 6.54	**68.30** ± 4.86	**94.00** ± 1.17	**93.40** ± 1.70
Lupinus latifolius	Lupine	**16.80** ± 6.77	**46.10** ± 3.56	**68.50** ± 6.34	**28.10** ± 3.21
Eriophyllum lanatum	Woolly Sunflower	**1.40** ± 1.20	**7.80** ± 2.35	**19.30** ± 6.78	**63.10** ± 4.32
Phlox diffusa	Spreading Phlox	**14.00** ± 3.91	**2.50** ± 0.64	**0.30** ± 0.09	**0.90** ± 0.24
Achillia millefolium	Yarrow	**3.60** ± 2.70	**2.10** ± 0.36	**0.40** ± 0.20	**1.50** ± 0.31
Castilleja sp.	Indian Paintbrush	±	**0.60** ± 0.24	**0.60** ± 0.23	
Lathyrus nevadensis	Purple Pea	**0.70** ± 0.54	**8.60** ± 1.63	**4.00** ± 1.82	*tr*
Prunella vulgaris	Heal-all	**0.40** ± 0.04	*tr*		*tr*
Seeds (Vaccinium sp.)					**0.70** ± 0.53
Arthropods			**1.70** ± 0.43	**1.30** ± 0.43	**1.00** ± 0.50
N of samples		12	24	12	12

Microclimate and special habitat features

Marmot distribution may be limited by summer temperature conditions (Türk and Arnold 1988, Arnold *et al.* 1991, Arnold 1990, Melchor *et al.* 1990). Marmots lack sweat glands and "panting" behavior, which allow other mammals to avoid overheating (Barash 1989). For this reason, marmots faced with high ambient temperatures are forced to stay underground (Webb 1980). Türk and Arnold (1988) suggested that a lower elevational limit to marmot distribution was established by this relationship, because animals with curtailed foraging opportunities may be unable to gain sufficient fat reserves to hibernate successfully. Body temperature data from radio-telemetered Vancouver Island marmots support these ideas (Figure 5).

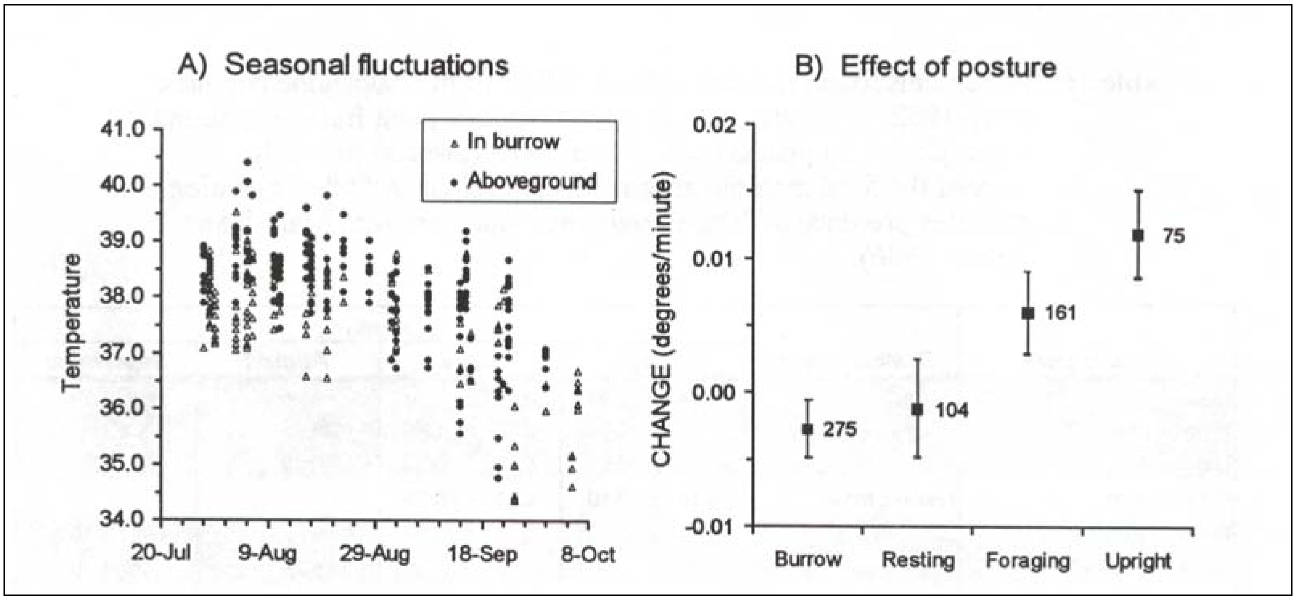

Figure 5. Body temperature fluctuations and the effect of posture. Body temperatures fluctuated daily and seasonally (A). The direction of temperature change was significantly associated with posture (B). It would appear that marmots use behavior to thermoregulate, and that "resting" boulders are an important feature of marmot habitat. From Bryant (in prep.).

Body temperatures fluctuated from 35 º to 40 º C within the course of several hours, and this variation was correlated with environmental conditions and behavior. The relationship between body temperature, environment, and foraging opportunity could explain why large areas of clearcut habitat at lower elevations, or in more exposed locations, have not been colonized. Physiological requirements may also explain why large boulders are characteristic of high quality marmot habitats. Boulders may act as heat sinks which allow marmots to spend more time aboveground (Bryant in prep.).

GENERAL BIOLOGY

Colony size and social structure

Vancouver Island marmots live in colonies comprised of one or more family groups (Bryant 1990, Heard 1977). Families normally contain an adult male, one or more adult females and a variable number of sub-adults, yearlings and young-of-the-year (Heard 1977). Bryant and Janz (1996) reported that most reproductive colonies contained fewer than 5 adults ($\bar{x}$ = 3.86, SE = 0.61, n=34). The size and number of families varies between colonies and years, and this can produce dramatic fluctuations in population size (Bryant 1996*b*).

North American marmots may be monogamous (as in some populations of *M. caligata*; Holmes 1984), polygynous with males maintaining harems of several females (as in *M. flaviventris* and *M. olympus*: Barash 1989), or may fluctuate between these two extremes depending upon resource availability (as in *M. flaviventris*: Schwartz and Armitage 1981). Heard (1977) suggested that *M. vancouverensis* is monogamous but Milko (1984) predicted some degree of polygyny on the basis of vegetation resources. Observational data from 1987-1996 mostly suggest monogamy (A. Bryant unpublished data). However, on at least 3 occasions, single adult males apparently mated with more than 1 female (and produced more than 1 litter).

Reproduction and survival

Bryant (1996*a*) produced life-tables for Vancouver Island marmots based on 9 years of mark-recapture observations at 5 colonies. In general, *M. vancouverensis* exhibits low reproductive rates, with litter sizes of 2 to 5 ($\bar{x}$ = 3.36, SD = 0.83, n=36). Females are capable of breeding at age 3, but most animals do not breed until age 4 ($\bar{x}$ = 4.00, SD = 0.82, n=13), and display a non-reproductive interval of at least 1 year between litters ($\bar{x}$ = 1.83, SD = 0.76, n=6).

Perhaps the most striking observation is reduced marmot survival in logged habitats (Figure 6). The essential conclusion is that marmots inhabiting logged areas show reduced lifelong reproductive performance (Figure 7), and that clearcut habitats function as demographic “sinks” that consume more dispersers than they produce (see Pulliam 1988, Bryant 1996*a*, 1996*b*, in prep.).

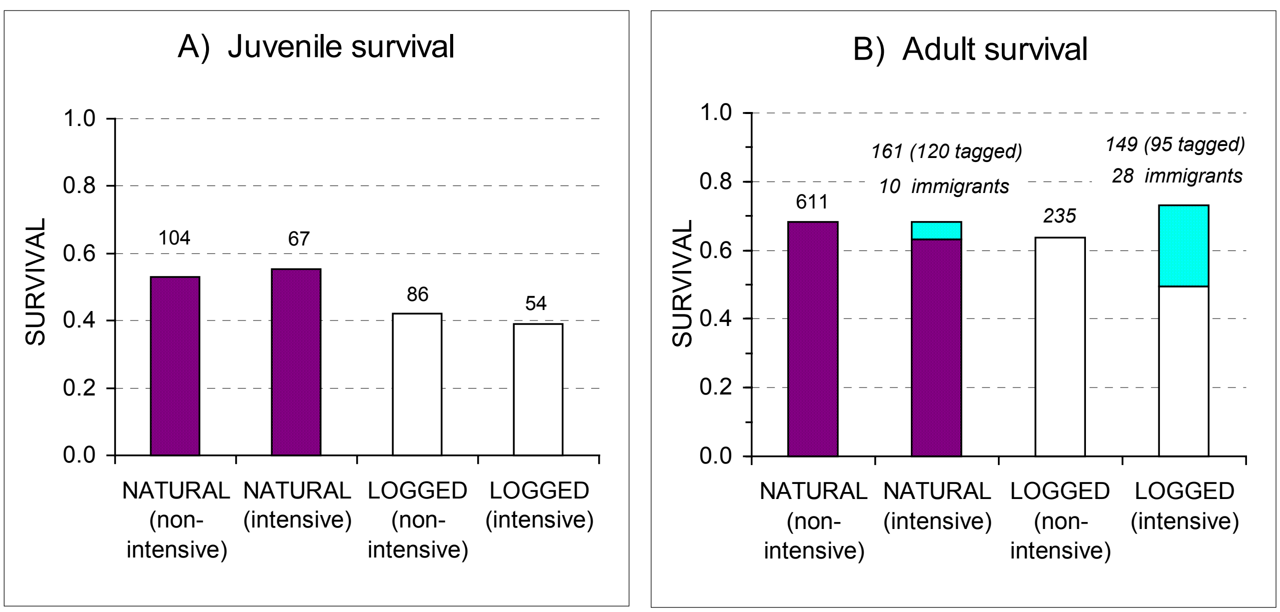

Figure 6. Survival rates estimated from ear-tagged colonies and non-intensive population counts. Results show significantly reduced juvenile survival in clearcuts (41% versus 54% at natural sites). Adult survival rates estimated from counts show no difference. However, intensive (ear-tagged) results indicate that immigrants make up a significantly higher proportion of “apparent” survivors in clearcuts. Persistence of tagged adults was significantly higher at natural sites (63%) than clearcuts (50%). From Bryant (in prep.).

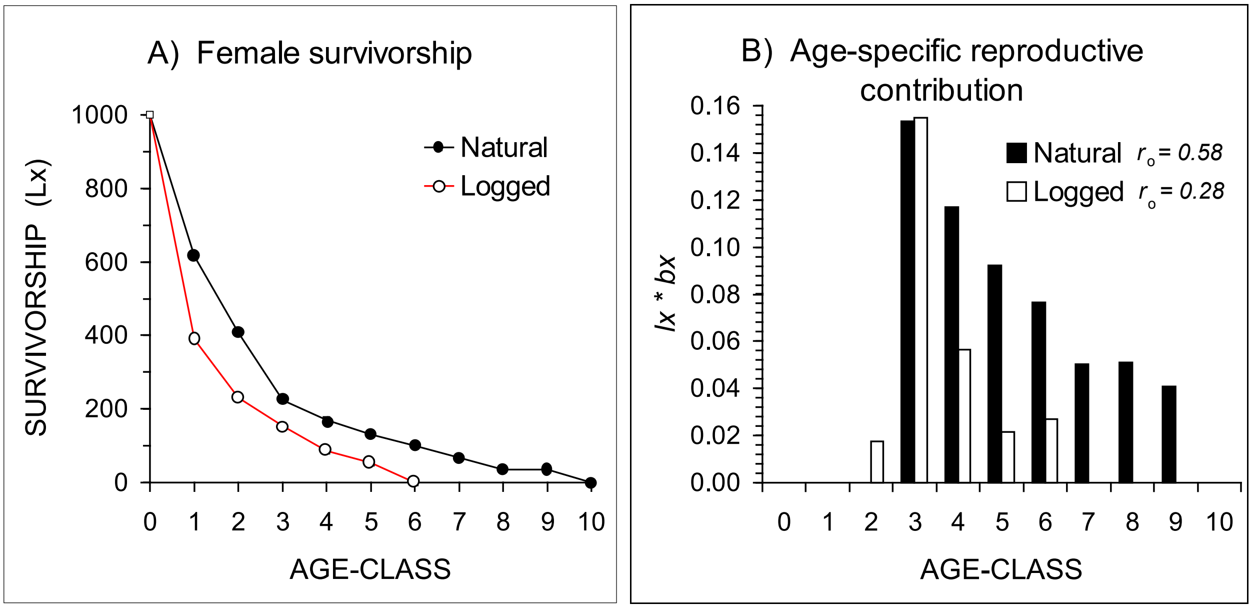

Figure 7. Effect of habitat type on demography. Female persistence rates (A) were significantly lower in clearcut habitats. The result was reduced lifetime reproductive contribution (B). Data are from tagged females monitored from 1987 through 1996. From Bryant (in prep.).

Dispersal and landscape connectivity

Dispersal records are limited. Based on tagged animals (Bryant 1996*a*, 1996*b*, in prep.), known dispersers include 2 two-year-old males, a single female that probably dispersed at age 2, and 2 animals that appeared to be adults when observed at the new site. Maximum dispersal distance was 7.4 kilometres. Evidence suggests that juvenile or yearling marmots do not disperse. All 35 immigrants observed at intensively studied colonies were judged to be adults when first observed, and 11 captured immigrants were adults (7 females, 4 males). Data are insufficient to calculate average dispersal distances or directions, and may not be representative.

Records of solitary marmots in low elevation habitats suggest many possible dispersal distances >7 km. Bryant and Janz (1996) compiled 22 records of solitary marmots during the 1972-1995 period, including 1 found “wandering” on the beach at Courtenay (12 July 1974), 1 photographed on Mount Demers (25 July 1977), and 1 which took up residence in a vegetable garden at Coombs (7 July 1980). Marmots are capable of showing up in unusual places, including a woodshed in Youbou (25 June 1986), a horse stable in Nanaimo (25 September 1991), a new subdivision at Bell's Bay on the west coast (May 1992), and a boat dock at Lake Cowichan (18 May 1993). Some of these records (e.g., Bell’s Bay, Cassidy, Duncan and Cedar) probably represent dispersal distances in excess of 25 km.

Bryant (1990, 1996*a*, 1996*b*) argued that clearcut logging shortens average marmot dispersal movements, simply by providing individuals with closer alternative habitats in which to settle. Proximity of colonization events to existing colonies supports this view (most colonizations occurred within 1 km of existing colonies), but some confounding evidence exists. Individual marmots can and do disperse across a complex landscape, and clearly do not necessarily stop in the first available habitat.

Genetic variation and effective population size

Bryant (1990) used electrophoresis of blood samples to assay genetic variation. His sample was small both in terms of animals (n = 44), colony structure (n = 3) and numbers of loci examined (n = 22). Results revealed levels of genetic variability comparable to *M. flaviventris* and *M. monax* (n=22 scorable loci, estimated polymorphic loci P=0.18, average expected heterozygosity H=0.073; see Schwartz and Armitage 1980, Wright *et al.* 1987). Significant genetic differences were found between two colonies less than 20 kilometres apart, illustrating the importance of founder effects and infrequent dispersal. Effective population size N_e of the known population was close to 50 (based on a population estimate of ~250 animals, N_e = 34.6 to 64.4).

Bryant (1990) interpreted genetic data to suggest that *M. vancouverensis* was neither genetically depauperate nor highly inbred. Observed genetic patterns were likely caused by "founder effects" (i.e., rapid population increase from a small "founding" population which did not happen to carry particular alleles). Results suggest that close inbreeding is avoided in this species. Genetic differences among colonies provide additional support for the idea that "connectivity" (dispersal between colonies) occurs infrequently.

Behaviour and adaptability

M. vancouverensis is among the most social of marmots (Heard 1977). Bryant (1990) discussed the sociobiological significance of this, and concluded that most behavioural attributes can be traced to an evolutionary history which demanded survival in small and scattered habitats.

Much has been written about "adaptability" of *M. vancouverensis* to a human-modified landscape (Munro *et al*. 1985). Certainly many marmots live in clearcuts, but demographic information suggests that these habitats act as population sinks (Bryant 1996a, 1996b, in prep.). Marmots that colonized ski-runs (Green Mountain and Mount Washington) or mine tailings (Mount Washington) during the 1980s are either doing poorly or locally extinct. Perhaps the most important data are negative. Despite a huge amount of potential habitat created by logging of forests above 700 metres, only a small fraction was ever colonized, and the overall distribution of *M. vancouverensis* has shrunk in the last several decades.

LIMITING FACTORS

Climate and vegetation change

Nagorsen *et al*. (1996) suggested that long-term climate and habitat change could be inferred from finds of prehistoric bones well outside the core area of current distribution. This is undoubtedly correct. Extra-limital finds of prehistoric marmot bones tell a similar story in other parts of the world (e.g., Preleuthner *et al*. 1995, Grayson 1987). Replacement of tundra parkland by forest has drastically reduced the quantity of marmot habitat in the recent (Pleistocene-Holocene) prehistoric past. It remains unclear whether such processes also explain range reductions in historic times.

Milko (1984) suggested that vegetation changes have reduced habitat availability in recent decades (a view supported by Nagorsen *et al*. 1996). Under this interpretation, sites formerly occupied by marmots have changed in some qualitative way, and the species is confined to a shrinking geographic region in which suitable climatic and vegetation conditions are found. The "climatic regulation" hypothesis is consistent with the views of Thomas (1994), who argued that many rare species track environmental conditions, becoming locally extinct where conditions are no longer suitable, and colonizing sites where conditions improve. Several possible mechanisms have been suggested, including invasion of sub-alpine meadows by trees or *Pteridium* ferns, altered fire regime (Milko 1984), and changing food-plant availability (Martell and Milko 1986).

The evidence remains ambiguous. Invasion of sub-alpine meadows by trees has been documented for several areas in the Olympic (Fonda and Bliss 1969, Schreiner and Burger 1994) and Cascade mountains (Franklin *et al*. 1971). However, dendrochronological work at historic and extant *M. vancouverensis* colonies has produced quite surprising results (C. Laroque unpublished data). In Strathcona Provincial Park, where marmots apparently disappeared some 10-30 years ago, most trees are more than 300 years of age, and there is little evidence of forest succession. Paradoxically, some of the highest-quality habitats within the present core area of distribution show considerable evidence of tree invasion within the past 50 years, probably as a result of post-fire regeneration (i.e., the Green-Gemini-Haley-Butler ridge system).

Other evidence for climatic regulation is weak, at least over the short term. Although some authors have identified snow depths (Barash 1989) or duration (Van Vuren and Armitage 1991) as important determinants of marmot survival, Bryant (in prep.) found that annual environmental measurements (snowfall, snowpack, temperature, rainfall etc.) were mediocre predictors of *M. vancouverensis* survival and reproductive rates.

Changing predator-prey relationships

Predators are important causes of mortality. In 10 years of field study, 3 cases of predation by golden eagles were witnessed (Bryant in prep.). At least 4 telemetered animals were killed by terrestrial predators, including 3 of 7 animals equipped with radio-transmitters in 1994. It was not possible to identify the predator species, although it was likely cougar or wolf. One record of marmot fur in wolf scat exists (Janz *et al*. 1994), and several observers have observed cougars "stalking" marmots (Bryant 1996*a*).

Merilees (1980) suggested that increased golden eagle abundance may have had a detrimental impact upon marmots. While it is interesting that the first golden eagle nest record on Vancouver Island was close to a historic marmot colony (Upper Campbell Lake in 1954; Campbell *et al*. 1990), data with which to estimate eagle population trends are non-existent. Radio-telemetry of a single bird in the marmot core area shows quite striking site-fidelity over the past 2 years (D. Doyle unpublished data).

Estimates of wolf and cougar numbers in the core area of marmot distribution (K. Atkinson, unpublished hunter-sighting data) show no significant upward trend, and were not correlated with marmot survival rates (Figure 8). However, such data yield a very incomplete picture. Deer numbers have fallen precipitously in the marmot core area during the last decade (D. Janz, unpublished data). Wolf and cougar control programs have been abandoned. Moreover, logging which led to the creation of a widespread road network (possibly enhancing predator movements) and colonization of clearcuts by marmots has increased local population density (perhaps making it more profitable for a predator to remain in the area). Given the small geographic area currently occupied by marmots, I consider it highly probable that a small number of terrestrial predators have become quite adept at hunting *M. vancouverensis*, and may be exerting a profound population effect.

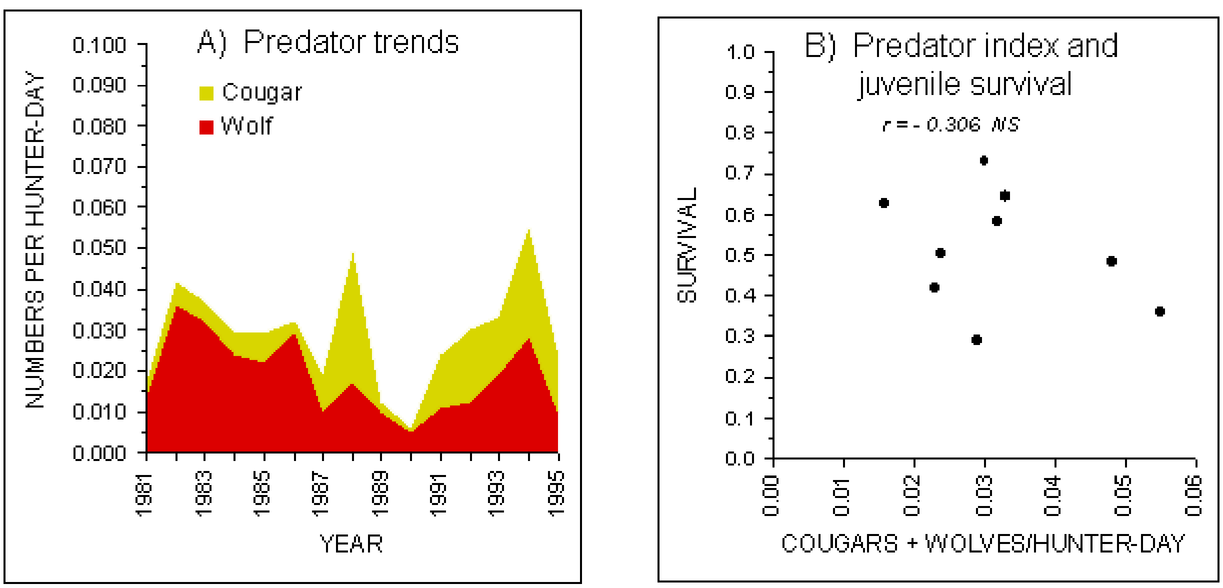

Figure 8. Wolf and cougar abundance (A) and relationship to observed juvenile survival rates (B). Such analyses are potentially misleading; these data ignore confounding factors such as reduced alternative prey (deer) numbers, and learned behaviour (e.g., hunting along logging roads, or in specific marmot habitats). From Bryant (in prep.).

Human predation and disturbance

Presence of marmot bones in a 1500-year-old archeological site at Port Alberni (Calvert and Crockford 1983) and tool-marked bones from high elevation caves (Nagorsen *et al*. 1996) is evidence that native peoples hunted *M. vancouverensis*, which they evidently used for robes and food. However, Nagorsen *et al*. (1996) dismiss the human overkill hypothesis as an explanation for range declines, and I concur.

There are no cases in which recent human hunting has lead to the extirpation of particular colonies, although Munro *et al.* (1985) documented two cases in which marmots were shot by human vandals. There was an unconfirmed shooting incident at the Green Mountain natural colony in August of 1990; no expended shell casings or marmot corpses were found, but several ear-tagged animals were not seen after this date (A. Bryant unpublished data).

Most extant colonies are currently “protected” by virtue of their being unpublicized, by occurring on private forestry lands, and by being difficult to get to (Janz *et al*. 1994). Intensively studied marmot colonies which experience daily human visitation show no measurable reduction in demographic performance compared to other colonies. I consider present levels of human disturbance to be negligible, and disagree with previous authors on the subject (e.g., Dearden 1983). Having said that, some colonies will experience increasing visitation pressure in the future, as *M. vancouverensis* becomes more widely known. The potential exists that some marmot colonies could be “loved to death” by ecotourists, but I consider this risk to be small.

Metapopulations and landscape ecology

One interpretation of current marmot distribution and recent trends is based on a metapopulation and source-sink perspective (Bryant 1990). Evidence for metapopulation structure in *M. vancouverensis* includes observations of local population fluctuations, extinctions and colonizations (Bryant 1990, Bryant and Janz 1996). Under the “metapopulation” hypothesis, some historic marmot habitats are vacant because local extinctions have not been balanced by recolonizations (Bryant 1996*a*, in prep.). This could occur if rates of successful dispersal have been altered by human activity.

What makes this hypothesis intriguing is also what makes it so difficult to test: that the essential change over time has not involved subalpine meadows so much as it has involved changes in the “landscape matrix” (Taylor *et al*. 1993, Fahrig and Merriam 1985) through which animals must disperse in order to recolonize vacant habitats or “rescue” colonies which are doing poorly. From life-table analyses we know that individual marmots do relatively poorly in clearcuts, and that colonies in such habitats consume more dispersing marmots than they produce (Bryant 1996*a*). However, evidence for reduced connectivity is equivocal. The idea that newly created but low-quality habitats adjacent to natural meadows impede dispersal is supported by genetic data (Bryant 1990) and spatial concentration of colonization events (Bryant and Janz 1996), but contrary evidence showing long-distance dispersal in a modified landscape is also available (Bryant 1996, Bryant and Janz 1996).

Logging of forests above 800 metres during the 1960s, 1970s and 1980s created thousands of hectares of potential habitat. This, combined with conditions that permitted good reproduction and survival, allowed marmots to colonize new sites and expand in numbers during the early 1980s (Bryant and Janz 1996). That so little of the potential habitat was ever colonized may be largely attributable to reduced survival in these habitats. Bryant (1996*b*) showed that clearcut habitats do not allow female *M. vancouverensis* to attain the same lifelong reproductive performance that their counterparts in natural habitats exhibit, and suggested colonies in clearcuts were maintained only by continual immigration of new females.

Demographic and environmental stochasticity

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

With some mountains containing only 1 or 2 family groups, the fate of single individuals (predation, overwinter mortality, dispersal, successful immigration) can cause important population effects. Local extinctions, lack of reproduction, and immigration “rescue effects” (Brown and Kodric-Brown 1977) have been observed that were due to chance presence or disappearance of single adult males (Bryant 1996*b*). Similarly, the small geographic range makes *M. vancouverensis* susceptible to weather trends or “regional stochasticity” that apparently cause high overwinter mortality (e.g., 36% survival of juveniles during winter of 1994-1995; Bryant in prep.).

SPECIAL SIGNIFICANCE OF THE SPECIES

Marmota vancouverensis is one of only five endemic mammal species in Canada (Wilson and Reeder 1993). It is the only endemic mammal species that appears on the COSEWIC endangered list.

RECOMMENDATIONS/MANAGEMENT OPTIONS

This information is on file with the B.C. Ministry of Environment, Lands and Parks, Wildlife Branch.

EVALUATION AND PROPOSED STATUS

Recommended status is: ENDANGERED

ACKNOWLEDGEMENTS

I wish to thank D.W. Janz, W.T. Munro, S. Herrero, D. Eastman and the Vancouver Island Marmot Recovery Team, who provided unflagging support for my desire to spend a decade chasing obscure rodents. D. Nagorsen provided helpful comments on the draft. Financial support for this report was provided by the Vancouver Island Marmot Recovery Team.

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THE AUTHOR

Andrew Bryant is proprietor of *Andrew A. Bryant Services,* an independent consulting firm which specializes in the scientific research and management of threatened wildlife populations. He also serves as Scientific Advisor to the Vancouver Island Marmot Recovery Team, established in 1988. He holds a Bachelor degree from the University of Waterloo (1984) and a Masters from Calgary (1990), and was enrolled in a doctoral program at the University of Victoria (expected completion was 1998).

Mr. Bryant's research experience involved work on Red-Shouldered Hawks (Ontario), Burrowing Owls (B.C. and Washington State), hibernating bats (B.C.), old-growth forest songbirds (B.C.), aquatic plants (Quebec), grizzly bears (B.C.), rare butterflies (Ontario), spider monkeys (Costa Rica) and Vancouver Island marmots (B.C.). His current interests mostly involve landscape change, and consequent changes in dispersal processes that may regulate some populations (metapopulation ecology).

When not running his own business, struggling to complete his doctorate, or trying to garner public support for obscure mountain rodents, Andrew enjoys creating photographs and prose. For fun he goes birding, plays golf, or paddles.

ADDENDUM

Vancouver Island marmot population data for 1999 and 2000.

			1999				2000				2001			
Site #	**Colony Code**	**Mountain**	**n[1]**	**Ad.**	**n[2]**	**yoy.**	**n[1]**	**Ad.**	**n[2]**	**yoy.**	**n[1]**	**Ad.**	**n[2]**	**yoy.**
1	1.1	Green	21	**3**	15	*4*	22	**7**	16	*5*	16	**6**	12	*2*
2	1.2	Green					2	**0**			4	**0**	2	*0*
3	1.3	Green	1	**0**	1	*0*	1	**0**	1	*0*	8	**0**	2	*0*
4	1.4	Green	1	**0**	1	*0*	3	**0**	2	*0*	2	**0**	4	*0*
5	1.5	Green												
6	1.6	Green					2	**0**	1	*0*	4	**0**	4	*0*
7	1.7	Green												
8	1.8	Green	15	**8**	7	*6*	9	**1**	5	*0*	8	**0**	6	*0*
9	1.9	Green									2	**0**	1	*0*
10	2.1	Gemini	2	**0**	1	*0*	2	**0**	1	*0*	2	**0**	0	
11	2.2	Gemini					2	**0**	1	*0*	2	**0**		
12	2.3	Gemini					2	**0**	1	*0*	2	**0**		
13	2.4	Gemini									1	**0**		
14	2.5	Gemini												
15	2.6	Gemini												
16	2.7	Gemini	12	**1**	7	*0*	5	**0**	2	*0*	1	**0**		
17	3.1	Haley	14	**3**	10	*0*	10	**0**	3	*0*	5	**0**	3	*0*
18	3.2	Haley	1	**0**			4	**0**	2	*0*	4	**0**	3	*0*
19	3.3	Haley	1	**0**	1	*0*	1	**0**			4	**0**	1	*0*
20	4.1	Butler	2	**0**	2	*0*	1	**0**			3	**0**	1	*0*
21	4.2	Butler	1	**0**	1	*0*	1	**0**			2	**0**	1	*0*
22	4.3	Butler	1	**0**	1	*0*	1	**0**			2	**0**	1	*0*
23	4.4	Butler	7	**1**	6	*0*	10	**1**[4]	5	*0*	3	**0**	2	*0*
24	4.5	Butler					1	**0**			1	**0**		
25	5.1	Buttle	1	**0**	1	*0*	1	**0**			1	**0**		
26	5.2	Buttle	1	**0**	1	*0*	1	**0**			1	**0**		
27	6.1	Whymper					1	**0**			1	**0**		
28	6.2	Whymper					1	**0**			1	**0**		
29	6.3	Whymper	1	**0**	1	*0*	1	**0**	1	*0*	2	**0**	1	*0*
30	7.1	Landalt												
31	7.2	Landalt	14	**4**	8	*4*	5	**1**	2	*0*	5	**0**	3	*0*
32	8.1	Heather	6	**1**	3	*0*	10	**1**	4	*0*	6	**2**	5	*0*
33	9.1	Hooper	2	**1**	2	*0*	2	**0**	1	*0*	3	**0**	1	*0*
34	9.2	Hooper					1	**0**						
35	9.3	Hooper												
36	10.1	Hooper N.					2	**0**	1	*0*	2	**0**		
37	11.1	P. Mtn.	3	**1**	3	*0*	16	**2**	10	*0*	8	**2**	9	*2*
38	11.2	P. Mtn.	2	**0**	2	*0*	5	**0**	2	*0*	8	**0**	4	*0*
39	11.3	P. Mtn.	2	**0**	2	*0*	3	**0**	2	*0*	6	**2**	4	*0*
40	11.4	P. Mtn.	2	**0**	2	*0*	2	**0**	2	*0*	3	**0**	3	*0*
41	12.1	Moriarty	5	**4**	5	*0*	6	**3**	3	*0*	4	**1**	2	*0*
42	12.2	Moriarty					1	**1**	1	*0*	2	**0**	1	*0*
43	12.3	Moriarty	4	**1**	4	*0*	5	**1**	1	*0*	5	**0**	3	*0*
44	13.1	Franklin	7	**4**	2	*0*	5	**0**	1	*0*	3	**0**	2	*0*
45	14.2	Washington	14	**6**	11	*0*	9	**5**	7	*0*	11	**5**	11	*0*
46	14.2	Washington	2	**1**	2	*0*	4	**0**	1	*0*	2	**0**	2	*0*
47	14.3	Washington	5	**2**	4	*0*	7	**4**	5	*4*	9	**4**	10	*4*
48	15.1	Big Ugly	7	**9**	5	*0*	7	**5**	5	*0*	7	**4**	7	*0*
49	15.2	Big Ugly					1	**0**			2	**0**	0	*0*
Column totals			157	**50**	111	*14*	175	**32**	89	*9*	168	**26**	111	*8*
Total Marmots			**64**				**41**				**34**			
Animals removed for captive breeding			**19**				**5**				**—**			

[1]# of visits before July 1st [3]# of young-of-the-year
[2]# of visits after July 1st [4]transplanted animals