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Status of the Long-toed Salamander (Ambystoma macrodactylum) in Alberta

Karen L. Graham
G. Lawrence Powell

Alberta Wildlife Status Report No. 22

Alberta Conservation Association

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PREFACE

Every five years, the Fisheries and Wildlife Management Division of Alberta Natural Resources Service reviews the status of wildlife species in Alberta. These overviews, which have been conducted in 1991 and 1996, assign individual species to 'colour' lists that reflect the perceived level of risk to populations that occur in the province. Such designations are determined from extensive consultations with professional and amateur biologists, and from a variety of readily available sources of population data. A primary objective of these reviews is to identify species that may be considered for more detailed status determinations.

The Alberta Wildlife Status Report Series is an extension of the 1996 *Status of Alberta Wildlife* review process, and provides comprehensive current summaries of the biological status of selected wildlife species in Alberta. Priority is given to species that are potentially at risk in the province (Red or Blue listed), that are of uncertain status (Status Undetermined), or which are considered to be at risk at a national level by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Reports in this series are published and distributed by the Alberta Conservation Association and the Fisheries and Wildlife Management Division of Alberta Environmental Protection, and are intended to provide detailed and up-to-date information which will be useful to resource professionals for managing populations of species and their habitats in the province. The reports are also designed to provide current information which will assist the Alberta Endangered Species Conservation Committee to identify species that may be formally designated as endangered or threatened under the Alberta Wildlife Act. To achieve these goals, the reports have been authored and/or reviewed by individuals with unique local expertise in the biology and management of each species.

EXECUTIVE SUMMARY

The Long-toed Salamander (Ambystoma macrodactylum) is currently on the 'Yellow B List' in Alberta. This report summarizes information on the Long-toed Salamander in Alberta as a step in updating its status in the province.

The Long-toed Salamander occupies an assortment of habitats throughout its range. In Alberta, the species has a clumped distribution along the Front Range of the Rocky Mountains and is usually associated with low mountain passes or river valleys. No evidence currently exists to suggest a decline in the population or a contraction in the distribution of the Long-toed Salamander in Alberta. However, because of the lack of long-term data, conclusions pertaining to the stability of the population and range of the species in the province are tentative, at best. The main limiting factors for the Long-toed Salamander in Alberta appear to be the presence of predatory fish in breeding ponds, human disturbance such as roads between terrestrial habitat and breeding ponds and collection of adults by the public during the breeding season. Habitat alteration associated with forestry and mining do not appear to have serious long-term impacts on Long-toed Salamander populations. The effects of pesticides and other chemicals are largely unknown.

The Long-toed Salamander is likely not at risk of extirpation in Alberta. However, long-term population data is necessary in order to assess population trends accurately. Further research into the effects of human alterations to habitat and the effects of pesticides and other chemicals on Long-toed Salamander populations is necessary for management planning.

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INTRODUCTION

The Long-toed Salamander (Ambystoma macrodactylum) is one of two salamander species found in Alberta, both belonging to the Family Ambystomatidae, the mole salamanders (Russell and Bauer 1993). Five subspecies of the Long-toed Salamander have been identified, A. m. macrodactylum, A. m. columbianum, A. m. krausei, A. m. sigillatum and A. m. croceum. Only A. m. krausei occurs in Alberta (although some recent genetic work suggests A. m. columbianum may occur in the southwest corner of the province) where it is found in pockets on the western edge of the province as far north as the Peace River area (Russell and Bauer 1993, Nelson et al. 1995, Hamilton et al. 1996). The Long-toed Salamander overlaps very little in distribution with the other salamander species in Alberta, the Tiger Salamander (Ambystoma tigrinum), which reaches its western range limit along the foothills of the Front Range of the Rocky Mountains.

The Long-toed Salamander is currently on the 'Yellow B List*' in Alberta, meaning that the species is not at risk but attention should be given to potential limiting factors (Alberta Wildlife Management Division 1996). This report summarizes current and historical information on the Long-toed Salamander in Alberta as a step in updating its status in the province.

HABITAT

The Long-toed Salamander is found in habitats ranging from temperate rain forests to semi-arid sagebrush deserts and alpine meadows (Ferguson 1961, Froom 1982, Nussbaum et al. 1983, Stebbins 1985). This species does not seem to be part of the amphibian assemblage typical of the climax forests in the mountains of Oregon and Washington (Blaustein et al. 1995). This, together with its wide habitat range, suggests that the Long-toed Salamander may be a fugitive species, preferentially exploiting disturbed or marginal habitats rather than climax situations, at least in the western part of its range (Powell et al. 1997a).

In Alberta, most Long-toed Salamanders are found in the Cordilleran Ecoprovince, made up of the Montane and Subalpine Ecoregions (Strong 1992). This area is characterized as having a generally short summer with pronounced precipitation, and a climatically variable winter (Strong 1992). A significant number of Long-toed Salamanders are also found in the Boreal Ecoprovince consisting of the Lower Boreal-Cordilleran, Upper Boreal-Cordilleran, and Low Boreal Mixedwood Ecoregions (Strong 1992). This area typically has low annual precipitation, with short summers and long cold winters (Strong 1992). A few Long-toed Salamander populations are also found on the margins of the Fescue Grass Ecoregion (Strong 1992).

The Long-toed Salamander requires both aquatic habitat for breeding and terrestrial habitat. Breeding habitat in Alberta consists of lakes or ponds. Breeding lakes are often large and shallow, with boggy edges and abundant aquatic vegetation (Hamilton et al. 1996, Graham 1997). Deep lakes with little aquatic vegetation are also used when adjoining wetlands can provide the necessary shelter and shallow areas for egg-laying (Powell et al. 1993, Fukumoto 1995, Graham 1997). Long-toed Salamander larvae are generally not found in ponds with predatory fish such as Rainbow Trout (Oncorhynchus mykiss; Powell et al. 1993, B. Hunt, unpubl. data), however there are documented exceptions (Fukumoto 1995). A survey of lakes over a wide range of altitudes

* See Appendix 1 for definitions of selected status designations

in the Cascade Mountains found that larval salamander densities were significantly lower in lakes with fish than in lakes without fish and that coexistence seems to depend upon a spatially complex habitat (Liss et al. 1995). In Oregon, Tyler (1996) found that densities of larval Long-toed Salamanders in fishless lakes was positively correlated with high zooplankton productivity and thus food abundance. Similarly, a study in westcentral Alberta found that large, permanent and fishless lakes supported the largest breeding populations of Long-toed Salamanders (Graham 1997).

Ponds used as breeding habitat can be either natural or man-made and are usually shallow without an abundance of aquatic vegetation (Fukumoto 1995, Powell et al. 1997a). Information on Long-toed Salamander larvae was gathered in the Hinton area during the spring of 1987 (B. Hunt, unpubl. data). Breeding ponds were described as being small (<12 ha) and shallow (1 to 3 m), and located among regenerating Black Spruce (Picea mariana) and Tamarack (Larix laricina) woodlands that had been logged approximately 20 to 30 years previously (B. Hunt, unpubl. data).

The vegetation surrounding breeding ponds and the terrestrial habitat used by adult Long-toed Salamanders in the Fescue Grass Ecoregion is the rough fescue (Festuca spp.) - Parry oat grass (Danthonia parryi) association which occurs in wet areas and along forested riparian river valleys (Strong 1992). In the Montane Ecoregion, the habitat occupied by the Long-toed Salamander is the closed-canopy Lodgepole Pine (Pinus contorta) and Douglas-fir (Pseudotsuga menziesii) association; Balsam Poplar (Populus balsamifera) and willow (Salix spp.) tend to predominate in wet areas (Strong 1992). Because the majority of Alberta's Long-toed Salamanders are found in this ecoregion (Powell et al. 1997a), these vegetation associations are most closely correlated with the presence of the species in the province. Long-toed Salamanders have also been found on heavily modified agricultural land (Hamilton et al. 1996, Walsh 1998).

A terrestrial habitat use study conducted on the Long-toed Salamander in westcentral Alberta near Hinton determined that individuals were found primarily in well-drained areas with a thick litter layer on the forest floor and close to relatively permanent water bodies (Graham 1997). Factors such as tree canopy cover and downed woody debris, which are important habitat attributes to many other salamander species, were not associated with the abundance of Long-toed Salamanders in this area (Graham 1997). Terrestrial Long-toed Salamanders were abundant in seral (successional) stages ranging from three-year-old clearcuts to 180-year-old forests (Graham 1997). In addition, breeding population size (based on egg counts) was not associated with the area of clearcuts within 250 m or 500 m of the breeding ponds. These findings show that robust populations of Long-toed Salamanders can occur even with active logging in the area (Graham 1997; see 'Limiting Factors' section, below).

Almost all Long-toed Salamander localities in Alberta are situated on surficial deposits of a fluvial, aeolian, glaciofluvial, or lacustrine nature (Bayrock and Reimchen 1980). It is likely that a highly permeable substrate is necessary to maintain the high soil moisture required by terrestrial salamanders, and to recharge the temporary and permanent waterbodies used as breeding habitat. Terrestrial Long-toed Salamanders appear to be primarily fossorial in Alberta (Sheppard 1977, Powell et al. 1993), and a substrate featuring abundant interstitial spaces is necessary for a salamander with such weak burrowing abilities (Semlitsch 1983). Restriction of populations to valley bottoms in montane areas is thus to be expected, as the combination of permeable fluvial or glaciofluvial substrate with high water potential produces abundant terrestrial and breeding habitat in these areas.

CONSERVATION BIOLOGY

The Long-toed Salamander moves from upland areas to its aquatic breeding habitat as soon as the spring melt occurs (Bishop 1943, Kezer and Farner 1955, Knudsen 1960, Ferguson 1961, Anderson 1967, Nussbaum et al. 1983, Cook 1984, Beneski et al. 1986). The primary stimulus for breeding in the Bow Corridor population appears to be the thawing of the ground (G. L. Powell and A. P. Russell, unpubl. data). The number of adult salamanders at the breeding ponds in the Bow Corridor increased with both temperature and precipitation, indicating that movement and emergence are encouraged by these factors (G. L. Powell and A. P. Russell, unpubl. data).

Adult salamanders can be active in and around breeding ponds at temperatures as low as 4°C (Powell et al. 1993). However, Salt (1979) only observed breeding in water warmer than 11°C in the Jasper area. Males arrive first at the ponds to await the females (Nussbaum et al. 1983). Beneski et al. (1996) found that males of A. m. columbianum stayed in breeding ponds an average of 28 days whereas females stayed for an average of 18 days. Fukumoto (1995) observed stays of similar lengths in Waterton Lakes National Park.

Within the Alberta range of the Long-toed Salamander, egg-laying appears to take place between mid-April and June, depending upon spring weather and the elevation and latitude of the population (Salt 1979, Powell et al. 1993, Fukumoto 1995, G. L. Powell and K. Oseen, unpubl. data). Eggs are laid singly or in clumps on vegetation, logs or rocks and females can extend laying over several days (K. Graham, unpubl. data). Eggs in Alberta are typically deposited in water >10 cm deep and are seldom laid in positions where a moderate drop in water level would expose them to dessication (Sheppard 1977, Powell et al. 1993, Fukumoto 1995).

Nussbaum et al. (1983) state that clutch size ranges between 85 and 411 eggs, but these data represent salamanders from throughout the U.S. Pacific Northwest and should be considered a range of clutch sizes for the species. In Alberta, clutch sizes of 170 (Powell et al. 1997a), and 213-225 (Graham 1997) have been reported. A slight correlation exists between female size and clutch size (Nussbaum et al. 1983). Howard and Wallace (1985) found that high-elevation females of A. m. columbianum had significantly smaller clutches and larger egg size than low-elevation females.

Water temperature strongly affects the length of time between laying and hatching. In the Bow Corridor of Alberta, Sheppard (1977) found that development of eggs from laying to hatching took an average of 12 days. Fukumoto (1995) found up to five to seven weeks could pass between laying and hatching in the Waterton Lakes area. However, in the Peace River district, at a higher latitude but a lower elevation, eggs took 18 to 20 days to hatch (R. Walsh, unpubl. data).

Larval growth and development is a critical stage of an amphibian's life cycle (Woodward and Mitchell 1991). The Long-toed Salamander larva is in most regards a typical ambystomatid salamander larva. It is pond-dwelling, with a well-developed dorsal fin, deep body profile and large, bushy gills. In

Alberta, hatching has been noted as early as 2 May and as late as 24 June (Sheppard 1977, Salt 1979). The rate of larval development varies considerably over the geographic range because of the wide variance in the timing and length of the breeding season (Kezer and Farner 1955, Nussbaum et al. 1983) and in the mean temperature of the larval habitat.

In Alberta, metamorphosis (change from larval to adult body form) typically occurs in the first summer, usually in August (Powell et al. 1997b) when larvae are approximately 50 mm snout-to-vent length (Sheppard 1977, Watson 1997). Farner and Kezer (1953) and Kezer and Farner (1955) demonstrated that the length of the larval period depends upon the elevation (and thus the water temperature) of the breeding habitat. They found evidence that early metamorphosis is a facultative response to drying of the breeding pond, although metamorphosis may not always occur in time (Farner and Kezer 1953, Anderson 1967). Howard and Wallace (1985) found a transition from a single-season to a three-year larval period over an altitudinal gradient in A. m. columbianum. Two- and three-year larvae were found to metamorphose at a larger size and had a developmental advantage in attaining sexual maturity (Howard and Wallace 1985). There is some evidence that populations in high-altitude lakes in Waterton Lakes National Park (elevation 1930 m) and Spray Lakes in Banff National Park (elevation 1767 m) may overwinter as larvae (Fukumoto 1995, Nelson et al. 1995). The populations near Fairview, which is at a higher latitude but lower elevation than Waterton Lakes National Park and Spray Lakes, complete development within one season (Walsh 1998). Neotenic (does not metamorphose; retains larval characteristics as an adult) Long-toed Salamanders have not been found anywhere in the species' distribution (Anderson 1967, Powell et al. 1997a).

Long-toed Salamander larvae feed on a variety of prey including insects, crustacean zooplankton, and amphibian larvae (Sheppard 1977, Walls et al. 1993, Tyler 1996). In Washington, Long-toed Salamander larvae are major vertebrate predators in North Cascades lakes, especially those lacking native or introduced fish populations (Liss et al. 1995). Long-toed Salamander larvae are in turn, preyed upon by aquatic insects, fish, birds, and garter snakes (Thamnophis spp.; Ferguson 1961, Sheppard 1977, Nussbaum et al. 1983). Garter snakes are one of the main predators of terrestrial Long-toed Salamanders (Ferguson 1961, Beneski et al. 1986). When threatened, Long-toed Salamanders exude a sticky, white fluid from their tail and back, which is toxic and adhesive (Brodie et al. 1979, Williams and Anthony 1994, Powell et al. 1997a). Scars on the tails of captured salamanders suggest that this defence is effective against small predators such as shrews and birds (Powell et al. 1997a).

Post-metamorphic growth is highly variable. Sexual maturity occurs when salamanders are between 43 to 50 mm snout-to-vent length or between two and five years of age with most attaining maturity at three years (Russell et al. 1996). A study in the Bow River Valley showed that the lifespan of the Long-toed Salamander is usually six to seven years and up to 10 years (Russell et al. 1996). Anderson (1967) found that sexual maturity was reached at 50 mm snout-to-vent length, in the second year post-metamorphosis in a low-elevation California population, and at 55 mm snout-to-vent length in a third year high-elevation population. Growth rates appear to be determined largely by length of the growing season and availability of food (Russell et al. 1996).

Terrestrial Long-toed Salamanders, including sexually mature and immature individuals, spend most of their time below ground, often in small mammal burrows (Anderson 1967, Sheppard 1977, Douglas 1981). In the Bow Valley, however, Powell et al. (1993, 1997a, 1997b) recorded considerable surface activity throughout the spring and summer, well after breeding had ceased.

Little information is available on the overwintering habits of the Long-toed Salamander. Sheppard (1977) located three overwintering aggregations in the Bow River area by tracking individuals bearing radioactive tags. Groups of eight to 14 (mostly adult) salamanders were found together, buried 50 to 70 cm below the surface in loose gravel (Sheppard 1977). Each group was near large spruce trees in low, well-wooded areas with relatively high soil moisture and where snow cover remained until the spring. Temperatures at the overwintering site never dropped below 2°C (Sheppard 1977).

Long-toed Salamanders are noted for movements of breeding adults to and from breeding habitat and movements of new metamorphs from natal ponds to terrestrial habitat. Mass movements of breeding adults and emerging metamorphs have been observed (Anderson 1967, Howard and Wallace 1985, Beneski et al. 1986). Travel corridors have been reported for a population in Linnet Lake in Waterton Lakes National Park (Fukumoto 1995) and for a Bow Corridor population (Powell et al. 1993). One individual in the Bow Corridor was found 900 m from the only potential breeding pond, which suggests that this species can move over relatively long distances (Powell et al. 1993).

Home ranges of terrestrial adult and juvenile Long-toed Salamanders in the Bow Corridor were determined by locating salamanders that had been implanted with radioactive tags (Sheppard 1977). The mean estimated home range sizes for females, males and juveniles were 115.6 m^2, 167.5 m^2 and 281.6 m^2, respectively (Sheppard 1977). These are large home-range areas for a species that spends most of its time underground.

DISTRIBUTION

1. Alberta. **-** Most of the Long-toed Salamander populations in Alberta are concentrated in mountain passes and associated river valleys. These landforms likely served as colonization routes over the continental divide from British Columbia (Russell and Bauer 1993, Nelson et al. 1995, Hamilton et al. 1996, Powell et al. 1997a, Walsh 1998). There is some evidence that the Waterton Lakes, Castle River and Crowsnest Pass populations invaded from the south (Powell et al. 1997a, K. Graham, unpubl. data). Maximum elevations at which Long-toed Salamanders are found in Alberta range from 2260 m in the south to 1495 m in the north (Nelson et al. 1995, Hamilton et al. 1996, Powell et al. 1997a). The lower elevations occupied in the north are likely a function of the altitudinal decrease in the limits of the growing season with increasing latitude (Gadd 1986).

Powell et al. (1997a) provide the most recent and comprehensive review of the distribution of Long-toed Salamanders in Alberta. They describe the Alberta populations as nine distinct population groupings (Appendix 2) rather than as one continuous population along the Front Range of the Rocky Mountains. The groupings are associated with particular river valleys and are as follows: 1) Waterton Lakes - 11 locations, 2) Castle River - 15 locations; 3) Crowsnest Pass - 6 locations; 4) Stavely - 1 location; 5) Kananaskis Valley - 17 locations; 6) Spray Lakes - 3 locations; 7) Bow Valley - 23 locations; 8) Athabasca Valley - 43 locations; and 9) Peace River - 11 locations (Figure 1). Two additional reports of Long-toed Salamanders occurring at Pinto Lake in northern Banff National Park and in the Embarras River are unconfirmed or a result of mapping errors (Hamilton et al. 1996). The Stavely population could either represent a relict population or, more likely, an introduction.

It is generally accepted that the subspecies found in Alberta is A. m. krausei. However, recent genetic work suggests that only the populations east of the Crowsnest Pass and south to Waterton Lakes area may belong to this subspecies, and that the rest of the Alberta populations may belong to the subspecies found throughout most of British Columbia, A. m. columbianum (K. Graham, unpubl. data). Additional genetic work is needed to confirm this.

The Long-toed Salamander was not well studied in Alberta until recently, so it is not known if the species is experiencing a range change in the province (Powell et al. 1997a). Evidence suggests that the populations from the Bow River Valley south have reached their eastern limit along the edge of the Front Range of the Rocky Mountains (Powell et al. 1997a). The presence of Tiger Salamanders to the east and other unknown factors are likely limiting Long-toed Salamanders to their present range in this area. Not enough information exists on the Athabasca River and Peace River populations to determine if those distributions are static, expanding or contracting.

2. Other Areas. - The Long-toed Salamander occurs throughout northwestern North America. It ranges from the Alaska panhandle as far north as the Stikine and Taku Rivers in British Columbia, south through Oregon and Washington to northeastern California and as far east as the eastern slope of Montana (Bishop 1943, Ferguson 1961, Hodge 1976, Froom 1982, Nussbaum et al. 1983, Cook 1984, Russell and Bauer 1993, Corkran and Thoms 1996; Figure 2). A small relict population, A. m. croceum, also occurs in the Santa Cruz area of westcentral California (Ferguson 1961, Stebbins 1985; Figure 2). Of the four other subspecies, A. m. sigillatum occurs from southeastern Oregon to northeastern California. A. m. macrodactylum ranges from southwestern Oregon to southwestern British Columbia including Vancouver Island. A. m. columbianum occurs north from Oregon and Idaho and throughout most of British Columbia, with the exception of the Vancouver area and the eastern edge of the province. The northern range limit of this subspecies in the northern interior of British Columbia is not well documented (Powell et al. 1997a). A. m. krausei occurs in eastern British Columbia (east of the Columbia River Valley) and south to Idaho and Montana (Ferguson 1961). There is no evidence of a change in the continental range of the Long-toed Salamander.

POPULATION SIZE AND TRENDS

Population size and trend estimates are difficult to establish for fossorial salamanders that breed in water because these species generally violate population modelling assumptions such as random mixture of marked and unmarked individuals. In the case of the Long-toed Salamander, estimates are difficult to make because sexually immature individuals are difficult to find, differences exist in the amount of time individuals are present at the breeding habitat, individuals may not breed annually, and because of annual movement to and from the breeding habitat. Furthermore, longer term (i.e. spanning several generations of a population) data necessary to make conclusions as to population trend in the Long-toed Salamander (Perchman et al. 1991) are unavailable.

1. Alberta. - Many records of Long-toed Salamanders in Alberta consist of individual sightings of one or several salamanders at

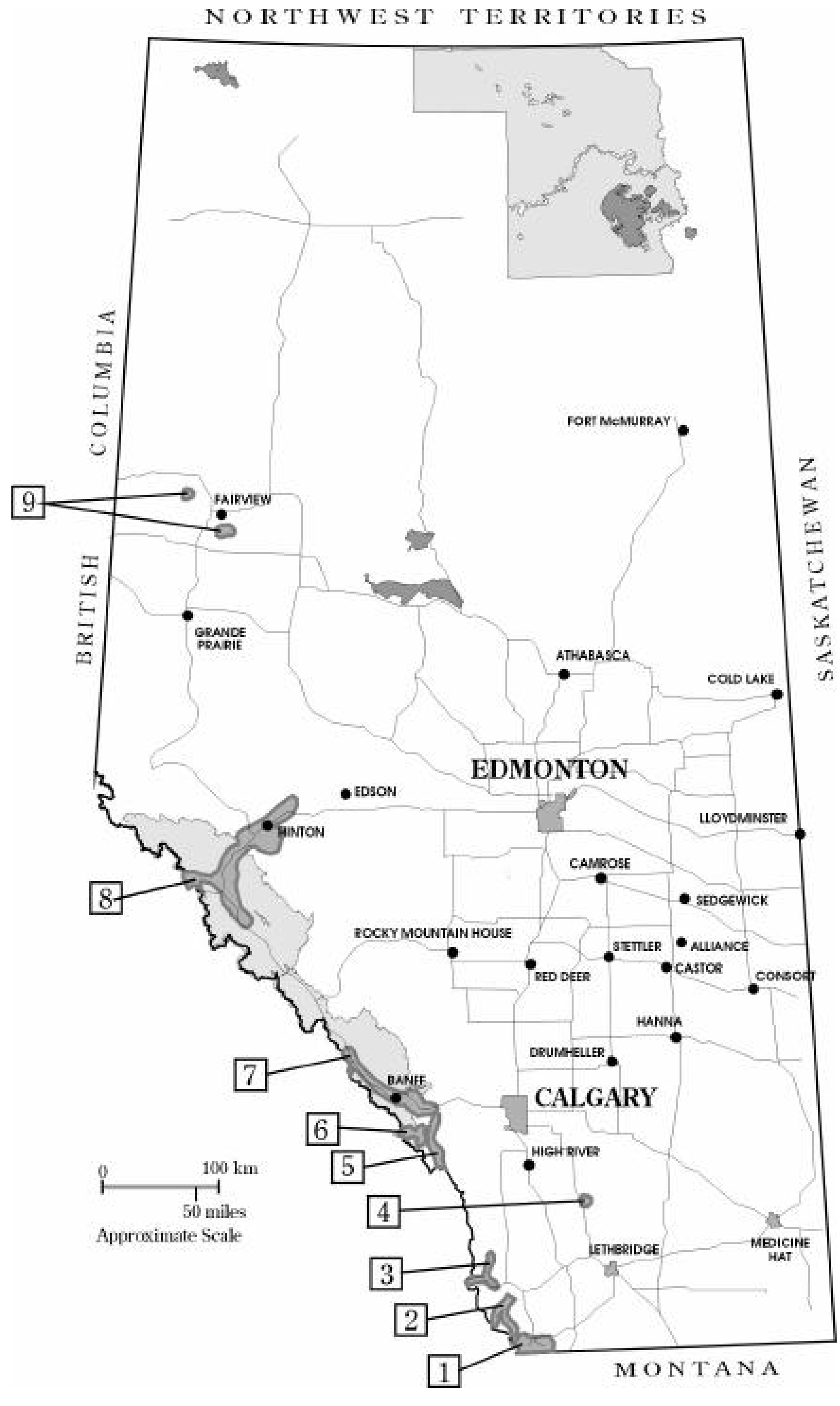

Figure 1. Distribution of the Long-toed Salamander in Alberta. Details of the nine population groupings are found in Appendix 2.

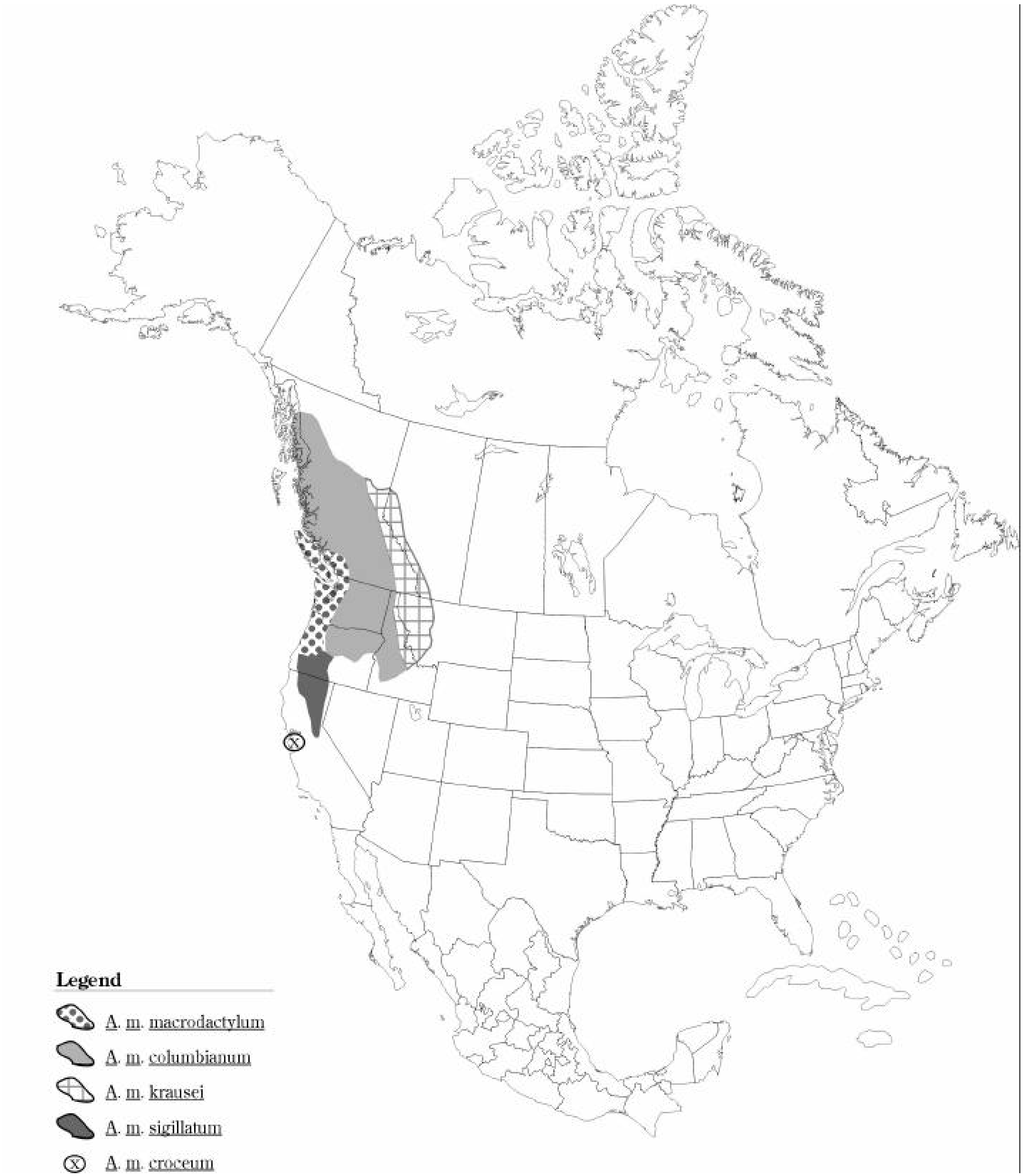

Figure 2. Distribution of the Long-toed Salamander in North America (modified from Stebbins 1985).

particular localities, without any rigorous counts or estimates of numbers (Oseen et al. 1995a, 1995b). For example, Sheppard (1977) noted that his study population in the Bow Corridor was large, without any quantification. The large population at Linnet Lake, in Waterton Lakes National Park, was first noted when over 1200 individuals were picked off the road between the terrestrial and breeding habitats in the spring of 1992 (Morrison 1992). It was clear that this represented only the adult portion of the population. Fukumoto (1995) later made an estimate of 3856 breeding individuals at this site. This estimate used only captures and recaptures made during the breeding migration, which omits the potentially large sexually immature component of the terrestrial population (Fukumoto 1995).

At the Lafarge borrow pit and Quarry Ponds in the Bow Valley, a total of 1725 and 1078 individuals, respectively, were captured during a four-year study (Powell and Russell 1996). Large year-to-year variations in capture and recapture numbers were recorded (Powell et al. 1997b). Powell and Russell (1996) suggested that this large fluctuation could be explained by a large, mainly subterranean population with a surface activity level dictated by conditions on the surface. The four-year data set for these two populations comprises the only multi-year records available for this species in this province, and is difficult to interpret. However, in the absence of any evidence of a decline over the study period, the Bow Corridor populations are considered to be stable (Powell et al. 1997).

2. Other Areas. - Relatively large numbers of Long-toed Salamander have been counted outside of Alberta (Ferguson 1961, Anderson 1967, Nussbaum et al. 1983, Leonard et al. 1993, Corkran and Thoms 1996). These reports, however, are almost always based on incidental sightings and do not involve rigorous population estimates. Large populations would likely be noted more frequently if the species were not so rarely seen outside of the breeding season (Ferguson 1961, Anderson 1967, Nussbaum et al. 1983). Farner and Kezer (1953) reported extremely high counts of terrestrial Long-toed Salamanders, both new metamorphs and older individuals, at Crater Lake National Park, Oregon, where terrestrial habitat is apparently limited and terrestrial salamanders tend to stay in the vicinity of the shoreline. In Idaho, Beneski et al. (1986) surrounded a 0.1 ha breeding pond with a drift fence and caught 2030 individuals. Correcting for the trapping efficiency of the fence, and not allowing for mortality, fence trespass, or salamanders remaining in the pond, they estimated the breeding population to be 3141 individuals. No studies outside of Alberta have been conducted in which population sizes over several years have been examined. Therefore, insufficient information exists on which to base population trend estimates.

LIMITING FACTORS

Limiting factors for the Long-toed Salamander include those that affect habitat suitability, and reduce the survivorship of adults or larvae. Climate and access to low elevation passes for colonization may limit population size, however, the following discussion focuses on human impacts.

1. Coexistence with Predatory Fish. - The presence of predatory fish may limit the distribution of Long-toed Salamanders on a local scale (Powell et al. 1993). Long-toed Salamander larvae can coexist with game fish, but coexistence depends upon a spatially complex habitat (Liss et al. 1995, Tyler 1996). Anecdotal evidence in Alberta strongly suggests a negative relationship between game fish and Long-toed Salamander numbers in the Front Range of the Rocky Mountains (Powell et al. 1997a). Therefore, stocking of game fish in breeding ponds may affect Long-toed Salamander populations negatively.

2. Human Disturbance. - Human disturbance such as building roads that separate terrestrial habitat and breeding ponds has a limiting effect on populations (Fukumoto 1995). Collection of adults by the public while the salamanders are in or on their way to breeding ponds in the spring can also impact breeding population size (Powell et al. 1993). The long-term result of these actions on salamander populations is unknown.

3. Habitat Alteration. - Long-toed Salamander habitat may be impacted directly by forestry or mining activities or indirectly by agricultural chemicals. Populations of the Long-toed Salamander exist in areas with periodic habitat alterations associated with forestry and mining (see 'Habitat' section, above). However, it is unclear whether local extirpation with rapid recovery occurs in some of the populations or if Long-toed Salamanders are able to withstand these changes over the long-term (Powell et al. 1997a). If local extirpation does occur, it is critical that source populations are present to recolonize recently disturbed habitats. The effect of pesticides, herbicides and other chemicals on Long-toed Salamander populations is unknown but could potentially have a detrimental impact on larvae and/or terrestrials. Long-toed Salamander larvae are sensitive to a combination of low pH and aluminum (Bradford et al. 1994), and thus vulnerable to industrial activity that might produce such conditions in their breeding habitat.

STATUS DESIGNATIONS

1. Alberta. - Based on more current information, the Long-toed Salamander was down-listed from Alberta's 'Red List' to the 'Yellow B List' in 1996 (Alberta Fish and Wildlife 1991, Alberta Wildlife Management Division 1996). 'Yellow List' species are those that are not currently at risk although there may arise potential problems related to low populations, limited provincial distribution or demographic/life history features that could make them vulnerable to anthropomorphic alterations (Alberta Wildlife Management Division 1996). The 'B' classification applies to species that are naturally rare but not in decline, have a clumped distribution or are associated with habitats potentially at risk (Alberta Wildlife Management Division 1996). The Alberta Natural Heritage Information Centre has assigned a provincial rank of S3 to the Long-toed Salamander because of its association with sensitive habitats (Alberta Natural Heritage Information Centre 1999).

2. Other Areas. - The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has not assigned a federal status to the Long-toed Salamander. In British Columbia, the species is on the provincial 'Yellow List' and is subclassified as 'Ye' meaning the species is not at risk and will be protected through ecosystem management (Corkran and Thoms 1996). To date, the British Columbia Conservation Data Centre has not assigned a rank to the Long-toed Salamander (British Columbia Conservation Data Centre 1999). Legal protection in British Columbia occurs through the Wildlife Act, which includes all native amphibians in the province.

In the United States, A. m. croceum populations in California are listed as 'endangered' and are fully protected under the Federal Endangered Species Act (California Department of Fish and Game 1999). The Nature Conservancy's (1999) Natural Heritage Network similarly lists A. m. croceum as S1 or 'critically imperiled' but lists the Long-toed

Salamander throughout its global range as G5 or 'demonstrably secure'. Other Long-toed Salamander populations in the United States are either not listed (e.g., Oregon, Idaho and Montana) or are listed as S5 or 'demonstrably secure (Washington; see The Nature Conservancy 1999 and associated links).

RECENT MANAGEMENT IN ALBERTA

Several projects have examined the ecology of Long-toed Salamanders in Alberta. These projects have been in response to an immediate perceived local management problem (Fukumoto 1995, Graham 1997, B. Hunt, unpubl. data) or in an effort to understand the demographics of the species in this province and formulate an overall management strategy (Powell et al. 1993, 1997a, 1997b, Oseen et al. 1995a, 1995b, Nelson et al. 1995, Hamilton et al. 1996).

Fukumoto (1995) investigated the demography and movement patterns of a population in Waterton Lakes National Park affected by a nearby road, and made management recommendations appropriate to the species in the park. The immediate result was modification of the road causing the problem (Fukumoto 1995). Graham (1997) examined the terrestrial habitat use of Long-toed Salamanders in the Hinton area and also looked at the genetic variation between the three Canadian subspecies (K. Graham, unpubl. data). A Habitat Suitability Index Model has been produced by Weldwood of Canada based on Graham's findings (K. Graham, unpubl. data). This model will predict potential effects of forestry operations on the terrestrial habitat of Long-toed Salamanders' at a landscape scale throughout an entire forestry management cycle of one to two centuries.

SYNTHESIS

The Long-toed Salamander does not appear to be in immediate danger of extirpation in Alberta. Although the species is limited in its distribution in the province, apparently robust populations occur in areas of the Front Range of the Rocky Mountains and the adjacent boreal forest. However, the lack of long-term information essential to estimate population trend in fossorial salamanders makes it difficult to assess the available population data accurately. Populations of the Long-toed Salamander are not widespread across the province and there is still much to learn about how anthropomorphic alterations affect this species. Further work needs to examine the long-term effects of industrial impacts associated with forestry and mining, pesticides and other chemicals on Long-toed Salamanders. Research is also required to examine genetic variation on a large scale (subspecies) and a population scale. The result of these studies would provide useful data which could help in making appropriate management decisions in the future.

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APPENDIX 1. Definitions of selected legal and protective designations.

A. Status of Alberta Wildlife colour lists (after Alberta Wildlife Management Division 1996)

Red	Current knowledge suggests that these species are at risk. These species have declined, or are in immediate danger of declining, to nonviable population size
Blue	Current knowledge suggests that these species may be at risk. These species have undergone non-cyclical declines in population or habitat, or reductions in provincial distribution
Yellow	Species that are not currently at risk, but may require special management to address concerns related to naturally low populations, limited provincial distributions, or demographic/life history features that make them vulnerable to human-related changes in the environment
Green	Species not considered to be at risk. Populations are stable and key habitats are generally secure
Undetermined	Species not known to be at risk, but insufficient information is available to determine status

B. Alberta Wildlife Act

Species designated as 'endangered' under the Alberta Wildlife Act include those defined as 'endangered' or 'threatened' by *A Policy for the Management of Threatened Wildlife in Alberta* (Alberta Fish and Wildlife 1985):

Endangered	A species whose present existence in Alberta is in danger of extinction within the next decade
Threatened	A species that is likely to become endangered if the factors causing its vulnerability are not reversed

C. Committee on the Status of Endangered Wildlife in Canada (after COSEWIC 1999)

Extirpated	A species no longer existing in the wild in Canada, but occurring elsewhere
Endangered	A species facing imminent extirpation or extinction
Threatened	A species likely to become endangered if limiting factors are not reversed
Vulnerable	A species of special concern because of characteristics that make it particularly sensitive to human activities or natural events
Not at Risk	A species that has been evaluated and found not to be at risk
Indeterminate	A species for which there is insufficient scientific information to support status designation

D. United States Endangered Species Act (after National Research Council 1995)

Endangered	Any species which is in danger of extinction throughout all or a significant portion of its range
Threatened	Any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range

E. Natural Heritage Element Rarity Ranks (after The Nature Conservancy 1999)

Global or G-rank: Based on the range-wide status of a species.
Sub-national or S-rank: Based on the status of a species in an individual state or province. S-ranks may differ between states or provinces based on the relative abundance of a species in each state or province.

G1 / S1	Critically imperiled because of extreme rarity (5 or fewer occurrences, or very few remaining individuals), or because of some factor of its biology making it especially vulnerable to extinction
G2 / S2	Imperiled because of rarity (6 to 20 occurrences), or because of other factors demonstrably making it very vulnerable to extinction throughout its range
G3 / S3	Either very rare or local throughout its range, or found locally in a restrcited range (21 to 100 occurrences)
G4 / S4	Apparently secure, though it might be quite rare in parts of its range, especially at the periphery
G5 / S5	Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery

APPENDIX 2. Locations of Long-toed Salamander populations in Alberta (Alberta Conservation Association and Alberta Environment 1999). The nine population groupings are mapped in Figure 1.

LOCATION	UTM*
1. Waterton Lakes Populations	
Lost Lake	708, 5448
Akamina Trailhead	716, 5434
Cameron Lake	716, 5434
Summit Lake	718, 5432
Red Rock Roadside Pond	282, 5444
Blakiston/Red Rock Beaver Ponds	289, 5442
Indian Springs	291, 5446
Lonesome Lake	289, 5440
Stable Pond	289, 5439
Linnet Lake	288, 5438
Giant's Mirror Beaver Pond	304, 5436
2. Castle River Populations	
Screwdriver Creek	699, 5482
Beaver Mines Creek	701, 5479
Mount Backus a	698, 5477
Mount Backus b	698, 5477
Castle River Wetland	694, 5476
Beaver Mines Lake Road 1	694, 5472
Beaver Mines Lake Road 2	694, 5471
Castle River Falls	693, 5477
West Castle Road	689, 5471
West Castle Backwater	691, 5472
West Castle River (north)	688, 5469
West Castle River (middle)	688, 5468
West Castle River (south)	688, 5467
Rainy Ridge Lake	691, 5459
South Castle River	708, 5451
3. Crowsnest Pass Populations	
Livingston Gap Pond	688, 5526
Vicary Creek	681, 5514
Grassy Mountain	682, 5511
Coleman	681, 5502
Frank 1	686, 5498
Frank 2	686, 5498
Hall Pond	673, 5502
4. Stavely Population	
Stavely	308, 5560
5. Kananaskis Valley Populations	
Kananaskis Minimum Security Facility	632, 5620
Mount Lorette Ponds	633, 5648
Boundary Stables	632, 5641
Kananaskis Forestry Road	629, 5635
Eau Claire Beaver Ponds	629, 5633
Fortress Junction	630, 5628
Kananaskis Administration Complex	633, 6619

LOCATION	UTM*
Peter Lougheed P. P. Winter Gate Ponds	634, 6620
Highway 40	634, 6619
Sounding Lake and vicinity	634, 6617
William Watson Lodge and vicinity	633, 6614
Sparrows Egg Lake	634, 6615
Elpoca Mountain	635, 6616
Marl Lake and vicinity	634, 6614
Lower Kananaskis Lake	633, 6611
Boulton Campground	634, 6611
Elk Pass	637, 6606
6. Spray Lakes Populations	
Marvel Lake	603, 5638
Watridge Lake	611, 5634
Burstall Lakes	617, 5626
7. Bow Valley Populations	
Pilot Pond	583, 5676
Muleshoe	589, 5671
Bow Valley Railroad	591, 5669
Bow Valley Parkway	594, 5669
First Vermilion Lakes	599, 5671
Sunshine Junction	590, 5668
Devil's Cauldron	503, 5670
Two-Jack Lake	605, 5676
Johnson Lake	606, 5673
Carrot Powerline	611, 5667
Hidden Pond	610, 5669
Banff Railroad	694, 5669
Mann's Pond	614, 5662
Kuhn's Pond	614, 5660
Arrow Pond	614, 5660
Quarry Pond	614, 5659
Railway Pond	616, 5659
Canmore Highway Pond	619, 5657
Sheppard's Pond	622, 5657
JamaR	623, 5657
Exshaw	629, 5658
Hamlet of Kananaskis	631, 5659
Lafarge Borrow Pit	635, 5661
8. Athabasca Valley Populations	
Honeymoon Lake	454, 5823
Athabasca Falls	441, 5837
Horseshoe Lake	442, 5839
Leach Lake Pond 1	439, 5837
Leach Lake Pond 2	440, 5836
Astoria River Crossing	431, 5848
Decoigne Warden Pond	405, 5860

LOCATION	UTM*
8. Athabasca Valley Populations Continued	
Decoigne Wetland	405, 5860
Decoigne Quarry	412, 5860
Virl Lake	417, 5859
Mildred Lake	429, 5860
Small Trefoil Lake	429, 5861
Mildred Pond	429, 5851
Palisades Pond	429, 5869
Snaring Beaver Pond	427, 5872
Celestine Road Pond	425, 5876
Fifth Bridge Pond	431, 5853
Merlin Trailhead Pond	428, 5879
Syncline Ridge Pond	435, 5891
Kinky Lake Pond 1	450, 5904
Kinky Lake Pond 2	449, 5905
Kinky Lake Pond 3	448, 5905
Weigh Scale Pond 1	452, 5904
Weigh Scale Pond 2	451, 5905
Airport Pond	450, 5908
Old Entrance Beaver Pond	450, 5914
Hinton Pond	460, 5915

LOCATION	UTM*
Maxwell Lake	461, 5915
Thompson Lake	463, 5916
Wigman Creek Pond	465, 5901
Cold Creek Pond	460, 5911
Robb Road km 17	470, 5908
Robb Road km 13	469, 5910
Robb Road km 16	472, 5909
McPherson Road Pond 1	469, 5914
McPherson Road Pond 2	470, 5915
McPherson Road km 21	472, 5917
McPherson Road km 32	480, 5915
Marsh Creek Pond	465, 5931
Emerson Gas Well Pond	468, 5928
Emerson Creek km 14	468, 5928
Emerson Creek km 40	486, 5943
Obed	483, 5937
9. Peace River Populations	
Walsh Farm ponds (8 locations)	413, 6200
Dam Ponds	415, 6198
East Pond	423, 6201
Eureka River	383, 6238

* Locations are given in UTM coordinates as easting, northing.

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