
History and Current Status of the Vancouver Island Marmot (*Marmota vancouverensis*) Captive-breeding Program

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Abstract: During the mid-1980s, the Vancouver Island marmot's (*Marmota vancouverensis*) population was estimated at 300–350 individuals and was considered to be stable or increasing; however, beginning in the late 1980s and throughout the 1990s, Vancouver Island marmot numbers demonstrated significant declines, and it became apparent that recovery efforts involving only field manipulation of the wild population would likely not prevent the extinction of this species. The National Recovery Plan for the Vancouver Island Marmot 2000 update (Janz et al. 2000) stated that “few animals exist for reintroductions or other management activities” and that “It is unlikely that wild populations will suddenly rebound of their own accord. Captive breeding and reintroduction present the only chance of increasing populations within a reasonable period of time and minimizing the risk of extinction.” In response to these concerns, the Vancouver Island Marmot Recovery Team initiated a rigorous program of captive breeding to (1) serve as a genetic lifeboat to safeguard Vancouver Island marmots against catastrophic events in the wild, (2) determine appropriate management and husbandry guidelines for the successful captive maintenance and propagation of Vancouver Island marmots, (3) conduct directed research, and (4) provide sufficient numbers of individuals for release and eventual restoration of the wild population. Since its inception in 1997, this program has come to include the participation of three Canadian zoological institutions, the Toronto Zoo, the Calgary Zoo, and the Mountain View Conservation and Breeding Society, and a dedicated marmot facility on Vancouver Island. To date, there has been a total of 95 marmots in captivity, including 54 marmots captured from the wild and 41 born in captivity. There have been 18 mortalities in captivity. As of December 2003, the captive population consisted of 77 surviving marmots and 14 potential breeding pairs. This paper provides a summary of the first seven years of the Vancouver Island captive-breeding program and includes a history of the project, an overview of the marmots' captive management, and a description of the initial reintroduction of captive Vancouver Island marmots, which occurred in the summer of 2003.

Key Words: *Marmota vancouverensis*, Vancouver Island marmot, captive breeding, captive management, conservation, reintroduction, recovery, British Columbia

Background

The Vancouver Island marmot (*Marmota vancouverensis*) is endemic to Vancouver Island, which lies off the southwest coast of British Columbia (B.C.), Canada (Nagorsen 1987). *Marmota vancouverensis* is distinguished from other marmot species by its phenotype, karyotype, skull structure, vocalizations, and behavior (Bryant 1998). The Vancouver Island marmot naturally inhabits steep, south- to west-facing, subalpine meadows at 1000–1400 m elevation. Suitable subalpine meadows are relatively small and patchy in distribution on the mountains of Vancouver Island, and this has acted to greatly restrict the population size and range of this species.

Over the last few decades, the numbers and distribution of the Vancouver Island marmot have changed significantly. Prior to 1970, this species had been documented at 28 sites on 25 mountains. Since the early 1970s, when the first scientific studies of this species began, marmots or marmot burrows have been found at 47 sites on 15 mountains. In the early 1980s, the Vancouver Island marmot began colonizing high elevation (above 700 m), recently-logged habitat located in close proximity to its natural subalpine meadows (Bryant and Janz 1996). These colonizations of human-altered sites apparently resulted in a transient population increase. Marmot inventory conducted in 1984 resulted in a count of 235 marmots and a population estimate of 300–350 animals. The changing pattern of marmot habitat use ultimately altered the distribution and dispersal of this species, which may have had a negative, long-term effect on the population. Marmots established colony sites in the vicinity of logging roads, and they may have been at increased risk as wolves (*Canis lupus*) utilized these same roads as travel corridors. As the trees at the logged colony sites rejuvenated, there may have been increased cover and hunting success for stalking predators such as cougars (*Felis concolor*)¹. The increased foraging opportunities provided by logged habitat may have also promoted an increase in the numbers of golden eagles (*Aquila chrysaetos*) (Campbell et al. 1990). In addition, declining populations and changes in distribution of black-tailed deer (*Odocoileus hemionus*)² on Vancouver Island may have caused predators such as cougars and wolves to shift to secondary prey species such as marmots.

Throughout the 1990s, the Vancouver Island marmot demonstrated a steady and significant population decline. Intensive field counts conducted in 1994 revealed only 162 marmots, and in 1996, only 105 marmots were counted. In 1996, an effort was made to begin reestablishing marmots at natural, historically occupied locations. Six wild marmots were moved from clearcut sites to Mount McQuillan, which had previously supported marmots. This translocation was initially successful in that four of the six transplanted marmots remained at the release site, excavated old burrows, and hibernated communally. Unfortunately, the translocation was ultimately unsuccessful in that the four marmots died during their first hibernation at the release site.

¹The BC Species and Ecosystems Explorer (December 2004) lists this species as *Puma concolor*.

²The BC Species and Ecosystems Explorer (December 2004) lists this species as the mule deer.

The steadily declining marmot population and the failed translocation attempt were important considerations as the Vancouver Island Marmot Recovery Team updated the 1994 Vancouver Island Marmot Recovery Plan. In the new document, published in 2000, it was maintained that the initial recovery objectives of the 1994 plan to “establish a population target of 400–600 marmots dispersed in three discrete areas of Vancouver Island” was still valid and that “sufficient natural habitat exists on Vancouver Island to support three metapopulations of 150–200 animals.” It also concluded, however, that “few animals exist for reintroductions or other management activities” and that it is “unlikely that wild populations will suddenly rebound on their own”; therefore, “captive breeding and reintroduction present the only chance of increasing populations within a reasonable period of time and minimizing the risk of extinction” (Janz et al. 2000). In 1997, the Vancouver Island Marmot Recovery Team initiated a program of captive breeding and reintroduction as one of the main components of a recovery effort for the critically endangered Vancouver Island marmot.

The Vancouver Island Marmot Recovery Plan outlined a two-pronged approach for the captive-breeding program consisting of a zoo-based program and a dedicated marmot facility on Vancouver Island (Janz et al. 2000). The zoo-based program would involve the coordinated participation of Canadian zoos and would (1) safeguard the small Vancouver Island marmot population against the risk of a catastrophic event, (2) establish a long-term reservoir of genetic material, (3) develop appropriate husbandry and breeding techniques, (4) conduct directed research, and (5) provide animals for release back into the wild. In addition to supporting the aforementioned goals, the dedicated marmot facility on Vancouver Island would also provide captive marmots with pre-release exposure to natural conditions such as elevation, weather patterns, temperature, photoperiod, and diet. This facility would also greatly simplify the management of potential disease risks and the logistics of marmot reintroduction. During the summer of 1997, wild marmots were captured and sent to the Toronto Zoo in Scarborough, Ontario to begin the zoo-based program. In August 1998, the Calgary Zoo received its first Vancouver Island marmots and became the second Canadian zoo to become involved in the project. In June 2000, the Mountain View Breeding and Conservation Society (formerly called the Mountain View Breeding and Conservation Centre) in Langley, British Columbia became the third facility to receive marmots. In the fall of 2001, construction on the first phase of the dedicated marmot facility on Vancouver Island (named the Tony Barrett Mount Washington Marmot Recovery Centre) was completed, and it received its first marmots in October 2001.

Overview of the Captive Population

Since 1997, there has been a total of 95 individual marmots in captivity. This includes 54 marmots captured from the wild (57%) and 41 born in captivity (43%) (Fig. 1). Eighteen mortalities have occurred in captivity. As of December 2003, the captive population consisted of 77 surviving marmots, of which 40 (52%) were wild caught and 37 (48%) were captive born.

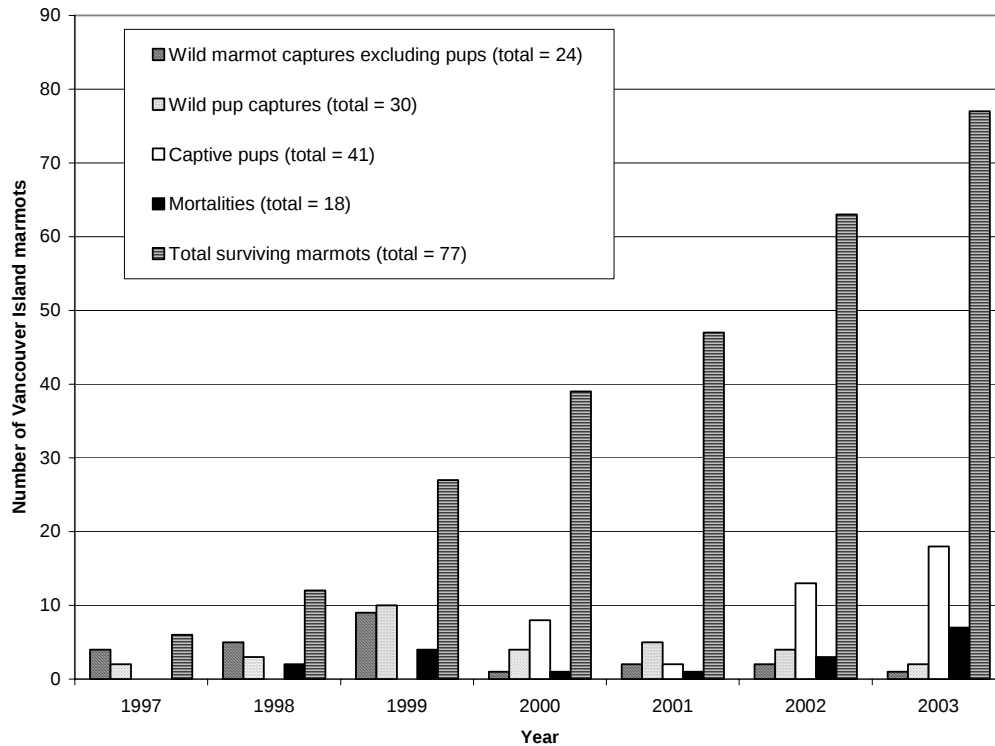


Figure 1. Growth of the captive population of Vancouver Island marmots (1997 to 2003).

Wild Captures

Of the 54 wild marmots in the captive program, 6 were captured in 1997, 8 in 1998, 19 in 1999, 5 in 2000, 7 in 2001, 6 in 2002, and 3 in 2003. Thirty of the marmots were captured from five clearcut colonies, 16 were captured from five natural colonies, and 8 were captured from Mount Washington. In most instances, marmot captures focused on declining clearcut colonies, solitary individuals, juveniles, or genetically important individuals³. During the course of this program, no breeding age females (and only one breeding age male) were captured from any of the natural colony sites. Once-thriving marmot sites, such as those at Haley Lake and Butler Peak, demonstrated very rapid declines in the mid- to late 1990s, and unfortunately these extirpated

³The genetic importance of an individual was based upon previous genetic work and 'best guesses' about the relatedness of individuals, and was influenced by the need to make timely management decisions in a rapidly declining population as a means of avoiding potential loss of genetic variability. Genetically important individuals were those individuals who (1) did not have related individuals in captivity, (2) originated from mountains or distinct colonies where there was no captive representation, and (3) had the potential to be founders in the captive population. The actual selection of genetically important individuals was a dynamic process and depended upon a number of criteria including survival, reproductive performance, and representation in the captive population, and survival, age, dispersal and reproductive performance in the wild. Because the Mount Washington colony is 100 km away from any other known colonies, it is geographically isolated from them. Based upon previous genetic work, Mount Washington marmots were determined to be genetically distinct from marmots in other colonies. Early on in the program it was important to ensure that Mount Washington genes were represented in the captive program. Over the years, as these marmots propagated in captivity, the need to capture new individuals from Mount Washington declined to the point where it is no longer necessary to do so.

colonies are not represented in the captive population. Of the 54 marmots captured from the wild since 1997, 40 (74%) currently survive.

Thirty of the 54 wild captures have been young of the year. As they mature, these individuals may become part of the captive-breeding population, or alternatively they may be candidates for future release. Of the 28 pups captured between 1997 and 2002, 25 (89%) survived their first year. This juvenile survival rate is markedly higher than that which has been documented in the wild (approximately 48%) (Bryant 1996). All three of the juvenile mortalities occurred within 23 days of capture, potentially indicating pre-existing illness or poor adaptation to captive conditions. All of the juveniles taken from the wild since 2000 have survived their first year, possibly due to improved management protocols for newly captured marmots.

Captive Reproduction

The program's first two captive litters (total of 8 weaned pups) were born at the Calgary Zoo in 2000. In 2001, despite higher expectations based upon the number of potential breeding pairs ($n = 7$), only a single litter and 2 weaned pups were produced. In 2002, 5 of the 9 (56%) captive pairs successfully bred, producing a total of 13 weaned pups. This included two litters at the Toronto Zoo, one at the Calgary Zoo, and two at the Mountain View Breeding and Conservation Society. In 2003, all four of the marmot facilities had successful reproduction, with 7 of the 12 (58%) captive pairs producing a total of 18 weaned pups. Two litters were born at the Toronto Zoo, two at the Calgary Zoo, two at the Mountain View Breeding and Conservation Society, and one at the Tony Barrett Mount Washington Marmot Recovery Centre. Of the 23 weaned pups born between 2000 and 2002, all survived their first year. Unfortunately, one of the 18 captive pups weaned in 2003 died in hibernation during the winter of 2003/04. To date, captive litters have averaged 2.7 pups (range 1–5), which is smaller than the 3.3 pups/litter that has been documented for wild litters (Bryant 1998). Limited video observation of captive litters suggests that, in some instances, there is a reduction in litter size from birth to weaning, therefore, wild and captive litter sizes refer to the number of weaned pups or, more specifically, the number of pups observed outside the natal nest box or burrow rather than to the number of pups actually born.

The probability of a captive female producing weaned pups is comparable to that of a wild female (A. Bryant, pers. comm.). The increased breeding success in 2002 and 2003 appears to be associated with improved management protocols including a reduction of disturbance and stress during the breeding period, and increased physical separation between the breeding pairs, which minimizes the potential for reproductive suppression. A potential breeding pair is considered to be one in which both the male and female are four years of age or older. Currently, 44 marmots or 57% of the captive population are younger than four years of age, and the overall breeding potential of the captive population will increase as more individuals sexually mature in the years to come. The captive population has 45 (58%) males and 32 (42%) females; therefore, a portion of the males may not have breeding opportunities in captivity (Fig. 2). Breeding

recommendations for captive Vancouver Island marmots are based upon the VIM Studbook, established in 1998, which seeks to equalize the captive population's mean kinship values and reduce the possibility of inbreeding. In the spring of 2004, the captive program will have up to 14 potential breeding pairs.

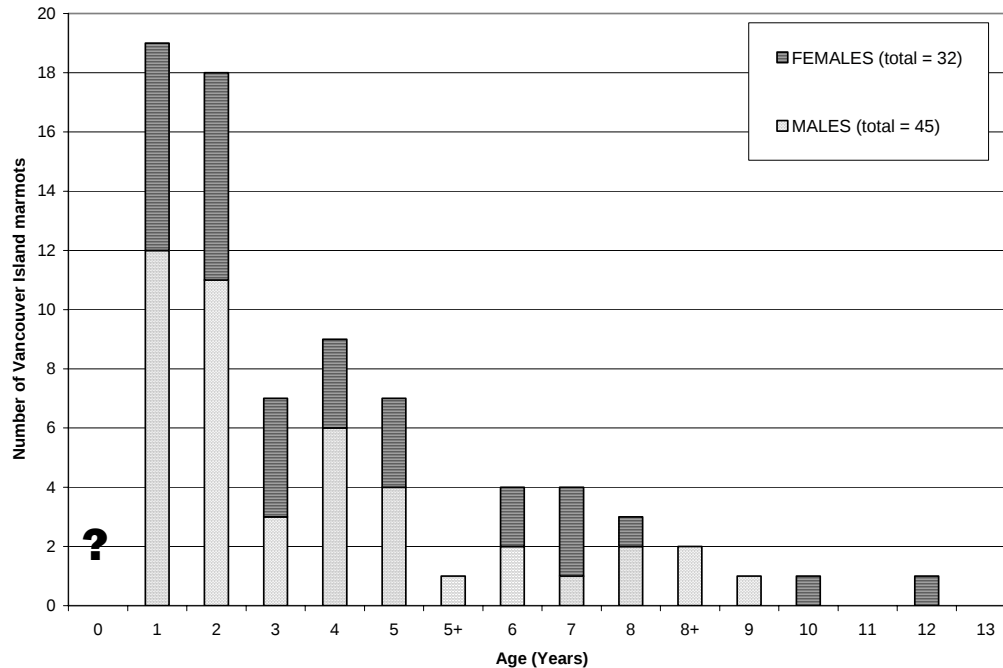


Figure 2. Sex/age distribution of the captive population of Vancouver Island marmots (spring 2004).

Causes of Mortality and Morbidity

Since the captive program began in 1997, there has been a total of 18 marmot mortalities, of which 14 have been wild-caught marmots and 4 have been captive-born marmots.

In four of these cases, the marmot's death seems to be associated with recent capture and the animal's initial adjustment to captivity. Mortality events of this nature include (1) an acute *Escherichia coli* septicemia which led to disseminated intravascular coagulation 3 days after the marmot was placed in captivity, (2) a cecal rupture which lead to acute peritonitis and fulminating septicemia 9 days after the marmot was captured, (3) a fulminating septicemia from gastrointestinal changes 17 days after capture, and (4) a *Mycoplasma pneumonia* 23 days after capture. Stress and diet change seem to be the major complicating factors in these cases; therefore, handling and interference with newly captured wild marmots is minimized as much as possible. New marmots are provided with familiar, natural vegetation in order to facilitate their transition to an artificial, captive diet. Readily fermentable foodstuffs such as fruits, which may lead to bacterial overgrowth in the hindgut, are avoided.

Two captive marmots suffered from congenital disorders. In one case, a two year-old, wild-caught male was diagnosed with an atrial septal defect and chronic heart failure, and was subsequently euthanized. A captive-born female demonstrated stunted development, unilateral anophthalmia, and scoliosis. This individual died at two years of age from a bacterial enteritis.

Two marmot mortalities were management related. Both animals died as a result of hypothermia associated with unsuitably cold temperatures in their artificial hibernaculum.

Two additional marmots died from acute, bacterial bronchopneumonia. In one case, the pneumonia was caused by *Pseudomonas alcaligenes*, and in the other, by *Yersinia enterocolitica*. In each of these cases, it is possible that the implicated bacteria represented a primary pathogen, or the marmot was debilitated or immunocompromised for some other reason and was, therefore, more susceptible to the infectious agent. It is also possible that chronic infection with *Mycoplasma*, which has been routinely cultured from the oropharynx of captive and wild marmots, may have predisposed these individuals to more severe respiratory infections.

Four older marmots died from conditions that may have been age related. These include (1) the death of a 6-year-old male which was attributed to splenic neoplasia, diagnosed as malignant histiocytosis, (2) a 9+-year-old female that was euthanized because of an aggressive carcinoma which originated in the glandular tissue of the nasal cavity or retrobulbar tissues and widely metastasized, (3) a 13+-year-old female that died from cerebral hemorrhage of the left cerebral cortex, and (4) a 8+-year-old female that died from a severe, acute, necrotizing pancreatitis with associated peritonitis and hepatocellular necrosis.

Three of four captive marmots that were released into the wild in 2003 were subsequently predated. Additionally, during the winter of 2003/04, a captive-born pup died during its first hibernation. This is the program's first hibernation mortality since the winter of 1998/99 and the first death of a weaned captive-born pup during its first year. The death appears to have been associated with a chronic infection (lymphoplasmacytic perivascularitis of the stomach lining and the heart), although the etiological agent has yet to be determined.

Health Management

Animals maintained in multi-species facilities such as zoos are at an increased risk for exposure to exotic pathogens. In order to reduce the potential for exposing the captive Vancouver Island marmots to a novel infectious agent, all marmots are maintained under conditions of permanent quarantine. This includes (1) minimizing the marmots' exposure to other animals including domestic, wild, exotic or pest species, (2) limiting the number of persons having contact with the marmots, (3) keeping all marmots off public exhibit, and (4) maintaining a strict adherence to sanitation protocols including the use of disinfectant footbaths, dedicated clothing, masks, and disposable gloves. In addition, any marmots moved from facility to facility or from the wild into captivity are physically separated from the larger marmot group and maintained in quarantine until their health status is determined.

Hibernation

In order to preserve appropriate circannual cycles, all captive marmots are hibernated, unless there are specific health concerns. In the fall, captive marmots are exposed to diminishing photoperiod and temperatures. Food is either gradually withdrawn, or provided until it is spontaneously refused by the marmot. The onset of hibernation in captive marmots is somewhat variable; it seems to depend upon the location of the facility and, to some extent, the individual marmot. Hibernating marmots are maintained at an ambient temperature of 5–7°C. The marmot areas are cooled down and maintained at these temperatures, or the marmots and their nest boxes are transferred into an environmental chamber, a cooling unit, which maintains a constant temperature and humidity. During hibernation, the marmots are monitored using (1) closed circuit video cameras and time lapse video cassette recorders, (2) data loggers to record changes in nest box temperatures, which are associated with the rhythm of torpor and arousal that characterizes marmot hibernation, and (3) regular weighing every 4–6 weeks to monitor patterns of weight loss. Marmots are weighed only while torpid, and if timed correctly, this does not seem to precipitate additional arousals. If the marmots show any indications of activity or euthermia, the weighing is postponed. Because of the potential for diminished immune function and increased susceptibility to infectious agents, hibernating marmots are always treated as if they are immunocompromised. When hibernating marmots are weighed or examined, the handlers wear surgical masks, latex gloves, and dedicated boots and coveralls.

From 1997 to 2002, there was a total of 194 captive marmot hibernations involving 70 marmots; 192 or 99% of these hibernations were considered to be successful in that the marmot survived. In one case, a captive-born female with congenital anomalies remained active and still survived the winter. As mentioned previously, two cases of management-related hibernation mortality resulted from hypothermia due to unsuitably cold hibernaculum temperatures in the artificial hibernacula, and during the winter of 2003/04, a captive-born pup died during its first hibernation.

Diet

The main component of the captive diet is commercial, alfalfa-based rabbit pellets. Supplemental items such as fresh vegetables, high fiber primate biscuits, and hay are also provided. At the Tony Barrett Mount Washington Marmot Recovery Centre, marmots are also provided with a large amount of natural vegetation (grasses, sedges, forbs), which is collected from local meadows.

Housing

All marmots are provided with nest boxes, which act as a substitute for natural burrows. The captive marmots have accepted nest boxes that are of varying dimensions and made from a variety of different materials including plywood, plastic polymers, and sheet metal. Although a nest box of 60 x 60 x 60 cm is suitable for a single marmot or a pair, it is considered too small for an entire family group. Marmots are maintained on a substrate of straw and white wood shavings. The marmots' outside enclosures typically have a soil substrate of varying depth. If the soil is sufficiently deep, the marmots will create elaborate burrow systems. The marmots are provided with a variety of cage 'furniture' including large rocks, rock piles, concrete blocks, plastic tubes, tree stumps, and wooden shelves and ramps. Captive marmots have demonstrated a tremendous ability to squeeze through small openings, undo metal bolts, break welds, and bend and break metal; therefore, enclosures need to be constructed of heavy gauge metal with all openings less than 4 cm.

2003 Reintroduction

In the summer of 2003, four captive marmots (two males, two females) were released at the summit of Green Mountain, a site at which marmots had been recently extirpated. Two of the marmots had been born in captivity and two had been born in the wild. One of the wild-born individuals had been captured at Green Mountain in 2002. All four individuals were genetically well represented in the captive population and were, therefore, expendable to the captive-breeding population. All four individuals had spent at least one winter at the Mount Washington marmot facility in order to acclimate them to high elevation conditions on Vancouver Island. Prior to release, all of the marmots were surgically implanted with abdominal radio transmitters, and their health status was evaluated by physical examination, hematology and serology. Leading up to the reintroduction, the marmots were provided with natural vegetation as part of their captive diet and were habituated to their release boxes. Before the marmots' were released, these boxes were disassembled and then reassembled at the release site. The release boxes were packed with the marmots' familiar bedding. The release boxes were situated so that they also provided direct access to an existing natural burrow.

The marmots were released on 2 July at a time when the subalpine meadows were starting to green up and an increasing abundance of natural food was available. For their first night at the release site, the marmots were prevented from exiting their nest boxes so that they would be forced to explore the adjacent natural burrow. For a period of time following the release, the marmots were provided with familiar supplemental foods such as rabbit pellets, peanut butter, and commercial primate biscuits. The marmots were monitored as much as logistically possible on a daily basis by field staff.

Although there was a significant amount of individual variation in the marmots' response to their new environment, they seemed to demonstrate a positive adaptation to the natural conditions

of their release site. They were seen utilizing natural vegetation, burrows, rocks, etc., demonstrating normal social interactions, and responding to the threat of an eagle overhead. A quantitative analysis of the marmots' post-release behavior is ongoing. Three of the marmots remained at Green Mountain. One of the males moved south to Butler Peak but was subsequently recaptured and returned to the release site on 4 August where he remained. Unfortunately, on 16 August, the two captive-born marmots were found dead in close proximity to one another. On 17 August, one of the two wild-born marmots was also found dead. All three deaths were due to cougar predation. The fourth marmot was recaptured and returned to the Mount Washington facility on 18 August. Field crews saw a cougar on Green Mountain within the first few days of releasing the marmots. Fallers working on the western portion of Green Mountain reported seeing a mother cougar and two kittens prior to the marmot deaths, and field workers saw a cougar close to the Green Mountain summit on 18 August while they were attempting to catch the fourth marmot. The cougar did not seem to be particularly alarmed by the close proximity of people.

Discussion

During the summer of 2003, a total of only 27 wild marmots (including 5 young of the year) were counted on six mountains on Vancouver Island. Of this 27, one yearling male and two pups were captured and taken into captivity. In August, three breeding age adults (one male and two females) from three different mountains were killed by predators. Currently *Marmota vancouverensis* has a wild population that probably numbers less than 25 individuals and has as few as 4 wild breeding pairs. Given the increasingly precarious state of the wild population, captive breeding and reintroduction still represents the best chance for preventing extinction and recovering this critically endangered species. The captive population of Vancouver Island marmots is young and healthy, and it has exhibited steady growth since its inception in 1997. In order for the captive population to maintain 90% of the genetic diversity of the original population over a 20-year period and to generate 10–30 individual marmots for annual release, the captive population will require 17 breeding pairs that breed at least twice per generation. This will require a total captive population of 85–110 individuals. Currently, the captive program is close to achieving these goals. As the captive population grows and becomes more robust, there will be continued opportunities to release relatively small numbers of captive marmots into formally occupied natural habitat and into existing colonies that require supplementation. These initial reintroductions will provide an excellent learning opportunity and will be intensely monitored and evaluated. As experience with reintroduction and numbers of captive marmots increase, the program will hopefully shift to operational reintroductions, which will involve the release of moderate numbers of captive animals (approximately 20 per year) over a multi-year period. Ultimate success of this program will depend upon effective captive management protocols combined with effective release strategies and predator and habitat management strategies.

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