CHIPMUNKS (*TAMIAS*) OF THE KOOTENAY REGION, BRITISH COLUMBIA: DISTRIBUTION, IDENTIFICATION, TAXONOMY, CONSERVATION STATUS

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Cover Figure: Least Chipmunk (*Tamias minimus*) by Michael Hames taken from the *Rodents and Lagomorphs of British Columbia*, RBCM handbook manuscript by David Nagorsen

EXECUTIVE SUMMARY

Introduction

In 1996, the Columbia Basin Fish and Wildlife Compensation Program (CBFWCP), British Columbia Ministry of Environment, Lands and Parks (MELP), the Royal British Columbia Museum (RBCM), and TerraMar Environmental Research Ltd. initiated a collaborative study to investigate the taxonomy, distribution, and conservation status of four chipmunk taxa from the Kootenay region of southeastern British Columbia that are listed by the province as potentially at risk. The listed chipmunk taxa represent two subspecies (*ruficaudus*, *simulans*) of the Red-tailed Chipmunk (*Tamias ruficaudus*) and two subspecies (*oreocetes*, *selkirki*) of the Least Chipmunk (*Tamias minimus*).

A sample of 134 voucher specimens of the *T. minimus*, *T. ruficaudus*, and the Yellow-pine Chipmunk (*T. amoenus*) with associated habitat data were collected from various elevations and habitats from the southern Columbia Mountains and Rocky Mountains in southeastern British Columbia from 1996 to 1999. In addition, 214 historical museum specimens of the three chipmunk species from the study area were examined. The objectives of the chipmunk study were to: evaluate the reliability of various traits for identifying the three chipmunk species; develop identification keys for identifying live chipmunks and museum specimens from the study area; record habitat characteristics and land-management history (with particular reference to forest practices) at each sample location; determine the geographic ranges of *T. amoenus*, *T. minimus*, and *T. ruficaudus* in the Columbia Mountains and southern Rocky Mountains of British Columbia; assess the taxonomic validity of *T. m. selkirki*, *T. m. oreocetes*, *T. r. ruficaudus*, and *T. r. simulans*; assess the conservation status of *T. m. selkirki*, *T. m. oreocetes*, *T. r. ruficaudus*, and *T. r. simulans*; and recommend future research priorities.

Identification

We studied 134 voucher specimens taken during 1996-99 and 72 historical museum specimens with genital bones retained in their skins from the southern Rocky Mountains and Columbia Mountains. For each voucher specimen, we prepared an associated study skin, skull, and cleared and stained genital bone; tissue samples (all sent to the University of Idaho) were preserved for DNA analysis. We found that museum or voucher specimens with genital bone preparations could be identified unequivocally as *T. amoenus*, *T. minimus*, or *T. ruficaudus* from measurements taken from stained bacula or baubella or radiograph images of genital bones. Few museum specimens had associated genital bone preparations, but as many as a third of the existing museum skins had genital bones inadvertently preserved in their skins. They could be identified from x-rays that reveal genital bone images. For adult museum specimens that lack genital bones, identifications can generally be made using discriminant classification functions developed from cranial measurements. An exception is in the Columbia Mountains where adult *T. amoenus* and *T. ruficaudus* converge in cranial morphology making identification unreliable.

Anaesthetised or restrained adult chipmunks held in the hand can be identified with less certainty from either discriminant classification functions derived from body measurements or using pelage colour (dorsal, underside of the tail, belly fur). In the Columbia Mountains where adult *T. amoenus* and *T. ruficaudus* converge in body size

and pelage, these species cannot be reliably identified in the field and positive identification requires voucher specimens with genital bones. Because of sampling inadequacies bias, the geographic range and elevational range of chipmunks in southeastern British Columbia is poorly known. Therefore, until more inventory work is done, we recommend that identifications not be based on assumptions of elevation or geographic range.

We developed separate identification keys for the southern Columbia Mountains and the Rocky Mountains for identifying chipmunks in the field and identifying museum specimens from genital bone morphology, or skull morphology. Our identification keys can be applied only to adult animals. More research is needed to develop identification keys for immature chipmunks, and to develop a reliable aging technique for use on live animals. Other identification techniques such as recording vocalizations or applying molecular markers such as mitochondrial or microsatellite DNA should be explored.

Taxonomy

Red-tailed Chipmunk (Tamias ruficaudus)

Our analyses were based on 52 adult skulls (28 *T. r. simulans*, 34 *T. r. ruficaudus*), 19 bacula, and 11 baubella from the southern Columbia Mountains and Rocky Mountains. The samples included historical museum specimens and voucher specimens taken in 1996-99. We assessed variation in genital bone morphology, pelage colour, and skull morphology among the two subspecies; tissues from all *T. ruficaudus* voucher specimens were analyzed by Jeff Good and Jack Sullivan at the University of Idaho for mtDNA sequences.

In Canada, at the northern periphery of their distributions, *T. r. ruficaudus* and *T. r. simulans* differ in male and female genital morphology, cranial morphology, and pelage colour. The genital bone morphology of these northern forms is concordant with the occurrence of two non-overlapping morphs throughout the range. Results from the mitochondrial DNA analysis suggests a similar genetic pattern. The differences in pelage and cranial morphology are consistent with clinal patterns that are associated with ecological or environmental gradients.

Because the northern forms of *T. ruficaudus* are allopatric, the only potential contact zone for testing introgression is in Idaho and Montana. Preliminary mtDNA research Jeff Good and Jack Sullivan has shown some hybrization among *T. r. ruficaudus* and *T. r. simulans* in the Clearwater drainage of central Idaho. Until more genetic work is done in the contact zone to assess the degree of introgression, taxonomic status of the two forms is unresolved. However, because they differ in morphology, distribution, and ecology the Canadian populations of *T. r. ruficaudus* and *T. r. simulans* should be treated as distinct evolutionary units for conservation and management.

Least Chipmunk (Tamias minimus)

We assessed variation in genital bone morphology and cranial morphology among five selected samples of *T. m. selkirki*, *T. m. oreocetes,* and *T. m. borealis* from British Columbia and south-western Alberta. Our analyses were based on 129 adult skulls and 23 bacula from voucher specimens taken 1996-99 and historical museum specimens. Tissue samples from all *T. minimus* taken as vouchers were sent to the University of Idaho but they have not been sequenced.

Inadequate samples prohibit definitive conclusions on the taxonomy of *T. minimus* in the southern Columbia and Rocky Mountains of Canada. Existing data demonstrate that *T. m. selkirki* is differentiated from Rocky Mountain populations of *T. minimus* in male genital bone (bacula) morphology and cranial morphology. Because it is allopatric separated by 100 km from *T. minimus* in the Rocky Mountains and represents a relict population, we recommend that it be considered a distinct taxonomic unit. Molecular studies applying our tissue samples are needed to evaluate genetic divergence in this population.

There are inadequate bacular samples from Rocky Mountain *T. minimus* populations to assess geographic variation in male genital bone morphology, but univariate analysis of body measurements and multivariate analyses of cranial morphology suggest clinal patterns with no evidence for a step-cline across the Bow River the putative boundary between *T. m. oreocetes* and *T. m. borealis*. Given this pattern of clinal variation in the Rocky Mountains, the taxonomic validity of *T. m. oreocetes* is dubious. However, until more bacular samples are obtained and molecular studies, it is prudent to continue to recognize populations south of the Bow River and Kicking Horse pass in the Canadian Rocky Mountains as a separate subspecies, *T. m. oreocetes*.

Distribution and Habitat Relations

In the Kootenay region, *T. minimus* is restricted to alpine habitats in the Purcell Mountains and the Rocky Mountains. *T. m. selkirki* appears to have a restricted range in the Purcell Mountains where it is known from the type locality (the Paradise Mine), adjacent contiguous areas, and a nearby disjunct area (upper Hopeful Creek drainage and Mt. Brewer). This taxon is restricted to the Alpine Tundra (AT) biogeoclimatic zone where it has been found from 2134 to 2380 metres. Confined to the Rocky Mountains where its precise northern limits are unknown, *T. m. oreocetes* is isolated from *T. m. selkirki* by the Rocky Mountain trench. This taxon has been recorded in the AT and Englemann Spruce-Subalpine Fir (EESF) biogeoclimatic zones from 1900 to 2318 metres.

T. r. simulans is restricted to the southern Selkirk Mountains. It has been recorded in the ESSF and Interior Cedar-Hemlock (ICH) biogeoclimatic zones where it has been found from 560 to 1829 metres. We found no evidence for *T. ruficaudus* in the Purcell Mountains. *T. r. ruficaudus*, the subspecies that inhabits subalpine areas in the southern Rocky Mountains north to Middle Kootenay Pass is isolated from *T. r. simulans* by the Kootenay River valleys and the Purcell Mountains. *T. r. ruficaudus* is limited to the ESSF biogeoclimatic zone where it occupies a narrow elevational band from 1780 to 1900 metres.

In contrast, *T. amoenus* is widespread throughout the study area from valley bottoms to sub-alpine habitats in the Columbia and Rocky mountains where it occupies the Interior Douglas-fir (IDF), ICH, Montane Spruce (MS), and ESSF biogeoclimatic zones. In areas where *T. a. luteiventris* co-occurs with *T. minimus* and/or *T. r. ruficaudus*., *T. amoenus* appears to be excluded from the alpine. However, in areas where it is the sole chipmunk species (e.g., northern Sekirk or Purcell mountains), *T. amoenus* extends into the alpine and the associated AT biogeoclimatic zone.

Trapping success was highly variable and often low, possibly as a function of availability of natural food, even where chipmunks are known to be present. Shooting is a

more efficient means of securing specimens. Chipmunk habitat is generally characterized by having a high degree of physical complexity, which may afford protection from predators. This complexity can take the form of coarse woody debris, complex rocky substrates, and/or low woody vegetation. Chipmunks were generally found over a wide range of slopes and aspects, suggesting that neither factor is important in determining distribution. However, few chipmunks were observed at N-facing sites at higher elevations, where persistent snow may limit habitability. Chipmunks generally appear to tolerate or even benefit from the effects of human activities such as mining and logging. Logging (and fire) in particular appears to create open habitat with a high density of food plants and abundant coarse woody debris. The distribution of the various chipmunk taxa is poorly understood in the Kootenay region. More inventory is needed in the northern Selkirk and Purcell mountains and in the Rocky Mountains west of the Flathead River valley.

Conservation Status Assessments

T. m. oreocetes

Although the validity of this subspecies is questionable, we recommend that it continue to be treated as a separate unit for conservation until more taxonomic research is done. Although there are no reliable data on population numbers or trends, this species clearly is not at risk provincially or nationally. Size of its distributional area, its presumed continuous range along the continental divide, and potential rescue effects from populations in Montana and across the continental divide between British Columbia and Albert precludes an Endangered or Threatened designation. Most important there are no known threats other than habitat loss from open pit coal mines. Any impacts from open pit mining are probably offset by the protection of much of its range in British Columbia and Alberta in the national and provincial park systems of the southern Rocky Mountains. Although its limited range and few occurrences contribute to its provincial designation as S2S3 (Blue List) by the CDC, it is unlikely that this taxon would qualify as a COSEWIC candidate for Special Concern. This subspecies has not been listed by the Natural Heritage Information Centres of Alberta or Montana.

T. m. selkirki

Genetic studies are essential to confirm the validity of this subspecies but the morphological data and its isolated range endemic to the Purcell Mountains suggest that it is distinct from populations of *T. minimus* in the Rocky Mountains. Sullivan and Nagorsen (1998) ranked this taxon as Vulnerable D2 with the IUCN criteria based on its restricted range and an area of occupancy less than 100 km^2. When Sullivan and Nagorsen (1998) did their assessment, *T. m. selkirki* was known from only from historical museum records collected from the type locality at the Paradise Mine. However, even with new data from our field studies this subspecies would still be ranked as Vulnerable D2 with the IUCN criteria. It is known from only two general locations in the Purcell Mountains, has an area of occupancy less than 100 km^2, consists of fewer than 1,000 animals, and is isolated with no potential for rescue. These same criteria would qualify *T. m. selkirki* as a candidate for Threatened under the COSEWIC criteria. Nevertheless, no threats have been identified other than stochastic extinction events associated with small isolated populations.

T. r. ruficaudus

This subspecies is ranked as S2 (Red List) in British Columbia because of its limited range and few known locations. Similarly it is ranked as S2 by the Alberta Natural Heritage Information Centre and is on the province's Blue List (see Bennett 1999). *T. ruficaudus* is not being tracked by Natural Heritage Information Centres of Montana and Idaho. In BC and Alberta this species has small ranges and is limited to a narrow elevational belt. Nonetheless, much of its distributional area falls within the boundaries of Waterton Lakes National Park and Akamina-Kishinena Provincial Park and no threats are known. Moreover, because the Canadian populations are contiguous with populations in adjacent areas of Montana, there is potential for a rescue effect. Although extensive logging is occurring within its elevational range in the Flathead River valley of British Columbia, this species inhabits early and later successional stages. A potential impact from forestry is that *T. amoenus* could invade logged habitats and displace *T. ruficaudus* through interspecific competition. However, no data exists to test this hypothesis. This subspecies clearly is not a COSEWIC candidate for Endangered or Threatened but may qualify as a candidate for Special Concern.

T. r. simulans

This taxon is currently ranked as S3S2 (Blue List) in British Columbia largely on the basis of its small distributional area. The Washington Sate Natural Heritage Information Centre has ranked it as S2?. In contrast to *T. r. ruficaudus, T. r. simulans* occupies a wide elevational range and a variety of habitats including the floodplain of the Creston Valley, mid elevation forests (mature and logged), and subalpine habitat in Stagleap Provincial Park. Contiguous with populations in Washington and Idaho, there is considerable potential for rescue effect. No threats are known. Despite its provincial listing, we suggest that this taxon does not qualify as a COSEWIC candidate for Special Concern.

Chapter 1

INTRODUCTION

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BACKGROUND

In 1996, the Columbia Basin Fish and Wildlife Compensation Program (CBFWCP), British Columbia Ministry of Environment, Lands and Parks (MELP), the Royal British Columbia Museum (RBCM), and TerraMar Environmental Research Ltd. initiated a collaborative study to investigate the taxonomy, distribution, and conservation status of various small mammals including four chipmunk taxa (see Fig. 1-1A,B) from the Kootenay region of southeastern British Columbia that are listed by the province as potentially at risk. The listed chipmunk taxa represent two subspecies of the Red-tailed Chipmunk (*Tamias ruficaudus*) and two subspecies of the Least Chipmunk (*Tamias minimus*):

Red-tailed Chipmunk (ssp. *ruficaudus*)	*Tamias ruficaudus ruficaudus*
Red-tailed Chipmunk (ssp. *simulans*)	*Tamias ruficaudus simulans*
Least Chipmunk (ssp. *oreocetes*)	*Tamias minimus oreocetes*
Least Chipmunk (ssp. *selkirki*)	*Tamias minimus selkirki*

When the study was initiated all four chipmunk taxa were on the province's red list as potentially threatened or endangered (Cannings et al. 1999). Nevertheless, with little known about their distribution and habitat requirements, the conservation status of these taxa was largely speculative. There were also unresolved questions about the taxonomy of the four subspecies and the appropriateness of treating them as distinct units for conservation. In addition, the Yellow-pine Chipmunk (*Tamias amoenus*) also inhabits the Kootenay region (Fig. 1-1C) and may co-occur with *Tamias ruficaudus* and *Tamias minimus* in some habitats. Although *T. amoenus* is not at risk in British Columbia, it may be difficult to distinguish from *T. ruficaudus* and *T. minimus* raising questions about the reliability of identifications for live animals captured in field studies and historical museum specimens.

The objectives of the chipmunk study were:

1. Collect a representative series of voucher specimens of chipmunks from various elevations and habitats in the Columbia Mountains and southern Rocky Mountains of British Columbia.
2. Identify all voucher specimens to species and determine the chipmunk species present in the Columbia Mountains and southern Rocky Mountains.
3. Record habitat characteristics and land-management history (with particular reference to forest practices) at each sample location.
4. Develop identification keys for identifying live chipmunks and museum specimens from the study area.
5. Use the voucher specimens taken 1996-1999 and historical museum specimens identified from our keys to determine the geographic ranges of *T. amoenus*, *T. minimus*, and *T. ruficaudus* in the Columbia Mountains and southern Rocky Mountains of British Columbia.
6. Use the voucher specimens taken 1996-1999 and historical museum specimens to assess the taxonomic validity of *T. m. selkirki*, *T. m. oreocetes*, *T. r. ruficaudus*, and *T. r. simulans*.

7. Assess the conservation status of *T. m. selkirki, T. m. oreocetes*, *T. r. ruficaudus*, and *T. r. simulans* and recommend future research priorities.

For preliminary reports see Fraker et al. (1997), Fraker and Nagorsen (1998), Nagorsen and Fraker (2000), and Nagorsen et al. (2000). This report represents the final summary report for the project. It is based on four years of field research (1996-99) and associated research on historical museum specimens.

STUDY AREA AND COLLECTING SITES

Field studies and chipmunk voucher specimens were collected from the southern Columbia Mountains and Rocky Mountains in southeastern British Columbia (Fig. 1-2). The primary objective of our sampling was to collect representative voucher specimens that could be used in the identification and taxonomy studies. A combination of trapping and shooting was used to collect chipmunks (see Chapter 4). We attempted to sample a range of elevations and different habitats in both the Columbia and Rocky Mountains. However, no attempt was made to systematically sample all habitats nor determine the relative abundance of chipmunks in different habitats.

In addition to the field work, one of us (DWN), examined about historical museum specimens of chipmunks collected from southeastern British Columbia and the southern Rocky Mountains of Alberta housed in seven museums by visits and loans.

Southern Columbia Mountains

Study sites in the Purcell Mountains (Fig. 1-2A, C) were located on the east side of the Creston Valley (1996), in the Columbia River valley near Invermere (1996, 1997) and montane habitats west and northwest of Invermere (1997, 1999). Biogeoclimatic zones sampled included the Interior Douglas Fir, Montane Spruce, Engelmann Spruce-Subalpine Fir, and Alpine Tundra Biogeoclimatic zones. Elevations ranged from about 900 m in the Rocky Mountain Trench and 700 m near Creston to as high as 3400 m on some mountains; however, our surveys did not extend above 2400 m. Most of our effort was focused on high elevation areas where *T. m. selkirki* might occur. However, several mining roads and a horse trail allowed us to sample habitats from a full range of elevations from valley bottoms to alpine.

Three areas were visited in the southern Selkirk Mountains in 1996 (Fig. 1-2C): the mountains south of Nelson; the lower Pend d'Oreille River drainage; and the Creston Valley area. The west side of the Creston Valley and the mountains south of Nelson were revisited in 1999. The biogeoclimatic zones represented in the study sites were Interior Cedar-Hemlock and Engelmann Spruce-Subalpine Fir. Elevations ranged from about 700 m to 2400 m. We searched throughout the accessible elevation ranges up to about 1500 m since both *T. r. simulans* and *T. a. luteiventris* were thought to occur in the region. No sampling was done in alpine habitats.

Southern Rocky Mountains

Study areas in the Rocky Mountains covered a relatively large region from the southeastern corner of BC in the Flathead Valley and along the Continental Divide north to several sites east of the Elk River valley north of Crowsnest Pass (Fig. 2-B). These areas encompassed Montane Spruce, Engelmann Spruce-Subalpine Fir, and Alpine Tundra biogeoclimatic zones. Elevations range from about 1200 m to 3100 m. Although

our focus was on high elevation areas where *T. m. oreocetes* and *T. r. ruficaudus* were expected to occur, our sampling covered a range of elevations from about 1300 m to 2100 m.

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We especially thank John Krebs, Ted Antifeau, and Larry Ingham for their strong support of the study. We are indebted to Ian Parfitt for his GIS skills and preparation of the colour maps. Andrew Neimann scanned the colour images of chipmunk study skins. Kelley Sendell assisted with the preparation of the radiographs. We appreciate the assistance provided by Paul Brett, Ray Bon, Jason Kerr, Dean Browne, and Laura Hooper. Lyle and Scott Barsby (Toby Creek Outfitters Ltd., Panorama, BC) provided horseback transportation into areas of the Purcell Mountains**.** Mike Sumanik (Canadian Helicopters, Cranbrook) provided helicopter transport into Middle Kootenay Pass in the Rocky Mountains. Doug Braybrook (Cresbrook Forest Products, Sparwood) provided maps and keys for logging road access; Frank de Boon (Conservation Officer Service, Fernie) found freezer facilities for storing frozen specimens.

We acknowledge Ian McT. Cowan for sharing his insights into the distribution and ecology of *T. m. selkirki* and other chipmunks of the Kootenays.

We thank Christine Adkins (Cowan Vertebrate Museum, University of British Columbia), Judy Eger (Royal Ontario Museum), Michelle Gosselin (Canadian Museum of Nature), Bryn Mader (American Museum of Natural History), Bruce McGillvray (Provincial Museum of Alberta, Wayne Roberts (University of Alberta Museum of Zoology), and Gary Shugart (Slater Museum, University of Puget Sound) for loans and allowing us to measure material in their collections.

Jack Sullivan, Jeffrey Good, and John Demboski of the University of Idaho accepted tissues from our chipmunk specimens for mitochondrial DNA analysis and provided unpublished results from their research. We especially thank Jeff for analysing additional samples beyond the scope of his thesis research.

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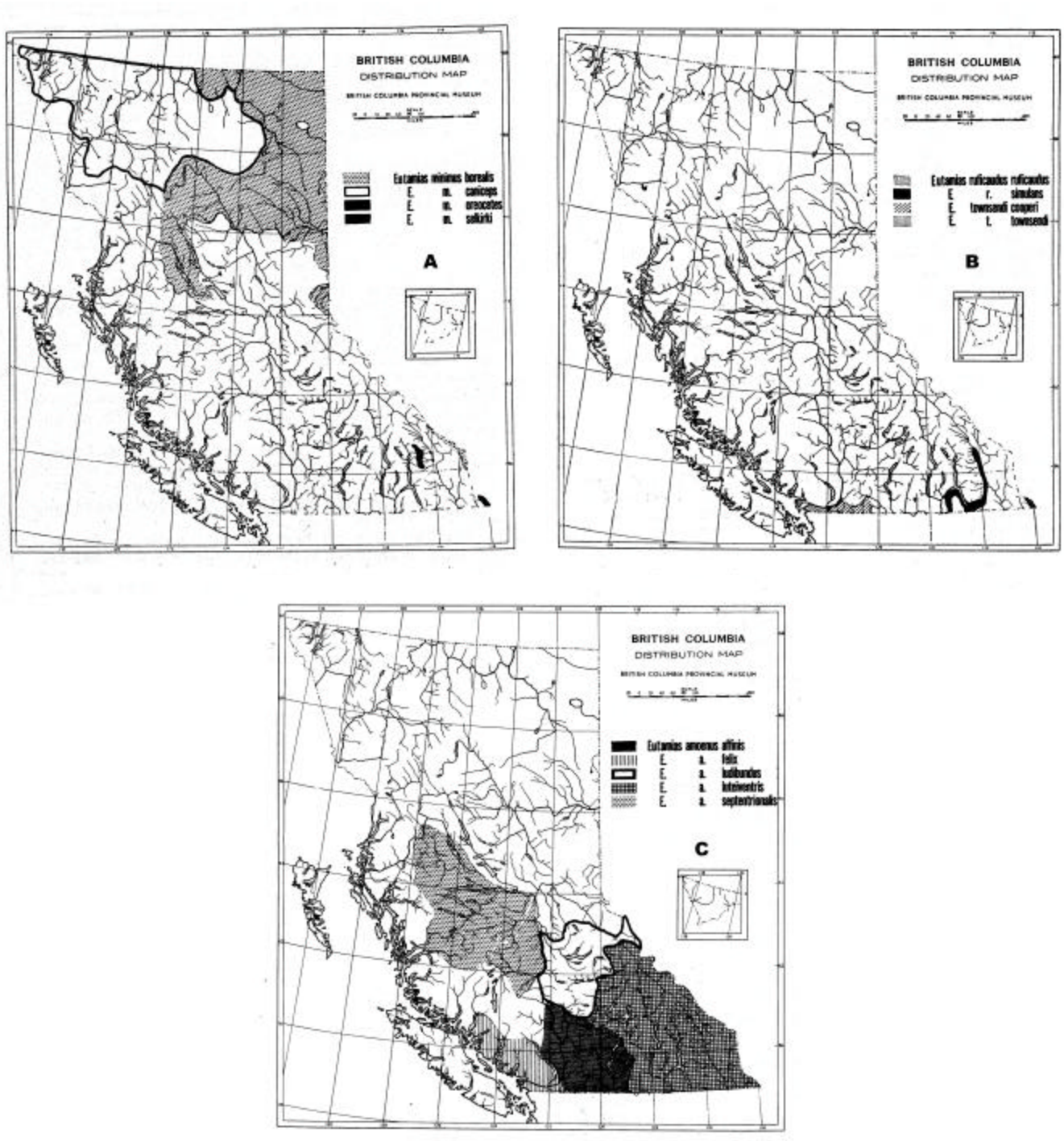
Figure 1-1. Distribution and subspecies of three chipmunk species in British Columbia according to Cowan and Guiguet (1965). A Least Chipmunk (*Tamias minimus*), B. Red-tailed Chipmunk (*Tamias ruficaudus*), C. Yellow-pine Chipmunk (*Tamias amoenus*).



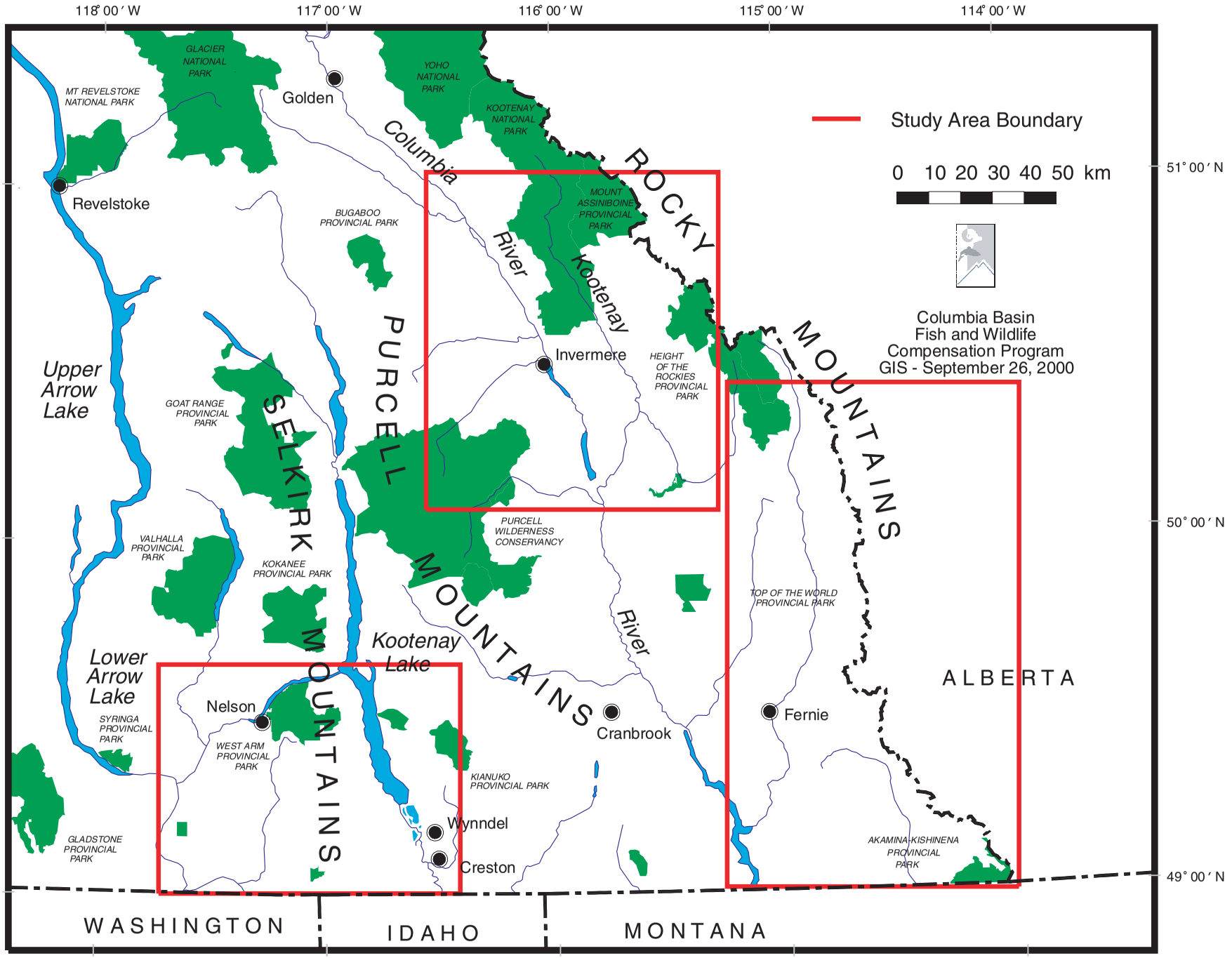


Figure 1-2. Chipmunk study areas in the southern Columbia Mountains and Rocky Mountains.

Chapter 2

IDENTIFICATION

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INTRODUCTION

An important objective of this study was to evaluate chipmunk identification in the Kootenay region and develop identification keys. Reliable identification of voucher specimens taken during our field inventories and any existing historical museum specimens collected from our study area was essential. It was also important to assess the feasibility of distinguishing *T. amoenus*, *T. minimus*, and *T. ruficaudus* in the field from morphological traits such as pelage colour and size. *T. amoenus*, *T. minimus*, and *T. ruficaudus* show elevational and habitat separation in the Columbia and Rocky mountains. Nevertheless, because they are parapatric in some areas with two or even all three species co-occurring at some locations (see Chapter 4), they cannot be identified to species simply on the basis of elevation or geographic location. Cowan and Guiguet (1965) provided no identification keys to separate *T. amoenus*, *T. minimus*, and *T. ruficaudus* in British Columbia. Using skull size and colour of the fur on the underside of the tail and abdomen, Howell (1929), Ingles (1965), Hall (1981), and Sutton (1992) provided general identification keys for separating these three chipmunk species. However, because these species demonstrate considerable geographic variation with a number of distinct subspecies recognized, their keys are of limited use for identifying chipmunks in a local region.

Cowan and Guiguet (1965) noted that although chipmunks vary geographically across British Columbia, the species are distinct in any given region. Nevertheless, identification in some areas of the Columbia Mountains has been problematic. Maillard (1932) identified a series of chipmunks taken in the Creston Valley in 1928 as *T. ruficaudus*, but Anderson (1934) and Cowan (1946) subsequently identified them as *T. amoenus*. Historical museum specimens housed in the Canadian Museum of Nature that were collected in the Creston Valley, southern Purcell Mountains, and Invermere region are also problematic. According to notations on their study skin tags, some were initially identified as *T. ruficaudus* and then changed to *T. amoenus*. Similarly, using pelage colour and cranial size, Dalquest (1948) was unable to positively identify a number of chipmunk specimens from the Selkirk Mountains in northeastern Washington State where *T. amoenus* and *T. ruficaudus* evidently co-occur. Identification problems are also associated with chipmunks taken in the southern Rocky Mountains of Canada. Historical museum specimens housed in the Canadian Museum of Nature that were collected in the Flathead River valley were initially identified as *T. ruficaudus* then changed to *T. amoenus*. Cowan (1946) noted a *T. ruficaudus* taken Jasper National Park that was described as a northern record for this species by Anderson and Rand (1943) was actually a misidentified *T. amoenus*.

Identification from morphological traits such as pelage colour and cranial size is often hindered by morphological convergence among different chipmunk species in response to local environmental effects (Sutton and Patterson 2000). Pronounced seasonal and age variation is another limitation of fur colour as an identification trait. The most reliable morphological trait for identifying chipmunks is the size and shape of the male and female genital bone (i.e., baculum, baubellum). The utility of genital bones for identifying *T. ruficaudus*, *T. minimus*, and *T. amoenus* was demonstrated by White (1953) and Sutton (1982, 1995).

To avoid circularity with identifications based on *a priori* assumptions of species differences in ecology, fur colour, or cranial morphology, our approach was to define reference groups of *T. amoenus*, *T. minimus*, and *T. ruficaudus* with specimens that we identified to species solely from genital morphology. These reference groups of the three species were then used to assess the reliability of various morphological traits that could be used to identify live chipmunks captured in field studies or museum specimens lacking genital bone preparations. Because populations of *T. ruficaudus* and *T. minimus* inhabiting the east and west sides of the Rocky Mountain trench are differentiated at the subspecies level demonstrating intraspecific differences in pelage and other morphological traits (Cowan and Guiguet 1965), we subdivided our reference groups into two geographic samples: Columbia Mountains and Rocky Mountains (see Fig. 2-1).

METHODS

Specimens Examined and Reference Groups

A total of 134 voucher specimens (Appendix 2-1) were taken during the 1996-99 inventory work. All were prepared as study skins, skulls, and skeletons and were deposited in the research collections of the Royal British Columbia Museum (RBCM). Before preparation, voucher specimens were x-rayed in lateral view (life size) to reveal genital bone morphology. Genitalia were then removed, cleared in a 2% KOH solution, and genital bones were stained with Alizarin red. The stained genital bones were then dissected from the genitalia and most of the tissue was removed. The prepared genital bones were stored in glycerine. In 1996 the genital bones of 10 specimens were damaged during preparation; therefore, cleared and stained genital bone preparations existed for 124 of the vouchers. Tissue samples from each specimen were frozen for possible future DNA studies. Tissues samples of 15 *T. amoenus* and 28 *T. ruficaudus* were donated to the University of Idaho for phylogeographic studies with mitochondrial DNA being done by John Demboski and Jeff Good.

In addition to the vouchers collected 1996-99, we examined 214 historical museum specimens housed in 7 museums that were collected from the southern Columbia and Rocky mountains of British Columbia and Alberta. Only ten had associated cleared and stained bacula preparations; none had prepared baubella. For the 204 specimens lacking genital bone preparations, we took radiographs of their study skins (dorsal view, actual size) to determine if their genital bones had been retained in the skins during preparation; 72 study skins had genital bones.

Our reference groups consisted of the 201voucher and historical museum specimens identified from genital bones: 97 from the Columbia Mountains, 104 from the Rocky Mountains (Fig.2-1; Appendix 2-2). Our Columbia Mountains sample encompassed the Purcell and Selkirk mountains in British Columbia from the United States border north to Glacier and Mount Revelstoke National parks. Specimens from low elevations on the west side of the Rocky Mountain trench were included in this sample. The Rocky Mountains sample ranged from low elevations on the east side of the Rocky Mountain trench across the Rocky Mountains to the eastern slopes in Alberta. Northern limits were defined by the south side of the Bow

River and Kicking Horse Pass the putative limits of the range of *T. minimus oreocetes* (Banfield 1958).

Species Identification From Genital Bones

Cleared and stained genital bones were examined with a stereomicroscope (20X). We made outline drawings of all bacula and baubella using *camera lucida* projections. Nine bacular measurements (Sutton and Nadler 1974; Patterson 1982) were taken: total length, shaft length, tip length, base width, tip width, shaft bend, neck width, keel height, and tip angle. We measured tip angle with a protractor from *camera lucida* drawings. We took other measurements directly with an ocular micrometer. Tip/shaft ratio was derived from the tip length and shaft length measurements. As an initial exploratory technique, we assessed the bacular data for adults and subadults with a principal components analysis using a correlation matrix. With this technique data are treated as a single statistical sample with no *a priori* assumptions of groups. Using an ocular micrometer, four measurements (modified from Adams and Sutton 1968; Sutton 1982) were taken from the baubella: tip to base length, shaft depth, flange length, and keel height. We compared our genital bone drawings and measurements with published data for *T. amoenus*, *T. ruficaudus* and *T. minimus* (White 1953; Beg and Hoffmann 1977; Sutton 1982, 1995) to identify voucher specimens to species.

After describing genital bone morphology of the three species from the cleared and stained preparations, we tested the reliability of genital bone morphology revealed in their radiographs to identify our vouchers using the sample of 124 vouchers with radiographs and associated genital bone preparations. In a blind experiment, both of us independently assigned the radiographs (marked only with catalogue numbers) taken of carcasses to species on the basis of size and shape of the bacular or baubellar image. Our identifications were then compared with their identifications made from their associated genital bone preparations. Because the our analyses demonstrated that radiographs were a reliable identification tool, we then assigned the 72 museum skins with genital bones to species using images of their genital bones in radiographs. Radiographs (all life size) of carcasses and study skins were taken with a Hewlitt Packard Faxitron© (model 43805N) desk top x-ray system. All radiographs were examined with both a light table and hand lens and a stereomicroscope.

Other Identification Traits

We tested the reliability of three sets of characters for identifying the reference samples to species: pelage colour, body measurements, and cranial morphology. To control ontogenetic variation, we classified chipmunks into three age categories using the maxillary molariform teeth (Beg and Hoffmann 1977): juvenile (molars not fully erupted, deciduous premolars), subadult (molars fully erupted, deciduous premolars), and adult (molars fully erupted, permanent premolars present). According to Beg and Hoffmann (1977), *T. ruficaudus* obtains its permanent upper premolars by 79 to 87 days. Therefore, our adult category includes both young-of-the-year (>79 days) and animals one year or older. Although *T. minimus*, *T. amoenus*, and *T. ruficaudus* demonstrate sexual size dimorphism (Sheppard 1965, Levenson

1990, Schulte-Hostedde and Miller 2000), sample sizes were too small to separate sexes in our analyses. All morphometric analyses were done with SYSTAT® 9 programs (SPSS Inc.).

A. Pelage colour

After skins were removed from animals we examined the flesh side of pelts to assess moult patterns. Dark pigmented regions were sketched onto outline drawings of the ventral and dorsal pelts. We also examined moult lines and evidence of winter pelage on the fur side of the prepared study skins. To assess colour, we examined pelage in two regions on prepared study skins: underside of the tail, and the abdomen. We scored colour using the colour charts from Smithe (1974, 1975, 1981). Although more sophisticated colour chart systems exist, we used Smithe's charts because his manuals are designed for describing colour in the field. Colour descriptions and comparisons were made under a Gregtad Macbeth Sol Source© desk lamp with a daylight filter.

B. Body size

Standard mammalian body measurements taken included: tail vertebrae length, total length, hind foot length, ear length (all in mm) and weight (grams). Body length was calculated from total length minus tail vertebrae length. For historical museum specimens, we used measurements recorded on their skin tags. We calculated standard univariate statistics and compared means with analyses of variance. Because the three species generally could not be separated by any single variable, we used discriminant analyses based on three measurements (total length, tail vertebrae length, hind foot length) to calculate linear functions that would best separate the species. We used a jacknife procedure (leave-one-out method) as a cross-validation technique to assess classification error in our discriminant functions (Lance et al. 2000). Multivariate techniques require full data sets with no missing variables; therefore, we excluded any specimens missing a total length, tail vertebrae length, or hind foot length value from these discriminant analyses. We did not include the variables ear length or weight in the discriminant analyses because they were missing for many historical specimens.

C. Cranial morphology

We used 10 cranial measurements (defined by Patterson 1983): greatest length of skull, zygomatic breadth, nasal length, maxillary toothrow length, interorbital breadth, nasal width, diagonal length of orbit, cranial depth, mandibular length, and coronoid height. Measurements were taken to the nearest 0.1 mm with dial calipers. We calculated standard univariate statistics and compared means with analyses of variance. Because *T. amoenus* and *T. ruficaudus* could not be separated by any single variable, we used discriminant analysis based on the 10 cranial measurements to calculate linear functions that would best separate the two species. To find the smallest set of cranial variables that would best classify the species, we employed a step-wise technique. A jacknife procedure (leave-one-out method) was used as a cross-validation technique to assess classification error in our discriminant functions (Lance et al. 2000). We excluded specimens missing more than one measurement from the discriminant analyses. For the few specimens missing values for a single variable, we estimated values for these variables with the maximum likelihood algorithm of SYSTAT 9.

RESULTS

I. Identification From Genital Bones

A. Bacula

The first principal component derived from the nine bacular measurements for the 42 specimens from the Columbia Mountains described increasing size (and size-related shape) among the linear measurements and decreasing tip angle; the second component was mostly correlated with increasing tip angle. In total, the two components accounted for 95.8% of the variation in the bacular data with the first component accounting for most (84.5%). A bivariate plot of component scores for the 42 specimens on the first two principal components revealed three discrete, non-overlapping groups: A, B, C (Fig. 2-2). Group C which separated on the first component had large robust bacula. We identified this group as *T. r. simulans* because their morphology and measurements are consistent with White's (1953) and Patterson and Heaney's (1987) data for this taxon. Groups A and B had smaller, thinner bacula than group C. They overlapped on the first axis, but separated clearly on the second axis. Group A differs from group B primarily by a less obtuse tip angle and a shorter shaft with a broader base. Based on the illustrations in White (1953) and Sutton (1995) we identified group A as *T. amoenus* and group B as *T. minimus*. Bacular measurements for the 42 bacula from the Columbia Mountains are summarized in Table 1. *T. ruficaudus* show no overlap with the ranges of *T. amoenus* and *T. minimus* for eight linear measurements and the tip/shaft ratio. Ranges of *T. amoenus* and *T. minimus* overlap for six linear measurements but they show no overlap for tip length, shaft bend, tip angle and tip/shaft ratio.

Similar to the sample from the Columbia Mountains, the first principal component derived from the nine bacular measurements for the 32 specimens from the Rocky Mountains described increasing size (and size-related shape) among the linear measurements and decreasing tip angle; the second component was mostly correlated with tip angle and explained increasing tip angle. In total, the two components accounted for 92.8% of the variation in the bacular data with the first component accounting for most (89.6%). Although groupings were less distinct than in the sample from the Columbia Mountains, a bivariate plot of component scores for the 32 specimens on the first two principal components revealed three non-overlapping groups: A, B, C (Fig. 2-3). Similar to the Columbia Mountains analysis, group C consisted of specimens with large robust bacula. They are consistent with measurements and illustrations given in White (1953), Beg and Hoffmann (1977), and Patterson and Heaney (1987) for *T. r. ruficaudus*. Groups A and B had smaller, thinner bacula than group C. They separated mostly on the on the first axis. Group A differs from group B primarily by longer broader tip and a thicker shaft. Based on the illustrations in White (1953) and Sutton (1995) we identified group A as *T. amoenus* and group B as *T. minimus*. Bacular measurements for the 32 bacula from the Rocky Mountains are summarized in Table 2-1. *T. ruficaudus* show no overlap with the ranges of *T. amoenus* and *T. minimus* for seven linear measurements. ratio. Ranges of *T. amoenus* and *T. minimus* overlap for seven linear measurements but they show no overlap for tip length, keel height, and tip/shaft ratio.

B. Baubella

Three distinct morphs were evident in the samples of baubella from the Columbia Mountains and Rocky Mountains (Fig. 2-4). Although the baubella tended to be more variable than the bacula especially at their proximal end, they demonstrated greater interspecific differences than the bacula. Although the base was the most variable region of the baubellum, curiously the most distinctive features for separating the morphs was the curvature, length, and shape of the base. Both samples contained a large robust morph with a long shaft, high keel, and a base that terminated at the proximal end as two blunt projections with a groove. We identified this morph as *T. ruficaudus* on the basis of Sutton (1982). A second morph had a small tip with a low keel and a distinct "U" shaped base that tapered near the proximal end. This form is consistent with the Sutton's (1982) figures and descriptions for *T. minimus*. A third form was characterised by moderately robust baubella with indistinct bases. In the Columbia Mountains sample, this morph had a short base and the proximal end was often notched (Fig. 2-4). A similar baubellar form
occurred in the some of the Rocky Mountains sample; others had a longer base (Fig. 2-4). None of these baubella had the curved tapered projection shown by Sutton (1982) for his single *T. a. luteiventris* specimen from Montana. Nevertheless, we conclude that baubella of this morph represented *T. a. luteiventris*. They were too small and lacked the two projections on the proximal end of the base to be *T. ruficaudus*; they lacked the tapered proximal end characteristic of *T. minimus*. Baubella measurements are summarized in Table 2. *T. ruficaudus* showed no overlap in the ranges of the four measurements with *T. minimus* or *T. amoenus*. *T. amoenus* baubella were larger than those of *T. minimus* and in both samples the two species showed no overlap in their ranges for two of four measurements.

C. Radiographs

Of the radiographs taken for the 124 voucher specimens with genital bone preparations, 93 had genital bone images of sufficient quality for identification. The other 31 radiographs either failed to reveal a genital bone or did not show the baculum or baubellum in a clear lateral view. Because these x-rays were taken of whole animals, the genital bones were obscured by limb bones or vertebrae in some specimens. Of the 93 radiographs used in the analysis, 86 (92.5%) were identified correctly by DN and 83 (89.2%) were identified correctly by NP using their radiographs. Most errors involved *T. amoenus* and *T. minimus*.

The radiographs of the study skins revealed clearer images of genital bones than the radiographs of whole animals because they were filled material such as cotton that readily transmitted x-rays. An exception were skins that had been treated with metallic preservatives that obscured the x-ray with a white shadowing. Of the 204 historical study skins examined, 72 (35.3%) showed genital bone images on their radiographs that could be confidently identified. There was no marked sex bias in the occurrence of genital bones: the 72 radiographs with genital bone images consisted of 40 bacula and 32 baubella. Presumably the genital bones were inadvertently retained in the skin during preparation. Of the 132 skins that showed no genital bones in their radiographs, a few had a white shadowing from a metallic preservative (see Williams and Hawks 1987) that would have obscured any small bones. Metal tail wires also

could have obscured the genital bones in a few specimens. However, for most specimens that did not reveal a genital bone image we suspect that these small bone structures were simply lost during skinning.

II. Identification From Other Traits

A. Pelage colour

Dorsal pelage colour was variable but interspecific differences were evident. In the Rocky Mountains sample, adult *T. ruficaudus* had a dark reddish wash in the dorsal pelage that extended along the shoulders and nape (Fig. 2-5). *T. minimus* tended to have a duller, more grey dorsal pelage. *T. amoenus* was intermediate with some buffy or reddish wash but less pronounced as in *T. ruficaudus*. We had too few immature skins to evaluate age variation but immature animals tended to be paler. A juvenile *T. ruficaudus* for example lacked the reddish wash of adults and resembled *T. amoenus* (Fig. 2-6). The study skins especially *T. minimus* demonstrated seasonal variation related to the moults. At Middle Kootenay Pass some adult *T. minimus* were still in pale worn winter pelage, others taken on the same day were moulting into their brighter summer pelage (Fig. 2-7). Species differences in dorsal pelage colour differences were less distinct in Columbia Mountains sample (Fig. 2-8). *T. ruficaudus* tended to be duller than the Rocky Mountains population (i.e., *T. r. ruficaudus*). Their skins lacked the bright rufous wash and tended to converge in dorsal pelage colour with *T. amoenus*. *T. minimus* were generally duller in colour. Sample sizes were sufficiently large for *T. amoenus* to assess age and seasonal variation (Fig. 2-9). Immature *T. amoenus* were paler; a few nursing females still in old winter pelage were paler and duller than adults in summer pelage.

We used 11 colour categories (Table 2-3) to describe ventral tail colour in the three species. In the Rocky Mountains samples, *T. ruficaudus* tended to be distinct with dark rufous ventral tails (Fig. 2-10). Nevertheless, 6 (23%) adults were assigned to Antique Brown or Mikado Brown, colours that occurred in several *T. amoenus* and *T. minimus*. Ventral tail colour was similar for both *T. amoenus* and *T. minimus* with most animals having a Cinnamon coloured ventral tail. Samples sizes of immature animals were too small to assess age variation in tail colour among the Rocky Mountains samples. However, an juvenile *T. ruficaudus* has a duller ventral tail and approached *T. amoenus* in colour (Fig.2-11). Chipmunks from the Columbia Mountains were more similar their ventral tail colours (Fig.2112, Table 2-3). *T. ruficaudus* generally had darker more rufous ventral tails as in the Rocky Mountains. But they lacked the rich, reddish colours that characterize the Rocky Mountains subspecies *T. r. ruficaudus*. Moreover, 9 (37.5%) adult *T. ruficaudus* were assigned to Cinnamon 123A, the most frequent ventral tail colour shown by *T. amoenus* and *T. minimus* from the Columbia Mountains. *T. minimus* tended to have slightly brighter ventral tails than *T. amoenus* but this was difficult to delimit with the coarse range of colours available in the colour chips with adults of the two species overlapping extensively in the colour designations. Subadults and juveniles tended to have paler fur on the underside of the tail. This was especially evident for the large sample of subadult *T. a. luteiventris*. Most had paler tails (Tawny Olive) than the adults.

The most consistent difference in ventral pelage was the greyish-white fur of *T. minimus* (see Figs. 2-10, 2-12). In contrast *T. amoenus* had a buffy wash or tinge to its ventral

pelage. *T. ruficaudus* was variable with some animals having dull greyish-white ventral pelage similar to that of *T. minimus*, but others showing a buffy tinge to the ventral pelage. Nonetheless, ventral fur colour was difficult to delimit with colour chips. We used only four of Smithe's colour chips to describe ventral pelage colour in the three species (Table 2-4); none of these colours closely matched the actual fur colour. We found that a subjective classification assigning animals to two categories (buffy abdomen versus whitish-grey abdomen) as effective for revealing colour differences as the colour chips. In the Rocky Mountains sample (Fig. 2-10) , *T. minimus* demonstrated the palest abdomens with most assigned to Pale Neutral Grey. Only one had a buffy belly; 13 of 14 (93%) adult *T. minimus* had whitish-grey abdomens. *T. amoenus* and *T. ruficaudus* demonstrated a greater range of ventral pelage colour (Table 2-4). Of the 45 adult *T. amoenus*, 41 (95.6%) had buffy abdomens. *T. ruficaudus* were more difficult to identify from ventral colour with 17 of 23 adults (74%) having buffy abdomens. Among the samples from the Columbia Mountains (Fig. 2-12), all adult *T. minimus* had whitish-grey abdomens and were scored as Pale Neutral Gray by the colour chips (Table 2-4). *T. ruficaudus* and *T. amoenus* from the Columbia Mountains tended to be duller and lacked the strong buffy abdomens shown by these species in the Rocky Mountains. Of 25 *T. amoenus*, 21 (84%) had buffy abdomens. Most *T. ruficaudus* had greyish-white abdomens similar to *T. minimus*, but 6 of 27 adults (22%) were classified as buffy.

B. Body size

In both groups, the species clearly differed in body size with *T. minimus* smallest, *T. amoenus* intermediate, and *T. ruficaudus* largest. In the Columbia Mountains sample (Table 2-5), adult *T. minimus* could be readily identified from total length which showed no overlap with either adult *T. amoenus* or adult *T. ruficaudus*. Even subadult *T. amoenus* showed no overlap with adult *T. minimus* in their total lengths. *T. ruficaudus* was generally larger than *T. amoenus* in body size. A one-way analysis of variance revealed that *T. ruficaudus* were larger in total length (F= 29.25, P<0.0001), tail vertebrae length (F= 15.67, P<0.0001), and hind foot length (F=17.67, P<0.0001), but not in ear length (F=0.01, P=0.913) or weight (F=0.003, P=0.954). However, ranges of their body measurements overlapped and no single measurement separated adults of the two species. A two-group discriminant analysis of adult *T. amoenus* and *T. ruficaudus* based on total length, tail vertebrae length, and hind foot length (Table 2-6) classified only 77% of the 48 specimens correctly.

In the sample from the Rocky Mountains, a one-way analysis of variance revealed that *T. amoenus*, *T. minimus*, and *T. ruficaudus* differed in all body measurements (P<0.0001). Nevertheless, adults of the three species overlapped in all their body measurements (Table 2-7) and the species could not be identified by any single measurement. A three-group discriminant analysis of adults based on total length, tail vertebrate length, and hind foot length (Table 2-8) classified 82% of the 74 specimens correctly.

For the Columbia Mountains sample we could only test age variation in body size variation among adult and subadult *T. amoenus* (Table 2-5). Adults were larger than subadults for total length (F=5.949, P<0.0001), tail vertebrae length (F=6.092, P=0.017), hind foot (F=5.005, P=0.030), and weight (F=18.618, P<0.001). Only ear length was similar in the two age categories. The few juvenile *T. amoenus*, and subadult, juvenile *T. minimus* also

suggest a smaller body size for immature animals. It is noteworthy that juvenile *T. amoenus* overlap substantially with adult *T. minimus* in body measurements. For the Rocky Mountains sample we could test age variation among juvenile and adult *T. amoenus* and *T. minimus* (Table 2-7). Adult *T. amoenus* were larger than juveniles for all body measurements ($P<0.0001$) Adult *T. minimus* were larger than juveniles for total length ($F=5.565$, $P=0.026$) and weight ($F=42.970$, $P<0.0001$) but not for tail vertebrae length, hind foot, or ear length.

C. Cranial morphology

Similar to body size, the species clearly differed in cranial size in both groups with *T. minimus* smallest, *T. amoenus* intermediate, and *T. ruficaudus* largest. In the sample of adults from the Columbia Mountains (Table 2-9), *T. minimus* could be readily identified on the basis of small cranial size. It showed no overlap with adult *T. amoenus* in three measurements: greatest length of skull, nasal width, and mandibular length. Even subadult *T. amoenus* showed no overlap with adult *T. minimus* in mandibular length. Five measurements (greatest length of skull, zygomatic breadth, nasal width, cranial depth, and mandibular length) showed no overlap among adult *T. minimus* and *T. ruficaudus*. A one-way analysis of variance revealed that *T. ruficaudus* were larger than *T. amoenus* in eight variables: greatest length of skull ($F= 4.53$, $P=0.039$), zygomatic breadth ($F= 9.27$, $P=0.004$), maxillary toothrow length ($F= 10.19$, $P=0.002$), interorbital breadth ($F=8.05$, $P=0.006$), nasal width ($F=13.98$, $P<0.0001$), cranial depth ($F=7.01$, $P=0.011$), mandible length ($F=13.04$, $P=0.001$), and coronoid height ($F=25.98$, $P<0.0001$). Nasal length and diagonal length of the orbit did not differ among the two species. Nevertheless, their cranial measurements overlapped and no single measurement separated the adult *T. amoenus* and *T. ruficaudus* (Table 2-9). The step-wise, two-group discriminant analysis of adults (Table 2-10) classified 85% of the 46 specimens correctly. The discriminant function contained only three variables (maxillary toothrow length, nasal width, and coronoid height) and described a pattern of increasing size.

For the Rocky Mountains sample, *T. minimus* could be readily identified on the basis of small cranial size. It showed no overlap with adult *T. amoenus* in greatest length of skull (Table 2-11); eight measurements (greatest length of skull, zygomatic breadth, nasal length, maxillary toothrow length, nasal width, diagonal length of orbit, cranial depth, and mandibular length) showed no overlap among adult *T. minimus* and *T.* ruficaudus. A one-way analysis of variance revealed that *T. ruficaudus* were larger than *T. amoenus* in eight variables: greatest length of skull ($F= 95.29$, $P<0.0001$), nasal length ($F= 62.21$, $P<0.0001$), maxillary toothrow length ($F= 49.83$, $P<0.0001$), interorbital breadth ($F=13.09$, $P=0.001$), diagonal length of the orbit ($F=53.91$, $P<0.0001$), cranial depth ($F=86.30$, $P<0.0001$), mandible length ($F=171.10$, $P<0.0001$), and coronoid height ($F=54.43$, $F<0.0001$). Zygomatic breadth and nasal width did not differ among the two species. All cranial measurements, however, overlapped among adult *T. amoenus* and *T. ruficaudus*; no single measurement separated the two species (Table 2-11). The step-wise, two-group discriminant analysis of adults (Table 2-12) classified 97% of the 59 specimens correctly. The discriminant function consisted of seven variables: greatest length of skull, zygomatic breadth, nasal length, interorbital breadth, diagonal length of the orbit, cranial depth, mandible length, and coronoid height. It described a pattern of variation that contrasted decreasing zygomatic breadth with increasing skull size and height.

Because of limited sample sizes of immatures, age variation in the Columbia Mountains sample could only be evaluated among adult and subadult *T. amoenus*. Adult *T. amoenus* were larger for 7 of 10 variables: greatest length of skull ($F=25.245$, $P<0.0001$), zygomatic breadth ($F=47.43$, $P<0.0001$), nasal length ($F=28.079$, $P<0.0001$), maxillary toothrow length ($F=4.607$, $P=0.0370$, diagonal length of orbit ($F=10.350$, $P=0.002$), mandibular length ($F=17.832$, $P<0.0001$), coronoid height ($F=15.997$, $P<0.0001$). Interorbital breadth, nasal width, and cranial depth did not differ among the two age categories. The few specimens of juvenile *T. amoenus* and subadult *T. minimus* suggest that immature skulls are smaller than adults and they may overlap with adults of another species (e.g., juvenile *T. amoenus* versus adult *T. minimus*). Limited sample sizes for immature animals (Table 2-11) prohibited a rigorous evaluation of age variation in *T. amoenus*, *T. minimus*, and *T. ruficaudus* from the Rocky Mountains. But the few immature skulls of *T. amoenus* and *T. minimus* suggest that immature animals have smaller skulls

DISCUSSION

Identification of Vouchers and Museum Specimens

Chipmunks from the southern Columbia and Rocky mountains of Alberta and British Columbia can be reliably identified as *T. amoenus*, *T. minimus*, or *T. ruficaudus* from their genital bone morphology. In both regions, the species can be separated by one or more genital bone measurements and we captured these traits in our identification keys (Appendix 2-3). However, differences in genital bone morphology among the three species are so pronounced that a researcher can learn to identify the three species by simple visual inspection of cleared and stained bacula and baubella with a dissecting microscope. Our results provide additional evidence for the utility of the chipmunk genital bones for species identification and demonstrate the importance of saving the genital bones from any chipmunks collected as voucher specimens.

Unfortunately few existing chipmunk museum specimens have genital bone preparations. Only 4% of the 214 historical specimens that we examined from our study area had associated genital bone preparations and all were bacula. Nevertheless, if the genital bone has been retained in the skin during preparation, the specimen can be identified from a magnified radiograph that reveals genital bone morphology. Our data suggest that about a third of the existing museum study skins may have genital bones inadvertently preserved in their skins. Although Patterson (1984) suggested that the baubellum was more likely to be preserved in study skins, we found no evidence for sexual bias. About 55% of the skins with genital bones were males. Radiographs are a simple, cost effective, and non-destructive tool for verifying identifications. Most identification problems in our study area involve *T. amoenus* and *T. ruficaudus*. The heavy robust male and female genital bones of *T. ruficaudus* are readily discriminated in an x-ray. Our results support Panian (1996) who identified live chipmunks from the southern Selkirk Mountains of British Columbia by radiographs revealing genital bones. Before using radiographs as an identification tool, however, investigators must familiarize themselves with the genital bone morphology of these chipmunk species by studying cleared and stained bacular and baubellar preparations.

For museum specimens that lack genital bone preparations or genital bones in their study skins (about 65% of the skins we examined), one has to rely on skull morphology

(Appendix 2-3). In the southern Columbia Mountains and Rocky Mountains where *T. minimus* is smaller than *T. amoenus* and *T. ruficaudus*, adult *T. minimus* can be readily discriminated from single measurements that reflect skull length. In a study of *T. amoenus* and *T. minimus* from the east slopes of the Rocky Mountains in Alberta, Sheppard (1965) also found no overlap in greatest length of the skull, although the two species did overlap in five other skull measurements. In their key, Hoffmann and Pattie (1968) distinguished *T. minimus* from *T. amoenus* and *T. ruficaudus* in Montana on the basis of skull length (occipitonasal length <31. 7 mm), but no statistics were given.

In contrast, although adult *T. ruficaudus* are larger than adult *T. amoenus*, cranial measurements of the two species overlap and their skulls can only be differentiated by multivariate discriminant analysis. Published mammal guides and identification keys for the Rocky Mountains (Hoffmann and Pattie 1968, Smith 1993) have not used cranial morphology as a diagnostic trait to distinguish *T. amoenus* and *T. ruficaudus* but relied on pelage colour or bacular morphology. Our results demonstrate that in the Rocky Mountains of Canada adults of these two species separate out clearly on skull morphology. Our discriminant function was a reliable tool for identifying skulls with only one specimen of each species identified incorrectly. In contrast, in the southern Columbia Mountains where *T. ruficaudus* appears to converge with *T. amoenus* in size and cranial morphology, their skulls are less distinguishable. The discriminant function that we calculated for identifying *T. amoenus* and *T. ruficaudus* will classify about 85% of the specimens correctly. In the adjacent Selkirk Mountains of Washington, Dalquest (1948) also found some specimens of *T. amoenus* and *T. ruficaudus* that he could not positively identify from cranial morphology. These differences among adjacent samples from the Columbia and Rocky Mountains suggest that there are marked regional differences in the reliability of cranial morphology to identify these chipmunk species. Investigators should develop discriminant classification functions derived from skulls taken from their local study area.

The major limitation to using skull morphology for identifying museum specimens is that it can only be applied to adults and specimens with measurable skulls. Our inability to identify subadult or juvenile skulls is not a problem for taxonomic studies because they are usually based on mature animals. But, it may preclude using immature museum specimens for distributional records unless their identifications can be confirmed from genital bone morphology.

Field Identification

Genital bone preparations require sacrificing animals. Taking radiographs of anaesthetised live chipmunks either in the field or transporting them to a veterinary lab as proposed by Panian (1996), is not practical as a field technique especially for wildlife biologists conducting surveys in inaccessible alpine areas. The only traits that we studied with potential as field traits for identifying live animals are pelage colour and body measurements.

A. Pelage Colour

Pelage features such as colour of the belly fur, colour of underside of the tail, darkness of the lateral stripes, and the length of the median dorsal stripe are the morphological traits most often used by researchers to distinguish *T. minimus*, *T. amoenus*, and *T. ruficaudus*

(Sheppard 1965; Meredith 1975; Hoffmann and Pattie 1968; Smith 1993). We observed some pelage differences among the three species in both study areas. Nonetheless, it is difficult to describe these colour differences in an identification key using a few simple absolute traits or colour codes from standard (Smithe 1971, 1974, 1981) colour chips. Colour differences can only be perceived after examining series of study skins of known identification. Ventral tail colour and abdominal fur colour are complex colours that are not easily described with simple codes from colour chips. Moreover, colour of the undersides of the tail and dorsal pelage are highly variable influenced by age and the stage of the spring moult. The 1996 specimens were collected mid September to early October (Appendix 2-1) and they had largely attained their full summer pelage. In contrast, specimens taken 1997-99 were collected in July and August. They were still undergoing the spring moult and many specimens showed a mix of old winter and fresh summer pelage. A few nursing females taken in July and early August were still largely in old, worn winter pelage. They differed strikingly in colour from adults in partial or full summer pelage taken in the same areas. A number of researchers (Merriam 1897; Howell 1929; Johnson 1943) have observed that colour differences in the summer and winter pelages of a chipmunk species may be more striking than comparable pelages in different chipmunk species.

Our results generally support Soper (1964), Cowan and Guiguet (1965), Hoffmann and Pattie (1968), and Smith (1993) who concluded that in the Rocky Mountains of Canada and Montana, adult *T. amoenus*, *T. ruficaudus*, and *T. minimus* can be identified from belly and ventral tail colour. The most distinct feature of adult *T. ruficaudus* is the rufous on the underside of the tail, shoulders, and back. Although Hoffmann and Pattie (1968), Cowan and Guiguet (1965), and Smith (1963) described the belly fur as white, abdominal fur colour varies with some individuals having some buffy wash. The most consistent colour trait of *T. amoenus* is its buffy abdomen which contrasts with the whitish-grey belly of *T. minimus*. Soper (1964) noted the distinct pale grey pelage of the Rocky Mountain race of *T. minimus* (*T. m. oreocetes*), and several naturalists have described it as 'ghostly'. Nevertheless, some of this pale colour can be attributed to old faded, winter pelage. Because it is restricted to alpine areas in the Canadian Rocky Mountains (see Chapter 4), the spring moult is delayed in this species with some animals not acquiring their bright summer pelage until early autumn. Meredith (1975) used the length of the median stripe on the head area to separate *T. m. borealis* and *T. a. ludibundus* in Jasper National Park, but we found no differences in this trait for *T. m. oreocetes* and *T. a. luteiventris*.

T. minimus in the Columbia Mountains is distinguished by its greyish-white abdomen, but *T. amoenus* and *T. ruficaudus* in this region evidently converge in ventral tail and belly pelage confounding any identifications using on fur colour. Dalquest (1948) noted similar identification problems for *T. amoenus* and *T. ruficaudus* in the adjacent Selkirk Mountains of eastern Washington. It is noteworthy that most of the identification problems associated with historical museum specimens from our study area involved specimens of *T. amoenus* and *T. ruficaudus* from the Columbia Mountains. Panian's (1996) conclusion that *T. amoenus* and *T. ruficaudus* in the Selkirk Mountains of British Columbia can be identified from pelage is flawed and his identification of 30 live captures as *T. r. simulans* from pelage is dubious. Panian (1996) did not provide locality data or catalogue numbers for the museum skins he examined, but localities recorded on specimen tags shown in his figures indicate that his reference samples

of *T. amoenus* skins consisted of Washington populations of *T. a. canicaudus* and *T. a. affinis,* pale subspecies that are allopatric with *T. r. simulans*. The appropriate subspecies for comparison is *T. a. luteiventris*, a subspecies that is co-occurs with *T. r. simulans* in British Columbia, Washington, northern Idaho, and northwestern Montana. It is notably darker than *T. a. affinis* or *T. a. canicaudus*.

B. Body Size

Although adults of three species differ in body size, they generally overlap in their standard body measurements. One exception is the southern Columbia Mountains where adult *Tamias minimus* differ from adult *T. amoenus* and *T. ruficaudus* in total length. This measurement will also separate subadult *T. amoenus* from adult *T. minimus*. However, for *T. ruficaudus* and *T. amoenus* in the Columbia Mountains and all three species in the southern Rocky Mountains identification cannot be made from any single body measurement and even discriminant functions calculated from total length, tail vertebrate length, and hind foot length are not particularly effective for identification. In the Columbia Mountains where *T. ruficaudus* and *T. amoenus* converge in body size, only 77% of the specimens were identified correctly from our discriminant function. Although Davis (1939) used a hind foot length of 33 mm to separate *T. r. simulans* from *T. a. luteiventris* in Idaho, the two taxa overlap extensively in hind foot length in the Columbia Mountains of British Columbia. Overlap in body size among the three species was also evident in the Rocky Mountain with only about 80% of the adult individuals of each species were identified correctly by our three group discriminant analysis. Sheppard (1965) reported overlap in total length and tail vertebrae lengths among *T. minimus* and *T. amoenus* from the Rocky Mountains in Alberta. Hoffmann and Pattie (1968) separated *T. minimus* from *T. amoenus* in Montana a body length <110 mm but in the southern Rocky Mountains of Canada these species overlap substantially in this measurement.

Several factors may have reduced the effectiveness of body measurements for identification in our study. We could not separate the sexes because our sample sizes were too small. *T. amoenus*, *T. minimus*, and *T. ruficaudus* demonstrate sexual size dimorphism with females generally larger than males in body size (Sheppard 1965, Levenson 1990, Schulte-Hostedde and Miller 2000). Partitioning the sexes with larger samples, may improve the classification results with discriminant functions. Because our samples included both recent vouchers collected and measured by us and historical museum specimens measured by various preparators, measuring differences could have increased the variability of body measurements. A sample measured by a single investigator may improve the resolution of body measurements for identification.

C. Recommendations

Our identification keys for identifying adult live chipmunks from the southern Columbia Mountains and Rocky Mountains (Appendix 2-3) of Canada are based on both pelage and body measurements. These traits can only be used on anaesthetised or restrained chipmunks held in the hand. Beg (1969) reputedly discriminated *T. ruficaudus* and *T. amoenus* in the Rocky Mountains of Montana, and Meredith (1975) claimed to identify *T. amoenus* and *T. minimus* from the Rocky Mountains of Alberta using pelage traits viewed on animals in the

field with binoculars. Given the variation demonstrated in our study, we suggest that pelage colour should only be used on animals in the hand. Moreover, we assessed pelage colour under ideal conditions using study skins held under a standard light source. A live animal (even hand held) viewed in the field would be expected to demonstrate colour differences under different lighting conditions associated with time of day, weather conditions, or shading from vegetation cover. Before any field study, biologists should examine museum specimens to familiarize themselves with the various pelages associated with seasonal and age variation. For problematic animals, voucher specimens will be essential to confirm identifications. In the Columbia Mountains where *T. amoenus* and *T. ruficaudus* cannot be reliably identified from external traits, positive identification of these two species can only be made with voucher specimens with genital bones.

Future Research

A major limitation of our keys is that they apply only to adult animals. Small sample sizes prohibited a rigorous assessment of pelage colour, body size, and cranial morphology for the immature age categories (subadult and juvenile) of *T. amoenus*, *T. minimus*, and *T. ruficaudus*. Nevertheless, because our limited samples demonstrate that both juvenile and subadult animals may differ in body size and pelage colour from adults, separate identification keys would have to be developed for immature chipmunks. This requires additional samples of immature chipmunks from our study area.

Even if separate keys are developed to identify immature chipmunks, they may be impossible to apply on live chipmunks because of problems with distinguishing juvenile, subadult, and adult chipmunks in the field. Although chipmunks captured in early spring (before emergence of the young) or autumn could be assumed to be adults, captures during the breeding season would contain a mix of age categories. The breeding season of *T. amoenus*, *T. minimus*, and *T. ruficaudus* has not been determined in our study area but studies from adjacent areas suggest that juveniles first appear above ground in June or July (Sheppard 1969; Beg 1971). If adult dentition is obtained about 79 to 87 days as reported by Beg and Hoffmann (1977), then juvenile or subadult chipmunks would occur in populations from June to early September. Collecting dates for our immature (juvenile, subadult) voucher and historical museum specimens are consistent with this pattern. We defined our three age categories from stages of tooth eruption and premolar replacement determined from occlusal views of the maxillary molariform teeth observed in cleaned skulls with a dissecting microscope. Distinguishing deciduous from permanent premolars, or determining the degree of eruption in the third molar is probably impossible to observe on a live chipmunk even with a hand lens because clear occlusal views of the upper toothrows are obscured by the tongue. Juvenile animals may be distinguishable in the field from their dull sparse pelage but distinguishing subadults from adults by pelage seems unlikely. Developing a reliable, non-destructive aging technique that can be applied on live animals is essential for field identification. Panian (1996) determined tooth eruption from radiographs taken on live chipmunks transported to a vet lab but this technique is not a practical field technique. Potential techniques that should be explored include dental impressions or the use of dental mirrors to view upper toothrows *in situ*.

Identification would be simplified if geographic and elevational distribution could be incorporated into the keys. For example, if *T. ruficaudus* is absent from the Purcell Mountains in British Columbia (Chapter 4), then field identification is simplified in this region as *T. amoenus* and *T. minimus* are separable by body length and belly fur colour. Moreover, as *T. minimus* appears to occur only above 2000 metres elevation in the Purcell Mountains (Chapter 4), any chipmunk taken from low or mid elevation forest could be assumed to be *T. amoenus*. However, our inventory data for chipmunks in southeastern British Columbia are inadequate (Chapters 4, 5). The reliability of maps showing the distributional limits and elevational ranges of *T. amoenus*, *T. minimus*, and *T. ruficaudus* in southeastern British Columbia is seriously limited by sampling gaps and bias. Until more inventory work is done, we recommend that it would be prudent for biologists to avoid any identifications based solely on assumptions of elevation or geographic range. As an example of the pitfalls, until 1999 we had no evidence that *T. amoenus* inhabited the southern Selkirk Mountains within the range of *T. r. simulans* (area delimited by the Kootenay and Columbia rivers) and we assumed that *T. ruficaudus* was the only chipmunk in that region. Four live animals x-rayed by Panian (1996), the vouchers collected in 1996 (Appendix 2-1; Fraker and Nagorsen 1998), and 20 historical museum specimens that were identified from radiographs or genital bone preparations from the southern Selkirk Mountains (Appendix 2-2) were all *T. ruficaudus*. However, in 1999 we collected a single *T. amoenus* from the Topaz Creek Forestry Road at 900 metres elevation. This location occurs within the elevational range of *T. r. simulans* and suggests that two species may co-occur in parts of the southern Selkirk Mountains. This record also raises doubts about Panian's (1996) putative 30 *T. r. simulans* captures from the southern Selkirk Mountains that were identified on assumptions of allopatry rather than genital bone morphology.

Our study was restricted to morphological traits. Other identification traits that should be explored in future research are genetic markers such as DNA. Presumably hair or skin samples collected in the field from live animals and preserved in ethanol could be used as a non-destructive identification tool. Tissue samples from our vouchers of *T. amoenus* and *T. ruficaudus* were sent to the University of Idaho for phylogeographic studies of these species based on mitochondrial DNA. According to John Demboski and Jeff Good (unpublished data) these two taxa demonstrate differences in their mtDNA profiles. Nevertheless, a few individuals were carrying the incorrect mtDNA. For example, the chipmunk specimens from Sage Creek and Kishinena Creek in the Flathead River Valley were clearly *T. amoenus* from their genital bone and skull morphology yet were carrying *T. r. ruficaudus* haplotypes (Jeff Good, unpublished data). Clearly more genetic research is needed before these species can be identified from molecular markers. Recordings of chip call vocalizations (Gannon and Lawlor 1989) is another potential field technique that should be explored.

CONCLUSIONS

1. In the southern Rocky Mountains and Columbia Mountains, museum or voucher specimens with genital bone preparations can be identified unequivocally as *T. amoenus*, *T. minimus*, or *T. ruficaudus* from measurements taken from stained bacula or baubella or radiograph images of genital bones. Although few museum specimens have associated genital bone preparation, as

many as a third of the existing museum skins have genital bones inadvertently preserved in their skins. They can be identified from x-rays that reveal genital bone images. For adult museum specimens that lack genital bones, identifications can generally be made from cranial morphology. An exception is in the Columbia Mountains where adult *T. amoenus* and *T. ruficaudus* converge in cranial morphology making identification difficult.

2. Anaesthetised or restrained adult chipmunks held in the hand generally can be identified from body measurements and pelage colour (dorsal, underside of the tail, belly fur). However, in the Columbia Mountains where adult *T. amoenus* and *T. ruficaudus* converge in body size and pelage these species cannot be reliably identified in the field and positive identification requires voucher specimens with genital bones.

3. Because of sampling inadequacies bias, the geographic range and elevational range of chipmunks in southeastern British Columbia is poorly known. Therefore, until more inventory work is done, we recommend that identifications not be based on assumptions of elevation or geographic range.

4. Our identification keys can be applied only to adult animals. More research is needed to develop identification keys for immature chipmunks, and to develop a reliable aging technique for use on live animals. Other identification techniques such as recording vocalizations or applying molecular markers such as mitochondrial or microsatellite DNA should be explored.

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Table 2-1. Bacular measurements (means ±1 standard deviation, ranges) for three chipmunk species from the southern Columbia Mountains and Rocky Mountains of British Columbia and Alberta. Linear measurements in millimetres, tip angle in degrees. Based on specimens taken in 1996-99 and historical museum specimens.

Measurement	*T. amoenus*		*T. minimus*		*T. ruficaudus*	
	Mean	Range	Mean	Range	Mean	Range
Columbia Mts	N=22		N=9		N=11	
Total length	2.84±0.16	2.44-3.04	3.10±0.08	2.93-3.22	4.14±0.21	3.82-4.48
Shaft length	2.51±0.12	2.19-2.70	2.70±0.07	2.59-2.78	3.58±0.07	3.43-3.70
Tip length	0.91±0.06	0.74-0.96	0.63±0.06	0.56-0.70	1.65±0.06	1.52-1.75
Base width	0.54±0.04	0.48-0.59	0.44±0.04	0.37-0.52	0.86±0.06	0.75-0.93
Tip width	0.37±0.03	0.26-0.41	0.34±0.04	0.30-0.41	0.56±0.05	0.54-0.67
Shaft bend	0.35±0.03	0.30-0.41	0.23±0.03	0.19-0.26	0.62±0.04	0.56-0.70
Neck width	0.17±0.02	0.11-0.19	0.13±0.02	0.11-0.15	0.34±0.04	0.29-0.41
Keel height	0.32±0.04	0.22-0.37	0.23±0.02	0.22-0.26	0.60±0.03	0.56-0.67
Tip angle	121.2±3.0	114.0-126.0	136.6±1.01	135.0-138.0	120.1±2.94	116.0-125.0
Tip/shaft ratio	0.36±0.02	0.30-0.39	0.24±0.02	0.20-0.26	0.46 ±0.02	0.43-0.49
Rocky Mts	N=17		N=7		N=8	
Total length	3.17±0.20	2.71-3.52	3.00±0.15	2.78-3.19	5.10±0.09	4.74-5.52
Shaft length	2.68±0.13	2.37-2.93	2.70±0.07	2.56-2.85	4.41±0.08	4.07-4.74
Tip length	0.93±0.06	0.82-1.04	0.68±0.02	0.67-0.70	1.56±0.04	1.37-1.74
Base width	0.47±0.06	0.37-0.59	0.43±0.07	0.33-0.52	0.77±0.03	0.63-0.93
Tip width	0.41±0.03	0.37-0.44	0.31±0.04	0.26-0.37	0.59±0.02	0.52-0.67
Shaft bend	0.32±0.04	0.26-0.41	0.21±0.03	0.19-0.26	0.55±0.01	0.52-0.59
Neck width	0.17±0.03	0.11-0.22	0.13±0.03	0.11-0.18	0.27±0.01	0.22-0.30
Keel height	0.32±0.03	0.26-0.37	0.23±0.04	0.19-0.30	0.51±0.01	0.48-0.52
Tip angle	134.6±3.6	124.0-140.0	139.4±1.7	129.0-141.0	121.4±2.0	118.0-124.0
Tip/shaft ratio	0.35±0.02	0.32-0.40	0.25±0.01	0.24-0.28	0.35±0.03	0.33-0.42

Table 2-2. Baubellar measurements (means ±1 standard deviation, ranges) for three chipmunk species from the southern Columbia Mountains and Rocky Mountains of British Columbia and Alberta. All measurements in millimetres. Based on specimens taken in 1996-99.

Measurement	*T. amoenus*		*T. minimus*		*T. ruficaudus*	
	Mean	Range	Mean	Range	Mean	Range
Columbia Mts	N=14		N=5		N=3	
Total length	1.20±0.14	0.96-1.42	0.92±0.02	0.91-0.96	2.90±0.28	2.73-3.22
Base width	0.35±0.04	0.27-0.40	0.28±0.03	0.24-0.31	0.64±0.02	0.62-0.67
Flange length	0.57±0.03	0.51-0.62	0.46±0.20	0.44-0.49	0.98±0.12	0.84-1.09
Keel height	0.24±0.03	0.20-0.27	0.14±0.02	0.11-0.16	0.48±0.01	0.47-0.49
Rocky Mts	N=9		N=4		N=8	
Total length	1.39±0.24	1.11-1.76	1.02±0.07	0.91-1.07	2.25±0.19	2.00-2.56
Base width	0.35±0.04	0.29-0.42	0.30±0.02	0.27-0.31	0.52±0.03	0.47-0.56
Flange length	0.60±0.06	0.51-0.67	0.46±0.02	0.44-0.49	0.92±0.07	0.82-1.02
Keel height	0.25±0.03	0.22-0.31	0.18±0.06	0.13-0.27	0.45±0.04	0.40-0.53

Table 2-3. Ventral tail colour of three chipmunk species from the southern Columbia Mountains and Rocky Mountains of British Columbia and Alberta. Based on voucher specimens and historical museum specimens identified by genital bone morphology. Colour names and codes from Smithe (1974, 1975, 1981).

Colour	*T. amoenus*			*T. minimus*			*T. ruficaudus*		
	Ad	**Sub**	**Juv**	**Ad**	**Sub**	**Juv**	**Ad**	**Sub**	**Juv**
Columbia Mountains									
Antique Brown (37)	2	0	0	2	0	0	13	-	-
Mikado Brown (121C)	0	0	0	0	0	0	2	-	-
Cinnamon (123A)	14	2	0	10	1	0	9	-	-
Cinnamon (39)	2	0	0	0	1	1	0	-	-
Clay Color (26)	7	5	0	1	1	0	0	-	-
Clay Color (123B)	0	0	0	0	0	0	0	-	-
Tawny Olive (223D)	0	14	4	0	0	0	0	-	-
Buff (124)	0	0	0	0	0	1	0	-	-
Sample Size	25	21	4	13	3	2	24	0	0
Rocky Mountains									
Raw Sienna (136)	0	0	0	0	0	0	9	-	0
Amber (36)	0	0	0	0	0	0	7	-	0
Robin Rufous (340)	0	0	0	0	0	0	1	-	0
Antique Brown (37)	2	1	0	1	0	0	5	-	1
Mikado Brown (121C)	0	0	0	1	0	0	1	-	0
Cinnamon (123A)	34	1	9	11	1	2	0	-	0
Cinnamon (39)	0	0	0	0	0	0	0	-	0
Clay Color (26)	7	2	2	1	1	4	0	-	0
Tawny Olive (223D)	0	0	0	0	0	1	0	-	0
Sample Size	43	4	11	14	2	7	23	0	1

Table 2-4: Abdominal colour in three chipmunk species from the southern Columbia Mountains and Rocky Mountains of British Columbia and Alberta. Based on voucher specimens and historical museum specimens identified by genital bone morphology. Colour names and codes from Smithe (1974, 1975, 1981).

Colour	*T. amoenus*			*T. minimus*			*T. ruficaudus*		
	Ad	**Sub**	**Juv**	**Ad**	**Sub**	**Juv**	**Ad**	**Sub**	**Juv**
Columbia Mountains									
Pale Neutral Gray (86)	3	4	1	13	3	2	14	-	-
Drab Gray (119D)	15	17	2	0	0	0	12	-	-
Pale Pinkish Buff (121D)	5	0	0	0	0	0	1	-	-
Tawny Olive (223D)	2	0	0	0	0	0	0	-	-
Sample Size	25	21	3	13	3	2	27	0	0
Rocky Mountains									
Pale Neutral Gray (86)	1	0	0	13	2	8	8	-	0
Drab Gray (119D)	25	4	8	1	0	0	11	-	1
Pale Pinkish Buff (121D)	12	0	2	0	0	0	4	-	0
Tawny Olive (223D)	7	0	0	0	0	0	0	-	0
Sample Size	45	4	10	14	2	8	23	0	1

Table 2-5. Body measurements (means ±1 standard deviation, ranges) for three species of chipmunks from the southern Columbia Mountains of British Columbia. Weights in grams, linear measurements in millimetres. Based on voucher specimens taken in 1996-99 and historical museum specimens identified by genital bone morphology.

Measurement	**Adults**			**Subadults**			**Juveniles**		
T. amoenus luteiventris	Mean	Range	N	Mean	Range	N	Mean	Range	N
Total length	213.7±8.7	198-230	26	204.2±6.1	194-216	21	184.5±8.7	173-193	4
Body length	119.4±4.4	111-132	26	113.5±4.1	105-122	21	101.0±7.3	91-108	4
Tail length	94.3±7.4	79-110	26	90.7±4.7	80-98	21	83.5±1.7	82-85	4
Hind foot	31.6±1.2	29-34	26	31.0±0.8	29-32	21	29.5±0.8	28-30	4
Ear	15.7±1.8	11-18	18	16.6±0.6	15-17	20	16.0±1.6	15-17	4
Weight	55.3±7.0	45.3-73.3	16	46.4±4.6	37.0-55.0	20	35.7±1.6	34.3-37.9	4
T. minimus selkirki	Mean	Range	N	Mean	Range	N	Mean	Range	N
Total length	185.5±6.0	172-193	14	185.0±7.0	177-190	3	177		1
Body length	105.6±1.2	100-112	14	103.0±7.8	98-112	3	99		1
Tail length	79.9±4.4	69-86	14	82.0±7.9	76-91	3	77		1
Hind foot	30.4±1.2	27-32	14	30.0±1.2	29-31	3	28		1
Ear	14.0±1.2	12-16	12	14		1	13		1
Weight	41.4±4.10	38.1-52.8	12	36.2		1	26.7		1
T. ruficaudus simulans	Mean	Range	N	Mean	Range	N	Mean	Range	N
Total length	225.8±6.3	216-237	22						
Body length	123.9±6.0	116-135	23						
Tail length	102.1±5.9	93-115	22						
Hind foot	33.0±1.3	30-35	28						
Ear	15.8±1.7	13-19	23						
Weight	54.7±4.8	44.2-64.6	22						

Table 2-6. Jack-knifed classification matrix for two chipmunk species from the southern Columbia Mountains of British Columbia. Based on a two-group discriminant analysis of adults using total length, tail vertebrae length, and hind foot length.

	T. amoenus	***T. ruficaudus***	**% Correct**
T. amoenus (N=26)	21	5	81
T. ruficaudus (N=22)	6	16	73

Table 2-7. Body measurements (means ±1 standard deviation, ranges) for three species of chipmunks from the southern Rocky Mountains of British Columbia and Alberta. Weights in grams, linear measurements in millimetres. Based on voucher specimens taken in 1996-99 and historical museum specimens identified by genital bone morphology.

Measurement	**Adults**			**Subadults**			**Juveniles**		
T. amoenus luteiventris	Mean	Range	N	Mean	Range	N	Mean	Range	N
Total length	210.5±5.4	200-223	42	191.0±9.2	191-207	3	184.4±6.7	173-198	15
Body length	117.9±4.6	109-128	42	108.7±9.1	102-119	3	99.6±5.3	87-111	15
Tail length	92.7±5.3	82-103	42	87.6±1.5	86-89	3	84.8±5.7	79-101	15
Hind foot	31.5±1.4	28-34	47	31.7±1.2	31-33	3	30.3±0.9	29-33	15
Ear	15.5±1.9	12-19	39	14.3±2.1	12-16	3	14.9±0.6	14-16	15
Weight	56.1±7.6	42.0-77.0	43	45.2±6.5	38.4-51.4	3	33.1±3.5	29.3-40.0	15
T. minimus oreocetes	Mean	Range	N	Mean	Range	N	Mean	Range	N
Total length	194.2±11.0	182-204	9	190.7±14.5	174-200	3	165.1±10.7	152-183	11
Body length	110.0±6.5	100-120	9	104.7±5.0	100-110	3	94.3±6.5	85-103	11
Tail length	80.2±3.7	75-87	9	86.0±10.6	74-94	3	70.7±5.6	61-83	11
Hind foot	30.1±1.2	28-32	11	31.3±1.2	30-32	3	28.5±1.1	26-30	11
Ear	13.7±1.4	11-16	11	16.3±2.5	14-19	3	12.1±1.1	11-14	11
Weight	45.3±3.4	38.9-50.3	12	37.5±4.2	33.8-42.0	3	25.9±5.1	19.2-35.0	11
T. ruficaudus ruficaudus	Mean	Range	N	Mean	Range	N	Mean	Range	N
Total length	221.5±8.3	207-234	22				208		1
Body length	125.9±7.5	114-139	21				113		1
Tail length	95.3±4.0	89-102	21				95		1
Hind foot	33.7±1.1	32-36	22				31		1
Ear	17.1±1.5	14-19	16				16		1
Weight	66.6±5.6	53.5-78.7	15				46.0		1

Table 2-8. Jack-knifed classification matrix for three chipmunk species from the southern Rocky Mountains of Alberta and British Columbia. Based on a three-group discriminant analysis of adults using total length, tail vertebrae length, and hind foot length.

	T. amoenus	***T. minimus***	***T. ruficaudus***	**% Correct**
T. amoenus (N=42)	35	2	5	83
T. minimus (N=9)	2	7	0	78
T. ruficaudus (N=21)	4	0	17	81

Table 2-9. Cranial measurements (means ±1 standard deviation, ranges) for three chipmunk species from the southern Columbia Mountains of British Columbia. All measurements in millimetres. Based on voucher specimens taken 1996-99 and historical museum specimens identified by genital bone morphology.

Measurement	Adults			Subadults			Juveniles		
T. amoenus luteiventris	Mean	Range	N	Mean	Range	N	Mean	Range	N
Greatest length	33.8±0.47	32.7-34.5	23	32.9±0.50	32.0-33.9	18	31.4±0.17	31.2-31.5	3
Zygomatic breadth	18.8±0.51	18.0-19.3	25	18.1±0.41	17.1-18.7	17	17.3±0.29	17.0-17.5	3
Nasal length	10.5±0.33	9.8-11.2	25	10.0±0.33	9.3-10.6	20	9.1±0.44	8.8-9.6	3
Maxillary toothrow length	5.3±0.14	4.9-5.5	26	5.3±0.14	4.9-5.4	20	5.0±0.10	4.9-5.1	3
Interorbital width	6.9±0.33	6.4-7.6	26	6.8±0.22	6.4-7.3	17	6.8±0.35	6.4-7.1	3
Nasal width	2.7±0.17	2.4-3.0	26	2.8±0.17	2.3-3.0	20	2.5±0.15	2.4-2.7	3
Diagonal length of orbit	8.0±0.29	7.5-8.5	25	7.8±0.30	7.3-8.4	18	7.2±0.27	7.0-7.5	3
Cranial depth	13.3±0.22	13.3-14.1	24	13.8±0.21	13.5-14.3	18	13.7±0.64	13.2-14.4	3
Mandibular length	18.3±0.38	17.5-18.9	21	17.8±0.27	17.3-18.3	19	17.1±0.17	16.9-17.2	3
Coronoid height	10.1±0.42	9.2-10.7	21	9.6±0.24	8.8-10.5	17	8.8±0.71	8.0-9.4	3
T. minimus selkirki	Mean	Range	N	Mean	Range	N	Mean	Range	N
Greatest length	31.3±0.36	30.4-32.0	13	30.5±0.59	30.1-31.2	3	29.7		1
Zygomatic breadth	17.8±0.35	17.0-18.3	13	17.1±0.30	16.0-17.4	3	17.0		1
Nasal length	9.0±0.36	8.3-9.6	14	8.5±0.40	8.1-8.9	3	8.1		1
Maxillary toothrow length	4.9±0.15	4.7-5.3	14	4.8±0.20	4.6-5.0	3	3.3		1
Interorbital width	6.9±0.25	6.3-7.2	13	6.5±0.15	6.4-6.7	3	6.6		1
Nasal width	2.1±0.18	1.7-2.3	14	1.9±0.12	1.8-2.0	3	2.0		1
Diagonal length of orbit	7.2±0.29	6.7-7.6	14	7.0±0.36	6.7-7.4	3	6.9		1
Cranial depth	12.9±0.30	12.5-13.3	11	13.0±0.17	12.8-13.1	3	13.1		1
Mandibular length	16.7±0.24	16.3-17.0	13	16.1±0.17	15.9-16.2	3	15.5		1
Coronoid height	9.1±0.25	8.5-9.9	13	8.7±0.35	8.4-9.1	3	-		1
T. ruficaudus simulans	Mean	Range	N	Mean	Range	N	Mean	Range	N
Greatest length	34.1±0.71	32.3-35.5	26						
Zygomatic breadth	19.0±0.35	18.4-19.6	26						
Nasal length	10.7±0.54	9.2-11.5	27						
Maxillary toothrow length	5.4±0.23	4.8-5.8	28						
Interorbital width	7.2±0.23	6.6-7.6	28						
Nasal width	3.0±0.23	2.5-3.4	28						
Diagonal length of orbit	8.1±0.27	7.5-8.6	27						
Cranial depth	13.9±0.26	13.4-14.4	26						
Mandibular length	18.7±0.38	18.0-19.6	28						
Coronoid height	10.7±0.42	9.9-11.3	28						

Table 2-10 . Jack-knifed classification matrix for two chipmunk species from the southern Columbia Mountains of British Columbia. Based on a two-group step-wise discriminant analysis of adults using 10 cranial measurements.

	T. amoenus	***T. ruficaudus***	**% Correct**
T. amoenus (N=20)	18	2	90
T. ruficaudus (N=26)	5	21	81

Table 2-11. Cranial measurements (means ±1 standard deviation, ranges) for three chipmunk species from the southern Rocky Mountains of British Columbia and Alberta. All measurements in millimetres. Based on voucher specimens taken 1996-99 and historical museum specimens identified by genital bone morphology.

Measurement	Adults			Subadults			Juveniles		
T. amoenus luteiventris	Mean	Range	N	Mean	Range	N	Mean	Range	N
Greatest length	33.8±0.47	32.7-35.0	40	32.7±0.55	32.1-33.2	3	31.6±0.58	30.7-32.3	7
Zygomatic breadth	18.8±0.45	17.8-19.9	43	18.0±0.30	17.7-18.3	3	17.1±0.49	16.3-17.8	7
Nasal length	10.2±0.35	9.3-11.2	45	9.7±0.51	9.3-10.3	3	9.0±0.37	8.6-9.6	7
Maxillary toothrow length	5.2±0.15	5.0-5.5	46	5.2±0.10	5.1-5.3	3	5.0±0.23	4.6-5.3	7
Interorbital width	7.1±0.28	6.5-7.8	43	6.7±0.20	6.5-6.9	3	6.7±0.18	6.5-7.0	7
Nasal width	2.9±0.27	2.2-3.5	46	2.8±0.12	2.7-2.9	3	3.0±0.22	2.7-3.0	7
Diagonal length of orbit	7.8±0.45	6.5-8.5	46	7.6±0.79	7.0-8.5	3	6.7±0.55	5.9-7.5	7
Cranial depth	13.8±0.20	13.3-14.2	40	13.7±0.27	13.5-14.0	3	13.6±0.36	13.2-14.3	7
Mandibular length	18.1±0.35	17.2-18.8	43	17.7±0.27	17.5-18.0	3	17.1±0.22	16.8-17.5	7
Coronoid height	10.4±0.27	9.7-11.2	40	9.8±0.23	9.7-10.1	3	9.2±0.42	8.6-9.9	7
T. minimus oreocetes	Mean	Range	N	Mean	Range	N	Mean	Range	N
Greatest length	32.4±0.42	31.2-32.4	12	31.0±0.21	30.8-31.1	2	29.3±0.00	29.3-29.3	2
Zygomatic breadth	18.2±0.33	17.6-18.7	12	17.6±0.35	17.3-17.8	2	16.2±0.67	15.4-17.0	4
Nasal length	9.4±0.34	8.8-9.9	12	8.6±0.52	8.0-8.9	3	8.2±0.27	8.0-8.6	2
Maxillary toothrow length	4.8±0.17	4.6-5.1	13	4.8±0.25	4.5-5.0	3	4.8±0.22	4.6-5.1	4
Interorbital width	6.8±0.27	6.4-7.2	12	6.3±0.30	6.0-6.6	3	6.2±0.21	5.9-6.4	4
Nasal width	2.2±0.17	1.9-2.5	12	2.2±0.42	1.7-2.5	3	2.0±0.24	1.8-2.3	4
Diagonal length of orbit	7.2±0.28	6.8-7.8	12	7.4±0.36	7.1-7.8	3	6.8±0.68	5.8-7.4	4
Cranial depth	13.2±0.27	12.8-13.7	11	13.4±0.07	13.3-13.4	2	12.8±0.40	12.4-13.2	3
Mandibular length	16.4±0.27	16.4-17.4	12	16.3±0.10	16.2-16.4	3	16.0±0.17	15.8-16.2	4
Coronoid height	9.8±0.27	9.5-10.3	12	9.5±0.35	9.1-9.8	3	8.3±0.52	7.7-8.9	4
T. ruficaudus ruficaudus	Mean	Range	N	Mean	Range	N	Mean	Range	N
Greatest length	35.2±0.44	34.0-35.8	19						
Zygomatic breadth	19.6±0.34	18.9-20.0	19						
Nasal length	11.0±0.26	10.5-11.5	21						
Maxillary toothrow length	5.5±0.16	5.2-5.7	21						
Interorbital width	7.4±0.23	6.9-7.8	20						
Nasal width	3.0±0.20	2.7-3.5	21						
Diagonal length of orbit	8.5±0.22	8.0-8.9	20						
Cranial depth	14.4±0.29	14.0-14.9	19						
Mandibular length	19.4±0.31	18.5-19.8	20						
Coronoid height	11.2±0.34	10.2-11.6	28						

Table 2-12. Jack-knifed classification matrix for two chipmunk species from the southern Rocky Mountains of British Columbia and Alberta. Based on a step-wise two-group discriminant analysis of adults using 10 cranial measurements.

	T. amoenus	***T. ruficaudus***	**% Correct**
T. amoenus (N=41)	40	1	98
T. ruficaudus (N=18)	1	17	94

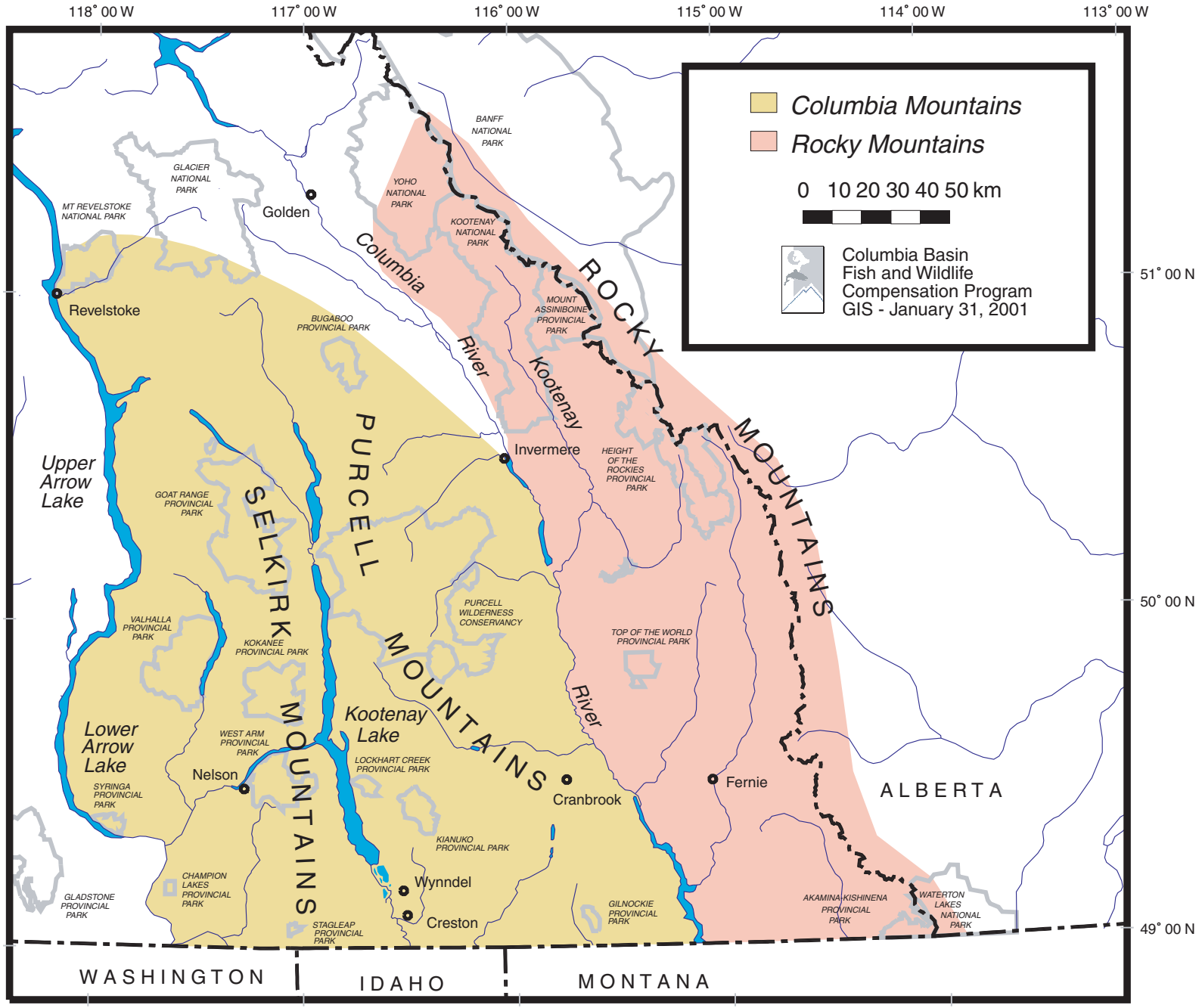

Figure 2-1. Geographic areas used in identification study.

Figure 2-2. Projection of 42 chipmunk bacular specimens from the southern Columbia Mountains of British Columbia on the first two principal components derived from 9 bacular measurements. Cluster A= *T. amoenus luteiventris*, cluster B= *T. minimus selkirki*, cluster C= *T. ruficaudus simulans*. Representative bacula all drawn to same scale.

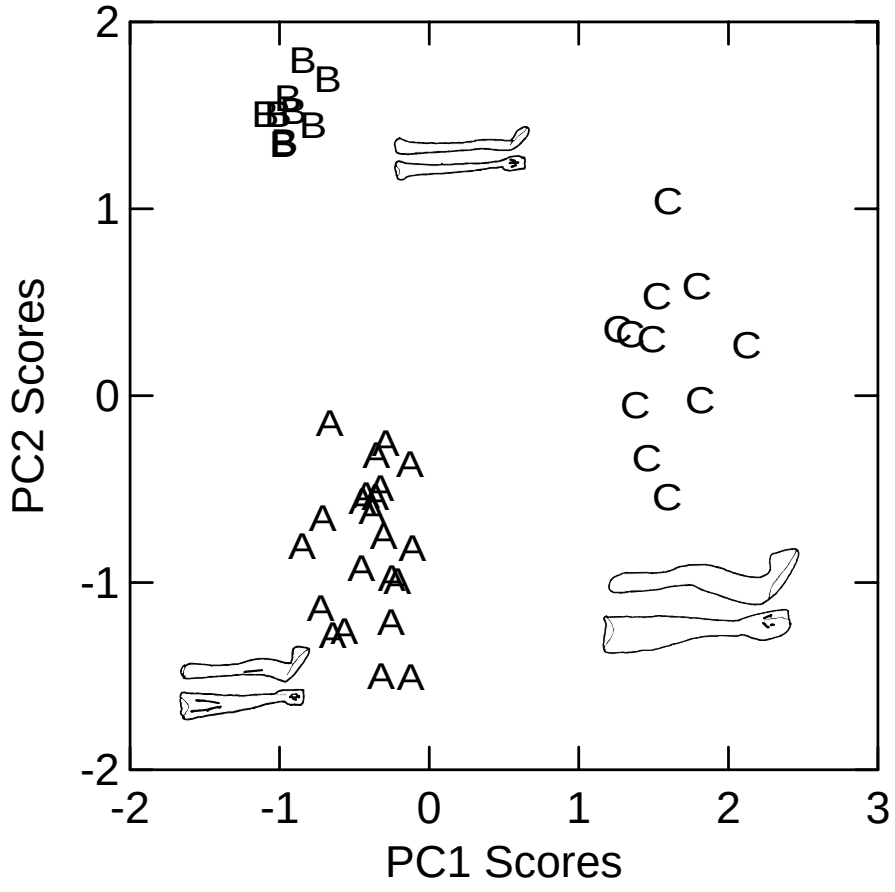

Figure 2-3. Projection of 32 chipmunk bacular specimens from the southern Rocky Mountains of British Columbia and Alberta on the first two principal components derived from 9 bacular measurements. Cluster A= *T. amoenus luteiventris*, cluster B= *T. minimus oreocetes*, cluster C= *T. ruficaudus ruficaudus*. Representative bacula all drawn to same scale.

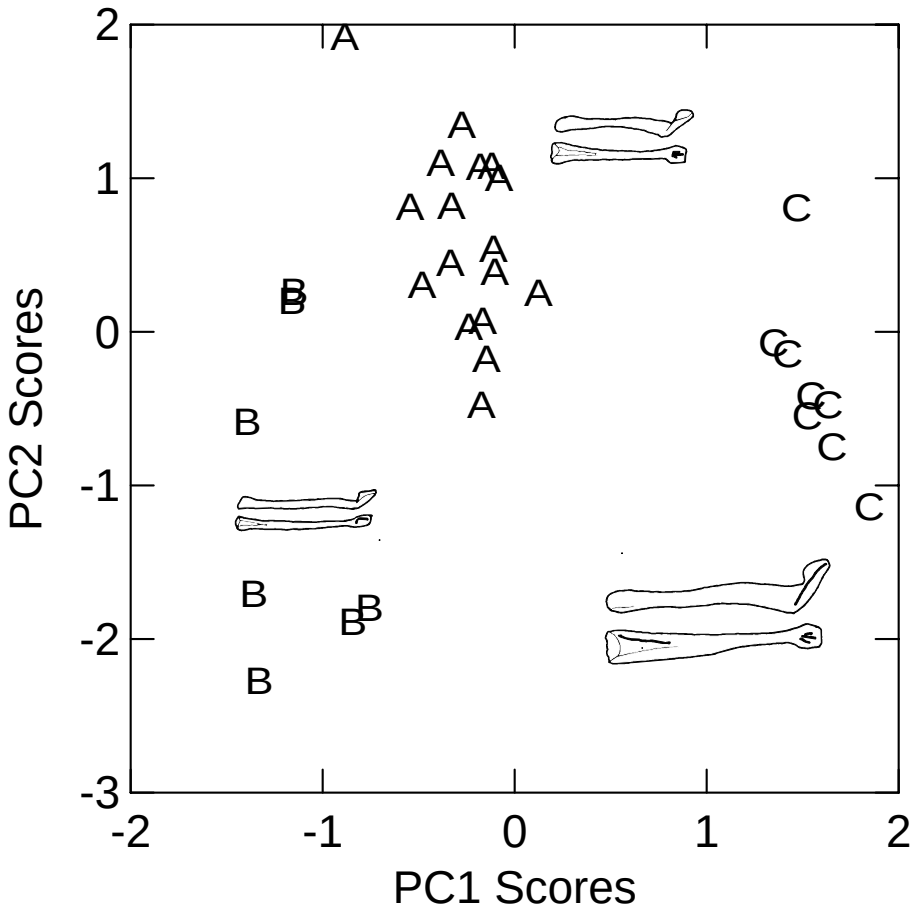

Figure 2-4. Examples of baubella for three chipmunk species from the southern Columbia and Rocky mountains of British Columbia and Alberta.
A=*T. ruficaudus simulans*, B=*T. amoenus luteiventris*, C=*T. minimus selkirki*, D= *T. ruficaudus ruficaudus*, E= *T. amoenus luteiventris*, F= *T. minimus oreocetes*

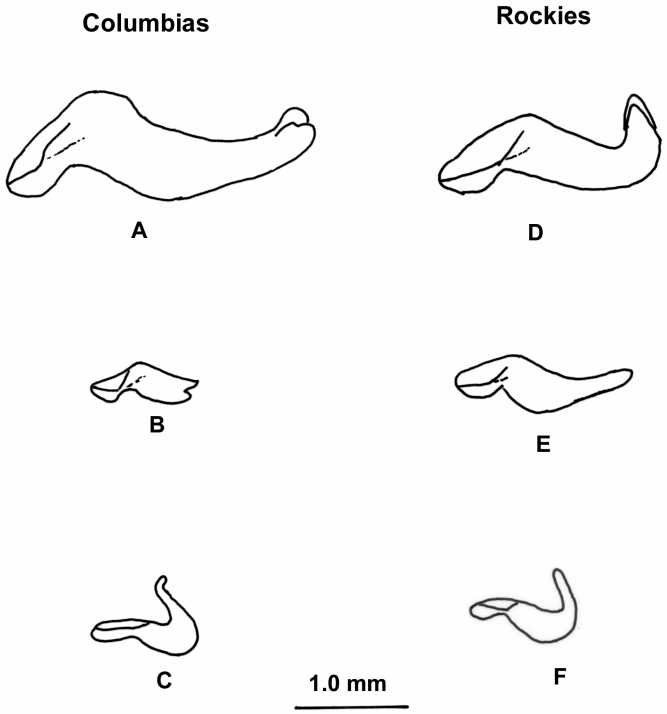

Figure 2-5. Representative adult study skins showing dorsal pelage in 3 chipmunk species from the southern Rocky Mountains of British Columbia. RBCM 19875- *T. r. ruficaudus*, Middle Kootenay Pass, taken 23 July 1998; RBCM 19897- *T. a. luteiventris*, Todhunter Creek, taken 30 July 1998; RBCM 19909- *T. m. oreocetes*, Middle Kootenay Pass, taken 22 July 1998.

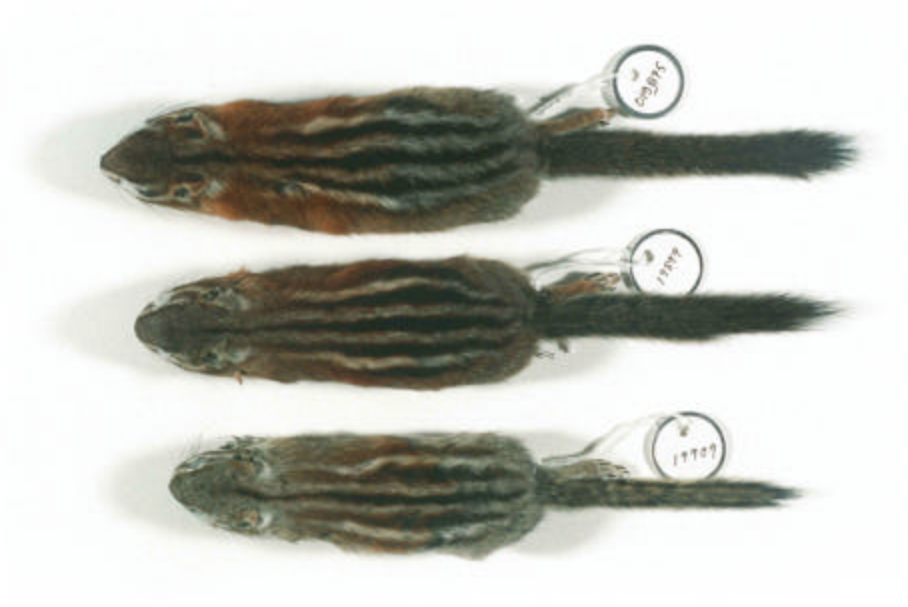

Figure 2-6. Study skins comparing dorsal pelage among adult *T. amoenus* and subadult *T. ruficaudus* from the southern Rocky Mountains of British Columbia. RBCM 19897- adult *T. a. luteiventris*, Todhunter Creek, taken 30 July; RBCM 19916-subadult *T. r. ruficaudus*, Middle Kootenay Pass, taken 24 July.

Figure 2-7. Study skins showing variation in dorsal pelage among adult *T. minimus* from the southern Rocky Mountains of British Columbia. RBCM 19909- *T. m. oreocetes*, Middle Kootenay Pass, taken 22 July 1998; RBCM 19876-*T. m. oreocetes*, Middle Kootenay Pass, taken 23 July 1998. RBCM 19876 is in winter pelage, most of the dorsum in RBCM 19909 is in summer pelage.

Figure 2-8. Representative adult study skins showing dorsal pelage in 3 chipmunk species from the southern Columbia Mountains of British Columbia. RBCM 20038- *T. r. simulans*, Giveout Creek, taken 16 July 1999; RBCM 20037- *T. a. luteiventris*, Topaz Creek, taken 15 July 1999; RBCM 19740- *T. m. selkirki*, Paradise Mine, taken 13 August 1997.

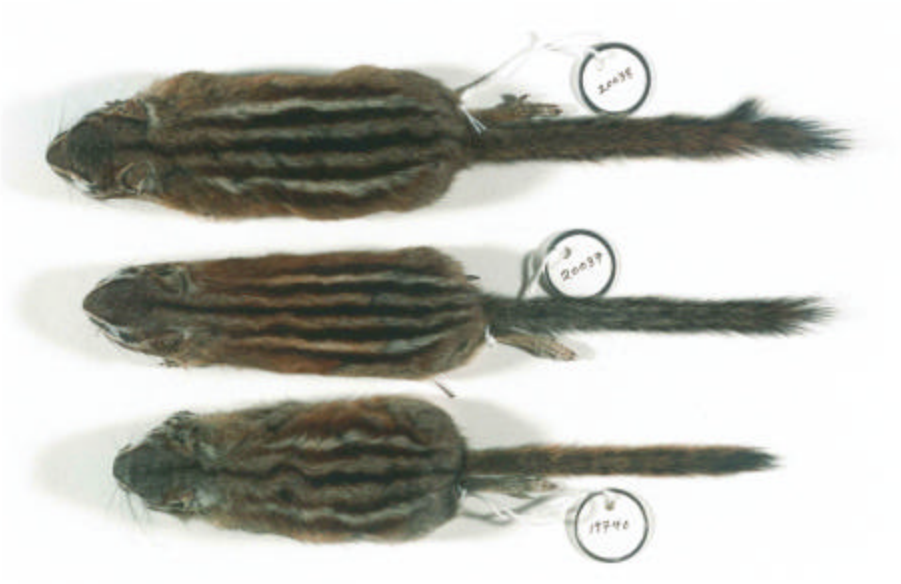

Figure 2-9. Study skins showing age and seasonal variation in dorsal pelage among *T. amoenus* from the southern Columbia Mountains of British Columbia. RBCM 19768- adult *T. a. luteiventris* in winter pelage, Hopeful Creek Creek, taken 20 August 1997; RBCM 19770- adult *T. a. luteiventris* in summer pelage, Hopeful Creek, taken 20 August 1997; RBCM 19767- subadult *T. a. luteiventris*, Hopeful Creek, taken 20 August 1997.

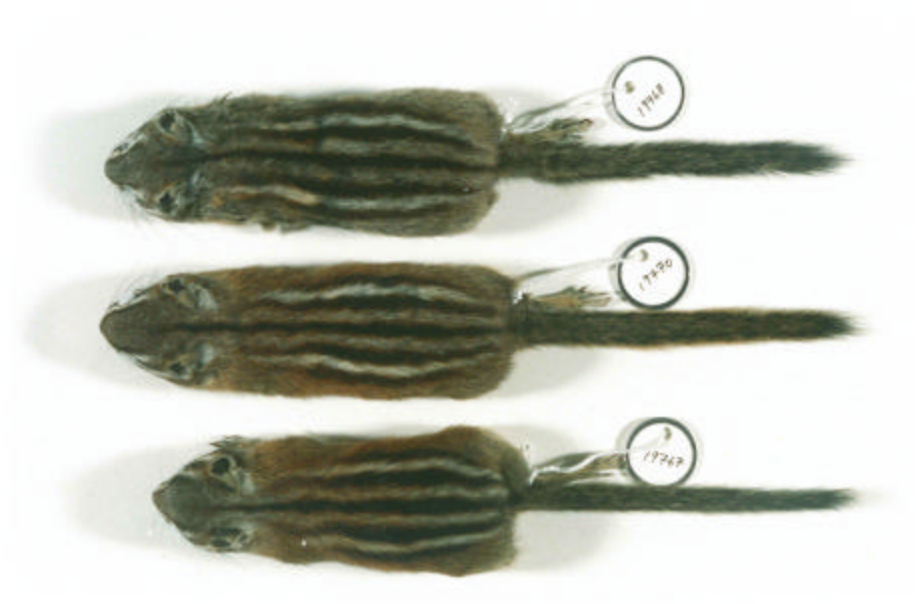

Figure 2-10. Representative adult study skins showing ventral pelage in 3 chipmunk species from the southern Rocky Mountains of British Columbia. RBCM 19875- *T. r. ruficaudus*, Middle Kootenay Pass, taken 23 July 1998; RBCM 19897- *T. a. luteiventris*, Todhunter Creek, taken 30 July 1998; RBCM 19909- *T. m. oreocetes*, Middle Kootenay Pass, taken 22 July 1998.

Figure 2-11. Study skins comparing ventral pelage among adult *T. amoenus* and subadult *T. ruficaudus* from the southern Rocky Mountains of British Columbia. RBCM 19897- adult *T. a. luteiventris*, Todhunter Creek, taken 30 July; RBCM 19916-subadult *T. r. ruficaudus*, Middle Kootenay Pass, taken 24 July.

Figure 2-12. Representative adult study skins showing ventral pelage in 3 chipmunk species from the southern Columbia Mountains of British Columbia. RBCM 20038- *T. r. simulans*, Giveout Creek, taken 16 July 1999; RBCM 20037- *T. a. luteiventris*, Topaz Creek, taken 15 July 1999; RBCM 19740- *T. m. selkirki*, Paradise Mine, taken 13 August 1997.

APPENDIX 2-1. VOUCHER SPECIMENS COLLECTED 1996-1999

*tissue samples sent to Department of Biological Sciences, University of Idaho for mitochondrial DNA analysis

1996

RBCM#	Field#	Species	Subspecies	Location	Site	Collector	Specimen	Sex	Age	Date	Remarks
19684	96040A	amoenus	luteiventris	Steamboat Mountain	KSM 015	Fraker, M.	skin; skull; skeleton; baculum	M	adult	22-Sep-96	*tissue sample for DNA; radiograph
19669	96036	amoenus	luteiventris	Kishinena Creek	KSM 014	Fraker, M.	skin; skull; skeleton; baculum	M	adult	19-Sep-96	*tissue sample for DNA; radiograph
19670	96037	amoenus	luteiventris	Kishinena Creek	KSM 014	Fraker, M.	skin; skull; skeleton	F	adult	19-Sep-96	*tissue sample for DNA; radiograph
19674	96038	amoenus	luteiventris	Kishinena Creek	KSM 014	Fraker, M.	skin; skull; baculum	M	adult	19-Sep-96	*tissue sample for DNA; radiograph
19675	96039	amoenus	luteiventris	Kishinena Creek	KSM 014	Fraker, M.	skin; skull; skeleton; baculum	M	adult	19-Sep-96	*tissue sample for DNA; radiograph
19679	96017	amoenus	luteiventris	Sage Creek; Sage Creek Road	KSM 002	Fraker, M.	skin; skull; skeleton	F	adult	15-Sep-96	*tissue sample for DNA; radiograph
19681	96025	amoenus	luteiventris	Sage Creek; Sage Creek Road	KSM 002	Fraker, M.	skin; skull; skeleton; baculum	M	adult	19-Sep-96	*tissue sample for DNA; radiograph
19682	96028	amoenus	luteiventris	Sage Creek; Sage Creek Road	KSM 002	Fraker, M.	skin; skull; skeleton	F	adult	17-Sep-96	*tissue sample for DNA; radiograph
19664	96002	amoenus	luteiventris	Sage Creek; Sage Creek Road	KSM 005	Fraker, M.	skin; skull; skeleton; baculum	M	adult	15-Sep-96	*tissue sample for DNA; radiograph
19665	96023	amoenus	luteiventris	Sage Creek; Sage Creek Road	KSM 005	Fraker, M.	skin; skull; skeleton; baculum	M	adult	15-Sep-96	*tissue sample for DNA; radiograph
19680	96024	amoenus	luteiventris	Sage Creek; Sage Creek Road	KSM 005	Fraker, M.	skin; skull; skeleton	F	adult	15-Sep-96	*tissue sample for DNA; radiograph
19650	96059	amoenus	luteiventris	Wynndel	KSM 022	Fraker, M.	skin; skull; skeleton	M	adult	09-Oct-96	*tissue sample for DNA; radiograph
19651	96060	amoenus	luteiventris	Wynndel	KSM 022	Fraker, M.	skin; skull; skeleton; baculum	M	adult	09-Oct-96	*tissue sample for DNA; radiograph
19683	96001	ruficaudus	ruficaudus	Wall Lake	KSM 001	Fraker, M.	skin; skull; skeleton; baubellum	F	adult	13-Sep-96	*tissue sample for DNA; radiograph
19656	96047	ruficaudus	simulans	Church Creek	KSM 019	Fraker, M.	skin; skull; skeleton; baculum	M	adult	07-Oct-96	*tissue sample for DNA; radiograph
19666	96049	ruficaudus	simulans	Church Creek	KSM 020	Fraker, M.	skin; skull	F	adult	07-Oct-96	*tissue sample for DNA; radiograph
19667	96050	ruficaudus	simulans	Church Creek	KSM 021	Fraker, M.	skin; skull; skeleton; baculum	M	adult	07-Oct-96	*tissue sample for DNA; radiograph
19668	96051	ruficaudus	simulans	Church Creek	KSM 021	Fraker, M.	skin; skull; skeleton; baculum	M	adult	07-Oct-96	*tissue sample for DNA; radiograph
19658	96040B	ruficaudus	simulans	Giveout Creek	KSM 016	Fraker, M.	skin; skull; skeleton; baubellum	F	adult	05-Oct-96	*tissue sample for DNA; radiograph
19659	96041	ruficaudus	simulans	Giveout Creek	KSM 016	Fraker, M.	skin; skull; skeleton	F	adult	05-Oct-96	*tissue sample for DNA; radiograph
19660	96042	ruficaudus	simulans	Giveout Creek	KSM 016	Fraker, M.	skin; skull; skeleton; baculum	M	adult	05-Oct-96	*tissue sample for DNA; radiograph
19661	96043	ruficaudus	simulans	Giveout Creek	KSM 016	Fraker, M.	skin; skull; skeleton; baculum	M	adult	05-Oct-96	*tissue sample for DNA; radiograph
19662	96046	ruficaudus	simulans	Giveout Creek	KSM 018	Fraker, M.	skin; skull; skeleton	F	adult	07-Oct-96	*tissue sample for DNA; radiograph
19654	96044	ruficaudus	simulans	Gold Creek	KSM 017	Fraker, M.	skin; skull; skeleton; baculum	M	adult	06-Oct-96	*tissue sample for DNA; radiograph
19655	96045	ruficaudus	simulans	Gold Creek	KSM 017	Fraker, M.	skin; skull; skeleton; baculum	M	adult	06-Oct-96	*tissue sample for DNA; radiograph

1997

RBCM#	FIELD#	Species	Subspecies	Location	Site	Collector	Specimen	Sex	Age	Date	Remarks
19751	97013	amoenus	luteiventris	Hopeful Creek	KSM 111	Fraker, M.	skin skull Skeleton baubellum	F	adult	18-Aug-97	*tissues for DNA, radiograph
19769	97031	amoenus	luteiventris	Hopeful Creek	KSM 111	Fraker, M.	skin skull Skeleton baculum	M	subadult	20-Aug-97	*tissues for DNA, radiograph
19770	97032	amoenus	luteiventris	Hopeful Creek	KSM 111	Fraker, M.	skin skull Skeleton baubellum	F	adult	20-Aug-97	*tissues for DNA, radiograph
19771	97033	amoenus	luteiventris	Hopeful Creek	KSM 111	Fraker, M.	skin skull Skeleton baculum	M	adult	20-Aug-97	*tissues for DNA, radiograph
19772	97034	amoenus	luteiventris	Hopeful Creek	KSM 111	Fraker, M.	skin skull Skeleton baubellum	M	adult	20-Aug-97	*tissues for DNA, radiograph
19767	97029	amoenus	luteiventris	Hopeful Creek	KSM 121	Fraker, M.	skin skull Skeleton baculum	M	subadult	20-Aug-97	*tissues for DNA, radiograph
19768	97030	amoenus	luteiventris	Hopeful Creek	KSM 122	Fraker, M.	skin skull Skeleton baubellum	F	adult	20-Aug-97	*tissues for DNA, radiograph
19777	97039	amoenus	luteiventris	Hopeful Creek	KSM 124	Fraker, M.	skin skull** Skeleton baculum	M	subadult	20-Aug-97	*tissues for DNA, radiograph
19773	97035	amoenus	luteiventris	Hopeful Creek	KSM 124	Fraker, M.	skin skull Skeleton baubellum	F	subadult	20-Aug-97	*tissues for DNA, radiograph
19774	97036	amoenus	luteiventris	Hopeful Creek	KSM 124	Fraker, M.	skin skull Skeleton baculum	M	adult	20-Aug-97	*tissues for DNA, radiograph
19775	97037	amoenus	luteiventris	Hopeful Creek	KSM 124	Fraker, M.	skin skull Skeleton baculum	M	subadult	20-Aug-97	*tissues for DNA, radiograph
19776	97038	amoenus	luteiventris	Hopeful Creek	KSM 124	Fraker, M.	skin skull** Skeleton baculum	M	subadult	20-Aug-97	*tissues for DNA, radiograph
19783	97045	amoenus	luteiventris	Lead Queen Mountain	KSM 128	Nagorsen, D.W.	skin skull Skeleton baculum	M	subadult	23-Aug-97	*tissues for DNA, radiograph
19753	97015	amoenus	luteiventris	Mount Brewer	KSM 112	Nagorsen, D.W.	skin skull Skeleton baculum	M	subadult	18-Aug-97	*tissues for DNA, radiograph
19752	97014	amoenus	luteiventris	Mount Brewer	KSM 112	Nagorsen, D.W.	skin skull Skeleton baculum	M	subadult	18-Aug-97	*tissues for DNA, radiograph
19764	97026	amoenus	luteiventris	Mount Brewer	KSM 113	Fraker, M.	skin skull Skeleton baubellum	F	subadult	19-Aug-97	*tissues for DNA, radiograph
19756	97018	amoenus	luteiventris	Mount Brewer	KSM 113	Fraker, M.	skin skull Skeleton baculum	M	subadult	19-Aug-97	*tissues for DNA, radiograph
19763	97025	amoenus	luteiventris	Mount Brewer	KSM 113	Fraker, M.	skin skull Skeleton baubellum	F	subadult	19-Aug-97	*tissues for DNA, radiograph
19757	97019	amoenus	luteiventris	Mount Brewer	KSM 114	Nagorsen, D.W.	skin skull Skeleton baculum	M	adult	19-Aug-97	*tissues for DNA, radiograph
19759	97021	amoenus	luteiventris	Mount Brewer	KSM 116	Fraker, M.	skin skull Skeleton baculum	M	juvenile	19-Aug-97	*tissues for DNA, radiograph
19766	97028	amoenus	luteiventris	Mount Brewer	KSM 120	Fraker, M.	skin skull Skeleton baubellum	F	juvenile	20-Aug-97	*tissues for DNA, radiograph
19739	97001	amoenus	luteiventris	Paradise Mine Road	KSM 101	Nagorsen, D.W.	skin skull** Skeleton baculum	M	subadult	13-Aug-97	*tissues for DNA, radiograph
19746	97008	amoenus	luteiventris	Paradise Mine Road	KSM 101	Nagorsen, D.W.	skin skull Skeleton baubellum	F	subadult	15-Aug-97	*tissues for DNA, radiograph
19747	97009	amoenus	luteiventris	Paradise Mine Road	KSM 101	Nagorsen, D.W.	skin skull Skeleton baculum	M	subadult	15-Aug-97	*tissues for DNA, radiograph
19778	97040	amoenus	luteiventris	Paradise Mine Road	KSM 125	Fraker, M.	skin skull Skeleton baubellum	F	subadult	21-Aug-97	*tissues for DNA, radiograph
19779	97041	amoenus	luteiventris	Paradise Mine Road	KSM 125	Fraker, M.	skin skull** Skeleton baubellum	F	subadult	21-Aug-97	*tissues for DNA, radiograph
19780	97042	amoenus	luteiventris	Paradise Mine Road	KSM 125	Fraker, M.	skin skull Skeleton baubellum	F	adult	21-Aug-97	*tissues for DNA, radiograph

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19781	97043	amoenus	luteiventris	Paradise Mine Road	KSM 125	Fraker, M.	skin skull Skeleton baubellum	F	adult	21-Aug-97	*tissues for DNA, radiograph
19782	97044	amoenus	luteiventris	Paradise Mine Road	KSM 125	Fraker, M.	skin skull Skeleton baculum	M	adult	21-Aug-97	*tissues for DNA, radiograph
19742	97004	amoenus	luteiventris	Springs Creek	KSM 106	Fraker, M.	skin skull Skeleton baculum	M	subadult	14-Aug-97	*tissues for DNA, radiograph
19748	97010	amoenus	luteiventris	Stoddart Creek	KSM 109	Fraker, M.	skin skull Skeleton baubellum	F	adult	16-Aug-97	*tissues for DNA, radiograph
19749	97011	amoenus	luteiventris	Stoddart Creek	KSM 109	Fraker, M.	skin skull** Skeleton baubellum	F	adult	17-Aug-97	*tissues for DNA, radiograph
19784	97046	amoenus	luteiventris	Stoddart Creek	KSM 129	Fraker, M.	skin skull Skeleton baubellum	F	adult	24-Aug-97	*tissues for DNA, radiograph
19750	97012	amoenus	luteiventris	Toby Creek	KSM 110	Fraker, M.	skin skull Skeleton baculum	M	subadult	17-Aug-97	*tissues for DNA, radiograph
19754	97016	minimus	selkirki	Mount Brewer	KSM 112	Fraker, M.	skin skull Skeleton baubellum	F	adult	18-Aug-97	*tissues for DNA, radiograph
19755	97017	minimus	selkirki	Mount Brewer	KSM 113	Fraker, M.	skin skull Skeleton baculum	M	adult	19-Aug-97	*tissues for DNA, radiograph
19758	97020	minimus	selkirki	Mount Brewer	KSM 115	Nagorsen, D.W.	skin skull Skeleton baculum	M	adult	19-Aug-97	*tissues for DNA, radiograph
19762	97024	minimus	selkirki	Mount Brewer	KSM 115	Fraker, M.	skin skull Skeleton baculum	M	adult	19-Aug-97	*tissues for DNA, radiograph
19760	97022	minimus	selkirki	Mount Brewer	KSM 117	Fraker, M.	skin skull Skeleton baubellum	F	adult	19-Aug-97	*tissues for DNA, radiograph
19765	97027	minimus	selkirki	Mount Brewer	KSM 117	Nagorsen, D.W.	skin skull Skeleton baculum	M	subadult	20-Aug-97	*tissues for DNA, radiograph
19761	97023	minimus	selkirki	Mount Brewer	KSM 118	Fraker, M.	skin skull Skeleton baubellum	F	juvenile	19-Aug-97	*tissues for DNA, radiograph
19740	97002	minimus	selkirki	Paradise Mine	KSM 102	Fraker, M.	skin skull Skeleton baculum	M	adult	13-Aug-97	*tissues for DNA, radiograph
19741	97003	minimus	selkirki	Springs Creek	KSM 106	Fraker, M.	skin skull Skeleton baculum	M	adult	14-Aug-97	*tissues for DNA, radiograph
19743	97005	minimus	selkirki	Springs Creek	KSM 107	Nagorsen, D.W.	skin skull Skeleton baubellum	F	adult	14-Aug-97	*tissues for DNA, radiograph
19744	97006	minimus	selkirki	Springs Creek	KSM 107	Nagorsen, D.W.	skin skull Skeleton baculum	M	adult	14-Aug-97	*tissues for DNA, radiograph
19745	97007	minimus	selkirki	Springs Creek	KSM 107	Fraker, M.	skin skull Skeleton baubellum	F	adult	14-Aug-97	*tissues for DNA, radiograph

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RBCM#	Field#	Species	Subspecies	Locname	Site	Collector	Specimen	Sex	Age	Date	Remarks
19888	98122	amoenus	luteiventris	Andy Good Creek	012	Nagorsen, DW	skin, skull, skeleton; baubellum	F	adult	27-Jul-98	*tissues for DNA, radiograph
19889	98123	amoenus	luteiventris	Andy Good Creek	013	Nagorsen, DW	skin, skull, skeleton; baubellum	F	adult	27-Jul-98	*tissues for DNA, radiograph
19926	98022	amoenus	luteiventris	Delphine Mine Trail	011	Fraker, M	skin, skull, skeleton; baubellum	F	adult	29-Jul-98	*tissues for DNA, radiograph
19927	98023	amoenus	luteiventris	Delphine Mine Trail	011	Fraker, M	skin, skull, skeleton; baculum	M	adult	29-Jul-98	*tissues for DNA, radiograph
19928	98024	amoenus	luteiventris	Delphine Mine Trail	011	Fraker, M	skin, skull, skeleton; baculum	M	juvenile	30-Jul-98	*tissues for DNA, radiograph
19905	98001	amoenus	luteiventris	Harvey Creek	001	Fraker, M	skin, skull, skeleton; baubellum	F	adult	22-Jul-98	*tissues for DNA, radiograph
19921	98018A	amoenus	luteiventris	Lodgepole Road	008	Fraker, ML	skin, skull, skeleton; baculum	M	subadult	25-Jul-98	*tissues for DNA, radiograph
19877	98109	amoenus	luteiventris	Middle Kootenay Pass	004	Nagorsen, DW	skin, skull, skeleton; baculum	M	adult	23-Jul-98	*tissues for DNA, radiograph
19879	98111	amoenus	luteiventris	Middle Kootenay Pass	003	Nagorsen, DW	skin, skull, skeleton; baculum	M	adult	23-Jul-98	*tissues for DNA, radiograph
19881	98113	amoenus	luteiventris	Middle Kootenay Pass	004	Nagorsen, DW	skin, skull, skeleton; baculum	M	juvenile	24-Jul-98	*tissues for DNA, radiograph
19882	98114	amoenus	luteiventris	Middle Kootenay Pass	004	Nagorsen, DW	skin, skull, skeleton; baubellum	F	juvenile	24-Jul-98	*tissues for DNA, radiograph
19878	98110	amoenus	luteiventris	Middlepass Creek	005	Panter, N	skin, skull, skeleton; baubellum	F	juvenile	23-Jul-98	*tissues for DNA, radiograph
19886	98118	amoenus	luteiventris	Middlepass Creek	005	Nagorsen, DW	skin, skull, skeleton; baubellum	F	juvenile	24-Jul-98	*tissues for DNA, radiograph
19910	98006	amoenus	luteiventris	Middlepass Creek	003	Fraker, M	skin, skull, skeleton; baubellum	F	adult	22-Jul-98	*tissues for DNA, radiograph
19922	98018B	amoenus	luteiventris	Paradise Mine Road	009	Hooper, LR	skin, skull, skeleton; baubellum	F	juvenile	27-Jul-98	*tissues for DNA, radiograph
19923	98019	amoenus	luteiventris	Paradise Mine Road	009	Hooper, LR	skin, skull, skeleton; baculum	M	subadult	27-Jul-98	*tissues for DNA, radiograph
19903	98137	amoenus	luteiventris	Racehorse Pass	018	Nagorsen, DW	skin, skull, skeleton; baculum	M	juvenile	30-Jul-98	*tissues for DNA, radiograph
19904	98138	amoenus	luteiventris	Racehorse Pass	018	Nagorsen, DW	skin, skull, skeleton; baculum	M	juvenile	30-Jul-98	*tissues for DNA, radiograph
19894	98128	amoenus	luteiventris	Todhunter Creek	015	Nagorsen, DW	skin, skull, skeleton; baculum	M	adult	29-Jul-98	*tissues for DNA, radiograph
19895	98129	amoenus	luteiventris	Todhunter Creek	015	Nagorsen, DW	skin, skull, skeleton; baubellum	F	subadult	29-Jul-98	*tissues for DNA, radiograph
19896	98130	amoenus	luteiventris	Todhunter Creek	016	Nagorsen, DW	skin, skull, skeleton; baubellum	F	juvenile	30-Jul-98	*tissues for DNA, radiograph
19897	98131	amoenus	luteiventris	Todhunter Creek	016	Nagorsen, DW	skin, skull, skeleton; baculum	M	adult	30-Jul-98	*tissues for DNA, radiograph
19898	98132	amoenus	luteiventris	Todhunter Creek	016	Nagorsen, DW	skin, skull, skeleton; baubellum	F	adult	30-Jul-98	*tissues for DNA, radiograph
19899	98133	amoenus	luteiventris	Todhunter Creek	016	Nagorsen, DW	skin, skull, skeleton; baculum	M	juvenile	30-Jul-98	*tissues for DNA, radiograph
19900	98134	amoenus	luteiventris	Todhunter Creek	016	Nagorsen, DW	skin, skull, skeleton; baculum	M	juvenile	30-Jul-98	*tissues for DNA, radiograph
19901	98135	amoenus	luteiventris	Todhunter Creek	017	Nagorsen, DW	skin, skull, skeleton; baculum	M	juvenile	30-Jul-98	*tissues for DNA, radiograph
20037	99017	amoenus	luteiventris	Topaz Creek Road	99-11	Nagorsen, DW	skin, skull, skeleton; baubellum	F	adult	15-Jul-99	*tissues for DNA, radiograph

1998-99 cont.

19872	98101	minimus	oreocetes	Middle Kootenay Pass	004	Nagorsen, DW	skin, skull, skeleton; baculum	M	juvenile	22-Jul-98	*tissues for DNA, radiograph
19873	98102	minimus	oreocetes	Middle Kootenay Pass	004	Nagorsen, DW	skin, skull, skeleton; baubellum	F	adult	22-Jul-98	*tissues for DNA, radiograph
19874	98103	minimus	oreocetes	Middle Kootenay Pass	004	Nagorsen, DW	skin, skull, skeleton; baculum	M	juvenile	22-Jul-98	*tissues for DNA, radiograph
19876	98108	minimus	oreocetes	Middle Kootenay Pass	004	Nagorsen, DW	skin, skull, skeleton; baubellum	F	adult	23-Jul-98	*tissues for DNA, radiograph
19883	98115	minimus	oreocetes	Middle Kootenay Pass	004	Nagorsen, DW	skin, skull, skeleton; baubellum	F	juvenile	24-Jul-98	*tissues for DNA, radiograph
19908	98004	minimus	oreocetes	Middle Kootenay Pass	002	Fraker, M	skin, skull, skeleton; baculum	M	adult	22-Jul-98	*tissues for DNA, radiograph
19909	98005	minimus	oreocetes	Middle Kootenay Pass	002	Fraker, M	skin, skull, skeleton; baculum	M	adult	22-Jul-98	*tissues for DNA, radiograph
19911	98007	minimus	oreocetes	Middlepass Creek	006	Fraker, M	skin, skull, skeleton; baculum	M	juvenile	23-Jul-98	*tissues for DNA, radiograph
19912	98008	minimus	oreocetes	Middlepass Creek	007	Fraker, M	skin, skull, skeleton; baculum	M	adult	23-Jul-98	*tissues for DNA, radiograph
19913	98009	minimus	oreocetes	Middlepass Creek	007	Fraker, M	skin, skull, skeleton; baubellum	F	adult	23-Jul-98	*tissues for DNA, radiograph
19890	98124	minimus	oreocetes	Todhunter Creek	014	Nagorsen, DW	skin, skull, skeleton; baculum	M	subadult	29-Jul-98	*tissues for DNA, radiograph
19891	98125	minimus	oreocetes	Todhunter Creek	014	Nagorsen, DW	skin, skull, skeleton; baubellum	F	juvenile	29-Jul-98	*tissues for DNA, radiograph
19892	98126	minimus	oreocetes	Todhunter Creek	014	Nagorsen, DW	skin, skull, skeleton; baubellum	F	juvenile	29-Jul-98	*tissues for DNA, radiograph
19893	98127	minimus	oreocetes	Todhunter Creek	014	Nagorsen, DW	skin, skull, skeleton; baubellum	F	adult	29-Jul-98	*tissues for DNA, radiograph
19902	98136	minimus	oreocetes	Todhunter Creek	014	Nagorsen, DW	skin, skull, skeleton; baubellum	F	juvenile	30-Jul-98	*tissues for DNA, radiograph
19924	98020	minimus	selkirki	Bruce Creek Drainage	010	Hooper, LR	skin, skull, skeleton; baculum	M	adult	28-Jul-98	*tissues for DNA, radiograph
19925	98021	minimus	selkirki	Bruce Creek Drainage	010	Hooper, LR	skin, skull, skeleton; baculum	M	adult	28-Jul-98	*tissues for DNA, radiograph
19875	98104	ruficaudus	ruficaudus	Middle Kootenay Pass	004	Nagorsen, DW	skin, skull, skeleton; baculum	M	adult	23-Jul-98	*tissues for DNA, radiograph
19880	98112	ruficaudus	ruficaudus	Middle Kootenay Pass	003	Nagorsen, DW	skin, skull, skeleton; baculum	M	adult	23-Jul-98	*tissues for DNA, radiograph
19885	98117	ruficaudus	ruficaudus	Middlepass	005	Panter, N	skin, skull, skeleton; baubellum	F	adult	24-Jul-98	*tissues for DNA, radiograph
19884	98116	ruficaudus	ruficaudus	Middlepass Creek	005	Nagorsen, DW	skin, skull, skeleton; baculum	M	adult	24-Jul-98	*tissues for DNA, radiograph
19887	98121	ruficaudus	ruficaudus	Middlepass Creek	005	Nagorsen, DW	skin, skull, skeleton; baubellum	F	adult	24-Jul-98	*tissues for DNA, radiograph
19906	98002	ruficaudus	ruficaudus	Middlepass Creek	003	Fraker, M	skin, skull, skeleton; baubellum	F	adult	22-Jul-98	*tissues for DNA, radiograph
19907	98003	ruficaudus	ruficaudus	Middlepass Creek	003	Fraker, M	skin, skull, skeleton; baculum	M	adult	22-Jul-98	*tissues for DNA, radiograph
19914	98011	ruficaudus	ruficaudus	Middlepass Creek	005	Fraker, M	skin, skull, skeleton; baculum	M	adult	24-Jul-98	*tissues for DNA, radiograph
19915	98012	ruficaudus	ruficaudus	Middlepass Creek	003	Hooper, LR	skin, skull, skeleton; baubellum	F	adult	24-Jul-98	*tissues for DNA, radiograph
19916	98013	ruficaudus	ruficaudus	Middlepass Creek	003	Fraker, M	skin, skull, skeleton; baculum	M	adult	24-Jul-98	*tissues for DNA, radiograph
19917	98014	ruficaudus	ruficaudus	Middlepass Creek	003	Fraker, M	skin, skull, skeleton; baubellum	F	adult	24-Jul-98	*tissues for DNA, radiograph
19918	98015	ruficaudus	ruficaudus	Middlepass Creek	003	Fraker, M	skin, skull, skeleton; baubellum	F	adult	24-Jul-98	*tissues for DNA, radiograph

1998-99 cont.

19919	98016	ruficaudus	ruficaudus	Middlepass Creek	003	Hooper, LR	skin, skull, skeleton; baubellum	F	adult	24-Jul-98	*tissues for DNA, radiograph
19920	98017	ruficaudus	ruficaudus	Middlepass Creek	003	Hooper, LR	skin, skull, skeleton; baculum	M	adult	24-Jul-98	*tissues for DNA, radiograph
20038	99018	ruficaudus	simulans	Giveout Creek	99-12	Nagorsen, DW	skin, skull, skeleton; baubellum	F	adult	16-Jul-99	*tissues for DNA, radiograph
20036	99025	ruficaudus	simulans	Gold Creek	99-18	Nagorsen, DW	skin, skull, skeleton; baubellum	F	adult	17-Jul-99	*tissues for DNA, radiograph

APPENDIX 1. SPECIMENS EXAMINED

Specimens used for species reference groups; all were identified from either genital bone (bacula, baubella) preparations or radiographs of study skins that revealed genital bones. AMNH= American Museum of Natural History, New York; CMN= Canadian Museum of Nature, Ottawa; PMA= Provincial Museum of Alberta, Edmonton; RBCM= Royal British Columbia Museum, Victoria; ROM= Royal Ontario Museum, Toronto; UAMZ= University of Alberta Museum of Zoology, Edmonton; UBC= Cowan Vertebrate Museum, University of British Columbia.

COLUMBIA MOUNTAINS

Tamias amoenus luteiventris

Genital Bones

BRITISH COLUMBIA. Delphine Mine Trail: RBCM 19926, female, adult, skin and skull; RBCM 19927, male, adult, skin and skull; RBCM 19928, male, juvenile?, skin and skull. Hopeful Creek: RBCM 19751, female, adult, skin and skull; RBCM 19769, male, subadult, skin and skull; RBCM 19770, female, adult, skin and skull; RBCM 19771, male, adult, skin and skull; RBCM 19772, male, adult, skin and skull; RBCM 19767, male, subadult, skin and skull; RBCM 19768, female, adult, skin and skull; RBCM 19777, male, subadult, skin and skull; RBCM 19773, female, subadult, skin skull; RBCM 19774, male, adult, skin and skull; RBCM 19775, male, subadult, skin and skull; RBCM 19776, male, subadult, skin and skull. Lead Queen Mountain: RBCM 19783, male, subadult, skin and skull. Mount Brewer: RBCM 19753, male, subadult, skin and skull; RBCM 19752, male, subadult, skin and skull; RBCM 19764, female, subadult, skin and skull; RBCM 19756, male, subadult, skin; RBCM 19763, female, subadult, skin; RBCM 19757, male, adult, skin and skull; RBCM 19759, male, juvenile, skin and skull; RBCM 19766, female, juvenile, skin and skull. Paradise Mine Road: RBCM 19739, male, subadult, skin and skull; RBCM 19746, female, subadult, skin and skull; RBCM 19747, male, subadult, skin and skull; RBCM 19778, female, subadult, skin and skull; RBCM 19779, female, subadult, skin skull; RBCM 19780, female, adult, skin and skull; RBCM 19781, female, adult, skin and skull; RBCM 19782, male, adult, skin skull; RBCM 19922, female, juvenile, skin and skull; RBCM 19923, male, subadult, skin and skull. Springs Creek: RBCM 19742, male, subadult, skin and skull. Toby Creek: RBCM 19750, male, subadult, skin and skull. Steamboat Mountain, Red Rock Road: RBCM 19684 male, adult, skin and skull. Topaz Creek Forestry Road: RBCM 20037, female, adult, skin and skull. Wynndel: RBCM 19651, male, adult, skin and skull.

Radiographs

BRITISH COLUMBIA. Creston, 6 mi E: ROM 28433, female, adult, skin and skull. Creston, Kootenay Flats: ROM 28439, female, adult, skin and skull. Goatfell: CMN 10172, male, adult, skin and skull. Invermere: AMNH 141702, female, adult, skin. Meadow Creek: CMN 10176, male, age, sex, skin and skull. Mount Revelstoke National Park [no other data]: RBCM 2227, female, age, skin and skull; RBCM 2232, male, adult, skin and skull; RBCM 2233, male, adult, skin and skull. Paradise Mine: UBC 1644, male, subadult, skin and skull. Sirdar: RBCM 5098, sex?, age, skin and skull. West Arm Demonstration Forest: RBCM 18585, female, adult, skin and skull (no mandibles). Wynndel: RBCM 19650, male, adult, skin and skull.

Tamias minimus selkirki

Genital Bones

BRITISH COLUMBIA. Bruce Creek Drainage: RBCM 19924, male, adult, skin and skull; RBCM 19925, male, adult, skin and skull. Mount Brewer: RBCM 19754, female, adult, skin and skull; RBCM 19755, male, adult, skin and skull; RBCM 19758, male, adult, skin and skull; RBCM 19762, male, adult, skin; RBCM 19760, female, adult, skin and skull; RBCM 19765, male, subadult, skin and skull; RBCM 19761, female, juvenile, skin and skull. Paradise Mine: RBCM 19740, male, adult, skin and skull. Springs Creek: RBCM 19741, male, adult, skin and skull; RBCM 19743, female, adult, skin and skull; RBCM 19744, male, adult, skin and skull; RBCM 19745, female, adult, skin

Radiographs

BRITISH COLUMBIA. Paradise Mine: RBCM 5029, unknown sex, juvenile, skin and skull; RBCM 5028, male, adult, skin and skull; UBC 1552, male, adult, skin and skull; UBC 1553, male, subadult, skin and skull.

Tamias ruficaudus simulans

Genital Bones

BRITISH COLUMBIA. Church Creek: RBCM 19656, male, adult, skin and skull; RBCM 19667, male, adult, skin and skull. Giveout Creek: RBCM 19658, female, adult, skin and skull; RBCM 19660, male, adult, skin and skull; RBCM 19661, male, adult, skin and skull; RBCM 20038, female, adult, skin and skull. Gold Creek: RBCM 19654, male, adult, skin and skull; RBCM 19655, male, adult, skin and skull; RBCM 20036, female, adult, skin and skull. Kootenay Pass [=Salmo-Creston Summit]: CMN 41277, male, adult, skin and skull; CMN 41282, male, adult, skin and skull; CMN 41286, male, adult, skin and skull; CMN 41264, male, adult, skin and skull; CMN 41266, male, adult, skin and skull. Salmon River [=Salmo River?]: CMN 1008, male, adult?, skin.

Radiographs

BRITISH COLUMBIA. Boundary Lake: ROM 28444, female, adult, skin and skull; Church Creek: RBCM 19666, female, adult, skin and skull; RBCM 19668, male, adult, skin and skull. Creston, Kootenay Flats: ROM 28422, female, adult, skin and skull. Giveout Creek: RBCM 19659, female, adult, skin and skull; RBCM 19662, female, adult, skin and skull. Kootenay Pass [=Salmo-Creston Summit]: CMN 41267, male, adult, skin and skull; CMN 41269, female, adult, skin and skull; CMN 41272, male, adult, skin and skull; CMN 41274, male, adult, skin and skull; CMN 41283, female, adult, skin and skull. West Creston: French's Farm: CMN 10169, male, adult, skin and skull. West Creston, Kootenay Flats: ROM 28453, male, adult, skin and skull; ROM 28454, female, adult, skin and skull.

ROCKY MOUNTAINS

Tamias amoenus luteiventris

Genital Bones

ALBERTA. Gibraltar Mountain: UAMZ 8088, male, adult, flat skin and skull. Sheep River: UAMZ 8094, male, adult, flat skin and skull; UAMZ 8095, male, adult, flat skin and skull

BRITISH COLUMBIA. Andy Good Creek: RBCM 19888, female, adult, skin and skull; RBCM 19889, female, adult, skin and skull. Harvey Creek: RBCM 19905, female, adult, skin and skull. Kishinena Creek: RBCM 19669, male, adult, skin and skull; RBCM 19670, female, adult, skin and skull; RBCM 19674, male, adult, skin and skull; RBCM 19675, male, adult, skin and skull. Lodgepole Creek Road: RBCM 19921, male, subadult, skin and skull. Middle Kootenay Pass: RBCM 19877, male, adult, skin and skull; RBCM 19879, male, adult, skin and skull; RBCM 19881, male, juvenile, skin and skull. RBCM 19882, female, juvenile, skin and skull. Middlepass Creek: RBCM 19886, female, juvenile, skin and skull; RBCM 19910, female, adult, skin and skull. Racehorse Pass: RBCM 19903, male, juvenile, skin and skull; RBCM 19904, male, juvenile, skin and skull. Sage Creek; Sage Creek Road: RBCM 19679, female, adult, skin and skull; RBCM 19681, male, adult, skin and skull; RBCM 19682, female, adult, skin and skull; RBCM 19664, male, adult, skin and skull; RBCM 196659, male, adult, skin and skull; RBCM 19680, female, adult, skin and skull. Stoddart Creek: RBCM 19748, female, adult, skin and skull; RBCM 19749, female, adult, skin and skull; RBCM 19784, female, adult, skin and skull. Todhunter Creek: RBCM 19894, male, adult, skin and skull; RBCM 19895, female, subadult, skin and skull; RBCM 19896, female, juvenile, skin and skull; RBCM 19897, male, adult, skin and skull; RBCM 19898, female, adult, skin and skull; RBCM 19899, male, juvenile, skin and skull; RBCM 19900, male, juvenile, skin and skull; RBCM 19901, male, juvenile, skin and skull

Radiographs

ALBERTA. Kananaskis Provincial Park: PMA 76.67.12, female, adult, flat skin and skull; PMA 76.105.9, female, adult, flat skin and skull; PMA 76.105.7, female. Adult, flat skin and skull; PMA 76.67.6, female, adult, flat skin and skull; PMA 76.79.5, female, adult; flat skin and skull. Pincher Creek: UAMZ 8157, female, adult, flat skin and skull. Sage Mountain: PMA 93.23.6, male, adult, skin and skull.

BRITISH COLUMBIA. Kootenay River, N of Elk River: RBCM 7783, female, adult, skin and skull; RBCM 7784, female, adult, skin and skull. Flathead River: CMN 22834, male, adult, skin and skull; RBCM 8461, female, adult, skin and skull. Kishinena Creek: RBCM 19669, male, adult, skin and skull[1]; RBCM 19670, female, adult, skin and skull. Newgate: RBCM 7434, male, adult, skin and skull; RBCM 7736, female, adult, skin and skull; ROM 28436, female, juvenile, skin. Sage Creek, Sage Creek Road: RBCM 19679, female, adult, skin and skull; RBCM 19682, female, adult, skin and skull. Yoho National Park , Lake O' Hara: RBCM 19394, male, adult, skin and skull. Yoho National Park, Emerald Lake: RBCM 19376, male, adult, skin and skull; RBCM 19378, female, adult, skin and skull; RBCM 19379, female, adult, skin and skull. Yoho National Park; Great Divide: RBCM 19313, male, subadult, skin and skull; RBCM 19314, male, adult, skin and skull. Yoho National Park, Mount Burgess: RBCM 19359, male, adult, skin and skull.

Tamias minimus oreocetes

Genital Bones

[1] Baculum prepared but too damaged to measure; identification based on radiograph taken before prep

ALBERTA. Sheep River: UAMZ 8180, male, adult, flat skin and skull; UAMZ 8181, male, adult, flat skin and skull; UAMZ 8182, male, adult, flat skin and skull.

BRITISH COLUMBIA.
Middle Kootenay Pass: RBCM 19872, male, juvenile, skin and skull; RBCM 19873, female, adult, skin and skull; RBCM 19874, male, juvenile, skin and skull; RBCM 19876, female, adult, skin and skull; RBCM 19883, female, juvenile, skin and skull; RBCM 19908, male, adult, skin and skull; RBCM 19909, male, adult, skin and skull. Middlepass Creek: RBCM 19911, male, juvenile, skin and skull; RBCM 19912, male, adult, skin and skull; RBCM 19913, female, adult, skin and skull. Todhunter Creek: RBCM 19890, male, subadult, skin and skull; RBCM 19891, female, juvenile, skin and skull; RBCM 19892, female, juvenile, skin and skull; RBCM 19893, female, adult, skin and skull; RBCM 19902, female, juvenile, skin and skull

Radiographs
BRITISH COLUMBIA. Mount Assiniboine Provincial Park, Sunburst Lake: AMNH 141682, male, juvenile, skin. Yoho National Park, Amiskwi River: RBCM 19383, female, subadult, skin and skull; RBCM 19408, male, subadult, skin . Yoho National Park Burgess Pass: RBCM 19358, male, adult, skin and skull; RBCM 19360, male, adult, skin and skull; RBCM 19362, male, adult, skin and skull.

Tamias ruficaudus ruficaudus
Genital Bones
ALBERTA. Castle River, headwaters: UAMZ 8174, male, adult, skin and skull

BRITISH COLUMBIA. Middle Kootenay Pass: RBCM 19875, male, adult, skin and skull; RBCM 19880, male, adult, skin and skull. Middlepass Creek: RBCM19885, female, adult, skin and skull; RBCM 19878, female, juvenile, skin and skull; RBCM 19884, male, adult, skin and skull; RBCM 19887, female, adult, skin and skull; RBCM 19906, female, adult, skin and skull; RBCM 19907, male, adult, skin and skull; RBCM 19914; male, adult, skin and skull; RBCM 19915, female, adult, skin and skull; RBCM 19916, male, adult, skin and skull; RBCM 19917, female, adult, skin and skull; RBCM 19918, female, adult, skin and skull; RBCM 19919, female, adult, skin and skull; RBCM 19920, male, adult, skin and skull. Wall Lake: RBCM 19683, female, adult, skin and skull.

Radiographs
ALBERTA. Waterton Lakes National Park [no other data]: UBC 1632, female, adult, skin and skull. Waterton Lakes National Park, Cameron Lake: CMN 16018, male, adult, skin and skull; CMN 16010, male, adult, skin and skull; UBC 3547, female, adult, skin and skull. Waterton Lakes National Park, Sage Creek: UBC 1630, adult, male, skin and skull; UBC 1631, male, adult, skin and skull

BRITISH COLUMBIA. Akamina Pass: RBCM 3571, male, adult(?), skin; UBC 1627, male, adult, skin. UBC 1628, male, adult, skin and skull.

APPENDIX. 2-3 IDENTIFICATION KEYS

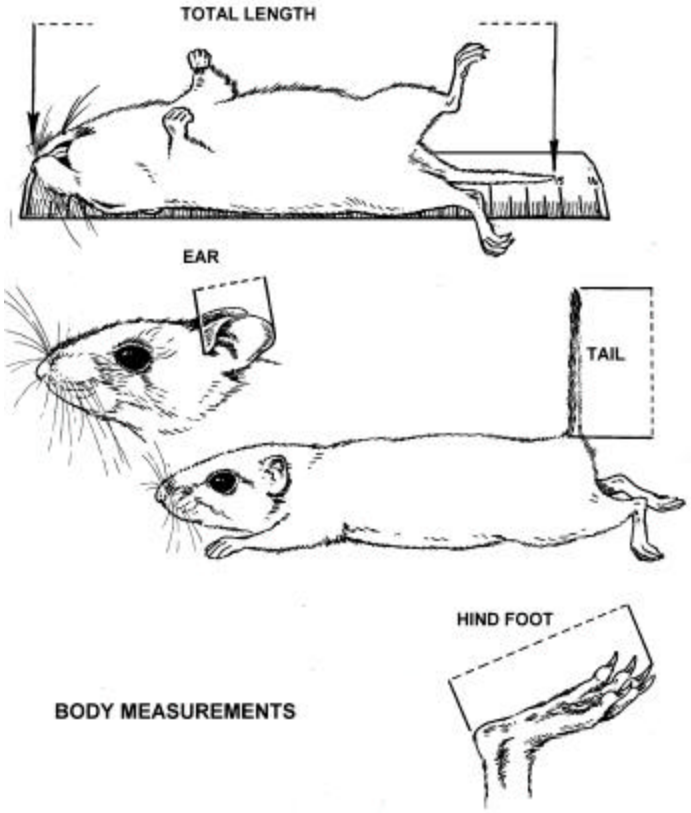
The following keys are provided to assist in the identification of live chipmunks captured in the field or museum voucher specimens. Because chipmunks from the Columbia Mountains and Rocky Mountains differ strikingly in a number of traits, it was necessary to develop separate keys for these two regions. The identification keys are dichotomous with diagnostic characters arranged into couplets; each couplet offers two mutually exclusive choices labelled a or b. Begin with couplet number one and select either a or b. This will give you a species name or direct you to another couplet in the key. By systematically working through the various steps, the user will eventually arrive at an identification.

There are several cautionary notes associated with using these keys. First the keys based on body and skull measurements are designed only for identifying adult chipmunks (fully erupted permanent cheek teeth). The keys based on genital bones can be applied to adult and subadult animals but not juveniles. Not only will the keys not identify immature chipmunks, but the user must be confident of the age (from tooth eruption) of the individual animal being identified. Although tooth eruption can be readily determined in skulls of museum specimens, unfortunately no reliable method exists for determining tooth eruption on live, hand-held animals captured in the field. Chipmunks captured during the breeding season, could include immature animals. Second keys by nature are based on only a few traits with absolute differences. It is impossible to capture the full range of variation shown by species in simple keys. There will always be a few aberrant individuals that contradict the diagnostic traits in the key. We recommend that biologists examine available museum specimens to familarize themselves with species differences before attempting to apply the keys. We also strongly urge wildlife biologists conducting chipmunk inventories in areas where several chipmunk species co-occur to collect a sample of voucher specimens to validate their identifications. Identification and voucher specimens should be carefully considered before any inventory or field research.

External body measurements are taken with a millimetre ruler to the nearest millimetre. Colour codes for pelage in the keys are based on Smithe (1974, 1975, 1981). Except for the tip angle of the baculum, genital bone measurements are taken with an ocular micrometer on cleared and stained genital bones. Tip angle of the baculum is measured to the nearest degree with a protractor on an outline drawing made with a camera lucida. Bacular measurements are from Patterson (1992); baubellar measurements are modified from Sutton (1982). Skull measurements are taken to the nearest 0.1 mm with calipers on cleaned skulls. Skull measurements and the drawing are from Patterson (1993).

SOUTHERN COLUMBIA MOUNTAINS-BRITISH COLUMBIA

I. Field Identification



1a. Total length< 195 mm;
belly fur whitish-grey…….. *Tamias minimus selkirki*

1b. Total length >195 mm;
belly fur buffy or whitish-grey……..…2

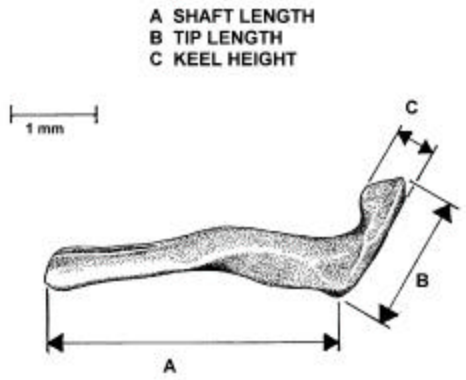
2a. Belly fur buffy,
discriminant function score[1]<0.50……...*Tamias amoenus luteiventris*

2b. Belly fur usually whitish,
discriminant function score[1]>0.50…….*Tamias ruficaudus simulans*

[1]Discriminant Score= -30.822 +total length(0.835) +tail Vertebrae(0.045) +hind foot (0.254). Insert the measurements for an individual, multiply each measurement by its coefficient, then sum for score.

II. Identifying Museum Specimens

A. Male Genital Bone (baculum)



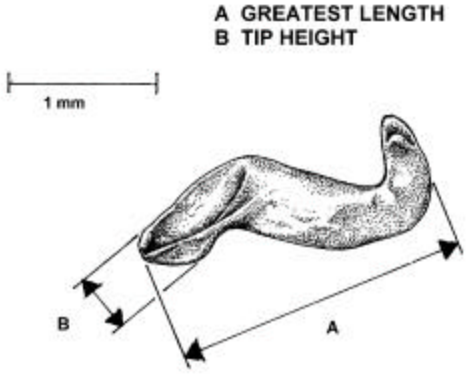
1a. Shaft length >3.0 mm, ratio of tip length/shaft length>0.40
……*Tamias ruficaudus simulans*

1b. Shaft length <3.0 mm, ratio of tip length/shaft length <0.40 ….……2

2a. Ratio of tip length /shaft length >0.29, tip angle <130°
……..... *Tamias amoenus luteiventris*

2b. Ratio of tip length/shaft length <0.29, tip angle >130°
……..……..... *Tamias minimus selkirki*

B. Female Genital Bone (baubellum)

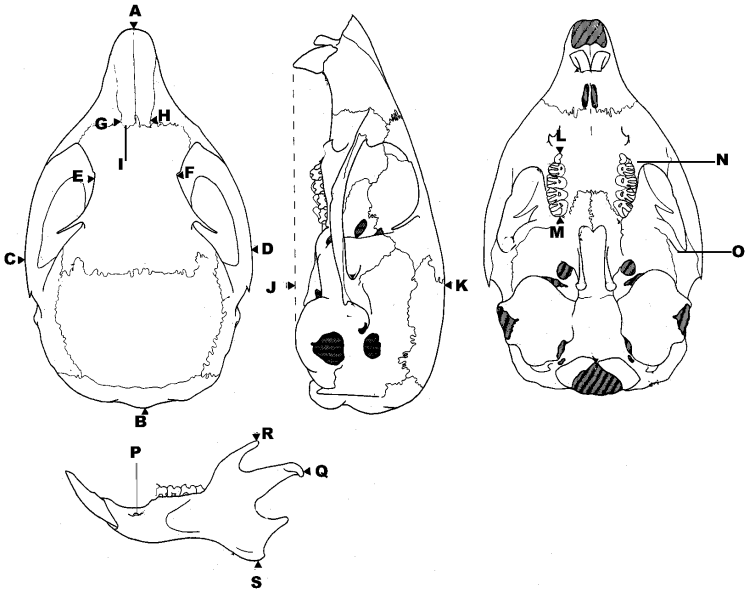


1a. Greatest length >2.0 mm, tip height >0.40 mm
…….. *Tamias ruficaudus simulans*

1b. Greatest length <2.0 mm, tip height <0.40 mm……2

2a. Baubellum with "U" shaped base, tip height <0.18 mm
…….…… *Tamias minimus selkirki*
2b. Baubellum lacking a "U" shaped base, tip height >0.18 mm
……. *Tamias amoenus luteiventris*

C. ***Skulls***



A-B: Greatest length of skull
P-Q: Mandibular length
L-M: Maxillary toothrow length
G-H: Nasal width
R-S: Coronoid height

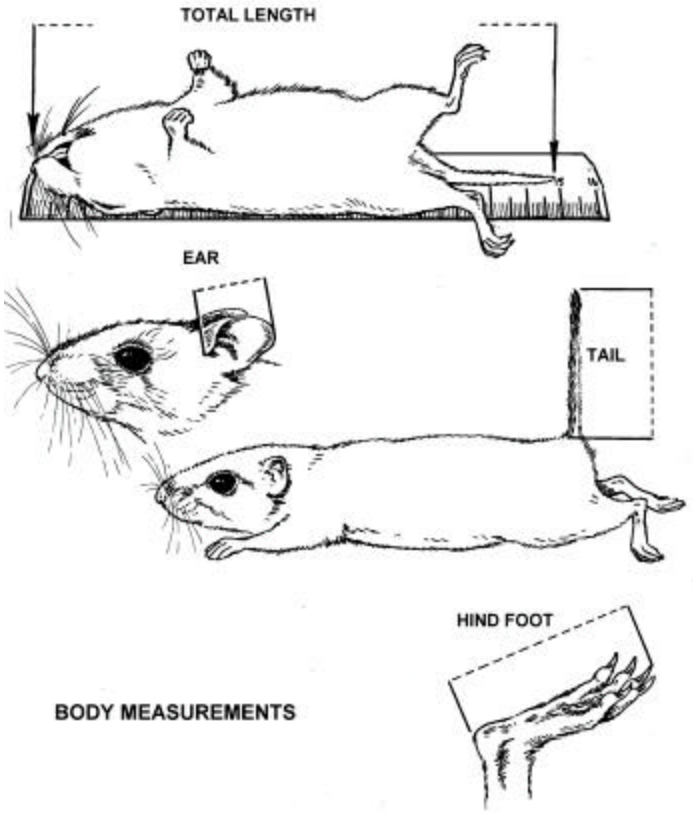
1a. Greatest length of skull <32.5 mm, mandibular length <17.4 mm
…….....….*Tamias minimus selkirki*
1b. Greatest length of skull >32.5 mm, mandibular length >17.5 mm……...2

2a. Discriminant function score[2] <-0.20……..…*Tamias amoenus luteiventris*
2b. Discriminant function score[2]>-0.20…….……*Tamias ruficaudus simulans*

[2]Discriminant Score= -33.480 +maxillary toothrow length(0.345) +nasal width(0.668) +coronoid height(0.584). Insert the measurements for an individual, multiply each measurement by its coefficient, then sum for score.

SOUTHERN ROCKY MOUNTAINS-BRITISH COLUMBIA AND ALBERTA

I. Field Identification



1a. Discriminant Score[1] <-2.0
belly fur whitish-grey…….. *Tamias minimus oreocetes*

1b. Discriminant Score[1] >-2.0
belly fur buffy or whitish-grey……..…2

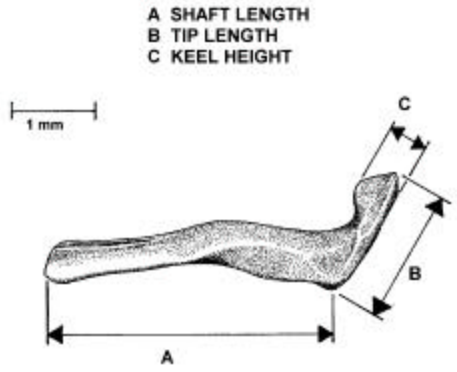
2a. Belly fur buffy,
underside of tail orange (Cinnamon)
……..……...*Tamias amoenus luteiventris*

2b. Belly fur usually whitish,
underside of tail rufous (Antique Brown to Raw Sienna),
…….*Tamias ruficaudus simulans*

[1]Discriminant Score= -33.023 +total length(0.002) +tail vertebrae(0.189) +hind foot (0.739). Insert the measurements for an individual, multiply each measurement by its coefficient, then sum for score.

II. Identifying Museum Specimens

A. Male Genital Bone (baculum)



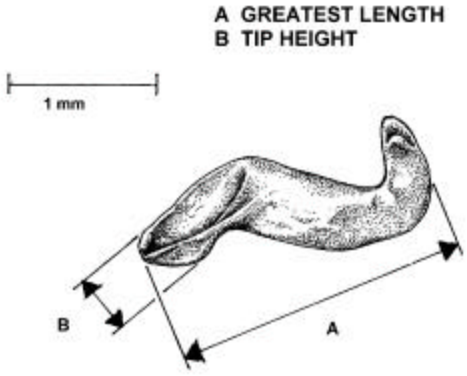
1a. Shaft length >3.5 mm, keel height >0.40 mm
……*Tamias ruficaudus ruficaudus*

1b. Shaft length <3.5 mm, keel height <0.40 mm……. ….……2

2a. Ratio of tip length /shaft length >0.30, tip length >0.75 mm
……..... *Tamias amoenus luteiventris*

2b. Ratio of tip length/shaft length <0.30, tip length <0.75 mm
……..……..... *Tamias minimus oreocetes*

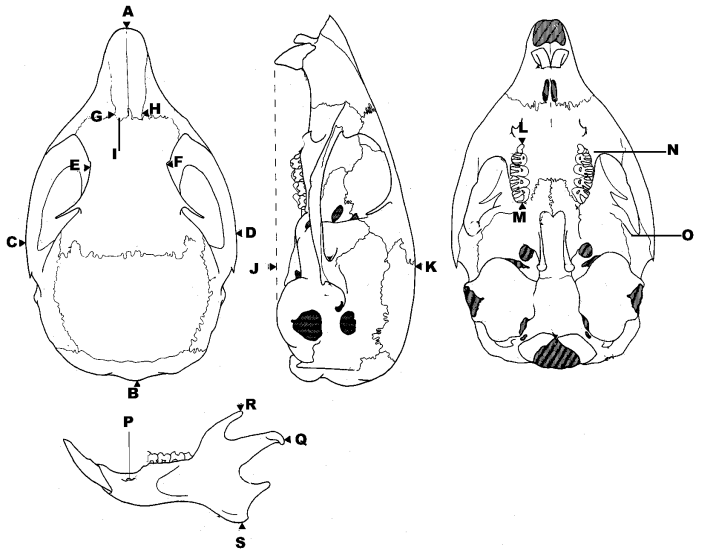
B. Female Genital Bone (baubellum)



1a. Greatest length >1.9 mm, keel height >0.35 mm
…….. *Tamias ruficaudus ruficaudus*
1b. Greatest length <1.9 mm, keel height <0.35 mm……2

2a. Baubellum with "U" shaped base, total length <1.10 mm
……..…… *Tamias minimus oreocetes*
2b. Baubellum lacking a "U" shaped base, total length >1.10 mm
……. *Tamias amoenus luteiventris*

C. Skulls



A-B: Greatest length of skull
P-Q: Mandibular length
C-D: Zygomatic breadth
A-I: Nasal length
E-F: Interorbital width
N-O: Diagonal length of orbit
J-K: Cranial depth

1a. Greatest length of skull <32.6 mm
……..….*Tamias minimus oreocetes*

1b. Greatest length of skull >32.6 mm……..……...2

2a. Discriminant function score[2]<-0.0...……..…*Tamias amoenus luteiventris*
2b. Discriminant function score[2]>-0.0.……*Tamias ruficaudus ruficaudus*

[2]Discriminant Score= -89.505+greatest length of skull(0.754) +zygomatic breadth (-1.479) +nasal length(1.429)+interorbital width(1.466)+diagonal length of orbit (0.867)+cranial depth(2.735)+mandible length(1.149). Insert the measurements for an individual, multiply each measurement by its coefficient, then sum for score.

Chapter 3

TAXONOMY

by

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TABLE OF CONTENTS

INTRODUCTION

Although two subspecies of the Red-tailed Chipmunk (*Tamias ruficaudus simulans, Tamias ruficaudus ruficaudus*) and two subspecies of the Least Chipmunk (*Tamias minimus selkirki, Tamias minimus oreocetes*) from the Kootenay region of southeastern British Columbia are on the province's Red/Blue List (Cannings et al. 1999), the taxonomic status of these taxa is unclear. One objective of the chipmunk study was to evaluate the systematic status of these four taxa, and their validity as distinct taxonomic or evolutionary significant units (see Nagorsen et al. 2000) that warrant conservation or special management.

Howell (1929) recognized two subspecies of *T. ruficaudus* (*T. r. simulans* and *T. r. ruficaudus*) largely on the basis of pelage. Based on their distinct male genital bones (bacula), White (1953) speculated that *T. r. simulans* and *T. r. ruficaudus* were distinct species. In a study of geographic variation among populations from Washington, Idaho, and Montana, Patterson and Heaney (1987) demonstrated that the two taxa were differentiated in bacular morphology, but overlapped in cranial morphology. They suggested that the two taxa were differentiated at the species level, although they noted that detailed studies of possible hybridization in contact zones were needed. Cowan (1946) described the general distribution of the two subspecies in Canada and summarized five cranial measurements for *T. r. ruficaudus*. However, morphological variation among Canadian populations of the two subspecies has not been assessed.

Twenty-one subspecies are recognized for *T. minimus* (Verts and Carraway 2001). The only taxonomic study applying modern techniques was done on several taxa from the south-western United States (Sullivan 1985; Sullivan and Petersen 1988). Taxonomy of *T. minimus* populations inhabiting the western Cordillera of Canada was last assessed more than 50 years ago by Cowan (1946) and the taxonomic validity of the two Red Listed subspecies in British Columbia is unknown. *T. m. selkirki* is an isolated subspecies restricted to high elevations in the Purcell Mountains described by Cowan (1946) from only five museum specimens all taken from the type locality (south-west of Invermere). Clearly a modern study with larger samples is needed to assess the taxonomic status of this population. *T. m. oreocetes* is a small, pale subspecies restricted to alpine habitats in the extreme southern Rocky Mountains of western Canada and Montana. Its differentiation from *T. m. borealis* the adjacent subspecies in the Canadian Rocky Mountains has not been assessed with a modern taxonomic study. The precise distributional limits of this subspecies in Canada is also contentious (Cowan 1946; Crowe 1943; Banfield 1958).

A preliminary taxonomic study of these chipmunk taxa was summarized by Nagorsen et al. (2000). However, it included few historical museum specimens and none of the voucher specimens taken 1998-99. Our analysis reported herein is more comprehensive. It includes the vouchers specimens taken in 1996-99 and samples of historical museum specimens from British Columbia and Alberta housed in eight museums. We analyzed pelage, cranial, and genital bone (i.e., baculum and baubellum) morphology. Because they are conservative characters, male and female genital bones have proven to be important taxonomic characters for studying geographic variation and subspecies in various chipmunks (Sullivan 1985; Patterson and Heaney 1987).

METHODS

Our techniques for measuring skulls, bacula, and baubella; and describing pelage colour are summarized in detail in Chapter 2. All taxonomic analyses were based on adult animals with fully erupted, permanent dentition (see Chapter 2 for ageing methods). Although *T. minimus* and *T. ruficaudus* demonstrate sexual size dimorphism (Sheppard 1965; Levenson 1990), sample sizes were inadequate for some groups to separate sexes in our analyses of body size and cranial morphology. All morphometric analyses were done with SYSTAT® 9 programs (SPSS Inc.).

A. Tamias ruficaudus

We assessed pelage colour and morphometric differences in body, cranial, bacular, and baubellar measurements in two samples: *T. r. simulans* from the southern Selkirk Mountains of British Columbia and *T. r. ruficaudus* from the southern Rocky Mountains of British Columbia and Alberta (see Appendix 3-1). Sample sizes were inadequate to assess possible geographic variation within these subspecies in Canada. Because *T. r. simulans* and *T. amoenus luteiventris* cannot be discriminated reliably from cranial or pelage traits (see Chapter 2), we restricted our sample of *T. r. simulans* to 28 specimens identified from either genital bone preparations or radiographs that revealed images of genital bones preserved in their study skins. Our sample of *T. r. ruficaudus* consisted of 22 specimens identified from genital bones (preparations or radiographs) and an additional 12 specimens lacking genital bones that were verified from cranial measurements using the discriminant function described in Chapter 2. All were classified as *T. r. ruficaudus* with probabilities of 0.97 to 1.0. Details on the samples of genital bones, study skins, and skulls used in the analyses are summarized in Appendix 3-1.

We assessed fur colour from the underside of the tail in 23 *T. r. simulans* and 31 *T. r. ruficaudus*. Colour codes were based on colour charts in Smithe (1974, 1975, 1981). We calculated standard univariate statistics and compared means of bacular measurements of the two taxa with paired t-tests based on separate group variances and Bonferonni adjusted probabilities. As an ordination technique, we assessed the bacular data (log transformed) with a principal components analysis using a variance-covariance matrix. With this technique data are treated as a single statistical sample with no *a priori* assumptions of groups. Univariate statistics were calculated for body and cranial measurements; we compared means among the two taxa with one-way analyses of variance. Cranial measurements were also assessed with a mulivariate analysis of variance (MANOVA) and a two-group discriminant analysis. A jack-knife procedure (leave-one-out method) was used as a cross-validation technique to assess classification error in our discriminant functions (Lance et al. 2000). Because multivariate methods require full data sets, we excluded specimens missing more than one measurement from the discriminant analyses. A single specimen was missing a value for zygomatic breadth. We estimated a value for this variable with a maximum likelihood algorithm. Our sample for the discriminant analysis consisted of 26 *T. r. simulans* and 30 *T. r. ruficaudus.*

B. Tamias minimus

We assessed variation in genital bone morphology and cranial morphology among selected samples of *T. m. selkirki*, *T. m. oreocetes,* and *T. m. borealis* from British Columbia and south-western Alberta. Bacular variation was analyzed in three samples: 1)

T. m. selkirki from the Purcell Mountains of British Columbia, 2) *T. m. oreocetes* from the Sheep River and Middle Kootenay Pass in the southern Rocky Mountains of British Columbia and Alberta, and 3) *T. m. borealis* from Fort Nelson in northeastern British Columbia. Because there are no baubellar preparations associated with historical museum specimens of *T. minimus* from western Canada, the analysis of baubellar variation was limited to the samples of voucher specimens of *T. m. selkirki* and *T. m. oreocetes* taken 1997-1998 from the Purcell and southern Rocky Mountains of British Columbia. We used five samples to evaluate geographic variation in cranial morphology: 1) *T. m. selkirki* from the Purcell Mountains, British Columbia; 2) *T. m. oreocetes* from the Sheep River area, Rocky Mountains, Alberta; 3) *T. m. borealis* from Banff National Park, Rocky Mountains, Alberta; 4) *T. m. borealis* from Jasper National Park, Rocky Mountains, Alberta, and 5) *T. m. borealis* from Fort Nelson in northern British Columbia. Only specimens taken from the north side of the Bow River were included in the Banff sample (see Banfield 1958; Meredith 1975). The Fort Nelson sample was in the Taiga Plains ecoprovince east of the northern Rocky Mountains. Details on the samples of genital bones and skulls used in the analyses are summarized in Appendix 3-2.

We calculated standard univariate statistics and compared means of bacular and cranial variables with one-way analyses of variance (ANOVA). Post hoc comparisons of pairs of means were done Tukey's studentized range statistic. Baubellar data were too few for significance tests. Bacular and cranial measurements were also assessed with a mulivariate analysis of variance (MANOVA) and a canonical variate analysis. Because multivariate methods require full data sets, we excluded skulls missing more than one measurement from the discriminant analyses. For specimens missing single variables, we estimated their values with a maximum likelihood algorithm. Our sample for the discriminant analysis consisted of Purcells-14, Sheep River-50, Banff-20, Jasper-28, Fort Nelson-12.

RESULTS

A. Tamias ruficaudus

The two subspecies demonstrated pronounced differences in pelage colour. *T. r. ruficaudus* skins had a dark reddish wash in the dorsal pelage that extended along the shoulders and nape. The colour of the underside of the tail was bright rufous ranging from Raw Sienna to Antique Brown (Fig. 3-1). *T. r. simulans* tended to be duller than *T. r. ruficaudus*. Their skins lacked the bright rufous wash on the shoulders and nape. The colour of the underside of the tail was paler ranging from Cinnamon to Antique Brown (Fig. 3-1). For photographs of study skins of the two taxa see Chapter 2 .

T. r. ruficaudus and *T. r. simulans* differed in 5 of 9 bacular measurements (Table 3-1). A bivariate plot of component scores for the 19 specimens on the first two principal components (Fig. 3-2) revealed no overlap among the two samples on the first axis but substantial overlap on the second axis. Component correlations for the first principal component derived from the nine bacular measurements for the 19 specimens demonstrated that this vector described a pattern of variation that mainly contrasted increasing keel height, basal width, neck width, and shaft bend with decreasing total length and shaft length. *T. r. simulans* differed from *T. r. ruficaudus* in having shorter, broader, and more robust bacula. Representative bacula of the two subspecies are

illustrated in Chapter 2. In total, the two components accounted for 77.14% of the variation in the bacular data with the first component accounting for most (62.26%).

Sample sizes of baubella were too small to test for differences among their means (Table 3-2) but the two samples showed no overlap in their ranges for total length and width of the base (Fig. 3-3). *T. r. simulans* differed from *T. r. ruficaudus* in having longer and broader baubella. Representative baubella of the two subspecies are illustrated in Chapter 2.

The two samples differed in 3 of 5 body measurements (Table 3-3). *T. r. ruficaudus* was larger than *T. r. simulans* for 8 of 10 cranial measurements. The MANOVA revealed that the centroids of the two taxa were different (Wilk's Lambda = 0.279, F=11.642, P<0.0001). The canonical discriminant function described a pattern of variation that contrasted increasing interorbital width and diagonal length of the orbit with decreasing maxillary toothrow length. Discriminant scores for the two groups separated clearly on the discriminant vector (Fig. 3-4) with only one individual of each subspecies overlapping scores from the other group. The jack-knifed analysis correctly classified 28 of 30 (93%) *T. r. ruficaudus* and 22 of 26 (85%) *T. r. simulans*.

B. Tamias minimus

Bacular measurements showed minor differences among the three samples (Table 3-4); nevertheless, the MANOVA demonstrated pronounced differences among the three group centroids (Wilks' lambda= 0.041, F=5.213, P=0.0001). The canonical variate analysis revealed three discrete groups. The first axis accounted for 89% of the variation and it clearly separated the northern sample of *T. m. borealis* from *T. m. selkirki* and *T. m. oreocetes*. This vector described a pattern of variation that contrasted increasing tip width with decreasing keel height, tip angle, and neck width. The second axis accounted for about 10% of the variation and it separated *T. m. selkirki* from *T. m. oreocetes*. This vector contrasted increasing total length and basal width with decreasing shaft and tip length. The two canonical variates essentially accounted for the entire variation in the bacular data. *T. m. oreocetes* had a longer baubellum than *T. m. selkirki* (Table 3-5) but the small sample sizes prohibited a rigorous analysis of population variation in this structure.

Body and cranial measurements for the five groups are summarised in Table 3-6. Means of the 6 body and 10 cranial measurements differed among the five samples. Generally the five groups demonstrated considerable overlap, but 6 of 10 cranial measurements for the Purcells sample formed unique subsets (Table 3-6). The univariate statistics suggest a clinal pattern with cranial and body size increasing with latitude especially among the samples from the Rocky Mountains. A MANOVA demonstrated marked differences among the five group centroids (Wilks' lambda= 0.193, F=5.680, P<0.0001).The first two canonical variates from the cranial data (Fig. 3-6) summarised 89.7% of the variation among the groups with the first canonical variate accounting for 80.5%. The ordination of the five samples on the first two canonical variates shows no discrete non-overlapping groups. Skulls from the Purcells fall to left of the plot but overlap to some extent with the Sheep River and Banff samples. The three samples from the Rocky Mountains (Sheep River, Banff, Jasper) and the Fort Nelson sample overlap substantially with no evidence for any morphometric discontinuities in the Rocky Mountains.

DISCUSSION

A. Tamias ruficaudus

Two distinct bacular morphs of *T. ruficaudus* occur in western Canada. Their morphology and geographic distribution is concordant with the pattern described by Patterson and Heaney (1987) for the two subspecies (*T. r. simulans*, *T. r. ruficaudus*) in Washington, Idaho, and Montana. Although several researchers (White 1953, Patterson and Heaney 1987) have used the baculum of *T. ruficaudus* as a taxonomic character, there has been no comparable study on the baubellum or os clitoris bone, the homologous female structure. Sutton (1982) examined six *T. r. simulans* and a single *T. r. ruficaudus*, but he pooled measurements from both taxa in his description and he illustrated the baubellum only for *T. r. simulans*. Samples are small, but our data demonstrate that the baubellum also differs among these two taxa. Baubellar variation should be assessed in other populations to determine if there are two distinct morphs concordant with the patterns of bacular variation.

The northern populations of *T. r. ruficaudus* and *T. r. simulans* are also differentiated in cranial morphology and pelage colour. In Canada, *T. r. simulans* exhibits greater differences in cranial and pelage morphology from *T. r. ruficaudus* than it does from contiguous or parapatric populations of *T. amoenus*. A similar pattern was reported by Sutton and Patterson (2000) for *Tamias siskiyou* and *Tamias senex* in California where inland and coastal forms of the two species taxa resemble each other more than inland and coastal populations of the same species. Although *T. r. ruficaudus* and *T. r. simulans* from the central core area of the range overlap in cranial morphology (Patterson and Heaney 1987), Canadian populations show little morphological overlap. These northern forms of *T. ruficaudus* appear to represent two extremes in a clinal pattern of increasing cranial size that extends from the Selkirk Mountains of Washington and British Columbia to the Rocky Mountains of northern Montana and Canada. This cranial variation may reflect natural selection or ecophenotypic variation associated with some environmental or ecological gradient. According to Patterson (1981, 1983) cranial morphology in chipmunks largely reflects ecological conditions.

Patterns of geographic variation in pelage colour among *T. ruficaudus* populations across the range have not been assessed quantitatively. *T. r. simulans* is generally described as being paler and less rufous than *T. r. ruficaudus* (Howell 1922, 1929; Best 1993). Gambs (1965) reported clinal variation in the intensity of the ventral tail colour among populations in the United States. According to Gambs (1965) populations at the extremes show marked differences in tail colour but populations from the core of the range evidently converge in pelage colour. The colour differences shown by *T. r. ruficaudus* and *T. r. simulans* in Canada are consistent with this pattern. Patterns in geographic variation in pelage colour among chipmunk populations are usually interpreted as a response to selection for camouflage (Patterson 1984, Sutton and Patterson 2000). The dull pelage of *T. r. simulans* in British Columbia is concordant with selection for concealing colouration against a dark background. The Selkirk Mountains of British Columbia are in an interior wet belt region with high precipitation. Most *T. r. simulans* occurrences are from the interior cedar-hemlock biogeoclimatic zone where forests are dominated by western redcedar and western hemlock (Meidinger and Pojar

1991). Dark or dull pelage is common trait of chipmunks populations associated with humid coastal forests (Sutton and Patterson 2000).

The maps in Gambs (1965), Hall (1981), and Patterson and Heaney (1987) imply that the distributions of *T. r. simulans* and *T. r. ruficaudus* are in contact in extreme southern British Columbia. Our data (see Chapter 4) show no evidence for a northern contact zone in Canada. At the northern edge of their range, the two taxa appear to be allopatric separated by about 180 kilometres. This pattern is probably a legacy of postglacial dispersal by these two taxa. The southern Columbia and Rocky Mountains of Canada were covered by the Cordilleran ice sheet during the last glaciation; glacial retreat in this region began by about 13,000 to 12,000 BP (Clague 1981). We hypothesize that the two northern forms of *T. ruficaudus* were derived from separate source populations that were isolated south of the Cordilleran ice sheet in the United States during the last glaciation. Isolated by physiographic barriers associated with the Kootenay River system in the Rocky Mountain Trench and the Creston Valley and intervening populations of *T. amoenus* in the Purcell Mountains, Canadian populations of *T. r. ruficaudus* and *T. r. simulans* have probably been allopatric throughout the entire Holocene.

A study of mtDNA by Good and Sullivan (in press), demonstrated distinct western and eastern haplotypes of *T. ruficaudus* that are concordant with the distribution of the *T. r. ruficaudus* and *T. r. simulans* bacular forms. The only contact zone between *T. r. simulans* and *T. r. simulans* where the critical test of introgression or hybridization can be made is in central Idaho and western Montana (Hall 1981, Patterson and Heaney 1987). Patterson and Heaney (1987) found no intergrades in bacular morphology in this region suggesting that *T. r. simulans* and *T. r. ruficaudus* were incipient or sibling species. But their geographic coverage was spotty. Good and Sullivan (2001), however, reported some introgression in mtDNA in a contact zone in the Clearwater drainage of central Idaho. Some males with *T. r. ruficaudus* haplotypes evidently had the *T. r. simulans* bacular form. Until more research is done to assess hybrization in the contact zone, it is prudent to treat *T. r. simulans* and *T. r. ruficaudus* as two well differentiated subspecies. From the perspective of conservation biology, it may be a mute point if these two forms represent sibling species or distinct subspecies. In Canada, the two taxa differ in genital bone morphology, cranial morphology, pelage colour, distribution, and ecology (see Chapter 4). Therefore, it is appropriate to consider them as separate evolutionary significant units for management or conservation.

B. Tamias minimus

Clifford Carl and George Hardy first discovered the isolated population of *T. minimus* in the Purcell Mountains of British Columbia in 1944 when they collected two specimens from the Paradise Mine west of Invermere (Carl and Hardy 1945). They assigned their specimens to the subspecies *T. m. oreocetes*; however, in his unpublished field notes Carl noted that they may represent a new undescribed subspecies. Based on the two RBCM specimens and three additional specimens taken in 1945, Cowan (1946) formally described and named this isolated population in the Purcell Mountains as *T. m. selkirki.* Cowan's criteria were based on pelage colour and tail length. His conclusion that *T. m. selkirki* has a shorter tail is not supported by our data (Table 3-6). We did not assess variation in pelage colour among our five groups. There are few adult study skins of *T. m.*

oreocetes in museum collections. The large sample from Sheep River for example collected as part of Sheppard's (1965) dissertation research, consists of skulls that lack associated skins. Although *T. m. selkirki* may be brighter than *T. m. borealis* with paler feet, and narrower median stripes (Cowan 1946), it is difficult to quantify these differences and to separate variation associated with seasonal moults.

Our morphometric analysis, however, suggest that *T. minimus* in the Purcell Mountains are differentiated from populations in the adjacent Rocky Mountains and lends support to Cowan's (1946) classification of this population as a distinct subspecies. The divergence in bacular morphology is noteworthy as various researcher have noted its importance as a taxonomic character in chipmunks (Patterson 1984; Sullivan 1985; Sullivan and Peterson 1988). Although the multivariate patterns of cranial variation show no non-overlapping groups, *T. minimus* from the Purcell Mountains demonstrate some divergence from the Rocky Mountains populations. Interestingly, the Fort Nelson population which is about 700 km north of the Banff and Jasper samples, shows less divergence from the Rocky Mountain populations than the population in the Purcell Mountains.

Known from only two localized areas above treeline (see Chapter 4), *T. m. selkirki* is allopatric with other populations of *T. minimus* in western Canada. Nearest populations of *T. minimus* in the Rocky Mountains are 80 to 100 kilometres east along the continental divide. They are separated from *T. m. selkirki* by extensive montane and lowland forests inhabited by *T. amoenus* (see Chapter 4) and the isolating barrier of the Columbia River in the Rocky Mountain trench. We hypothesize that *T. m. selkirki* is a relict population that was isolated in alpine habitats of the Purcell Mountains during the early postglacial. Given its broad ecological and habitat affinities (Verts and Carraway 2001) and its adaptation to boreal conditions, *T. minimus* would be expected to be first chipmunk species to colonize a postglacial landscape. It may have been widespread throughout the southern Columbia Mountains and Rocky Mountains in the open forest-tundra habitats associated with the late Pleistocene (Hebda 1995). With the shift to a warm dry period during the early Holocene and the development of pine and spruce forests (Hebda 1995), *T. minimus* was displaced from forested habitats by *T. amoenus* and *T. ruficaudus* through competitive exclusion but managed to persist in alpine landscapes where this species has a competitive and physiological edge (Sheppard 1971; Meredith 1975, 1977).

All of the *T. minimus* associated with the southern Columbia and Rocky mountains in Canada may be derived from a single lineage of that colonized this region in the early postglacial. According to this scenario, *T. m. selkirki* diverged from the Rocky Mountain populations during the past 10,000 to 12,000 years in response to selection pressures associated with minor environmental differences or genetic drift in a small isolated population. It is debatable that such recent divergence warrants recognition taxonomically as a subspecies. Smith and Patton (1988) supported the subspecies concept if it was applied to evolutionary units that share similar morphological and genetic traits, and a common biogeographic history rather than local variants attributable to genetic drift in small populations. Patterson (1980) described a subspecies of *Tamias quadrivittatus* from the Organ Mountains of New Mexico that he attributed to rapid divergence in a small isolated population during Recent time. On the other hand, Patterson (1982) concluded that populations of *T. minimus* in the south-western United States that were isolated from the southern Rocky Mountains in the postglacial demonstrated negligible

differentiation (but see Sullivan 1985). Alternatively, *T. m. selkirki* could represent a separate lineage of *T. minimus* derived from populations that share a separate phylogeographic history from populations in the Canadian Rocky Mountains and northern boreal forests. These competing hypotheses can only be tested with molecular studies.

T. m. oreocetes was described and named by Merriam (1897) as a distinct species (*Eutamias oreocetes*) on the basis of the type specimen taken from the Rocky Mountains of Montana. In his vague description, he distinguished it from *T. minimus* (subspecies not given) by its darker and heavier dorsal stripes and smaller skull. Howell (1922, 1929) reduced this taxon to a subspecies of *T. minimus* (*T. m. oreocetes*); he speculated that it ranged from northern Montana to south-western Alberta. According to Howell (1929), it differs from *T. m. borealis*, the adjacent subspecies in Canada, by: paler dorsal stripes, paler hind feet, a shorter tail, and a shorter skull. Nevertheless, in his remarks Howell (1929) astutely noted: "By reason of the small number of specimens available it is impossible to satisfactorily characterize this form. Most of the specimens are in worn winter pelage, there being but one in fresh summer pelage, and that not entirely complete". Subsequent taxonomic accounts (Crowe 1943; Banfield 1958; Soper 1964) essentially repeat Howell's (1929) diagnostic traits. However, Cowan (1946) described clinal variation in body measurements among small samples of *T. minimus* from the Canadian Rocky Mountains and the Peace River area and suggested that pelage traits were most reliable for distinguishing *T. m. oreocetes* and *T. m. borealis* particularly in their contact zone.

The geographic limits of the distribution of *T. m. oreocetes* in Canada has also been contentious. Cowan (1946) and Cowan and Guiguet (1965) suggested that it was restricted to the extreme southern Rocky Mountains in the Waterton Lakes-Akamina Pass area. The only potential ecological barrier for north-south dispersal by *T. minimus* in that region would be the Crowsnest Pass, a wide low elevation pass (1360 m) that separates alpine habitats by a 4 km-wide gap where populations of *T. amoenus* could isolate alpine populations of *T. minimus*. However, most researchers (Crowe 1943; Banfield 1958; Meredith 1975, 1977) consider the range of *T. m. oreocetes* to extend along the continental divide as far north as Banff and Yoho National parks where it is separated from *T. m. borealis* to the north by the Bow River and Kicking Horse Pass and intervening low elevation populations of *T. amoenus*.

If *T. m. oreocetes* is a valid taxon, then a sharp step-cline delimiting it from *T. m. borealis* would be expected across the Bow River area. Univariate variation in body measurements and multivariate patterns of cranial variation show no evidence for a step-cline or sharp morphometric discontinuity among the Rocky Mountains populations. The patterns of variation are consistent with the clinal trend suggested by Cowan (1946). This cline may reflect selection along an environmental or ecological gradient. Although our samples of *T. m. oreocetes* and *T. m. borealis* differ in bacular morphology, no genital bone samples are available for Rocky Mountain *T. m. borealis* and our analysis was limited to a single sample of *T. m. borealis* from northern British Columbia 700 to 800 km north of the *T. m. oreocetes* bacular sample. Additional samples from intervening areas in the Rocky Mountains may reveal morphological overlap.

Definitive conclusions about the taxonomy of *T. minimus* in the southern Columbia and Rocky Mountains of Canada are hindered by inadequate specimen samples. Bacular

samples from areas in the Rocky Mountains north of the Bow River are essential to evaluate bacular morphology among the Rocky Mountain populations. As most of this region falls within the boundaries of Banff and Jasper national parks, acquiring new specimen material is likely impossible. Radiographs of historical museum specimens collected in Banff and Jasper that are housed in the Canadian Museum of Nature revealed preserved genital bones in some skins. It is conceivable that these can be removed from the skin, cleared, and stained for measurement. A sample of skull and bacular specimens from the extreme southern Rocky Mountains is also needed to evaluate Cowan and Guiguet's (1965) proposed distributional limit south of Crowsnest Pass for *T. m. oreocetes*. *T. minimus* specimens available from this region consist only of our vouchers taken at Middle Kootenay Pass in 1998 and a few historical museum specimens from Waterton Lakes National Park. These collections comprise only 6 adult skulls and 4 bacular specimens-too few to use as a separate group in our analyses.

Molecular studies with allozymes and DNA are also essential to resolve the systematics of *T. m. selkirki* and *T. m. oreocetes*. Tissue samples for DNA analysis were collected from our voucher specimens of *T. m. selkirki* and *T. m. oreocetes* taken in 1997-98. Although the RBCM has no facilities for DNA analysis, the tissues are being stored for potential future research. Piaggio and Spicer (2000) reported high divergence in mitochondrial DNA among several subspecies of *T. minimus*. Their results suggest that *T. minimus* may consist of several distinct phylogeographic lineages.

CONCLUSIONS

1. In Canada at the northern periphery of their distributions, *T. r. ruficaudus* and *T. r. simulans* differ in male and female genital morphology, cranial morphology, and pelage colour. The genital bone morphology of these northern forms is concordant with the occurrence of two non-overlapping morphs throughout the range; their differences in pelage and cranial morphology are consistent with clinal patterns that are associated with ecological or environmental gradients.

2. Because the northern forms of *T. ruficaudus* are allopatric, the only potential contact zone for testing introgression is in Idaho and Montana. Until detailed genetic studies are done in the contact zone, taxonomic status of the two forms is unresolved. However, because they differ in morphology, distribution, and ecology the Canadian populations of *T. r. ruficaudus* and *T. r. simulans* should be treated as distinct evolutionary units for conservation and management.

3. Inadequate samples prohibit definitive conclusions on the taxonomy of *T. minimus* in the southern Columbia and Rocky Mountains of Canada. Existing data demonstrate that *T. m. selkirki* is differentiated from Rocky Mountain populations of *T. minimus* in male genital bone (bacula) morphology and cranial morphology. Because it is allopatric separated by 100 km from *T. minimus* in the Rocky Mountains and represents a relict population, we recommend that it be considered a distinct taxonomic unit. Molecular studies are needed to evaluate genetic divergence in this population.

4. There are inadequate bacular samples from Rocky Mountain *T. minimus* populations to assess geographic variation in male genital bone morphology, but univariate analysis of

body measurements and multivariate analyses of cranial morphology suggest clinal patterns with no evidence for a step-cline across the Bow River the putative boundary between *T. m. oreocetes* and *T. m. borealis*. Given this pattern of clinal variation in the Rocky Mountains, the taxonomic validity of *T. m. oreocetes* is dubious. However, until more bacular samples are obtained and molecular studies are done, it is prudent to continue to recognize populations south of the Bow River and Kicking Horse pass in the Canadian Rocky Mountains as a separate subspecies, *T. m. oreocetes*.

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Table 3-1. Bacular measurements (means ±1 standard deviation, ranges) for the two subspecies of the Red-tailed Chipmunk (*Tamias ruficaudus*) from the southern Selkirk Mountains and Rocky Mountains of British Columbia and Alberta. Linear measurements in millimetres, tip angle in degrees. Based on specimens taken in 1996-99 and historical museum specimens.

Measurement	***T. r. ruficaudus* (N=8)**		***T. r. simulans* (N=11)**		**Student's t-test**	
	Mean	Range	Mean	Range	*t*	*P*
Total length	5.10±0.09	4.74-5.52	4.14±0.21	3.82-4.48	9.056	<0.001
Shaft length	4.41±0.08	4.07-4.74	3.58±0.07	3.43-3.70	11.897	<0.001
Tip length	1.56±0.04	1.37-1.74	1.65±0.06	1.52-1.75	-2.277	ns
Base width	0.77±0.03	0.63-0.93	0.86±0.06	0.75-0.93	-2.579	ns
Tip width	0.59±0.02	0.52-0.67	0.56±0.05	0.54-0.67	1.456	ns
Shaft bend	0.55±0.01	0.52-0.59	0.62±0.04	0.56-0.70	-4.243	0.005
Neck width	0.27±0.01	0.22-0.30	0.34±0.04	0.29-0.41	-4.491	0.003
Keel height	0.51±0.01	0.48-0.52	0.60±0.03	0.56-0.67	-6.815	<0.001
Tip angle	121.4±2.0	118.0-124.0	120.1±2.94	116.0-125.0	1.092	ns

Table 3-2. Baubellar measurements (means ±1 standard deviation, ranges) for the two subspecies of the Red-tailed Chipmunk (*Tamias ruficaudus*) from the southern Selkirk Mountains and Rocky Mountains of British Columbia and Alberta. All measurements in millimetres. Based on specimens taken in 1996-99.

Measurement	***T. r. ruficaudus* (N=8)**		***T. r. simulans* (N=3)**	
	Mean	Range	Mean	Mean
Total length	2.25±0.19	2.00-2.56	2.90±0.28	2.73-3.22
Base width	0.52±0.03	0.47-0.56	0.64±0.02	0.62-0.67
Flange length	0.92±0.07	0.82-1.02	0.98±0.12	0.84-1.09
Keel height	0.45±0.04	0.40-0.53	0.48±0.01	0.47-0.49

Table 3-3. Body measurements, weights, and cranial measurements (means ±1 standard deviation, ranges) for the two subspecies of the Red-tailed Chipmunk (*Tamias ruficaudus*) from the southern Selkirk Mountains and Rocky Mountains of British Columbia and Alberta. Weights in grams, linear measurements in millimetres. Based on voucher specimens taken 1996-99 and historical museum specimens.

Measurement	***T. r. ruficaudus***			***T. r. simulans***			**ANOVA**	
	Mean	Range	N	Mean	Range	N	*F*	*P*
Total length	222.4±8.8	207-235	32	225.8±6.3	216-237	22	2.85	ns
Body length	127.5±7.8	114-145	31	123.9±6.0	116-135	23	2.71	ns
Tail length	94.7±4.5	85-102	31	102.1±5.9	93-115	22	24.47	<0.001
Hind foot	33.7±1.1	32-36	23	33.0±1.3	30-35	28	3.31	Ns
Ear	17.1±1.5	14-19	16	15.8±1.7	13-19	23	6.03	0.019
Weight	66.0±5.8	53.5-78.7	16	54.7±4.8	44.2-64.6	22	45.07	<0.001
Greatest length	35.3±0.54	34.0-36.1	31	34.1±0.71	32.3-35.5	26	39.74	<0.001
Zygomatic breadth	19.6±0.34	18.9-20.2	31	19.0±0.35	18.4-19.6	26	35.92	<0.001
Nasal length	11.0±0.30	10.2-11.7	34	10.7±0.54	9.2-11.5	27	7.14	0.010
Maxillary toothrow length	5.5±0.14	5.2-5.8	34	5.4±0.23	4.8-5.8	28	1.55	ns
Interorbital width	7.5±0.25	6.8-7.8	33	7.2±0.23	6.6-7.6	28	18.96	<0.001
Nasal width	3.0±0.22	2.7-3.5	33	3.0±0.23	2.5-3.4	28	2.78	ns
Diagonal length of orbit	8.5±0.22	8.0-8.9	33	8.1±0.27	7.5-8.6	27	47.84	<0.001
Cranial depth	14.4±0.26	13.8-14.9	31	13.9±0.26	13.4-14.4	26	41.71	<0.001
Mandibular length	19.3±0.30	18.5-19.8	33	18.7±0.38	18.0-19.6	28	49.33	<0.001
Coronoid height	10.2±0.30	10.2-11.6	33	10.7±0.42	9.9-11.3	28	22.05	<0.001

Table 3-4. Bacular measurements (means ±1 standard deviation, ranges) for three subspecies of the Least Chipmunk (*Tamias minimus*) from British Columbia and Alberta. Linear measurements in millimetres, tip angle in degrees. Based on specimens taken in 1996-99 and historical museum specimens.

Measurement	***T. m. selkirki* (N=9)**		***T. m. oreocetes* (N=7)**		***T. m. borealis* (N=7)**	
	Mean	Range	Mean	Range	Mean	Range
Total length	3.10±0.08	2.93-3.22	3.00±0.15	2.78-3.19	3.10±0.10	2.96-3.22
Shaft length	2.70±0.07	2.59-2.78	2.70±0.12	2.56-2.85	2.79±0.09	2.67-2.89
Tip length	0.63±0.06	0.56-0.70	0.68±0.02	0.67-0.70	0.76±0.06	0.67-0.85
Base width	0.44±0.04	0.37-0.52	0.43±0.07	0.33-0.52	0.49±0.05	0.41-0.56
Tip width	0.34±0.04	0.30-0.41	0.31±0.04	0.26-0.37	0.31±0.04	0.26-0.37
Shaft bend	0.23±0.03	0.19-0.26	0.21±0.03	0.19-0.26	0.25±0.03	0.22-0.30
Neck width	0.13±0.02	0.11-0.15	0.13±0.03	0.11-0.19	0.17±0.03	0.15-0.22
Keel height	0.23±0.02	0.22-0.26	0.23±0.04	0.19-0.30	0.26±0.04	0.22-0.30
Tip angle	136.6±1.0	135.0-138.0	139.0±4.61	129.0-141.0	141.4±2.57	138.0-145.0

Table 3-5. Baubellar measurements (means ±1 standard deviation, ranges) for the two subspecies of the Least Chipmunk (*Tamias minimus*) from the southern Selkirk Mountains and Rocky Mountains of British Columbia. All measurements in millimetres. Based on specimens taken in 1996-99.

Measurement	***T. m. selkirki* (N=5)**		***T. m. oreocetes* (N=4)**	
	Mean	Range	Mean	Mean
Total length	0.92±0.02	0.91-0.96	1.02±0.07	0.91-1.07
Base width	0.28±0.03	0.24-0.31	0.30±0.02	0.27-0.31
Flange length	0.46±0.20	0.44-0.49	0.46±0.02	0.44-0.49
Keel height	0.14±0.02	0.11-0.16	0.18±0.06	0.13-0.27

Table 3-6. Body measurements, weights, and cranial measurements (means ±1 standard deviation, sample sizes in parentheses) for five samples of the Least Chipmunk (*Tamias minimus*) from British Columbia and Alberta. Weights in grams, linear measurements in millimetres. Purcells= *T. m. selkirki;* Sheep River=*T. m. oreocetes*; Banff, Jasper, Fort Nelson=*T. m. borealis.* Asterisks denote the probablity of equality of means based on one-way ANOVA's. Letters in superscript define non-significant (*P*>0.05) subsets of groups determined by Tukey's studentized range statistic.

Measurement	Purcells, BC		Sheep River, AB		Banff, AB		Jasper, AB		Ft. Nelson, BC	
Total length ***	185.5±6.0^{a}	(14)	191.9±8.7^{ab}	(46)	195.3±8.9^{bc}	(18)	206.0±6.2^{d}	(23)	203.2±5.4^{cd}	(13)
Body length ***	105.6±4.0^{a}	(14)	112.3±4.7^{bd}	(47)	113.4±5.4^{bd}	(18)	119.4±8.6^{c}	(23)	111.3±6.2^{bd}	(14)
Tail length ***	80.6±5.1^{a}	(15)	79.6±5.8^{ab}	(46)	81.9±7.6^{ab}	(18)	86.6±8.6^{acd}	(23)	92.6±3.0^{cd}	(14)
Hind foot *	30.6±4.0^{a}	(15)	31.1±0.9^{ab}	(49)	31.2±1.0^{a}	(18)	31.6±1.3^{a}	(25)	31.1±1.2^{ab}	(15)
Ear ***	14.0±1.2^{a}	(12)	15.8±1.0^{a}	(49)	14.5±0.9^{a}	(10)	14.6±0.7^{a}	(16)	15.0±1.3^{a}	(11)
Weight **	41.4±4.0^{a}	(12)	43.9±4.3^{a}	(50)	42.7±3.9^{a}	(5)	53.8±8.7^{c}	(16)	45.9±7.7^{a}	(13)
Greatest length***	31.3±0.36^{a}	(14)	31.8±0.47^{bd}	(50)	32.3±0.50^{cd}	(18)	32.7±0.6^{cd}	(28)	32.2±0.38^{bcd}	(12)
Zygomatic breadth ***	17.8±0.36^{a}	(14)	18.1±0.29^{b}	(45)	18.2±0.34^{bc}	(20)	18.5±0.34^{d}	(25)	18.3±0.36^{bcd}	(12)
Nasal length ***	9.0±0.36^{a}	(15)	9.2±0.33^{b}	(50)	9.5±0.29^{bc}	(19)	9.7±0.45^{d}	(28)	9.6±0.26^{bcd}	(12)
Maxillary toothrow length ***	4.9±0.15^{a}	(15)	4.9±0.17^{ab}	(50)	4.9±0.15^{abc}	(20)	5.1±0.16^{acd}	(28)	5.1±0.14^{acd}	(13)
Interorbital width ***	6.9±0.25^{a}	(14)	6.6±0.29^{ab}	(50)	6.7±0.21^{abc}	(20)	7.0±0.31^{ad}	(28)	6.7±0.31^{abcd}	(13)
Nasal width ***	2.1±0.19^{a}	(15)	2.1±0.14^{ab}	(50)	2.2±0.19^{abc}	(20)	2.3±0.26^{cd}	(28)	2.4±0.12^{cd}	(13)
Diagonal length of orbit **	7.3±0.29^{a}	(15)	7.4±0.32^{ab}	(50)	7.6±0.31^{b}	(20)	7.6±0.31^{b}	(28)	7.6±0.23^{b}	(12)
Cranial depth **	12.9±0.29^{a}	(12)	13.1±0.22^{b}	(49)	13.3±0.23^{bc}	(18)	13.4±0.21^{c}	(27)	13.5±0.30^{c}	(11)
Mandibular length ***	16.7±0.34^{a}	(14)	17.1±0.31^{b}	(50)	17.3±0.44^{bc}	(20)	17.7±0.34^{d}	(28)	17.3±0.36^{bc}	(13)
Coronoid height ***	9.2±0.36^{a}	(14)	9.8±0.30^{b}	(45)	9.9±0.30^{bc}	(19)	10.4±0.22^{d}	(28)	10.1±0.38^{c}	(12)

* $P<0.05$
** $P<0.01$
*** $P<0.001$

Figure 3-1. Bar graph showing ventral tail colour for the two subspecies of the Red-tailed Chipmunk (*Tamias ruficaudus*) from the southern Selkirk Mountains and Rocky Mountains of British Columbia and Alberta. Colours are ordered by decreasing rufous from left to right. Based on voucher specimens and historical museum specimens. Colour names and codes from Smithe (1974, 1975, 1981). Sienna=Raw Sienna(136), Amber= Amber (36), Robin=Robin Rufous, Antique=Antique Brown (37), Mikado=Mikado Brown (121C), Cinammon=Cinnamon (123).

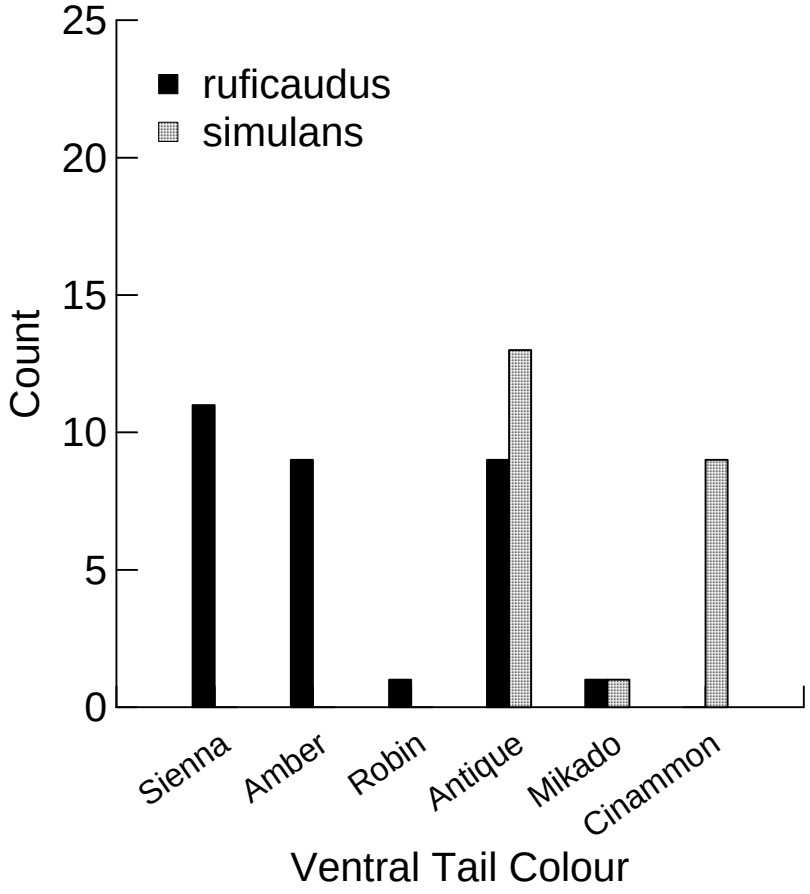


Figure 3-2. Projection of 19 bacular specimens of the Red-tailed Chipmunk (*Tamias ruficaudus*) from the southern Selkirk Mountains and Rocky Mountains of British Columbia and Alberta on the first two principal components derived from 9 bacular measurements. R= *T. r. ruficaudus*, S= *T. r. simulans*. Representative bacula all drawn to same scale.

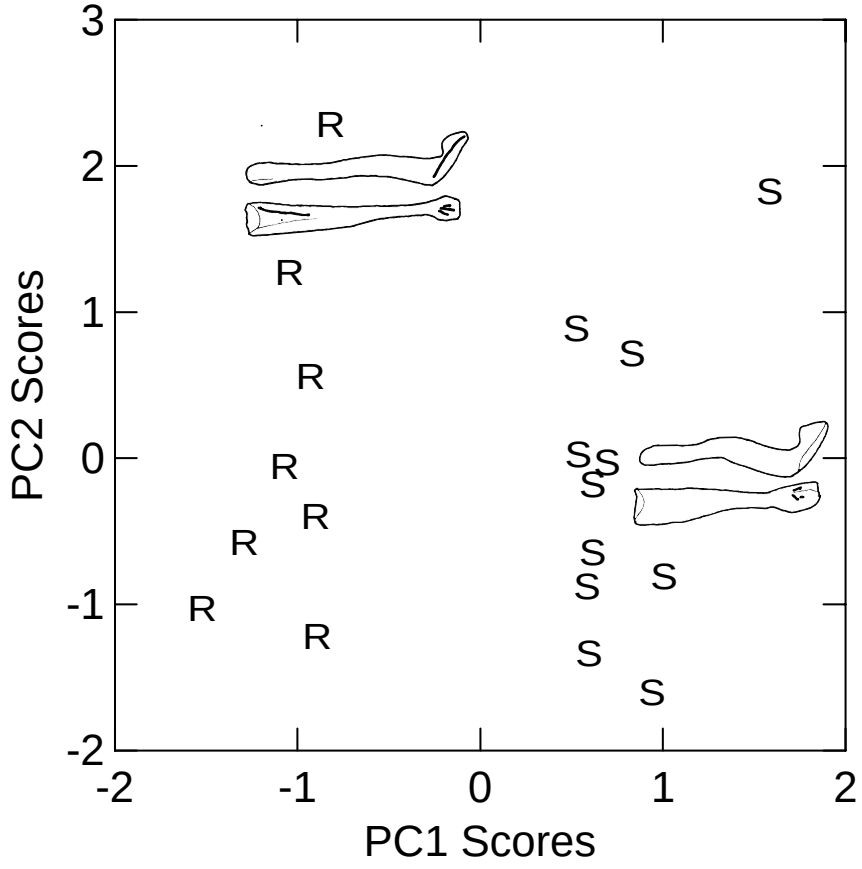


Figure 3-3. Bivariate plot of 11 baubellar specimens of the Red-tailed Chipmunk (*Tamias ruficaudus*) from the southern Selkirk Mountains and Rocky Mountains of British Columbia and Alberta. R= *T. r. ruficaudus*, S= *T. r. simulans*. Representative baubella all drawn to same scale.

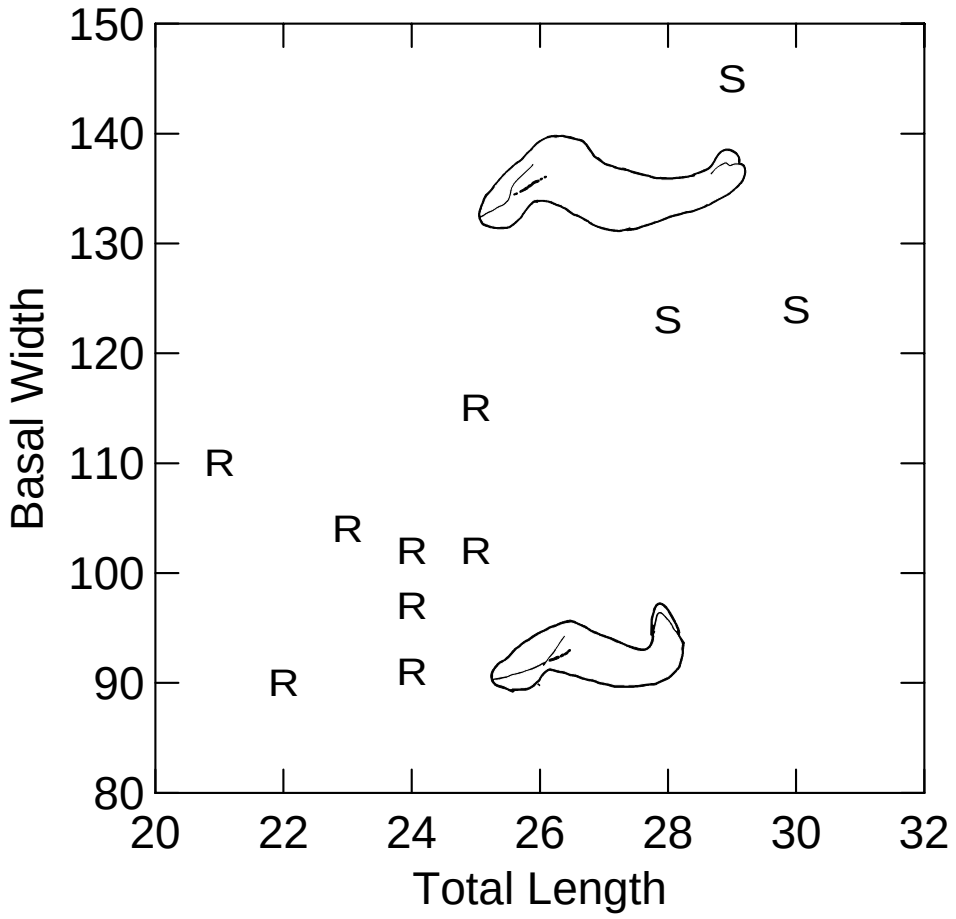


Figure 3-4. Histograms of discriminant scores for 30 *T. r. ruficaudus* and 26 *T. r. simulans* from the southern Selkirk Mountains and Rocky Mountains of British Columbia and Alberta. Based on a two-group discriminant analysis with 10 cranial variables.

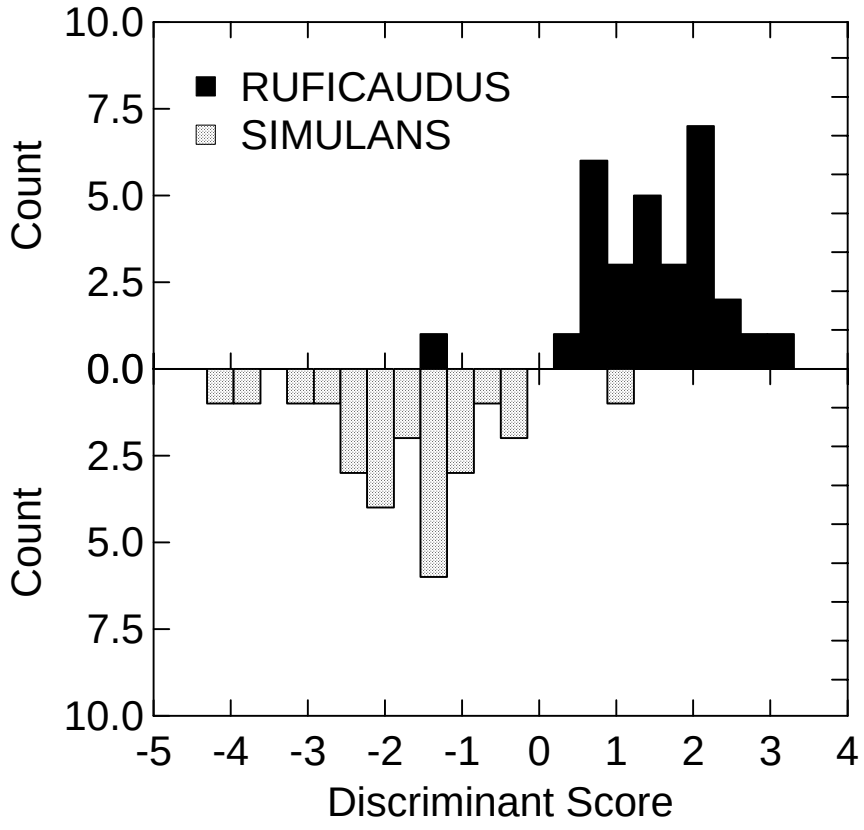


Figure 3-5. Projection of three bacular samples of the Least Chipmunk (*Tamias minimus*) on the first two canonical variates derived from nine bacular measurements. *T. m. selkirki*= Purcell Mountains, southern British Columbia; *T. m. oreocetes*= southern Rocky Mountains, British Columbia and Alberta; *T. m. borealis*= Fort Nelson area, northern British Columbia.

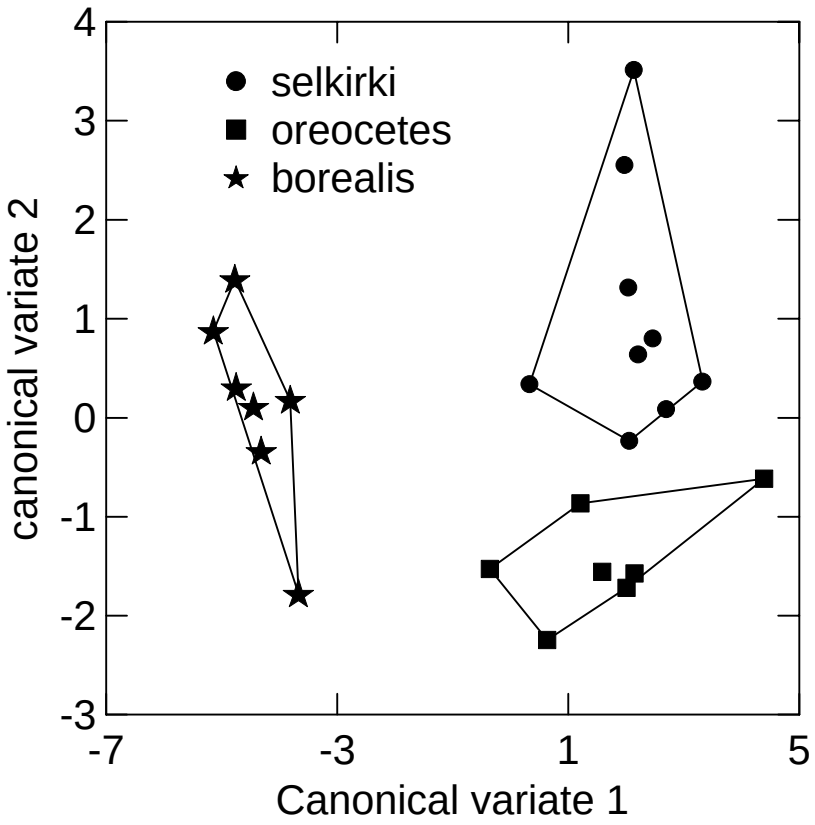
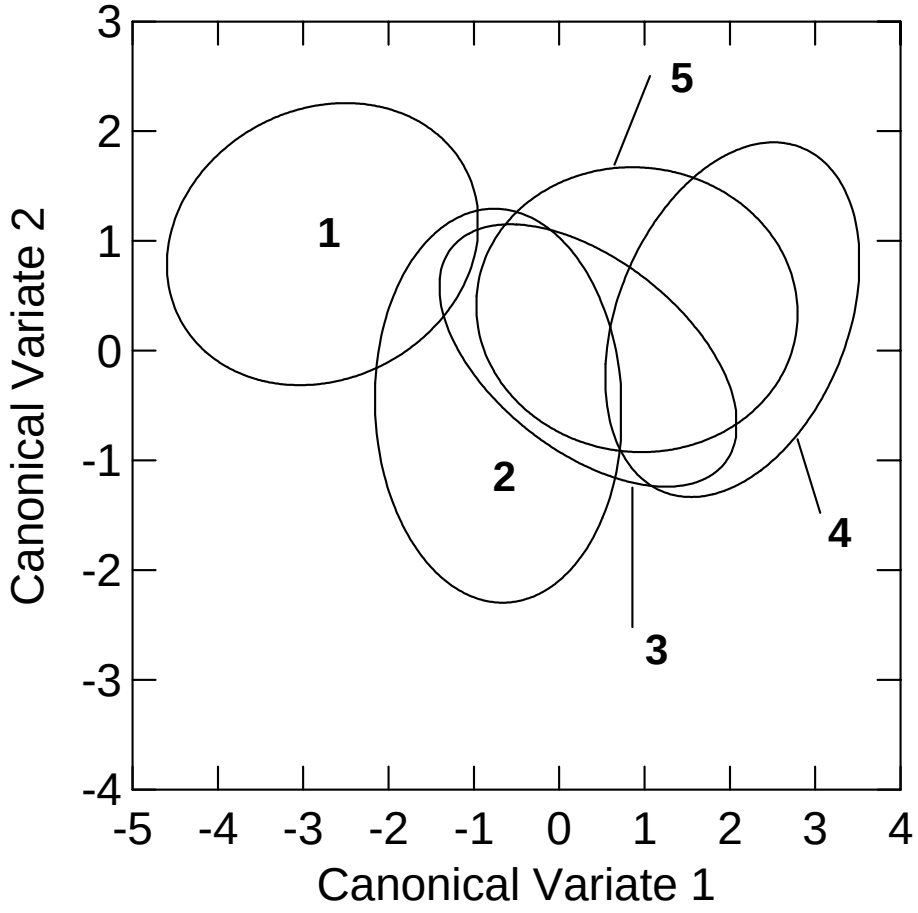


Figure 3-6. Projection of five samples of the Least Chipmunk (*Tamias minimus*) from British Columbia and Alberta on the first two canonical variates derived from 10 cranial measurements. Ellipses are confidence ellipses representing 1 standard deviation around the group centroids. 1=Purcells, BC; 2=Sheep River, AB; 3=Banff, AB; 4=Jasper, AB; 5=Fort Nelson, BC.



APPENDIX 3-1. TAMIAS RUFICAUDUS SPECIMENS EXAMINED

CMN= Canadian Museum of Nature, Ottawa; RBCM= Royal British Columbia Museum, Victoria; ROM= Royal Ontario Museum, Toronto; UAMZ= University of Alberta Museum of Zoology, Edmonton; UBC= Cowan Vertebrate Museum, University of British Columbia. "+"= Male , "*"= Female.

A. Genital Bones

***Tamias ruficaudus simulans* (11 +, 3 *)**

BRITISH COLUMBIA. Church Creek: RBCM 19656 +, RBCM 19667 +. Giveout Creek: RBCM 19658 *, RBCM 19660 +, RBCM 19661 +, RBCM 19668 +, RBCM 20038 *. Gold Creek: RBCM 19654 +, RBCM 19655 +, RBCM 20036 *. Kootenay Pass [=Salmo-Creston Summit]: CMN 41277 +, CMN 41282 +, CMN 41286 +. Salmon River [=Salmo River?]: CMN 1008 +.

***Tamias ruficaudus ruficaudus* (8 +, 8 *)**

ALBERTA. Castle River, headwaters: UAMZ 8174 +.
BRITISH COLUMBIA. Middle Kootenay Pass: RBCM 19875 +, RBCM 19880 +. Middlepass Creek: RBCM19885 *, RBCM 19884 +, RBCM 19887 *, RBCM 19906 *, RBCM 19907 +,RBCM 19914 +, RBCM 19915 *, RBCM 19916 +, RBCM 19917 *, RBCM 19918 *, RBCM 19919 *, RBCM 19920 +. Wall Lake: RBCM 19683 *.

B. Study Skins for Pelage

***Tamias ruficaudus simulans* (14 +, 9 *)**

BRITISH COLUMBIA. Boundary Lake: ROM 28444 *. Church Creek: RBCM 19656 +, RBCM 19667 +, RBCM 19668 +. Creston, Kootenay Flats: ROM 28422 *. Giveout Creek: RBCM 19658 *, RBCM 19659 *, RBCM 19660 +, RBCM 19661 +, RBCM 20038 *. Gold Creek: RBCM 19654 +, RBCM 19655 +, RBCM 20036 *. Kootenay Pass [=Salmo-Creston Summit]: CMN 41277 +, CMN 41266 +, CMN 41267 +, CMN 41269 *, CMN 41272 +, CMN 41274 +, CMN 41283 *, CMN 41286 +. West Creston, Kootenay Flats: ROM 28453 +, ROM 28454 *.

***Tamias ruficaudus ruficaudus* (20 +, 11 *)**

ALBERTA. Castle River, headwaters: UAMZ 8174, +. Spionkop Ridge: UAMZ 8154 *. Waterton Lakes National Park [no other data]: UBC 1632 *. Waterton Lakes National Park, Akamina Pass: CMN 18524 +. Waterton Lakes National Park, Cameron Lake: CMN 16010 +, CMN 16018 +, UBC 3547 *. Waterton Lakes National Park, Mount Carthew: CMN 16025.Waterton Lakes National Park, Sage Creek: UBC 1630 +, UBC 1631, +. Waterton Lakes National Park, Sheep Mountain: CMN 4598 +.
BRITISH COLUMBIA. Akamina Pass: RBCM 3571 +, UAMZ 1635 *, UBC 1625 +, UBC 1627 +, UBC 1628 +, UBC 1629 +. Middle Kootenay Pass: RBCM 19875 +, RBCM 19880, +. Middlepass Creek: RBCM 19884 +, RBCM19885 *, RBCM 19887 *, RBCM 19906 *, RBCM 19907 +,RBCM 19914 +, RBCM 19915 *, RBCM 19917 *, RBCM 19918 *, RBCM 19919 *, RBCM 19920 +. Wall Lake: RBCM 19683 *.

C. Skulls

***Tamias ruficaudus simulans* (17 +, 11 *)**

BRITISH COLUMBIA. Boundary Lake: ROM 28444 *. Church Creek: RBCM 19656 +, RBCM 19666 *, RBCM 19667 +, RBCM 19668 +. Creston, Kootenay Flats: ROM 28422 *. Giveout Creek: RBCM 19658 *, RBCM 19659 *, RBCM 19660 +, RBCM 19661 +, RBCM 19662 *, RBCM 20038 *. Gold Creek: RBCM 19654 RBCM 19655 +, RBCM 20036 *. Kootenay Pass [=Salmo-Creston Summit]: CMN 41277 +, CMN 41265 +, CMN 41266 +, CMN 41267 +, CMN 41269 *, CMN 41272 +, CMN 41274 +, CMN 41282 +, CMN 41283 *, CMN 41286 +. West Creston: French's Farm: CMN 10169 +. West Creston, Kootenay Flats: ROM 28453 +, ROM 28454 *.

***Tamias ruficaudus ruficaudus* (14 +, 20 *)**

ALBERTA. Castle River, headwaters: UAMZ 8174, +. Spionkop Ridge: UAMZ 8154 *. Waterton Lakes National Park [no other data]: UBC 1632 *. Waterton Lakes National Park, Akamina Pass: CMN 2889 *, CMN 18524 +, Waterton Lakes National Park, Cameron Lake: CMN 16018 +, CMN 16010 +, UBC 3547 *. Waterton Lakes National Park, Lone Lake: ROM 23112 *. Waterton Lakes National Park, Mount Carthew: CMN 16025. Waterton Lakes National Park, Sage Creek: UBC 1630 +, UBC 1631 +. Waterton Lakes National Park, Sheep Mountain: CMN 4598 +. Waterton Lakes National Park, Summit Lake, CMN 16026 *.

BRITISH COLUMBIA. Akamina Pass: UAMZ 1635 *, UBC 1625 +, UBC 1626 *, UBC 1628 +, UBC 1629 +. Middle Kootenay Pass: RBCM 19875 +, RBCM 19880, +. Middlepass Creek: RBCM19885 *, RBCM 19884 +, RBCM 19887 *, RBCM 19906 *, RBCM 19907 +,RBCM 19914 +, RBCM 19915 *, RBCM 19917 *, RBCM 19918 *, RBCM 19919 *, RBCM 19920 +. Wall Lake: RBCM 19683 *.

APPENDIX 3-2. TAMIAS MINIMUS SPECIMENS EXAMINED

AMNH= American Museum of Natural History, New York; CMN= Canadian Museum of Nature, Ottawa; PMA= Provincial Museum of Alberta, Edmonton; PSM= James Slater Museum, University of Puget Sound, Tacoma; RBCM= Royal British Columbia Museum, Victoria; ROM= Royal Ontario Museum, Toronto; UAMZ= University of Alberta Museum of Zoology, Edmonton; UBC= Cowan Vertebrate Museum, University of British Columbia, Vancouver.

A. Genital Bones

***T. m. selkirki* (9 +, 5 *)**

BRITISH COLUMBIA. Bruce Creek Drainage: RBCM 19924 +; RBCM 19925 +. Mount Brewer: RBCM 19754 *; RBCM 19755 +; RBCM 19758 +; RBCM 19760 *; RBCM 19762 +; RBCM 19765 +; RBCM 19761 *. Paradise Mine: RBCM 19740 +. Springs Creek: RBCM 19741 +; RBCM 19743 *; RBCM 19744 +; RBCM 19745 *.

***T. m. oreocetes* (7 +, 4 *)**

ALBERTA. Sheep River: UAMZ 8180 +; UAMZ 8181 +; UAMZ 8182 +.
BRITISH COLUMBIA. Middle Kootenay Pass: RBCM 19872 +; RBCM 19873 *; RBCM 19876 *; RBCM 19908 +; RBCM 19909 +. Middlepass Creek: RBCM 19912 +; RBCM 19913, *. Todhunter Creek: RBCM 19893 *.

***T. m. borealis* (7 +)**

BRITISH COLUMBIA. Fort Nelson: RBCM 10620 +; RBCM 10621 +; RBCM 10622 +; RBCM 10625 +; RBCM 10626 +; RBCM 10628 +; RBCM 11141 +.

B. Skulls

Sample 1- Purcells (10 +, 5 *)

BRITISH COLUMBIA. Bruce Creek Drainage: RBCM 19924 +; RBCM 19925 +. Mount Brewer: RBCM 19754 *; RBCM 19755 +; RBCM 19758 +; RBCM 19760 *; RBCM 19762 +; RBCM 19765 +. Paradise Mine: Paradise Mine: RBCM 5028 +; UBC 1552 +; CMN 34512 *; RBCM 19740 +. Springs Creek: RBCM 19741 +; RBCM 19743, *; RBCM 19744 +; RBCM 19745 *.

Sample 2- Sheep River (27 +, 23 *)

ALBERTA. Highwood Summit: CMN 41233 *. Sheep River: PSM UAMZ 8180 +, UAMZ 8181 +, UAMZ 8182 +. 10 mile radius of University of Alberta Biological Station: PSM 24590 *,PSM 24592 *, PSM 24593 *, PSM 24594 *, PSM 24595 +, PSM 24596 +, PSM 24597 +, PSM 24598 +, PSM 24599 *, PSM 24600 *, PSM 24601 *, PSM 24602 *, PSM 24603 *, PSM 24604 +, PSM 24606 +, PSM 24609 +, PSM 24610 *, PSM 24611 +, PSM 24613 *, PSM 24616 +, PSM 24618 *, PSM 24621 +, PSM 24622 +, PSM 24623 +, PSM 24624 *, PSM 24627 *, PSM 24629 +, PSM 24630 +, PSM 24631 +, PSM 24633 +, PSM 24633 +, PSM 24634 +, PSM 24635 *, PSM 24637 +, PSM 24638 +, PSM 24642 *, PSM 24645 *, PSM 24649 +, PSM 24653 *, PSM 24658 +, PSM 24662 *, PSM 24664 +, PSM 24667 *, PSM 24668 *.

Sample 3- Banff (11 +, 7 *, 2 unknown sex)

ALBERTA. Banff National Park, Baker Lake: UBC 1647 *. Banff National Park, Banff, 12 mi W: AMNH 141659 +, AMNH 14166 +, CMN 18634 *; UBC 1672 +. Banff National Park, Cascade Basin: CMN 10887 +; CMN 10889 *. Banff National Park, Castle Mountain: CMN 18660 +, CMN 18662 *. Banff National Park, Fortymile Creek: CMN 10875 +. Banff National Park, Inglismaldi Mountain: UBC 1673 *. Banff National Park, Parker's Ridge: CMN 1979-180 sex?. Banff National Park, Pipestone River: UBC 759 +. Banff National Park, Sunwapta Pass: CMN RK77-2 *; CMN RK77-16 sex?; CMN RK-20; CMN RK-77-63 *; CMN RK77-66 +. Canmore: CMN 278 +. Jasper National Park, Sunwapta Pass: UBC 1949 +.

Sample 4- Jasper (16 +, 12 *)

ALBERTA. Jasper National Park, [no other data]: CMN 3333 +, CMN 3578 *, CMN 3583 +; UAMZ 8141+; UAMZ 8142 +; UAMZ 8143 +; UAMZ 8144 +; UAMZ 8145 +; UAMZ 8146 *; UAMZ 8147 *; UAMZ 8148 *; UAMZ 8149 *; UAMZ 8150 *; UAMZ 8151 +; UAMZ 8152 *; UAMZ 8223 *. Jasper National Park, Jasper, 6 mi N : CMN 10848 +. Jasper National Park, Jasper-Banff Highway: CMN 16032 +. Jasper National Park, Jonas Creek: CMN RK77-25 *. Jasper National Park, Maligne Canyon: CMN 18778 *. Jasper National Park, Medicine Lake: CMN 18763 *; CMN 18764 *. Jasper National Park, Miette River: CMN 3272 +. Jasper National Park, Mount Sassenach: CMN FN 3129 +. Jasper National Park, Parker's Ridge: CMN RK-77-70 +. Jasper National Park, Snake Indian River: CMN 16853 +. Jasper National Park, Tekarra Creek: UBC 1022 *. Prairie Creek, 40 mi N Jasper: CMN 10839 +.

Sample 5- Fort Nelson (9 +, 6 *)

Fort Nelson: RBCM 9436 +, RBCM 9437 *. Kotcho Lake: RBCM 10620 +, RBCM 10622 +, RBCM 10623 *, RBCM 10624 *, RBCM 10628 +, RBCM 11141 +, RBCM 10629 *, RBCM 11142 *, RBCM 16025 +, RBCM 16027 +, RBCM 16026 +, RBCM 11140 *. Muskwa River at Alaska Highway: CMN 17453 +.

Chapter 4

DISTRIBUTION AND HABITAT RELATIONSHIPS

by

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INTRODUCTION

Chapter 4 presents the results of fieldwork on the distribution and ecology of chipmunks (*Tamias*) conducted during 1996 to 1999 in the Kootenay region of British Columbia (Fig. 4-1). Within this region were 2 sub-regions: the Southern Rocky Mountains and the Southern Columbia Mountains (including the Southern Selkirks and Purcells). At the time of the study, 4 chipmunk taxa of the region were on the provincial Red or Blue lists:

Red-tailed Chipmunk (ssp *ruficaudus*)	*Tamias ruficaudus ruficaudus*
Red-tailed Chipmunk (ssp *simulans*)	*T .r. simulans*
Least Chipmunk (ssp *oreocetes*)	*T. minimus oreocetes*
Least Chipmunk (ssp *selkirki*)	*T. m. selkirki*

A primary goal was to investigate the occurrence of an alpine chipmunk, *T. m. selkirki,* that was known from only 6 specimens collected in the Purcell Mountains. Another goal was to investigate the occurrence of other chipmunk taxa over a range of elevations to determine whether there was a relationship between chipmunks and elevation and to see if the Red-tailed Chipmunk *(T. r. simulans)* also occurred in the area. A brief background for this study is contained in Chapter 1; identification and taxonomic analyses are in Chapters 2 and 3, respectively. The Yellow-pine Chipmunk, *T. amoenus luteiventris,* was also included in this study because it occurs in the region and is very similar in appearance to the other chipmunk taxa.

METHODS

Collection

To collect chipmunks we used live traps (folding model Sherman or Longworth-type trap), snap traps, and .410 gauge shotguns using No. 12 or dust shot. Live traps were set and baited with flatted oats and/or crushed walnuts; snap traps were baited with peanut butter. Traps were not pre-baited. Non-target species were released alive when possible.

Live-trapped specimens were killed with an overdose of Halothane® anesthetic. Each specimen was then wrapped in a paper towel and placed inside an individual Ziploc® plastic bag. This bag was labeled with a unique specimen number, date, collector name, and location description, which included latitude, longitude, and elevation. When more than one specimen was collected from a given location, all specimens in their individual bags were consolidated into a single larger Ziploc® bag. Packaged specimens were placed in either a cooler containing dry ice or a freezer soon after collection.

We located chipmunks primarily by watching for them as we slowly drove forest roads, hiked, or traveled by horseback. Once chipmunks were detected, we attempted to collect them by shotgun or by setting traps. In certain areas no chipmunks were seen, even though there were areas that appeared to be suitable (e.g., open areas with abundant cover). In such situations, we sometimes set traps.

Trapping effort was measured as "trap-sets" (ts), although a single ts varied from just a few hours to overnight. In 1997, we quantified the amount of time spent actively searching on foot for chipmunks with a shotgun.

Identification

The identity of chipmunk specimens mentioned in this report relies on the positive identifications, based on genital bone morphology, that are discussed in Chapter 2.

Sampling Design

The primary purpose of the field program was to collect specimens for taxonomic analysis and positive identification, rather than to conduct a random or systematic sampling of the entire study area. Because a primary goal was to gain knowledge about Red- and Blue-listed taxa that inhabit higher elevations, we emphasized these areas, which generally restricted our surveys to areas with road access. We usually drove logging or mine roads, watching for chipmunks along the way. Access to alpine and sub-alpine areas near Mt. Brewer and the upper Delphine Creek drainage was by horseback. Access to the upper Middlepass Creek drainage was by helicopter. Other areas were accessed by 4-wheel drive truck.

Habitat

We gathered information about the habitat at each site where chipmunks were collected, as well at sites with apparently favourable habitat (i.e., relatively open, with significant amounts of coarse woody debris, low woody vegetation, and/or complex rocky substrate) where we set traps. This information included physical features (e.g., elevations, slope, and aspect) and biological features (e.g., plants species present and structural class of forested areas). The Biogeoclimatic Ecological Classification (BEC) zone and sub-zone was determined from BC Forest Service maps and by the vegetation present (Braumandl and Curran 1992). We used Parish et al. (1996) to identify plants and as a source of common plant names.

Three-dimensional environmental complexity, i.e., coarse woody debris (CWD), low-growing and prostrate woody vegetation (LWV), and complex rocky substrates (CRS), appears to be important to chipmunks, probably as protection from predators. CWD was defined as limbs, branches, or logs greater than 7.5 cm in diameter. CWD was subjectively classified as abundant, common, uncommon, or nil. LWV was rated on the same scale. The degree of complexity of CRS was ranked as high, medium, low, or nil. These classifications were applied to within 15 m of the collection site.

Locations were determined using a Magellan GPS 2000 or Garmin GPS 12 hand-held Global Positioning System (GPS) unit. In the field, positions were recorded in latitude and longitude and were later converted to UTM coordinates. A barometric altimeter (calibrated daily at points of known elevation) and/or topographic maps were used to determine elevation. Elevations and locations were cross-checked by plotting positions on 1:50,000 maps. Slope and aspect were determined using a clinometer and a compass, respectively.

Evidence of the land-use history, such as mining, logging, agriculture, etc., was recorded at each site. The information was determined on the basis of indicators, such as stumps, debris piles and the age of trees in the area. Any signs of fire were also recorded.

RESULTS

Sampling Effort and Success

Over the 4 years of study, we visited >75 sites within the East and West Kootenay regions (Fig. 4-1). Although we used both traps and .410 shotgun to secure specimens, far more (101) were collected by the latter means than by the former (29). The time represented by trap-sets (ts) varied from a few hours to overnight; sometimes chipmunks entered traps quickly or we had to leave an area after just a few hours, while on other occasions, traps were left set overnight.

In 1996, we collected 25 chipmunks during fieldwork carried out from 11-22 September in the Akamina-Kishinena and Invermere areas and from 04-09 October in the southern Selkirk Mountains and Creston Valley (Fig. 4-2b, 4-3a, 4-4abc). In the Akamina-Kishinena area, 1 *T. r. ruficaudus* and 10 *T. amoenus* were collected. Just 1 chipmunk, a *T. amoenus luteiventris,* was collected near Invermere. In the southern Selkirks we collected 11 chipmunks, all *T. ruficaudus simulans,* while the 2 chipmunks collected near Wynndel were both *T. amoenus.*

We made a total of 200 trap-sets (ts), resulting in the capture of 23 chipmunks and a capture rate of 11.5 captures / 100 ts (Table 4-1), while only 2 chipmunks were shot. Most of the trapping effort was expended at sites where chipmunks had first been seen, resulting in 22 captures in 120 trap-sets (18.3 captures / 100 ts), while only 1 capture occurred in 80 trap-sets (1.3 / 100 ts) where no chipmunks had been seen. In 1996, because chipmunks entered traps so readily, resulting in undamaged specimens, we generally relied on trapping, shooting only when time or situation meant that trapping was not possible.

In 1997, from 13-24 August, we worked entirely in the northeastern Purcells, where we collected 46 chipmunks from 23 sites (Fig. 4-3ab). Of these, 34 were *T. amoenus* and 12 were *T. m. selkirki.* Forty-one (89%) specimens were collected by shooting, while, in contrast to 1996, only 5 were trapped, with a catch-per-unit-effort of only about one-quarter to one-third of that of the previous year (Table 4-1). Compared with 1996 results, the chipmunks appeared very reluctant to enter traps, resulting in a much lower catch-per-unit-effort (Table 4-1).

From 21-31 July 1998, we focused on 16 sites in 2 general areas of the southern Rockies and 2 sites SW of Invermere, BC, (Fig. 4-2ab, 4-3b), collecting a total of 57 specimens: 24 *T. amoenus,* 15 *T. minimus oreocetes*, 2 *T. m. selkirki,* and 16 *T. r. ruficaudus*. We made a total of 110 trap-sets, but captured only 4 specimens (3.6 captures / 100 ts), all at traps set where chipmunks had been seen previously (Table 4-1). Catch-per-unit-effort rises to 6.0 / 100 ts when only sites where chipmunks were known to have been present prior to trapping are considered. The remaining 53 (93%) specimens were shot. No chipmunks

were caught at 3 locations that appeared favourable (i.e., coarse woody debris or physically complex rocky areas were present), but where we did not first see chipmunks.

In 1997, we quantified the amount of time spent walking, attempting to collect chipmunks with shotgun. During the 57 h spent actively searching, we collected 32 specimens (56 specimens / 100 h or 1.8 h / specimen).

Collection effort was very limited in 1999 and was not quantified.

Distribution

Tamias minimus selkirki

In 1997 and 1998, we collected 14 specimens of *T. m. selkirki.* One specimen was found at the type locality (Paradise Mine) and another 4 at the head of Springs Creek valley (Fig. 4-3b). Another 2 specimens were collected in an adjacent area in the Bruce Creek drainage. In addition, we collected 7 more in the upper Hopeful Creek and the adjacent upper Brewer Creek drainages, thus extending the known range of this taxon by about 10 km to a disjunct area of high-elevation habitat.

We found no specimens of *T. m. selkirki* anywhere else in the alpine and sub-alpine study areas that we visited in the Purcell Mountains. We searched such areas in the vicinity of Lead Queen Mountain and the upper Delphine Creek drainage (4-3ab), all of which appeared to have generally suitable habitat. In the former we found no chipmunks of any species, while in the latter, we collected only *T. a. luteiventris.*

Historical records are restricted to the immediate vicinity of the Paradise Mine (App. 2-2).

Tamias minimus oreocetes

We collected *T. m. oreocetes* in the upper Todhunter Creek and Middlepass Creek drainages (Fig. 4-2ab). Ten specimens came from the former location; 5 from the latter. We also searched the Racehorse Pass and Akamina Pass areas, but in neither case were we able to reach the sub-alpine habitats where we would have expected to find *T. m. oreocetes.*

Historical specimens from our region are known from Mt. Assiniboine Provincial Park and Yoho National Park (App. 2-2).

Tamias ruficaudus ruficaudus

We collected 16 *T. r. ruficaudus,* 1 at Wall Lake and 15 in the upper Middlepass Creek drainage, but not at locations further north (Fig. 4-2b). Given the apparently suitable habitat further north and our ability to collect both *T. m. oreocetes* and *T. a. luteiventris* there, we suspect that the distribution of *T. r. ruficaudus* ends somewhere in between, possibly south of Crows Nest Pass.

T. r. ruficaudus was known previously in BC from only Akamina Pass (App. 2-2).

Tamias ruficaudus simulans

We found *T. r. simulans* commonly at several locations throughout the southern Selkirk Mountains (Fig. 4-4ab). None were found in the Purcell Mountains.

Confirmed historical specimens are also restricted to sites within the southern Selkirk Mountains: South Kootenay Pass, Boundary Lake, and a few locations just west of the Kootenay Flats near Creston (App. 2-2).

Tamias amoenus luteiventris

T. a. luteiventris occurred commonly throughout the study region from low to higher elevations, except for the southern Selkirk Mountains (Fig. 4-2ab, 4-3ab, 4-4abc). Curiously, even with all of our effort, we found only a single specimen of this taxon in the southern Selkirks (Fig. 4-4c).

Historical records of *T. a. luteiventris* are known from throughout the study region, including Fruitvale in the southern Selkirks (See Chapter 2). However, the identification of these latter specimens cannot be confirmed because of the absence of genital bones on the study skins.

Physical Complexity of the Environment

The physical complexity of the chipmunks' environment was assessed by examining three features: coarse woody debris (CWD), complex rocky substrates (CRS), and the abundance of low and/or prostrate woody vegetation (LWV) (Photos 4-1-4-6). Only 1 of 62 sites with chipmunks had no CWD, CRS, or LWV (Table 4-2). A high degree of complexity characterized 52 % (32/62) of sites, while a medium degree characterized an additional 40 % (25/62). Thus 92 % (57/62) of sites with chipmunks were ranked as having a medium or high degree of environmental complexity.

Complex rocky substrates were most abundant at higher elevations, where talus slopes and unvegetated, exposed rocks were common in sub-alpine areas. Consequently, CRS habitats were most important to the high-elevation chipmunks, particularly *T. m. selkirki* and *T. m. oreocetes.* For *T. m. selkirki,* CRS was rated as "High" at 63 % (5/8) of sites where this taxon occurred, while at 2 other sites, LWV was ranked as "Common" or "Abundant." Just one specimen was collected where CWD was "Common," in this case, wood mining debris near the entrance to the Paradise Mine.

Complex Rocky Substrates provided a "High" degree of physical complexity at 2 of 5 sites where *T. m. oreocetes* was detected. Elsewhere, CWD was "Common" or "Abundant."

All 4 sites at which we found *T. r. ruficaudus* contained "Common" or "Abundant" CWD. Similarly, all 6 sites where we collected *T. r. simulans* contained "Common" or "Abundant" CWD.

T. a. lutieventris occurred over the widest range of elevations and habitat conditions. Of the 35 sites where this taxon was collected, all but 5 had physical complexity ratings of "Common/Medium" or "Abundant/High". The cover ranking for CWD was "Common" or

Abundant" at 63 % (22/35) of sites, "Medium" or 'High" for CRS at 23 % (8/35), and "Common" or Abundant" LWV at 14 % (5/35). (Five of the sites had 2 attributes ranked in the upper 2 categories.)

Behaviour

We observed that chipmunks, in particular *T. a. luteiventris* at mid-elevations, are active above ground for only part of the day and that there is a tendency for synchrony of above-ground activity. For example, on 20 August 1997, we arrived at Site 111 at 1715 h, and at that time no chipmunks were active. However, at about 1800 h, approximately 10 chipmunks emerged and began foraging. As another example, on 13, 16, and 21 August, we passed Site 125 on the Paradise Mine road. However, it was not until 21 August that we detected the presence of 8-10 chipmunks, which were very active and conspicuous at that time.

While working in the Middlepass Creek drainage in July 1998, we also noticed a general lack of activity during midday to late afternoon. The weather was quite hot (estimated to be >30°C) and sunny. Under these conditions, very few chipmunks or other diurnal, ground-dwelling squirrels were above ground, and those that were, were often in the shade of log or branch.

Chipmunks often appeared to be absent from areas that appear to be suitable (i.e., open habitat with suitable food plants and adequate physical environmental complexity). This is complicated by the fact that chipmunks are active above ground for only limited amounts of time. Thus comments about distribution have to be tempered by appreciating that chipmunks may be present in areas where they have not been detected. Patchiness of distribution is undoubtedly confounded with the chipmunks' limited periods of activity, which means that chipmunks are not always apparent even during daylight hours. For example, in September 1996 it was not until we passed site 014 for the third time that we saw a chipmunk there; and that animal was seen for <1 sec! Although we captured 4 near the spot where we saw the first animal from the truck, we observed only the single animal. Nor did we catch any others at a location about 0.5 km away, which was identical in every apparent aspect.

Elevation

Chipmunks were found at elevations of 543-2380 m (Fig. 4-5). *T. a. luteiventris* occurred over the broadest range: from 543 m near Creston, to 2345 m in sub-alpine habitats in the Purcells. In the Rockies, this taxon was recorded from 850 m in valley bottoms to 2020 m in the sub-alpine. The single record of *T. a. luteiventris* in the southern Selkirk Mountains was at 900 m.

T. m. selkirki was restricted to a narrow elevation range, extending from 2134 - 2380 m. We collected specimens from 2185-2380 m. The elevational range of detections made during our fieldwork in the Springs Creek valley was very narrow, 2300-2335 m, although historically it had been collected as low as 2134 m near old mine buildings that were destroyed early in 1997. In the Mt. Brewer area, we collected *T. m selkirki* between 2185-2380 m.

As with the previous taxon, *T. m. oreocetes* also occurred in a relatively narrow range of high-elevation locations (1813-2318 m). In the Middlepass Creek drainage, we found them at 1900-2090 m, while in upper Todhunter Creek, we found them at 2180 m. Further north, historical specimens are known from Yoho National Park (1813-2305 m) and from Mt. Assiniboine Provincial Park (2318 m).

We found *T. r. ruficaudus* at elevations ranging from 1780-1900 m in the Rockies, which includes the range of the historical specimens from Akamina Pass (1798 m). In contrast, in the southern Selkirk Mountains, *T. r. simulans* was found over a wide range of elevations (560 – 1829 m), where it appears to replace *T. a. luteiventris* as the chipmunk occupying a wide altitudinal range, as the latter does in the Purcells and Rockies.

Slope and Aspect

Slope does not appear to be an important determinant of habitat suitability for chipmunks. All taxa were found over a wide range of slopes, ranging from 0->50 % (Table 4-3). At one site inhabited by *T. m. selkirki,* the slope varied from flat areas with Krummholz vegetation to broken, vertical rocks faces, which the chipmunks negotiated easily.

Chipmunks were found inhabiting sites representing all aspects (Table 4-4), although sites facing north were uncommon. Nearly half (24/53) of the sites had a S-facing aspect, followed by W- (14) and E-facing (11) aspects. Only 4 sites faced N. It may be significant that just one N-facing site was recorded for a high-elevation form *(T. m. oreocetes)*, while the other 3 were for *T.amoenus* at lower elevations. However, because we made no attempt to randomly sample all aspects, it is possible that the apparent pattern could be explained by sampling bias.

Biogeoclimatic Zones and Subzones

In the Rockies, we encountered chipmunks in 5 biogeoclimatic subzones (Table 4-5). Only *T. m. oreocetes* was found in the highest elevation habitats of the AT / ESSFdkp. All 3 taxa were found within the ESSFdk, while only *T. a. luteiventris* was found at lower elevations in the MSdk and ICHmk.

In the Purcells, we again found *T. minimus* restricted to the highest elevation subzone (AT / ESSFdkp), while *T. a. luteiventris* extended over a broad range of subzones (Table 4-5).

In the southern Selkirks, *T. r. simulans* occurred over the ESSFwc, ICHmw, and ICHdw, while the single specimen of *T. a. luteiventris* occurred in the ESSFdk. The failure to detect *T. r. simulans* in the ESSFdk is probably a sampling artifact.

Presence of Other Diurnal Small Mammal Species

In high-elevation areas in the Purcells and Rockies, 2 or 3 chipmunk species co-occurred at certain sites. In the Purcells, both *T. m. selkirki* and *T. a. luteiventris* occupied 3 sites. In the Rockies, *T. m. oreocetes* and *T. a. luteiventris* co-occurred at one site, while these two taxa were joined by *T. r. ruficaudus* at another.

At the higher elevation sites in the Purcell and Rocky mountains, other species of diurnally active small mammals were often evident in the vicinity of chipmunks (Table 4-6). In the Purcells, in the upper part of Springs Creek valley, which included the Paradise Mine, Golden-mantled Ground Squirrels *(Spermophilus lateralis),* Columbian Ground Squirrels *(Spermophilus columbianus),* Common Pikas *(Ochotona princeps),* and Hoary Marmot *(Marmota caligata)* were all present. The nearby Mt Brewer area had a similar fauna, except for the absence of the Hoary Marmot. In contrast, in the vicinity of Lead Queen Mountain, which was superficially similar to the previous locations, we found only Columbian Ground Squirrels. In the southern Rocky Mountains, we found Golden-mantled Ground Squirrels and/or Common Pikas in areas where chipmunks were also present. In all 4 areas where we found *T. minimus,* we also encountered *S. lateralis,* and at 3 of these *O. princeps* was also present.

Land Management History

More than half of the areas where we found chipmunks had experienced some degree of apparent disturbance, either natural or anthropogenic (Table 4-7). This disturbance was often from timber harvest, mining, or road-building. Wildfire was the commonest form of natural disturbance. All taxa were found in disturbed habitats, and those occurrences in habitats that were not disturbed were usually open, lacking a closed tree canopy.

Chipmunks were often apparently abundant in clearcuts. Although we did not design our collection program to assess abundance, all sites where we trapped or shot 4-5 specimens were clearcuts, suggesting that some favourable combination of food and cover occurs in such places. *T. a. luteiventris* was abundant at two sites (111 and 124) in the Purcell Mountains in a clearcut, where they were associated with CWD that had been piled along a logging road, as well as with CWD that had been left on the ground. In both cases, we collected only 5 specimens because of our self-imposed restriction to not take >5 specimens from any given location. At a clearcut (site 014) in the Kishinena drainage, we captured 4 *T. a. luteiventris*. While we captured 4 *T. r. simulans* in a clearcut on Giveout Creek (site 016). Most of the animals were away from the clearcut edges.

Chipmunks occurred at other sites where anthropogenic disturbances had occurred. These included disturbed areas adjacent to roads and the site of the Paradise Mine.

Chipmunks occurred commonly in habitats naturally disturbed by wildfire, which had resulted in open habitats with common or abundant CWD. Most of the sites in the upper Middlepass Creek drainage, where we found all 3 species, had been burned many years earlier by a wildfire.

DISCUSSION

Sampling Effort and Success

In 1996, the trapping CPUE (catch-per-unit-effort) was about 3 times as great as it was in 1997 and 1998 (Table 4-1). Although no statistical analyses can be conducted on the CPUE results because the length of time (= effort) represented by a "trap-set" varied greatly, it seems

probable that the differences in CPUE between 1996 versus 1997 and 1998 were real, regardless of whether one compares overall values or only values for trap-sets where chipmunks had been observed prior to the setting of traps. I believe that the most likely explanation is that in late September and early October, when the 1996 fieldwork was conducted, natural foods were less abundant and chipmunks, actively seeking seeds for winter food stores, were easily attracted to seed baits. In contrast, in July and August, when fieldwork was carried out in 1997 and 1998, natural foods were probably readily available and food storage was not underway, so that chipmunks would not have been motivated to search widely enough to find the baits around the traps. Chipmunks might also be expected to be reluctant to enter traps, which would be novel features, unless strongly motivated. In addition, young-of-the-year chipmunks may have increased the above-ground population later in the season in 1996.

Most (101 / 130 = 77.7 %) of the specimens collected from 1996-1999 were obtained using a .410 shotgun. The proportion was higher for 1997-1999 data only (96 / 105 = 91.4 %). Especially considering that trapping was most effective when chipmunks were first observed in an area, shooting required less time and effort than trapping, except late in the season. In contrast to trapping, shooting does not require a return visit to an area, nor does it require transporting heavy, bulky traps. Thus, shooting is generally the most efficient means of sampling the chipmunk fauna in an area.

Shooting is also more selective than trapping, which often results in the capture of species that are not desired. For example, Deer Mice *(Peromyscus maniculatus)* frequently entered traps, necessitating cumbersome precautions to avoid exposure to hanta virus. Such measures are not required if traps are not used. Because traps are not selective, there is often collateral mortality to species that are not intended to be caught. Such species in this study included Ermine *(Mustela erminea),* Bushy-tailed Woodrat *(Neotoma cinerea),* Common Shrew *(Sorex cinereus),* and Water Vole *(Microtus richardsoni).*

Distribution

During this project we have increased the known ranges of some species and reduced those of others, compared with the ranges given by Cowan and Guiguet (1965). The ranges of *T. r. ruficaudus, T. minimus selkirki,* and *T. m. oreocetes* in BC have been extended, while the range of *T. r. simulans* has been reduced to exclude the Purcells. *T. amoenus luteiventris* is widely distributed below the alpine zone, but it status in the southern Selkirk Mountains is unclear. The existence of only one confirmed specimen of *T. a. luteiventris* from the southern Selkirks raises questions about the extent of its occurrence there. A lot of uncertainty attends our knowledge of the distribution of the various chipmunk taxa in the Kootenays (and elsewhere in the province). Huge gaps exist between areas that have been inventoried for small mammals, leaving many open questions about the extent of occurrences of these taxa.

On a micro-scale, chipmunks appear to be very patchily distributed, with a large proportion of apparently suitable habitat vacant. This patchiness is difficult to prove, given the limited amount of time that chipmunks spend above ground. However, the general failure to

capture chipmunks at sites where they were not first observed, suggests that failure to detect chipmunks often does reflect absence.

T. m. selkirki

Prior to this project, *T. m. selkirki* was known from only the type locality, the Paradise Mine. The first specimen that we collected was secured from a point within 100 m of the mine shaft entrance, source of the type specimen (Cowan, pers. comm.). All 6 pre-1997 specimens of this taxon were collected from near the mine and associated buildings. We have extended the known range to include other sites in the vicinity of the type locality, i.e., upper Springs Creek Valley (which includes the type locality) and the adjacent Bruce Creek drainage (Fig. 4-6), as well as a disjunct area near Mt. Brewer, about 10 km distant and separated from the type locality by the Toby Creek valley.

Assuming that both *T. m. selkirki* and suitable habitats are widespread Cowan and Guiguet (1965) provide a distribution map for this subspecies that encompasses the sub-alpine and alpine zones of the Purcell Mountains. By collecting *T. m. selkirki* on Mt. Brewer and adjacent areas, we have shown that this assumption was at least partially correct. On the other hand, our failure to detect *T. m. selkirki* on Lead Queen Mountain and in the upper Delphine Creek drainage suggests that this taxon may have habitat requirements that are sufficiently narrow to restrict its distribution within the Purcells.

T. minimus oreocetes

Cowan and Guiguet (1965) presumed that *T. m. oreocetes* occurred within BC given its nearby occurrence in Waterton Lakes National Park. We found *T. m. oreocetes* at high-elevation sites near Middle Kootenay Pass and in the headwaters of Todhunter Creek (Fig. 4-2ab). Historical specimens, formerly assigned to *T. m. borealis,* are also known from Mt. Assiniboine Provincial Park and Yoho National Park (see Chapter 2).

T. r. ruficaudus

Prior to our fieldwork, *T. r. ruficaudus* was known in British Columbia from only Akamina Pass (Cowan and Guiguet 1965). We have extended the range north to Middle Kootenay Pass (Fig. 4-2b). Bennett (1999) reviewed the records of this taxon in Alberta and found the most northerly occurrence in that province to be near Scarpe Mountain in the headwaters of the West Castle River, about 5 km south of our northernmost record. Whether the lack of more northerly records reflects the absence of *T. r. ruficaudus* north of Middle Kootenay Pass or a lack of survey effort is unknown.

T. ruficaudus simulans

We believe that *T. ruficaudus simulans* in absent from the Purcell Mountains, although Cowan and Guiguet (1965) show that it occurs from Creston to Invermere. Crowe (1943) reported from the Invermere area, and Cowan and Guiguet (1965), using Crowe's record, indicated that this taxon's range extended from the Creston area to near Invermere. We were unable to find *T. r. simulans* near Creston or Invermere, although we did find *T. amoenus*

frequently in these areas. Nagorsen (pers. comm.), who has examined Crowe's specimens at the American Natural History Museum, believes that they are, in fact, *T. amoenus* that Crowe had misidentified; similarly, other low-to-mid elevation specimens of *Tamias* from the Purcells that have included genital bones have all proven to be *T. amoenus* (see Chapter 2). J. Sullivan (University of Idaho, Moscow, ID, pers. comm.) has also been unable to detect the presence of *T. ruficaudus* in the Purcell Mountains in Montana, just south of our study area. Therefore, I conclude that *T. r. simulans* does not exist in the Purcell Mountains (Fig. 4-7)..

Panian (1996), working in the southern Selkirks, reported detections of *T. r. simulans* at several locations. We collected specimens from some of these sites, and these were positively identified by Nagorsen and Panter (2001). Nagorsen and Panter also confirmed the presence of *T. amoenus* at one site in the southern Selkirks. Because these taxa are very difficult to discriminate without careful examination of the genital bones, the identifications of chipmunks not supported by voucher specimen material is unreliable. Clearly, additional work, supported by voucher specimens, is required to determine the extent of occurrence of these taxa in the southern Selkirk Mountains.

T. amoenus luteiventris

We found *T. a. luteiventris* over much of the area that we searched (Fig. 8), confirming that it is widespread. However, although Cowan and Guiguet (1965) showed it as present throughout the southern Selkirks, we found only one confirmed specimen from this area; the specimens from near Fruitvale lack genital bones and cannot be confirmed (Nagorsen, pers. comm.). The status of this taxon in the southern Selkirks is uncertain.

Physical Complexity of the Environment

Physical complexity appears to be an important aspect of the environment of chipmunks (Table 4-2). This complexity can take the form of coarse woody debris (CWD), complex rocky substrates (CRS) with crevices and / or interstices into which chipmunks can retreat, or low woody vegetation (LWV), such a krummholz formations found at higher elevations.

Halvorsen (1982) found that after burning clearcuts following timber harvest, *T. r. ruficaudus* populations responded more quickly if the fire was of low intensity, leaving more CWD in the habitat (as well as encouraging more rapid growth of food plants). Soper (1973) observed that the habitat of *T. m. oreocetes* included "brushy Alpine meadows, stony gorges, talus slopes and stunted woods around rock slides," which is in accord with our observations. Gordon (1943) noted that "Chipmunks often have favored lanes of travel along logs and fences, stopping frequently at rocks, logs, or stumps to look around." We commonly observed that chipmunks of all taxa became alert when they became aware of us, and when approached, they quickly took cover by running under rocks, into CWD, or into krummholz vegetation. These observations all support the notion that physical environmental complexity is important to chipmunks.

Predation probably is an important factor in chipmunk ecology. Bergstrom and Hoffmann (1991) found that fewer than one-third of the chipmunks in their study survived the

winter in the mountains of Colorado and that some populations went extinct. Broadbrooks (1958) found that a Long-tailed Weasel *(Mustela frenata)* ate a chipmunk that was captive in a live trap and that weasels attempted to enter traps occupied by chipmunks on several occasions. He further noted that several other potential chipmunk predators lived in his study area: Coyotes *(Canis latrans),* Badgers *(Taxidea taxus),* Bobcats *(Lynx rufus),* and Goshawks *(Accipiter gentilis).* Foresman (pers. comm.) once observed an Ermine *(Mustela erminea)* kill all members of one chipmunk family in Montana. Callahan (1993) reviewed the literature and her own observations on squirrels as predators. She found that Red Squirrels *(Tamiasciurus hudsonicus)* and several species of ground squirrel *(Spermophilus* sp.) had all been documented to prey on chipmunks; the Eastern Chipmunk *(Tamias striatus)* has been recorded to prey on conspecifics. It seems reasonable that any small to medium-sized raptors, such as Merlins *(Falco mexicanus),* would also be potential predators. Thus, the ready availability of escape cover that could be provided by CWD, CRS, or LWV would be important.

Behaviour

The tendency for chipmunks at any given location to be synchronous in their above-ground activity may be related to predation. Presumably the vulnerability of any individual is reduced when more than one animal is abroad at the same time. This could result from the action of more than one mechanism. First, more than one chipmunk could increase the overall level of vigilance. Second, if more than one animal is potentially vulnerable and the predator can capture only one prey at a time, the vulnerability of each chipmunk is inversely proportional to the number of chipmunks that are abroad. On the other hand, a number of chipmunks active at any given time is probably more conspicuous than a single animal.

Elevation and Biogeoclimatic Zone

We found *T. m. selkirki* and *T. m. oreocetes* only in alpine and sub-alpine habitats (AT / ESSFdkp and ESSFdk). We did not find *T. m. selkirki* as low as 2134 m, where it was known historically, possibly because the habitat around the old mine buildings had been disturbed when the buildings were destroyed. *T. m. oreocetes* was encountered from 1900-2230 m, which is within the elevational range (1820-2360 m) where Soper (1973) found this taxon in Waterton Lakes National Park, Alberta.

T. r. ruficaudus was also found in a narrow elevational range (1780-1900 m) in the ESSFdk. Our limited data suggests that this taxon is not as widespread in BC as Soper (1973) reported for Waterton Lakes National Park (1575-2120 m). Perhaps further collecting will increase the known elevational range in BC.

In contrast to *T. r. ruficaudus, T. r. simulans* was found over a relatively broad range of elevations (1086-1829 m) and biogeoclimatic zones (Fig. 4-5, Table 4-5). In the southern Selkirk Mountains, this taxon appears to replace *T. a. luteiventris* as the common chipmunk found over a broad range of elevations.

Of all the chipmunk taxa in southeastern BC, *T. a. luteiventris* occurred over the widest range of elevations and biogeoclimatic zones. We found *T. a. luteiventris* from low elevation (770 m) habitats in the ICHdw to ESSFdkp / AT to elevations as high as 2345 m (Table 4-5).

In an attempt to locate additional areas occupied by *T. m. selkirki*, we searched alpine and subalpine habitats in the upper Delphine Creek drainage and Lead Queen Mountain. Even within different biogeoclimatic zone variants significant differences in environmental conditions may render certain areas unsuitable for chipmunks. Thus not all alpine and subalpine habitats that appeared suitable for *T. m. selkirki* were occupied. Perhaps more refined habitat classification to the site-series level (Braumandl and Curran 1992) would result in an improved ability to predict habitat suitability for chipmunks.

Slope and Aspect

We found chipmunks over a wide range of slopes and aspects (Tables 4-3, 4-4.) Overall, we found chipmunks at fewer sites facing north (4/53) in contrast to south (24/53), west (14/53), or east (11/53). For sites occupied by the high-elevation taxa (i.e., *T. minimus* and *T. r. ruficaudus*) combined, most faced S (6), W (5), or E (3), while only 1 faced N. It is possible that N-facing sites are less suitable for chipmunks at higher elevations because of the longer duration of snow at such sites. Whether the apparent tendency to avoid north-facing slopes, where snow may persist for a larger part of the year, is real or just a consequence of sampling bias is unknown.

Competition and Distribution

Although we did not study interspecific relations, the subject of competitive exclusion and its possible influence on distribution has been the subject of several studies (Meredith 1977, Heller 1971, Sheppard 1971, Beg 1969). In his study in Montana, Beg (1969) concluded that *T. amoenus* prefers more-open, lower-elevation habitats, while *T. ruficaudus* prefers moister, higher-elevation habitats. However, the 2 species are contiguously allopatric, and Beg implies that the exact boundary between them is determined by some sort of interaction that prevents them from occupying the same space. (How Beg discriminated between the 2 taxa is not clear, and one has to wonder about the validity of his conclusions given the difficulty of reliable identification described in Chapter 2.)

The interaction between *T. minimus* and *T. amoenus* in the southern Alberta Rockies, where the 2 species are parapatric, has been studied by both Meredith (1977) and Sheppard (1971). Sheppard concluded that the larger *T. amoenus* was able to exclude *T. minimus* from areas in subalpine habitats where it might otherwise have occupied. On the other hand, *T. minimus* may be better adapted to alpine habitats because of its smaller size and possibly other adaptations. Meredith carried out experiments that indicated that prior occupancy of an area by *T. minimus* could predispose that species to dominating when *T. amoenus* was introduced to the situation, but that *T. amoenus* dominated when the 2 species were introduced simultaneously. Thus, the pattern of distribution in the parapatric zone may be influenced by the

pattern of historical occupancy, which in turn may be determined by local extinctions and colonisations.

Thus, the presence of congeners must be added to habitat attributes as a determinant of distribution of chipmunks.

Land Management History and Conservation

T. m. selkirki occurs in high elevational areas, where there is limited intrusion by highly disturbing human activities, such as logging. Whatever effect the environmental disturbance that resulted from the Paradise Mine (roads, buildings, mine tailings, etc.) might have had is unknown. However, individuals of this taxon were present in the mid-1940s when Carl and Hardy (1945) and Cowan (1946) collected both *T. m. selkirki* and *T. a. luteiventris* from the immediate vicinity of the Paradise Mine and associated buildings. Low intensity human activities do not appear to pose a threat to *T. m. selkirki*. Mines could destroy habitat, but unless the area affected is large, mining disturbance would not pose a serious threat.

The main concern about the status of *T. m. selkirki* is its very limited known range. In this study, we have established that is occurs at several sites in the vicinity of the type locality and at several sites on nearby Mount Brewer. However, we failed to find this taxon on Lead Queen Mountain, which lies about 40 km to the northwest. Although Cowan and Guiguet (1965) suggest that *T. m. selkirki* should be found throughout the Purcell Mountains, its actual range has yet to be determined and may be restricted to a few islands of sub-alpine and alpine habitat. Only additional inventory effort can determine the actual extent of its the range.

T. a. luteiventris was common at certain locations where there had been disturbance from fire of unknown origin, as well as in logged areas (Photo 4-1). Chipmunks require food, which is probably more abundant in open areas, and a complex physical environment for security from predators. While physical environmental complexity can result from complex rocky substrates and low woody vegetation, these features are inherent in only certain locations. However, coarse woody debris (and open habitats) can result when forests are either burned or logged, thus producing conditions that are favourable for chipmunks.

Presence of Other Diurnal Small Mammal Species

The co-occurrence of *T. minimus* and *T. amoenus* in the Rockies has been reported previously by both Sheppard (1968) and Meredith (1977). The addition of a third species, *T. r. ruficaudus,* at the same site does not appear to have been previously detected.

Although we cannot be certain that we documented the complete fauna of diurnal small mammals at all sites that we visited, at least 2 other species were present at each locality where we detected chipmunks (Table 4-6).

Inventory Requirements

The ability to conduct a valid inventory of chipmunks is complicated by a number of factors:

1. There is an apparent tendency for chipmunks to minimize the amount of time that they are active above ground. Thus it is possible for chipmunks to be present in an area, but to be undetectable for much of the day.
2. The time of day when chipmunks are active above ground is probably a function of several factors (e.g., temperature, precipitation, hunger) which would make it difficult to effectively time survey effort to ensure a high probability of encountering chipmunks above ground.
3. The distribution of chipmunks is very patchy, and not all apparently suitable habitat is occupied.
4. In general, chipmunks appear to be more abundant open habitats with a high degree of physical complexity, and thus inventory effort could be focused in such areas. However, chipmunks also occur in closed-canopy forests with limited physical complexity.
5. Because of the difficulty in identifying specimens, even in the hand by experienced biologists, and the lack of clear, exclusive geographical ranges, it will usually be necessary to collect specimens for certain diagnosis.
6. Trapability varies widely, but often is low. It is possible that trapping is most productive in fall when populations are highest and chipmunks are searching for and storing seeds for the winter. Setting traps in apparently suitable habitats, where chipmunks have not been observed, has resulted in a very low catch-per-unit-effort (i.e., 0-1.3 captures / 100 trap-sets).
7. Shooting may be the best means for collecting chipmunks for several reasons: 1. poor trapability, 2. avoidance of trap mortality to non-target species, 3. avoidance of risk of exposure to hanta virus (carried by *Peromyscus*) by investigators. Particularly in remote locations, where repeated visits may not be possible or logistics difficult, a .410 shotgun may provide the only practical means of obtaining the required specimens.

CONCLUSIONS

1. The chipmunk, *Tamias minimus selkirki,* previously known from only the type locality, presently occurs at the type locality (the Paradise Mine) and adjacent contiguous areas and in a nearby disjunct area (upper Hopeful Creek drainage and Mt. Brewer). However, it apparently does not occur in similar habitat at Lead Queen Mountain or the upper Delphine Creek drainage. Thus, its range appears to be more restricted than assumed by Cowan and Guiguet (1965), who suggested that it was present in alpine and sub-alpine areas throughout the Purcell Mountains.
2. *Tamias ruficaudus simulans* was found at several locations in the southern Selkirk Mountains. However, no evidence of this taxon was found in the Purcell Mountains, and given that the putative specimens of this taxon that were collected from near Invermere apparently belong to *Tamias amoenus,* we conclude that this chipmunk is absent from the Purcell Mountains.

3. *Tamias amoenus luteiventris* is widespread from valley bottoms to sub-alpine habitats in the Purcell and Rocky mountains. At higher elevations, *T. a. luteiventris* may co-occur with *T. minimus* and/or *T. r. ruficaudus*.
4. Live-trapping success is highly variable and often low, possibly as a function of availability of natural food, even where chipmunks are known to be present. Shooting is a more efficient means of securing specimens.
5. Chipmunk habitat is generally characterized by having a high degree of physical complexity, which may afford protection from predators. This complexity can take the form of coarse woody debris, complex rocky substrates, and/or low woody vegetation.
6. Chipmunks tend to be active above ground for only limited parts of the day, and when they are active, there is a tendency for several to be abroad at the same time. This synchronicity may afford protection from predators as a result of increased vigilance.
7. *T. m. selkirki* was found only in high-elevation alpine and sub-alpine habitats in the ESSFdkp / AT biogeoclimatic subzones at elevations ranging from 2185-2380 m. *T. a. luteiventris* was found from the IDFun through to the ESSFdkp subzones at elevations from 1005-2340 m.
8. Chipmunks were generally found over a wide range of slopes and aspects, suggesting that neither factor is important in determining distribution. However, few chipmunks were observed at N-facing sites at higher elevations, where persistent snow may limit habitability.
9. Chipmunks generally appear to tolerate or even benefit from the effects of human activities such as mining and logging. Logging (and fire) in particular appears to create open habitat with a high density of food plants and abundant coarse woody debris.
10. The distribution of the various chipmunk taxa is poorly understood in the Kootenays. Inventory of chipmunks, which requires collection and preparation of specimens, is problematic for a number of reasons, including limited and unpredictable periods of above-ground activity, variable trapability, and patchy distribution.

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Table 4-1. Catch-per-unit-effort of chipmunk trapping. Selected trap-sets = traps set in areas where chipmunks had been seen. Overall values include results from trap-sets in areas where chipmunks had not been seen previously.

Field Period	Overall Captures / Trap-sets	Overall Captures / 100 Trap-sets	Captures / Selected Trap-sets	Captures / 100 Selected Trap-sets
11-22 Sep 96 04-09 Oct 96	23 / 200	11.5	22 / 120	18.3
13-24 Aug 97	5 / 135	3.7	5 / 105	4.8
21-31 Jul 98	4 / 110	3.6	4 / 67	6.0

Table 4-2. Relative physical environmental complexity at sites with chipmunks. Physical complexity was comprised of coarse woody debris (CWD), complex rocky substrates (CRS), or low woody vegetation (LWV). The subjective ranking scheme ranged from nil to abundant for CWD and LWV and from nil to high for CRS.

Physical Complexity Rating	**Number of Sites with Chipmunks**				
	T. m. selkirki	***T. m. oreocetes***	***T. r. ruficaudus***	***T. r. simulans***	***T. a. luteiventris***
Nil	0	0	0	0	1
Uncommon / Low	0	0	0	0	4
Common / Med.	2	2	2	4	14
Abundant / High	7	3	1	7	14
TOTALS	**9**	**5**	**3**	**11**	**33**

Table 4-3. Percent slope for sites where chipmunks were recorded.

Percent Slope	Number of Sites with Chipmunks				
	T. m. selkirki	***T. m. oreocetes***	***T. r. ruficaudus***	***T. r. simulans***	***T. a. luteiventris***
0-10	2	1	2	1	8
11-20	1	0	0	1	2
21-30	0	0	0	2	6
31-40	0	2	1	1	1
41-50	3	1	0	1	3
<50	2	0	0	0	8
0-vertical	1	0	0	0	0

Table 4-4. Aspect for sites where chipmunks were recorded. A "0" aspect indicates generally flat topography where no aspect was apparent.

Aspect	**Number of Sites with Chipmunks**				
	T. m. selkirki	***T. m. oreocetes***	***T. r. ruficaudus***	***T. r. simulans***	***T. a. luteiventris***
N	0	1	0	0	3
E	2	1	0	1	7
S	4	1	1	2	16
W	3	0	2	3	6
0	0	1	1	0	0

Table 4-5 Distribution of chipmunk species according to biogeoclimatic zone and variant. The failure to detect *T. r. simulans* in the ESSFdk is probably an artifact of sampling.

Biogeoclimatic Zone / Subzone	**Chipmunk Species**		
	T. minimus	***T. ruficaudus***	***T. amoenus***
	Southern Rocky Mountains		
AT / ESSFdkp	**X**		
ESSFdk	**X**	**X**	**X**
MSdk			**X**
ICHmk			**X**
	Purcell Mountains		
AT / ESSFdkp	**X**		**X**
ESSFdk			**X**
MSdk			**X**
IDFun			**X**
ICHdw			**X**
	Southern Selkirk Mountains		
ESSFwc		**X**	
ESSFdk			**X**
ICHmw		**X**	
ICHdw		**X**	

Table 4-6. The composition of diurnal small mammal faunas at selected sub-alpine locations. Locations excluded from listing here were not searched adequately to be confident of the composition of the small mammal fauna. Species codes are: TAMI = *Tamias minimus,* TARU = *T. ruficaudus,* TAAM = *T. amoenus,* SPCO = *Spermophilus columbianus,* SPLA = *S. lateralis*, MACA = *Marmota caligata,* OCPR = *Ochotona princeps.*

AREAS	TAMI	TARU	TAAM	SPCO	SPLA	MACA	OCPR
Upper Springs Cr. Valley	**X**		**X**	**X**	**X**	**X**	**X**
Mt Brewer Area	**X**		**X**	**X**	**X**		**X**
Lead Queen Mountain				**X**			**X**
Upper Middlepass Cr Valley	**X**	**X**	**X**	**X**	**X**		**X**
Racehorse Pass	**X**		**X**		**X**		
Upper Todhunter Cr Valley	**X**		**X**				**X**

Table 4-7. Land disturbance history at sites where chipmunks were detected. Undisturbed habitats included those with open and closed canopies; disturbed habitats included those disturbed naturally by wildfire, as well as by logging and other anthropogenic activities such as mining and road building.

CHIPMUNK TAXON	UNDISTURBED		DISTURBED		
	Open	Closed	Wildfire	Logging	Other
T. minimus selkirki	**8**	**-**	**-**	**-**	**1**
T. m. oreocetes	**3**	**-**	**2**	**-**	**-**
T. r. ruficaudus	**-**	**1**	**3**	**-**	**-**
T. r. simulans	**-**	**-**	**-**	**4**	**2**
T. amoenus	**9**	**-**	**3**	**6**	**4**

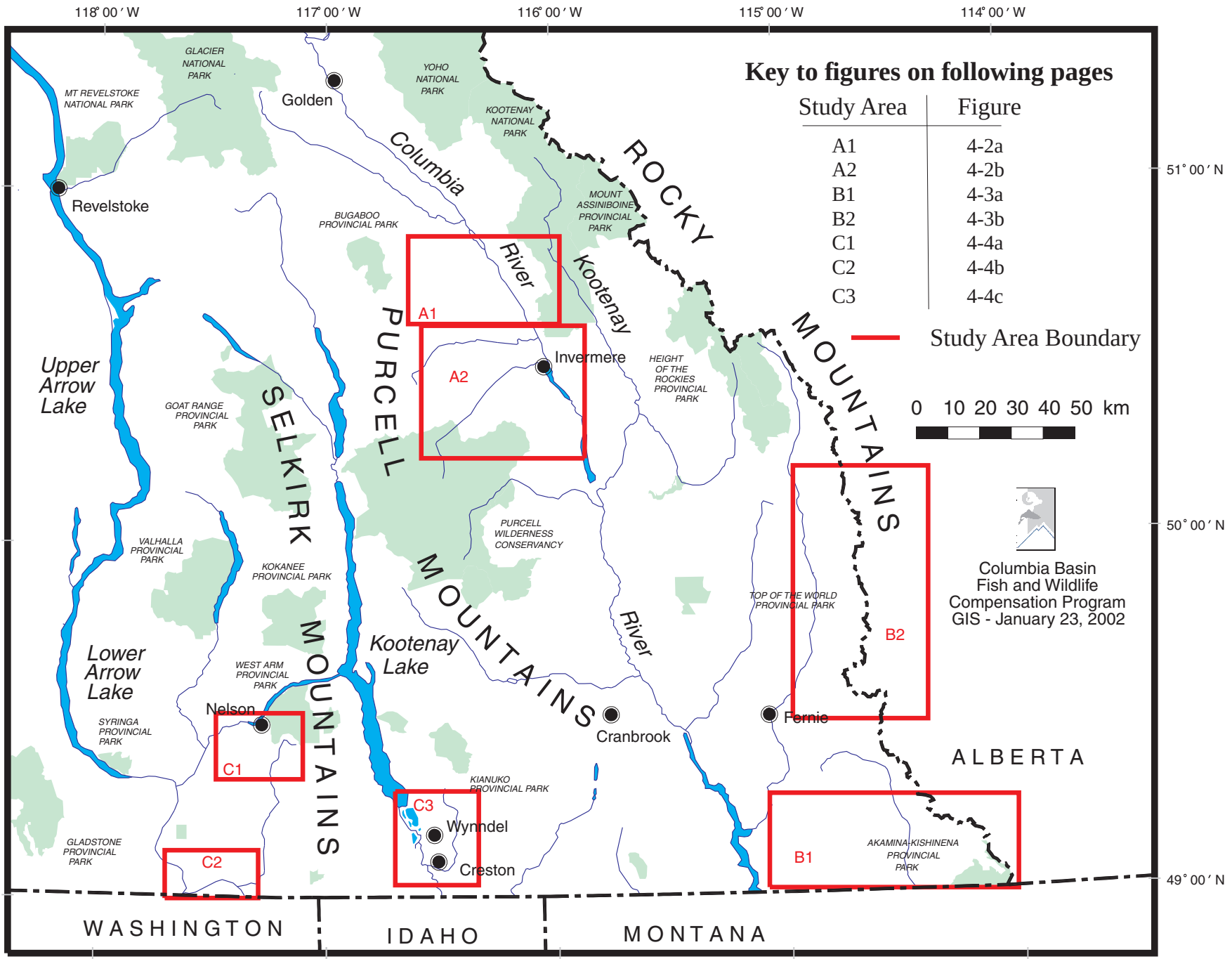


Figure 4-1. Kootenay small mammals study areas, 1996-1998. The 7 study areas are shown in more detail in figures on following pages.

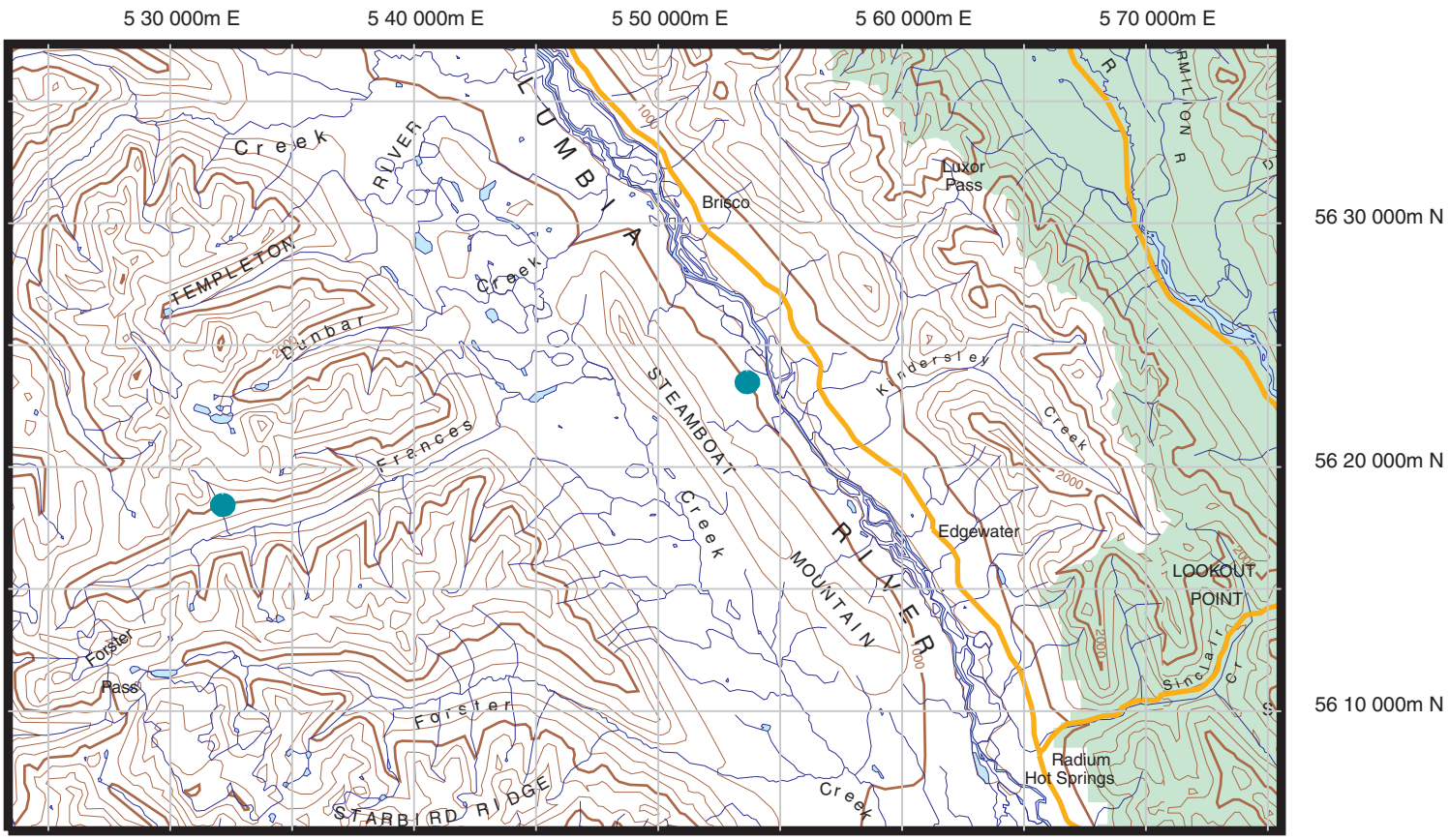


Figure 4-2a. Purcell Mountain study areas: Frances Creek, Steamboat Mountain area.
Columbia Basin Fish and Wildlife Compensation Program -- January 24, 2002

● *AMOENUS LUTEIVENTRIS*

0 5 10 15 20 25 km

Scale: 1:300,000 - Map Projection: UTM Zone 11 - Datum: NAD 83 - Contour Interval 100m

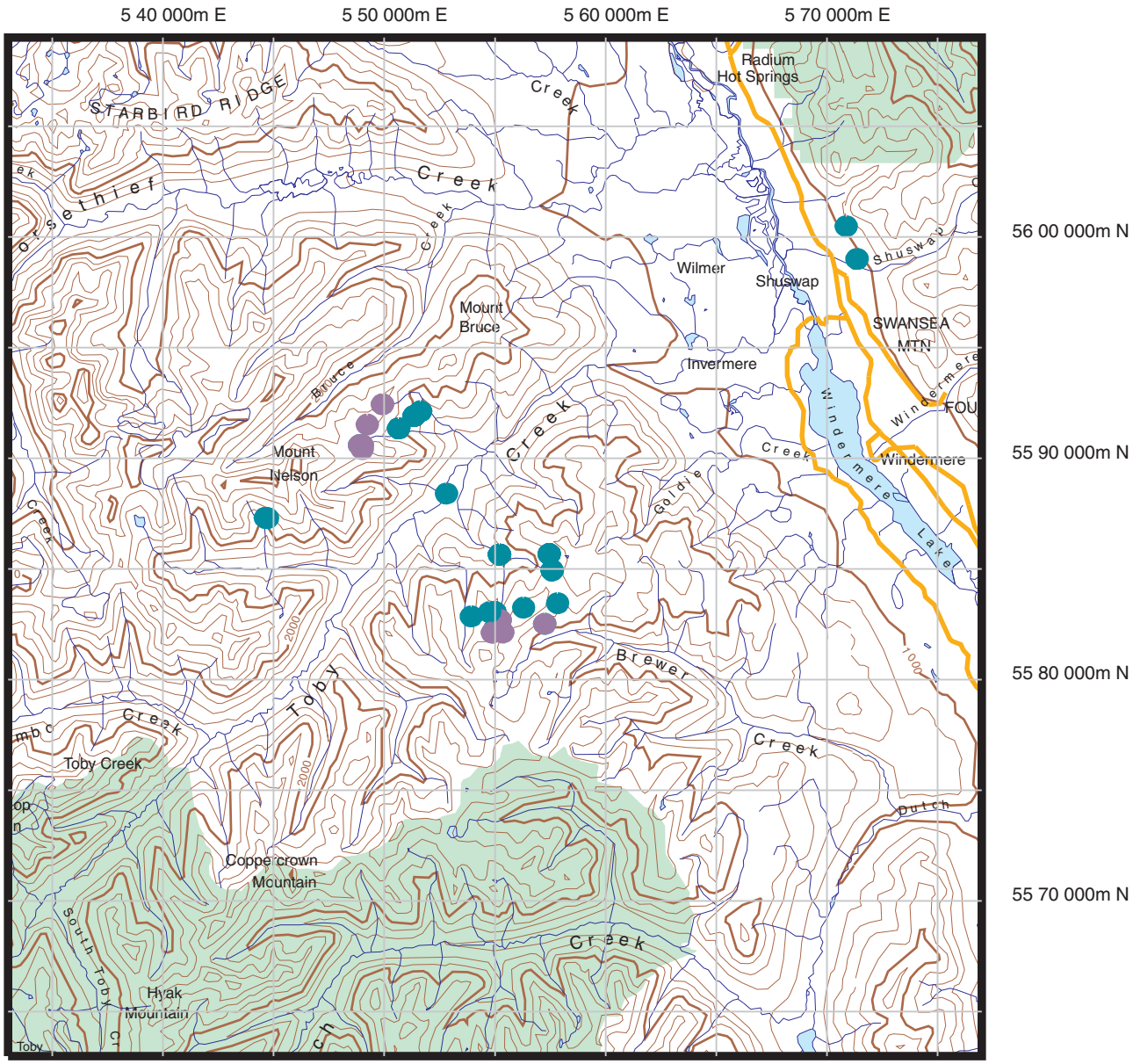


Figure 4-2b. Purcell Mountain study areas: Paradise Mine, Mt Brewer, Invermere area.

Columbia Basin Fish and Wildlife Compensation Program -- January 28, 2002

- *AMOENUS LUTEIVENTRIS*
- *MINIMUS SELKIRKI*

0 5 10 15 20 25 km

Scale: 1:300,000 - Map Projection: UTM Zone 11 - Datum: NAD 83 - Contour Interval 100m

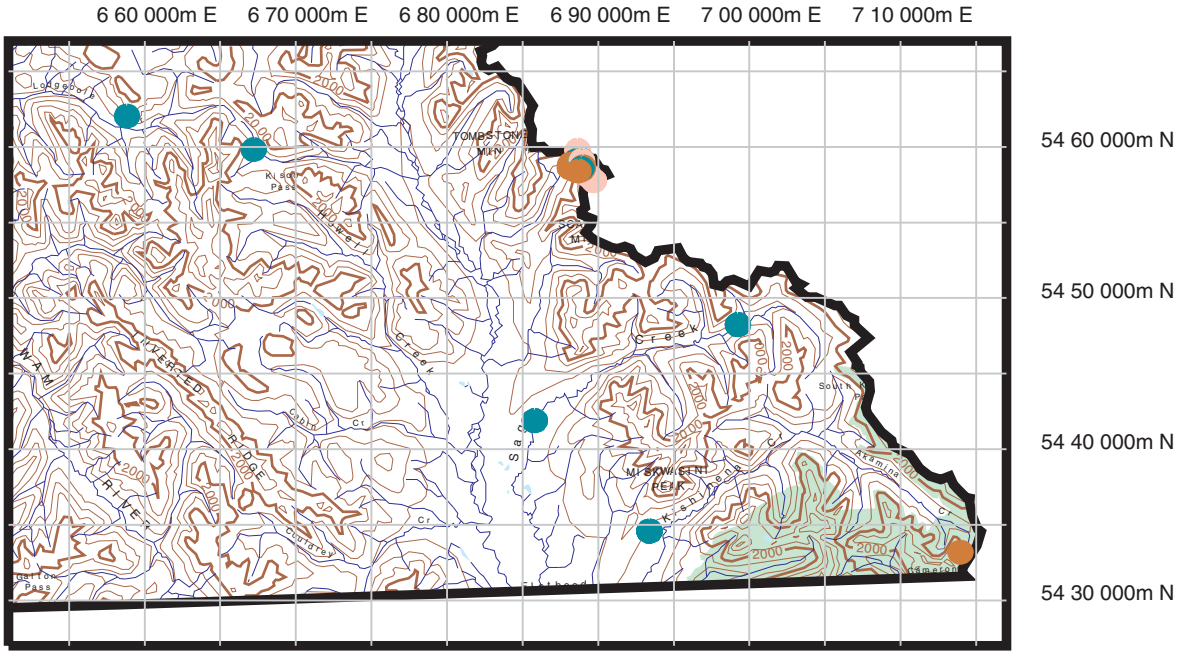


Figure 4-3a. Rocky Mountains study areas: Akamina-Kishineau, Sage Creek, Middle Pass areas.
Columbia Basin Fish and Wildlife Compensation Program -- January 28, 2002

- *AMOENUS LUTEIVENTRIS*
- *MINIMUS OREOCETES*
- *RUFICAUDUS RUFICAUDUS*

0 5 10 15 20 25 km

Scale: 1:500,000 - Map Projection: UTM Zone 11 - Datum: NAD 83 - Contour Interval 100m

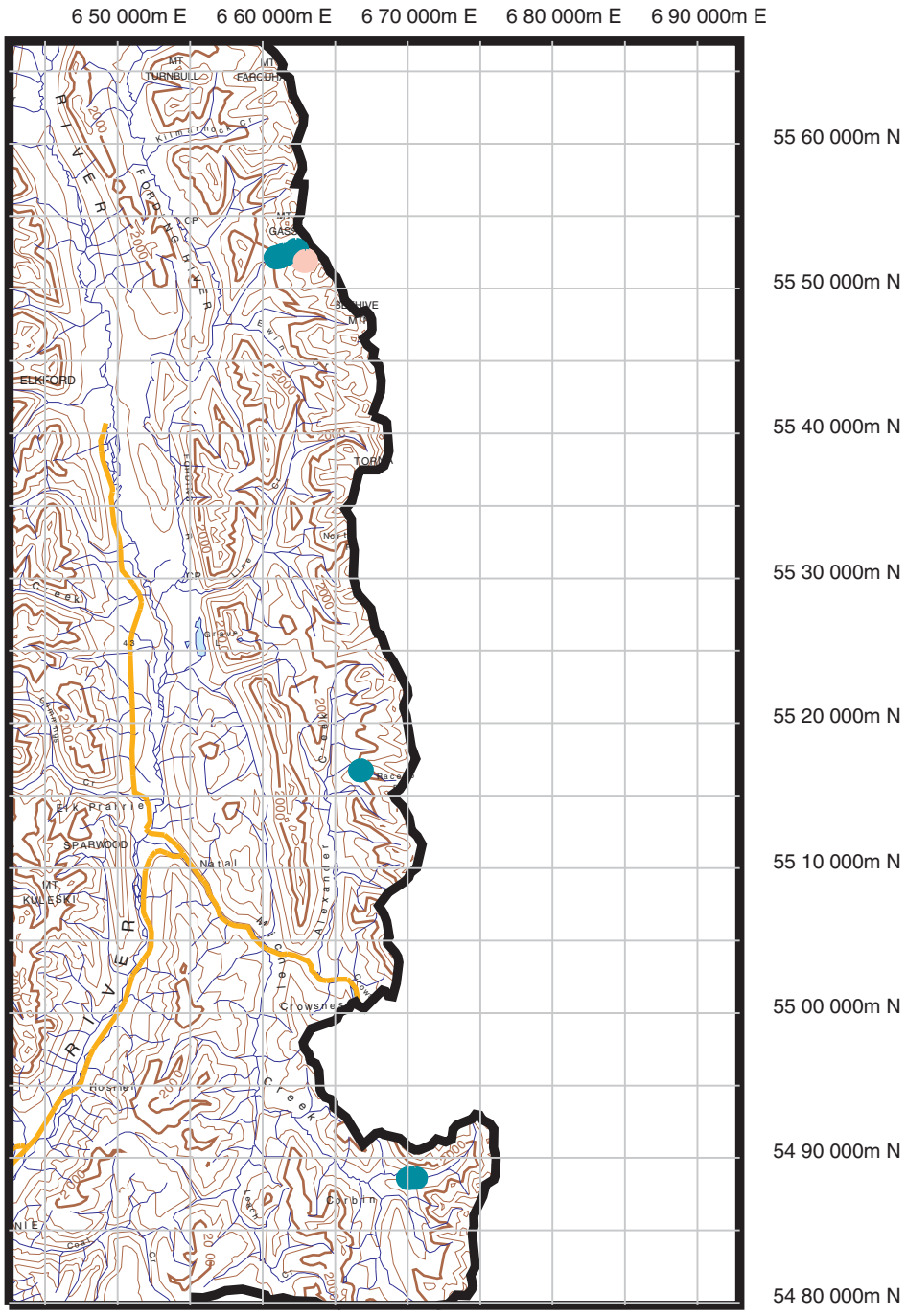


Figure 4-3b. Rocky Mountains study areas: Todhunter Creek, Racehorse Pass areas.

Columbia Basin Fish and Wildlife Compensation Program -- January 24, 2002

- *AMOENUS LUTEIVENTRIS*
- *MINIMUS OREOCETES*

Scale: 1:500,000 - Map Projection: UTM Zone 11 - Datum: NAD 83 - Contour Interval 100m

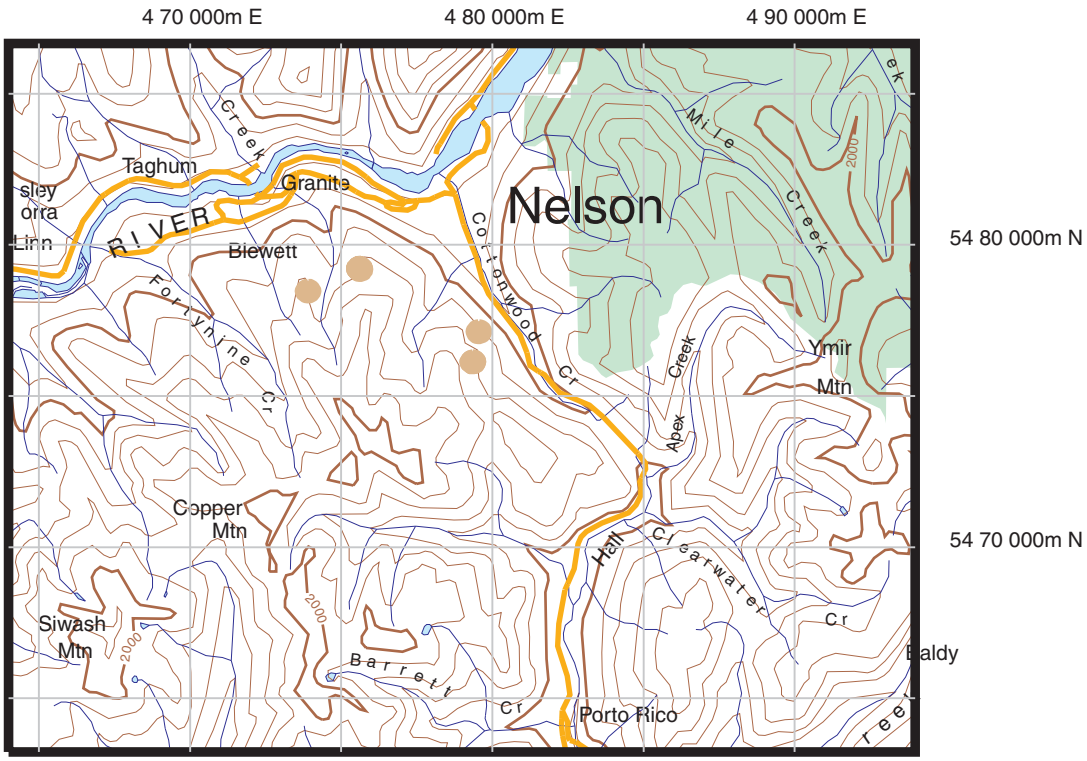


Figure 4-4a. Selkirk Mountains - Creston Valley study areas: Nelson area.

Columbia Basin Fish and Wildlife Compensation Program -- January 24, 2002

● *RUFICAUDUS SIMULANS*

Scale: 1:250,000 - Map Projection: UTM Zone 11 - Datum: NAD 83 - Contour Interval 100m

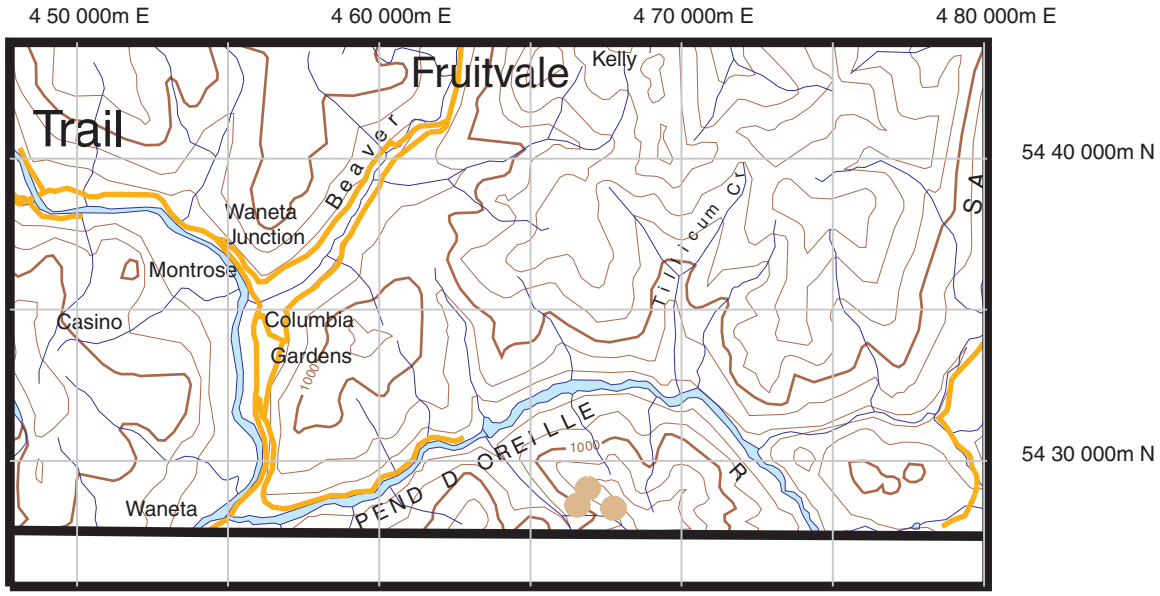


Figure 4-4b. Selkirk Mountain - Creston Valley study areas: Pend d'Oreille area.

Columbia Basin Fish and Wildlife Compensation Program -- January 24, 2002

● *RUFICAUDUS SIMULANS*

0 5 10 15 20 25 km

Scale: 1:250,000 - Map Projection: UTM Zone 11 - Datum: NAD 83 - Contour Interval 100m

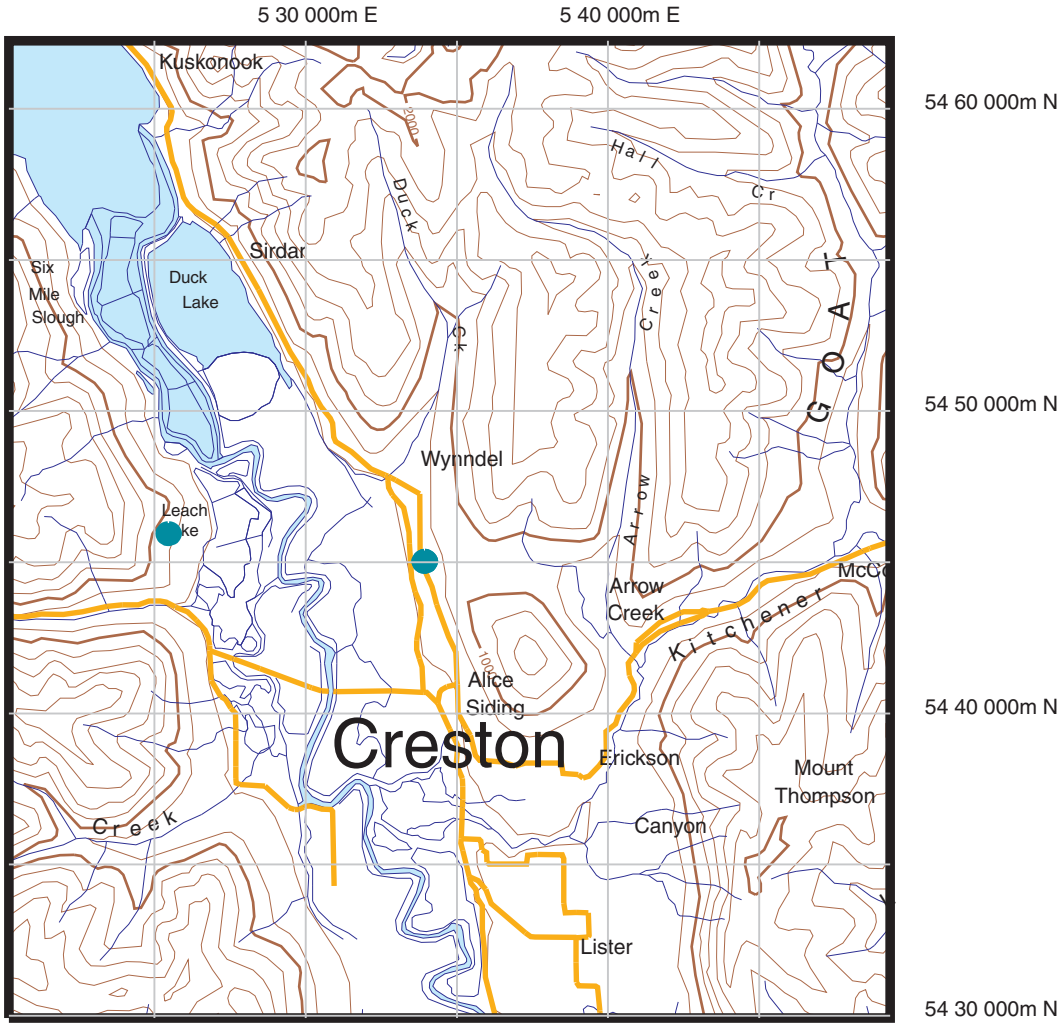
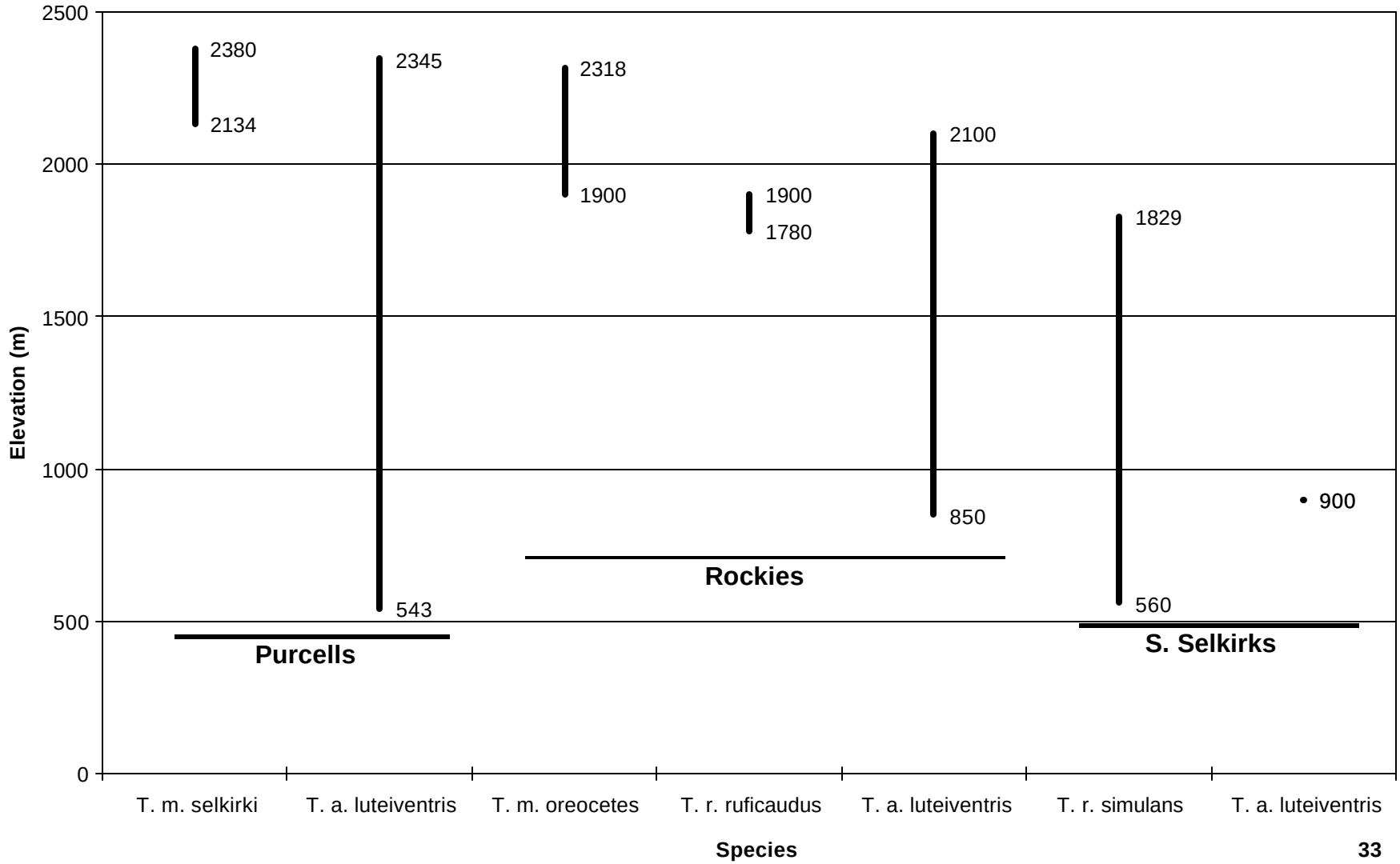


Figure 4-4c. Selkirk Mountains - Creston Valley study areas: Creston area
Columbia Basin Fish and Wildlife Compensation Program -- January 24, 2002

● *AMOENUS LUTEIVENTRIS*

0 5 10 15 20 25 km

Scale: 1:250,000 - Map Projection: UTM Zone 11 - Datum: NAD 83 - Contour Interval 100m


2500
2000
1500
1000
500
0
Elevation (m)
2380
2134
2345
543
2318
1900
1900
1780
2100
850
1829
560
900
Purcells
Rockies
S. Selkirks
T. m. selkirki
T. a. luteiventris
T. m. oreocetes
T. r. ruficaudus
T. a. luteiventris
T. r. simulans
T. a. luteiventris
Species

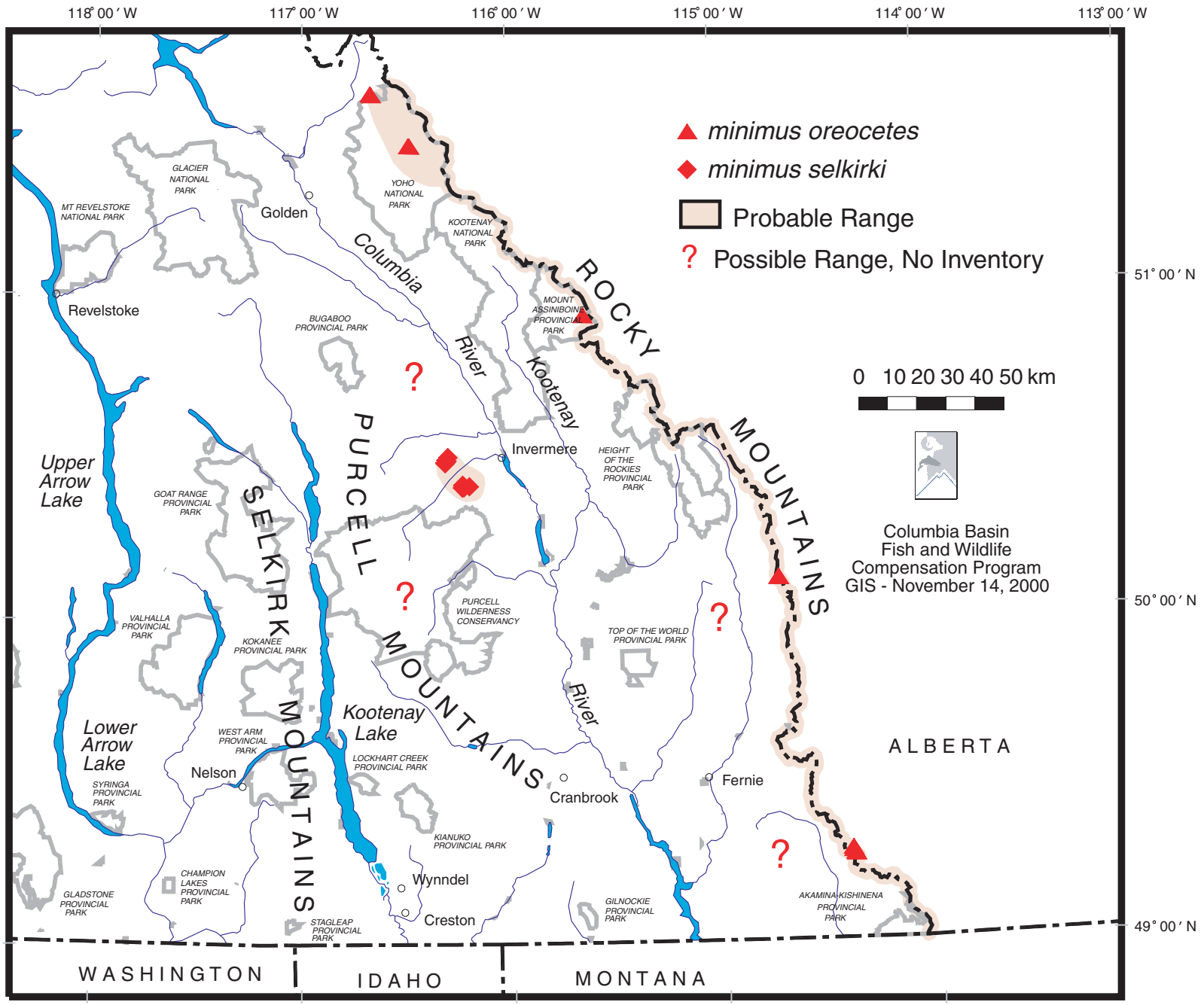


Figure 4-6. The distribution of the Least Chipmunk, *Tamias minimus*, in the Kootenay Region, British Columbia.

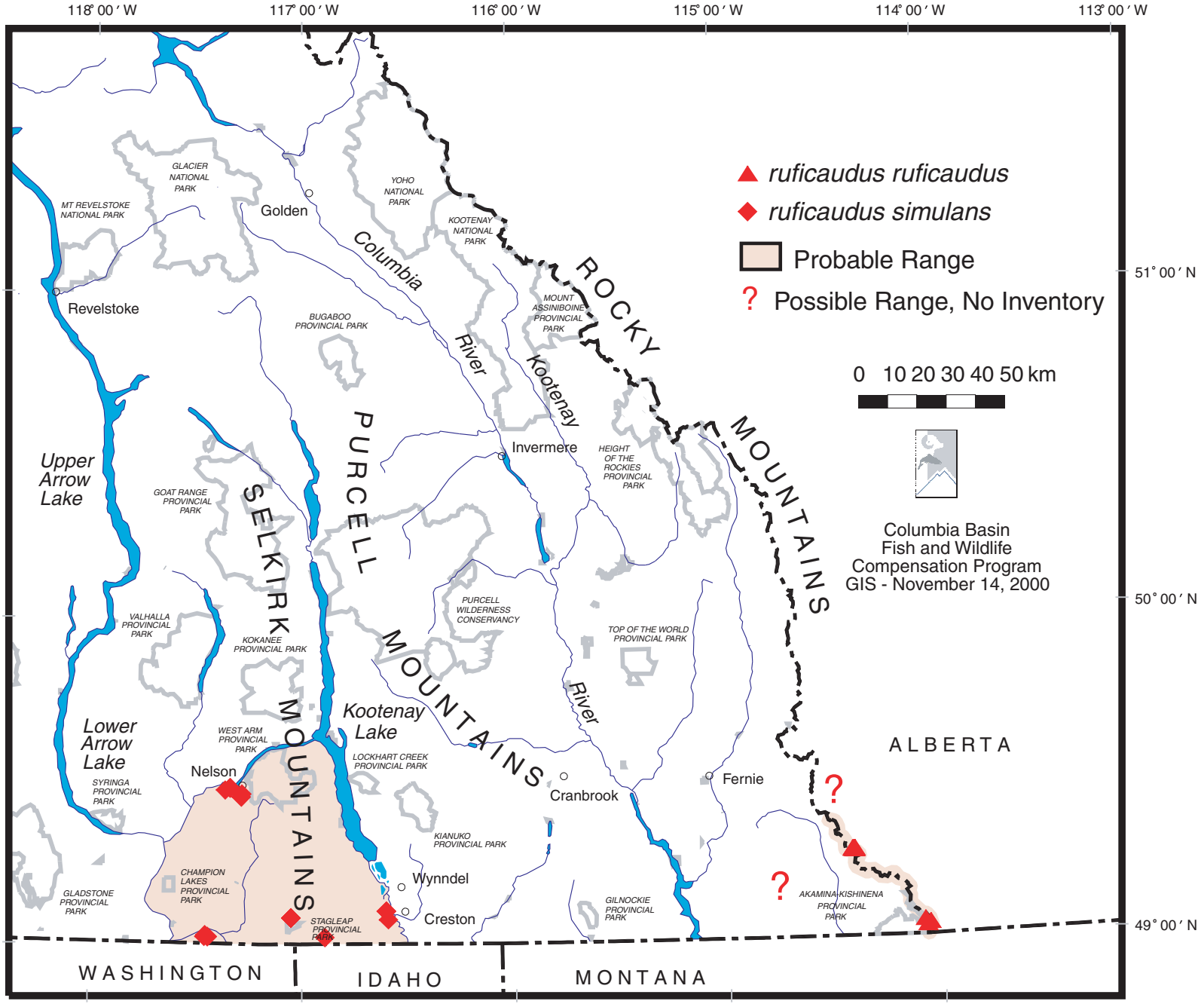


Figure 4-7. The distribution of the Red-tailed Chipmunk, *Tamias ruficaudus*, in the Kootenay region, British Columbia.

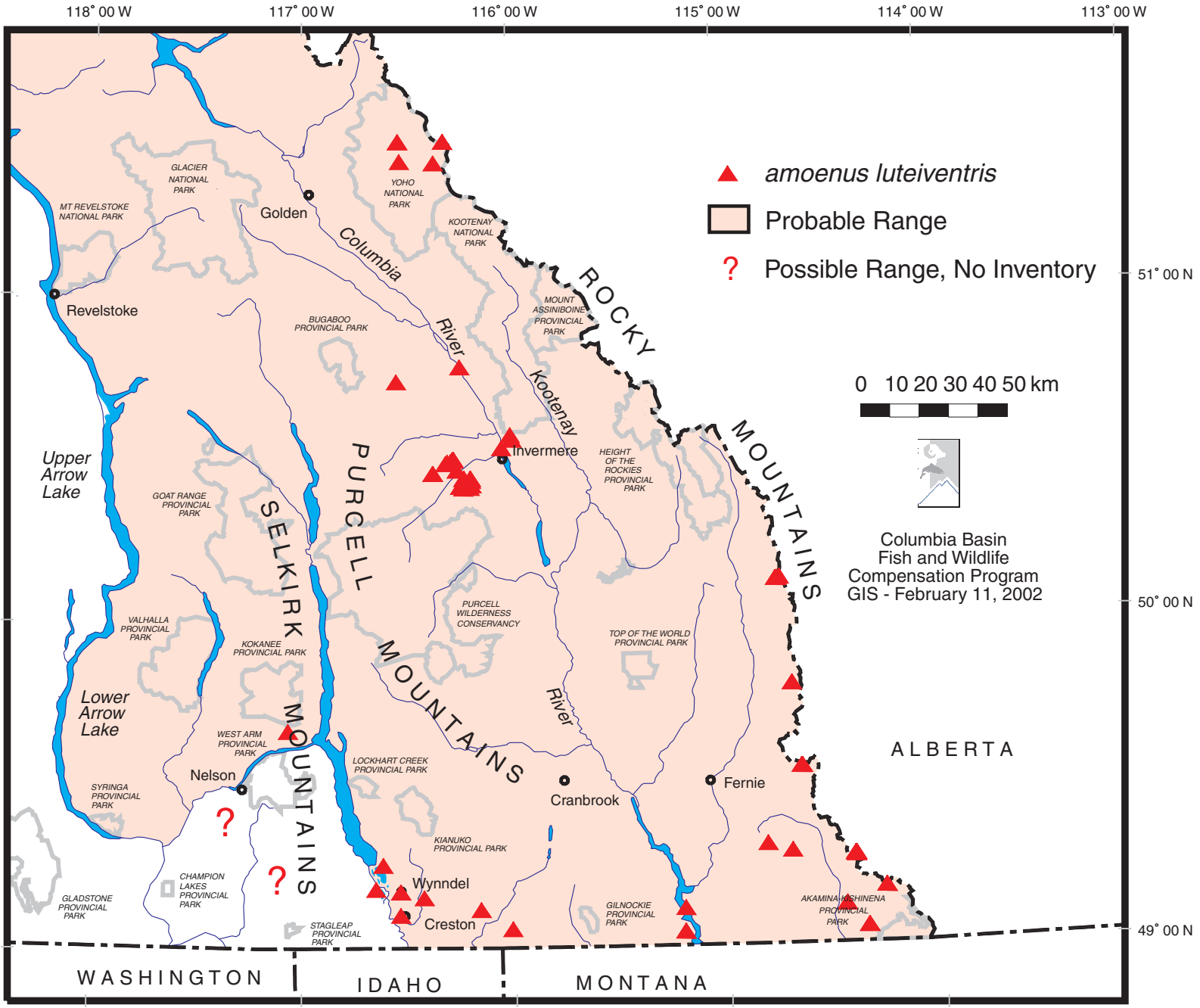


Figure 4-8. The distribution of the Yellow-pine Chipmunk, *Tamias amoenus,* in the Kootenay Region, British Columbia. Symbols indicate the collection sites of confirmed specimens. In the southern Selkirk Mountains, all but 1 chipmunk were *T. ruficaudus simulans.* Elsewhere, *T. amoenus* occurred from valley floors to alpine habitats.

Photo 4-1. A clearcut in the Hopeful Cr. drainage, Purcell Mountains. A total of 10 *T. a. luteiventris* were collected at sites just below the road that runs through the centre of the photo. Coarse woody debris was abundant in this area.

Photo 4-2. Burn in the upper Middlepass Creek drainage, Rocky Mountains. *T. r. ruficaudus*, *T. a. luteiventris*, and *T. m. oreocetes* were common in this general area. Coarse woody debris was common.

Photo 4-3. Head of Springs Creek valley, Purcell Mountains. Both *T. m. selkirki* and *T. a. luteiventris* occurred here. Complexity of the rocky substrate was rated as high, while the low woody vegetation (krummholz) was ranked as common.

Photo 4-4. Talus in the upper Hopeful Creek drainage, Purcell Mountains. The complexity of the rocky substrate was ranked as high, and *T. m. selkirki* occurred here.

Photo 4-5. Alpine vegetation near Brewer Pass, Purcell Mountains. *T. m. selkirki* occurred here where the only cover was provided by low woody vegetation, which was ranked as common.

Photo 4-6. Talus and low woody vegetation on Mt. Brewer, Purcell Mountains. Both *T. a. luteiventris* and *T. m. selkirki* frequently moved between the complex rocky substrate, which was rated as high, and the low woody vegetation, which was rated as common.

Chapter 5

CONSERVATION STATUS AND RECOMMENDATIONS

by

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CURRENT DESIGNATIONS

Three systems (see Alvo and Oldham 2000) have been used to designate British Columbian mammals at risk. Internationally the World Conservation Union (IUCN) ranks species and subspecies using criteria based on the probability of extinction. Threatened taxa are classified as either Critically Endangered, Endangered, or Vulnerable by the IUCN system. The Rodent Specialist Group of the Species Survival Commission of the IUCN recently assessed the status of all North American rodents in a conservation action plan (Hafner et al. 1998). Twelve species and 73 subspecies of rodents were listed in the IUCN threatened categories. Of the four chipmunk subspecies considered at risk in our study, only *T. m. selkirki* was considered of conservation concern by the IUCN (Table 5-1) with Sullivan and Nagorsen (1998) ranking it as Vulnerable D2.

The Committee on the Status of Endangered Species in Canada (COSEWIC) ranks species and nationally significant populations at a national scale. Ranks are based on status reports. Its Endangered and Threatened categories are based on criteria modified from the IUCN system and these two categories will have legislative implications if the proposed national species at risk act is passed. Special Concern is a non-quantitative rank used by COSEWIC to identify species of concern because of rarity, limited range, or specialized life history traits. To date, none of the chipmunks assessed in our study have been evaluated by COSEWIC, although *T. ruficaudus* has been recently listed as a candidate species by the Terrestrial Mammals Specialist Group.

Provincially, the BC Ministry of Environment, Lands and Parks (MELP) through its associated Conservation Data Centre (CDC) assigns S (subnational) ranks to the province's vertebrates at risk using a system developed by The Nature Conservancy (Harcombe 2000). S ranks for the four chipmunk taxa in British Columbia were summarized in Cannings et al. (1999). *T. r. ruficaudus* and *T. r. simulans* were designated as S2 (imperilled) and assigned to the province's Red List because of their small range and few occurrences. *T. m. oreocetes* and *T. m. selkirki* were designated S1S3 and assigned to the province's Blue List. Based largely on data from our study, in 2000 the CDC downlisted *T. r. simulans* to S3S4 (Blue List) and *T. m. oreocetes* to S2S3 (Blue List) (Table 5-1).

STATUS ASSESSMENTS

Assessment data currently available for each of the chipmunk subspecies are summarized in Appendix 5-1.

T. m. oreocetes

Although the validity of this subspecies is questionable, we recommend that it continue to be treated as a separate unit for conservation until more taxonomic research is done. Although there are no reliable data on population numbers or trends, this species clearly is not at risk provincially or nationally. Size of its distributional area, its presumed continuous range along the continental divide, and potential rescue effects from populations in Montana and across the continental divide between British Columbia and Albert precludes an Endangered or Threatened designation. Most important there are no known threats other than habitat loss from open pit coal mines. Any impacts from open pit mining are probably offset by the protection of much of its range in British Columbia and Alberta in the national and provincial park systems of the southern Rocky Mountains.

Although its limited range and few occurrences contribute to its provincial designation as S2S3 (Blue List) by the CDC, it is unlikely that this taxon would qualify as a COSEWIC candidate for Special Concern. This subspecies has not been listed by the Natural Heritage Information Centres of Alberta or Montana.

T. m. selkirki

Genetic studies are essential to confirm the validity of this subspecies but the morphological data and its isolated range endemic to the Purcell Mountains suggest that it is distinct from populations of *T. minimus* in the Rocky Mountains. Sullivan and Nagorsen (1998) ranked this taxon as Vulnerable D2 with the IUCN criteria based on its restricted range and an area of occupancy less than 100 km^2. When Sullivan and Nagorsen (1998) did their assessment, *T. m. selkirki* was known only from historical museum records collected from the type locality at the Paradise Mine. However, even with new data from our field studies this subspecies would still be ranked as Vulnerable D2 with the IUCN criteria. It is known from only two general locations in the Purcell Mountains, has an area of occupancy less than 100 km^2, consists of fewer than 1,000 animals, and is isolated with no potential for rescue. These same criteria would qualify *T. m. selkirki* as a candidate for Threatened under the COSEWIC criteria. Nevertheless, no threats have been identified other than stochastic extinction events associated with small isolated populations.

T. r. ruficaudus

This subspecies is ranked as S2 (Red List) in British Columbia because of its limited range and few known locations. Similarly it is ranked as S2 by the Alberta Natural Heritage Information Centre and is on the province's Blue List (see Bennett 1999). *T. ruficaudus* is not being tracked by Natural Heritage Information Centres of Montana and Idaho. In BC and Alberta this species has small ranges and is limited to a narrow elevational belt. Nonetheless, much of its distributional area falls within the boundaries of Waterton Lakes National Park and Akamina-Kishinena Provincial Park and no threats are known. Moreover, because the Canadian populations are contiguous with populations in adjacent areas of Montana, there is potential for a rescue effect. Although extensive logging is occurring within its elevational range in the Flathead River valley of British Columbia, this species inhabits early and later successional stages. A potential impact from forestry is that *T. amoenus* could invade logged habitats and displace *T. ruficaudus* through interspecific competition. However, no data exists to test this hypothesis. This subspecies clearly is not a COSEWIC candidate for Endangered or Threatened but may qualify as a candidate for Special Concern.

T. r. simulans

This taxon is currently ranked as S3S2 (Blue List) in British Columbia largely on the basis of its small distributional area. The Washington Sate Natural Heritage Information Centre has ranked it as S2?. In contrast to *T. r. ruficaudus, T. r. simulans* occupies a wide elevational range and a variety of habitats including the floodplain of the Creston Valley, mid elevation forests (mature and logged), and subalpine habitat in Stagleap Provincial Park. Contiguous with populations in Washington and Idaho, there is

considerable potential for rescue effect. No threats are known. Despite its provincial listing, we suggest that this taxon does not qualify as a COSEWIC candidate for Special Concern.

RECOMMENDATIONS FOR RESEARCH

Throughout this report we have repeatedly noted three areas for more research: taxonomy, inventory to determine distributional ranges, and detailed habitat studies. The taxonomy of *T. ruficaudus* is largely resolved (see Chapter 3). Our study demonstrates that *T. r. ruficaudus* and *T. r. simulans* are two well-defined subspecies in British Columbia that differ in morphology and ecology. They warrant separate listings and conservation strategies. Molecular studies now being done by Jeff Good at the University of Idaho should resolve the question of the species status of these two forms. Major taxonomic questions, however, remain with *T. minimus*. If *T. m. oreocetes* is not a valid subspecies, it will be synonymized with *T. m. borealis* and will simply disappear from the provincial tracking lists as *T. m. borealis* is widespread and abundant across northern Canada. One of us (DWN) is searching for *T. m. oreocetes* specimens that may be held in US museums to increase the sample sizes and geographic coverage of the morphological analysis. Tissues from vouchers specimens of *T. minimus* collected in the Purcell Mountains and Rocky Mountains in 1997 and 1998 potentially could be used in a molecular study with mitochondrial DNA. We are attempting to find a researcher to analyze this material.

Inventory data for the four chipmunk subspecies in British Columbia are inadequate to confidently define their distributional ranges. However, before any inventory is done, the investigator must carefully consider identification and the necessity to take voucher specimens (see Appendix 2-3). The three chipmunk species in the Kootenay region can be positively identified from genital bones prepared from voucher specimens. However, until a technique is developed to age live animals, the keys based on pelage and body size given in Appendix 2-3 cannot be used reliably on live animals. Molecular markers from mitochondrial DNA or microsatellite DNA with non-destructive sampling of tissues such as hair has great potential as a tool for chipmunk field identification. However, given the introgression of *T. ruficaudus* mtDNA into some *T. amoenus* (unpublished data from Jeff Good and John Demboski) in British Columbia, more genetic work has to be done before this method can be applied. Identification problems associated with historical museum specimens, particularly from the Columbia Mountains also limit the use of museum specimen records for mapping distributions (see Chapter 2).

Highest priority is for detailed inventories of *T. m. selkirki.* In addition to surveys in the Purcell Mountains, alpine areas in the Selkirk Mountains should be surveyed for possible *T. minimus*. Although Cowan and Munro (1945) reported that *T. amoenus* was the only chipmunk species present in Revelstoke National Park, no chipmunk collections have been made from alpine areas of the Goat Range, the Valhalla Mountains, or the Kokanee Glacier area. Panian (1996) reported a male *T. minimus* from the Kokanee Glacier area but no voucher specimen was kept to substantiate his identification. Unfortunately the x-ray image in his report is too fuzzy to identify and no diagnostic bacular measurements were taken (see identification keys in Appendix 2-3). Additional inventory also needs to be done for *T. r. ruficaudus* in the southern Rocky Mountains. We hypothesized that it ranges as far north as Crowsnest Pass but this needs to be

confirmed. This species also could inhabit subalpine areas west of the Flathead River in British Columbia.

Because our focus was primarily on general inventory, detailed habitat data were not collected in this study. For *T. m. selkirki* and *T. r. ruficaudus*, the only chipmunk taxa that we consider potentially at risk, detailed habitat studies are needed to define critical habitat parameters and the impact of habitat disturbances such as logging, fire, ski developments, or mining. These subjects have the potential for several graduate student theses; we hope our report stimulates such research.

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Table 5-1. Current provincial and IUCN ranks for four chipmunk subspecies of conservation concern in British Columbia

Taxon	Provincial Rank[1]	IUCN Rank[2]
Tamias ruficaudus ruficaudus	S2 (Red List)	-
Tamias ruficaudus simulans	S3S4 (Blue List)	-
Tamias minimus oreocetes	S2S3 (Blue List)	-
Tamias minimus selkirki	S1S3 (Red List)	Vulnerable (D2)

[1] see Cannings et al. (1999) and BC CDC web page (url: www. elp.gov.bc.ca/rib/wis/cdc/vertebrates.htm)

[2] see Sullivan and Nagorsen (1998)

APPENDIX 5-1. SUMMARY OF STATUS ASSESSSMENT DATA

Least Chipmunk *oreocetes* ssp (*Tamias minimus oreocetes*)

Taxonomy - taxonomic validity of this subspecies is dubious. It is not differentiated from *T. m. borealis* in skull morphology; sample sizes inadequate to assess divergence in genital bone morphology.
Population trends - no data but probably stable.
Population size - unknown but in BC could range from 1,000-10,000.
Distribution - along the continental divide as far north as Kicking Horse Pass and the south side of the Bow River in Alberta. Extent of occurrence in BC is about 1,000 km^2 Distribution may be partially fragmented by low passes such Crowsnest Pass. BC populations contiguous with populations in Alberta and populations in Glacier National Park, Montana.
Habitat-open talus and krummholz in alpine areas, recent burns, above 1900 metres. No evidence for habitat loss.
Occurrences in Protected Areas - Mount Assiniboine Provincial Park, Yoho National Park, probably in Kootenay National Park, Height of the Rockies Provincial Park, and Akamina-Kishinena Provincial Park but no confirmed records. In Alberta occurs in a number of provincial and national parks adjacent to the BC border (e.g., Waterton Lakes National Park, Banff National Park)
Threats - no demonstrated threats; only potential threat is destruction of alpine areas for open pit coal mines. Possible impact from ski developments.
Data Deficiencies - more taxonomic research using additional samples of genital bones and molecular studies. Distribution is poorly documented; areas west of the Flathead River and Elk River valleys have not been inventoried.

Least Chipmunk *selkirki* ssp (*Tamias minimus selkirki*)

Taxonomy - differentiated from Rocky Mountain forms (*T. m. oreocetes*, *T. m. borealis*) in skull and genital bone morphology.
Population trends - no data but probably stable.
Population size - unknown but probably less than 1,000 individuals for the known range.
Distribution - endemic to the Purcell Mountains of BC where it is known from only two areas: Paradise Mine-Bruce Creek-Spring Creek drainage and Mount Brewer. Known extent of occurrence is less than 100 km^2. Distribution is 80 to 100 km from the nearest *T. minimus* populations in alpine areas of the Rocky Mountains; isolated by the Rocky Mountain Trench, Columbia River, and forested habitats from the Rocky Mountain populations.
Habitat-open talus, krummholz in dry alpine, subalpine areas above 2000 metres. No evidence for habitat loss.
Occurrences in Protected Areas - None but may occur in the Purcell Wilderness Conservancy.
Threats - no demonstrated threats but potential impacts from ski developments and mining; however, has persisted in disturbed habitat at the Paradise Mine for 60 years.

Data Deficiencies- taxonomic validity of this subspecies needs to be confirmed with molecular studies. Distribution is poorly documented; inventory needed in adjacent alpine areas of the Purcell Mountains and in the Selkirk Mountains. Habitat requirements not well documented.

Red-tailed Chipmunk *ruficaudus* ssp (*Tamias ruficaudus ruficaudus*)

Taxonomy- a strongly differentiated subspecies with Canadian populations differing from the Selkirk Mountain subspecies (*T. r. simulans*) in pelage colour, skull and genital bone morphology.
Population trends- unknown.
Population size- unknown, possibly less than 1,000 for BC.
Distribution- known from only three sites (Wall Lake, Akamina Pass, Middle Kootenay pass) but probably ranges along the continental divide as far north as Crowsnest Pass. Extent of occurrence in BC less than 100 km^2. Populations in Alberta on the east side of the Rocky Mountains are isolated from BC populations by intervening alpine populations of *T. minimus* but limited contact may occur in a few passes.
Habitat-subalpine forest in a narrow elevational belt from 1780-1900 metres. Inhabits recent burns and mature forest. No evidence for habitat loss. Relationship with forest harvesting unknown for BC population.
Occurrences in Protected Areas- Akamina-Kishinena Provincial Park; in Alberta occurs in Waterton Lakes National Park adjacent to the BC border.
Threats- no demonstrated threats but possible impact from disturbances such as logging that could result in the invasion of *Tamias amoenus* and competitive exclusion.
Data Deficiencies- Distribution is poorly documented; the northern and western limits of its range in BC unknown. Subalpine areas west of the Flathead River and north of Middle Kootenay Pass need to be surveyed. Habitat requirements particularly its association with early successional stages needs to be assessed.

Red-tailed Chipmunk *simulans* ssp (*Tamias ruficaudus simulans*)

Taxonomy- a strongly differentiated subspecies with Canadian populations differing from the Rocky Mountain subspecies (*T. r. ruficaudus*) in pelage colour, skull and genital bone morphology.
Population trends- no data but probably stable.
Population size- unknown but in BC may range from 3,000-10,000.
Distribution- occupies a small area in the southern Selkirk Mountains south of the Kootenay River, west of Kootenay lake, and east of the Columbia River. Known from 10 sites in BC; extent of occurrence in BC about 4,000 km^2. BC Populations contiguous with populations in northeastern Washington Sate and northwestern Idaho.
Habitat-occupies various forested habitats in a wide elevational range from 560-1830 meters. No evidence for habitat loss. Inhabits early successional stages from logging.
Occurrences in Protected Areas- Stagleap Provincial Park; probably also occurs in Champion Lakes Provincial Park and West Arm Provincial Park.
Threats- no known threats. Given the apparent rarity of *Tamias amoenus* in the southern Selkirk Mountains, competitive exclusion is not apparent

Data Deficiencies- precise limits of its range in BC unknown. More inventory is required in the southern Purcell Mountains to confirm that it is not found east of the Creston Valley; and north of the Kootenay River and west of the Columbia River in the Monashee Mountains where *T. amoenus* is supposedly the only chipmunk species present.