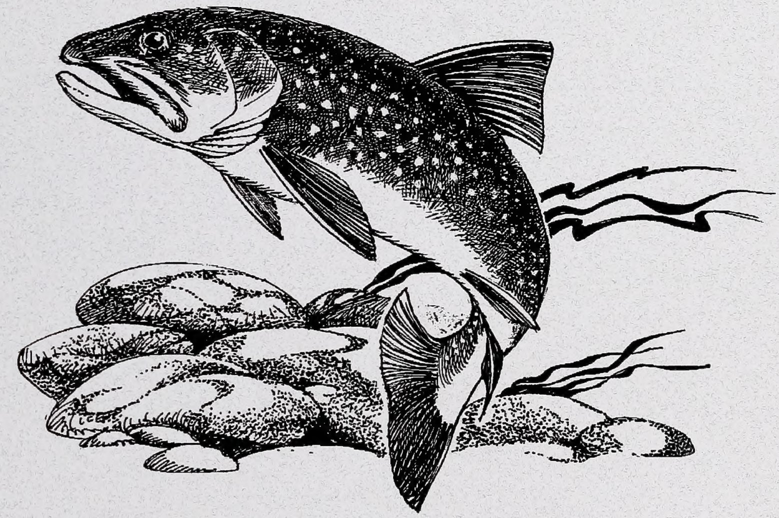
Fish & Wildlife Division

SPECIES AT RISK

# Status of the Bull Trout (*Salvelinus confluentus*) in Alberta:

# Update 2009



**Alberta Wildlife Status Report No. 39 (Update 2009)**

Government of Alberta

Alberta Conservation Association

# Status of the Bull Trout (*Salvelinus confluentus*) in Alberta:

# Update 2009

Prepared for:
**Alberta Sustainable Resource Development (ASRD)**
**Alberta Conservation Association (ACA)**


Update prepared by:
**Mike Rodtka**


*Much of the original work contained in the report was prepared by John R. Post and Fiona D. Johnston in 2002.*

*This report has been reviewed, revised, and edited prior to publication. It is an ASRD/ACA working document that will be revised and updated periodically.*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Edmonton, Alberta, Canada T5K 2M4

*Telephone: (780) 944-0313 or 1-877-944-0313*

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## PREFACE

Every five years, the Fish and Wildlife Division of Alberta Sustainable Resource Development reviews the general status of wildlife species in Alberta. These overviews, which have been conducted in 1991 (*The Status of Alberta Wildlife*), 1996 (*The Status of Alberta Wildlife*), 2000 (*The General Status of Alberta Wild Species 2000*), and 2005 (*The General Status of Alberta Wild Species 2005*) assign individual species "ranks" 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 key 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 general status exercise, and provides comprehensive current summaries of the biological status of selected wildlife species in Alberta. Priority is given to species that are *At Risk* or *May Be At Risk* in the province, that are of uncertain status (*Undetermined*), or that 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 Fish and Wildlife Division of Alberta Sustainable Resource Development. They are intended to provide detailed and up-to-date information that 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 that will assist Alberta's Endangered Species Conservation Committee in identifying species that may be formally designated as *Endangered* or *Threatened* under Alberta's *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

Bull trout (*Salvelinus confluentus*) is a char species native to western North America that colonized the major drainages of the eastern slopes of Alberta after the last glaciation. Since the early 1900s, this species has declined in both distribution and abundance, and is considered a *Species of Special Concern* in Alberta and *Threatened* under the *Endangered Species Act* throughout its range in the United States (lower 48 states). A review undertaken by the Fish and Wildlife Division of Alberta Sustainable Resource Development in 2008 determined that 38 out of the 47 core areas (81%) currently containing bull trout in Alberta are at risk of extirpation, and three other core areas were identified as already being extirpated. Declines have been attributed to the impacts of human activities, including migratory barriers, habitat degradation and fragmentation, angling pressure, past population management practices, and the stocking of non-native fish species. However, to more clearly understand and mitigate the factors leading to the decline of bull trout in Alberta, the complex biology and habitat requirements of this species require further study.

Bull trout in Alberta express three main types of life history strategies: stream-resident populations reside within the tributaries in which they were reared; fluvial populations spawn in tributaries but reside in mainstem rivers; adfluvial populations spawn in tributary streams but reside in lakes or reservoirs. As a result, bull trout have complex habitat requirements, and in some cases very large home ranges. The migratory patterns of bull trout, their spawning strategies, and their fidelity to spawning areas all have important management implications. Additionally, to maintain the genetic integrity of populations through genetic exchange from distinct populations, the development of regional (rather than localized) management plans is required. Long-term, standardized methods of population survey are required to monitor the status of bull trout populations within Alberta. A clearer understanding of the habitat requirements and population dynamics at all stages of growth and for the three different life history strategies is required to determine the potential impacts that human activity may have on these populations. Despite these uncertainties, the factors limiting bull trout recovery in the province are now well documented and need to be addressed in a comprehensive manner if the current trend of populations in decline is to be reversed.

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## INTRODUCTION

Bull trout (*Salvelinus confluentus*) is a char species native to western North America. A cold-water species, bull trout are thought to have been isolated in a number of glacial refugia during the Pleistocene and recolonized Alberta after the last glacial period (Bellerud et al. 1997, Haas and McPhail 2001, Nelson and Paetz 1992, Thomas et al. 2001). Bull trout is the only native, stream-dwelling char species in the North Saskatchewan and Red Deer river drainages, and the only native char to historically occupy all the drainages of the eastern slopes of Alberta (Berry 1994, Nelson and Paetz 1992). Bull trout display non-migratory (i.e., resident; see glossary, Appendix 1) and migratory (i.e., adfluvial, fluvial, and anadromous; see glossary, Appendix 1) life history strategies that have enabled a wide distribution.

Despite being widely distributed in western North America, bull trout are no longer abundant, and populations have been declining for the last century (Montana Bull Trout Restoration Team [MBTRT] 2000, Rieman et al. 1997). This decline is generally attributed to human impacts on fish populations and their habitat. Past management practices, including bull trout eradication, contributed to this decline (Colpitts 1997). During the 1920s, bull trout had a reputation as piscivorous, "junk fish," and were culled in an attempt to increase populations of "nobler species," such as the introduced rainbow, brook, and brown trout (Colpitts 1997). In November 1999, the bull trout was recognized as a *Threatened** species throughout its range in the United States (lower 48 states) under the *Endangered Species Act* (Haas 2001, Lohr et al. 2001, MBTRT 2000, United States Fish and Wildlife Service 2003), and is considered a *Species of Special Concern* in Alberta (Fish and Wildlife 2008).

This report summarizes current information available on bull trout in Alberta, and is an important step in updating its status in the province.

## HABITAT

Bull trout are found predominantly in cool, high-elevation watersheds (Nelson and Paetz 1992, Rieman et al. 1997, Watson and Hillman 1997) of western North America. They tend to select well-connected, structurally diverse streams that offer protection against high or low flow levels, the disruption of the stream bed, high water temperatures, freezing, and the loss of pools and cover (Cross and Everest 1997). This includes streams with stable channels and flows, low proportions of fine sediment, available cover, suitable water temperatures, and open migratory corridors (Haas 2001, McCart 1997, Watson and Hillman 1997). Watershed size and stream width appear to be important factors because they provide a connection between populations as sources of recolonization in the event of local extinction (Dunham and Rieman 1999, Rieman and McIntyre 1995, Rieman and McIntyre 1996). Habitat diversity and connectivity allow for the expression of all types of life history strategies, and the persistence of the species (Rieman and Clayton 1997).

Water temperature and groundwater input are critical habitat characteristics that limit the migration, spawning, and incubation periods of bull trout. Bull trout are believed to be among the most thermally sensitive fish species in cold water habitats in western North America (Dunham et al. 2003b, Selong et al. 2001); temperature limits the southern and eastern boundaries of bull trout distribution (Dunham et al. 2003b, MBTRT 2000). Bull trout are generally found in mountain streams with maximum water temperatures below 18°C (Berry 1994). Optimal habitat appears to be below or at 15°C, with the highest densities occurring at temperatures below or between

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* See Appendix 2 for definitions of selected status designations.

12°C and 13°C (Dunham et al. 2003b, Haas 2001, McCart 1997, Montana Bull Trout Scientific Group [MBTSG 1998]).

***1. Spawning and Rearing*** - Bull trout typically spawn in areas influenced by groundwater upwelling (Allan 1980, Baxter and Hauer 2000, Berry 1994, James and Sexauer 1997). Within these areas, they select localized areas of strong downwelling and high intragravel flows (Baxter and Hauer 2000) over coarse substrates with low levels of fine sediment. These characteristics increase substrate permeability allowing aeration of the eggs (Berry 1994, MBTRT 2000) and are typically found at the tailouts of pools formed at the heads of riffles (Baxter and Hauer 2000). In addition to its moderation of the thermal regime, groundwater prevents the formation of frazil and anchor ice (see glossary, Appendix 1), which can scour or disturb the substrate, compromising egg viability (Baxter and Hauer 2000, Fairless et al. 1994, MBTSG 1998). Preferred spawning substrate is gravel-cobble (16 mm – 64 mm diameter) with less than 10% fine sediment (<1.0 mm) (James and Sexauer 1997, McPhail and Murray 1979). Successful incubation requires appropriate gravel composition, permeability, water temperature and surface flow conditions. In general, the proportion of sediment smaller than 6.35 mm should not exceed 35% – 40% during incubation (MBTSG 1998); however, Fairless et al. (1994), found that survival was not related to the proportion of sediment of this size.

The young-of-the-year (YOY) bull trout emerge in the spring seeking stream margins with heterogeneous structure, low velocity backwaters, and side channels (Cross and Everest 1997, MBTSG 1998, McPhail and Murray 1979). The YOY have been documented overwintering in the interstitial subsurface flow, within and upstream of the spawning area, even under no visible surface water (Boag and Hvenegaard 1997).

Pool-and-run habitats with cobble and boulder substrates are preferred by juvenile bull trout (Mushens 2003), which exhibit a strong preference for low water velocity (Earle and McKenzie 2001). As they grow, bull trout seek out deeper pools often associated with large woody debris in lower tributary reaches (Connor et al. 1997, Cross and Everest 1997, Earle and McKenzie 2001, MBTSG 1998, McPhail and Murray 1979, Ratcliff et al. 1996). Avoidance of predation (including cannibalization) and competition greatly influence juvenile bull trout distribution (Earle and McKenzie 2001, Goetz 1997a, Mushens 2003, Sexauer and James 1997). Preferred habitats provide easy access to higher velocity waters with abundant food, but still provide velocity breaks that require lower energy expenditure to maintain their position within the stream (Baxter and McPhail 1997, Connor et al. 1997, Earle and McKenzie 2001, MBTRT 2000). Shade levels, undercut banks, large woody debris volume and pieces, substrate composition in riffles, and bank stability are all good predictors of juvenile bull trout presence (Dambacher and Jones 1997).

Juvenile bull trout often seek concealment during the day in the low-velocity areas under cobbles, and at night move out further from cover to feed in runs, channel margins and backwater areas of riffles (Baxter and McPhail 1997, Goetz 1997a, Mushens 2003, Sexauer and James 1997, Thurow 1997). Juveniles may exhibit fidelity for specific daytime refuges, with median diel (see glossary, Appendix 1) movements measured in the tens of metres (Mushens 2003). Juvenile bull trout also use different habitats seasonally. Although juveniles select low velocity areas in all seasons, the selection of water depth and substrate varies between seasons (Sexauer and James 1997). Overhead cover, deep stable water, low velocities, and lack of anchor ice appear to be important winter habitat criteria (Thurow 1997). Diel and seasonal differences in habitat use may affect the density of fish in sampling locations and the effectiveness of various techniques used to determine the distribution and abundance of bull trout.

***2. Adults*** - The habitat used by adult bull trout, similar to that of juveniles, is related to selection of low-velocity areas that provide the appropriate temperature, protective cover, access to forage and an ice-free refuge in the winter. During the summer, fluvial adults are strongly associated with pools (Clayton 1999, Popowich 2005). Bull trout may seek out groundwater as it provides a thermal refuge in both the summer and winter (Goetz 1997b, MBTSG 1998). Bull trout appear to return to the same overwintering habitat with high fidelity once they have completed their spawning migrations (Berry 1994, MBTSG 1998 , McLeod and Clayton 1997). Overhead or instream cover appear to be other important components of overwintering habitat (Rhude and Rhem 1995).

Adfluvial populations use a diversity of lake habitats, depending upon life stage. However, they are more abundant in the deeper sections of the lake where water temperatures are lower (Connor et al. 1997, MBTRT 2000, MBTSG 1998). Adult bull trout tend to use the pelagic area (see glossary, Appendix 1) more often in the spring and fall, and use the littoral zone (see glossary, Appendix 1) for foraging excursions (MBTSG 1998). Adfluvial bull trout mostly rest on the bottom during the day and activity peaks at night, especially on moonless nights (Connor et al. 1997). As with juvenile bull trout, consideration of this variable habitat use is important in selecting sampling locations and techniques.

## CONSERVATION BIOLOGY

***1. Identification*** - Bull trout is a char species native to Alberta and western North America, and is a member of the family Salmonidae. Bull trout was first described as a distinct species from Dolly Varden (*Salvelinus malma*) in 1978 (Cavendar 1978), and this was morphologically confirmed in 1991 (Haas and McPhail 1991).

Bull trout are long slender fish with a comparatively large head and jaws from which the name "bull" originated. They are olive-green to blue-grey in appearance, although lake-dwelling fish may have silvery sides (Berry 1994, Nelson and Paetz 1992). They have pale, yellow-orange round spots along their sides and backs. This distinguishes them from true trout species (i.e., rainbow [*Oncorhynchus mykiss*], cutthroat [*O. clarkii*], and brown trout [*Salmo trutta*]), which have dark spots, and brook trout [*Salvelinus fontinalis*], a char species with distinct, light-coloured, worm-like markings on top of the head, back and dorsal fin (Anonymous 1994, Nelson and Paetz 1992). Bull trout are often identified by the absence of black spots on the dorsal fin, which are present on other char and trout found in Alberta (Berry 1994). They usually have pale bellies, which may turn red or orange in spawning males (Berry 1994, Nelson and Paetz 1992). Their tail fin is only slightly forked, and pelvic or anal fins may have a white leading edge, but this is not followed by black as in brook trout (Anonymous 1994, Nelson and Paetz 1992). Bull trout larvae may be distinguished from other larval char by the presence of a prominent fleshy ridge underneath the chin (Gould 1987).

Bull trout are distinguished from Dolly Varden both geographically and morphologically. In Alberta, the non-native Dolly Varden are only found in Chester Lake (Kananaskis River Drainage), where bull trout do not occur (Nelson and Paetz 1992). Dolly Varden are commonly found in streams and lakes along the west coast of Canada and the northwestern United States and are mostly anadromous fish (Berry 1994, Nelson and Paetz 1992). There are locations where these two species live in sympatry (see glossary, Appendix 1); however, they maintain two distinct gene pools despite genetic evidence indicating that ancient introgression and more recent production of viable hybrids has occurred. This suggests that some form of reproductive isolation or natural selection exists between the species (Baxter et al. 1997, Haas and McPhail 1991, Hagen and Taylor 2001, Taylor et al. 2001).

Morphologically, bull trout are distinguished from Dolly Varden by a number of characteristics (Figure 1). In bull trout, the distance from the centre of the eye to the top of the head is less than the distance from the centre of the eye to the nostril. These distances are more equal in Dolly Varden. The head of the bull trout is broader in dorsal and anterior views as opposed to the more compressed appearance of the Dolly Varden head. Bull trout have stout gillrakers with strong teeth on the inner margin, whereas Dolly Varden have long gillrakers that lack teeth on the inner margin (Nelson and Paetz 1992). Morphometric identification protocol is discussed in Haas and McPhail (1991). Haas et al. (2001) found that the current misidentification rate is quite high even among fish biologists, with up to half of the bull trout being misidentified, whereas only a small proportion of Dolly Varden are misidentified.

Bull trout hybridize with brook trout in Alberta (Earle et al. 2007, Nelson and Paetz 1992). External characteristics that have proven effective for field identification of potential brook trout hybrids from a sympatric population in Quirk Creek (Elbow River drainage) include the presence of pale spots or faint black markings on the dorsal fin and faint worm-like markings on the dorsal surface (Earle et al. 2007). Based on external characteristics alone, Fredenberg et al. (2007) were over 96% accurate in identifying the two parental species and their hybrids; hybrids were found to exhibit patterns of marking, coloration and body shape intermediate between the two species.

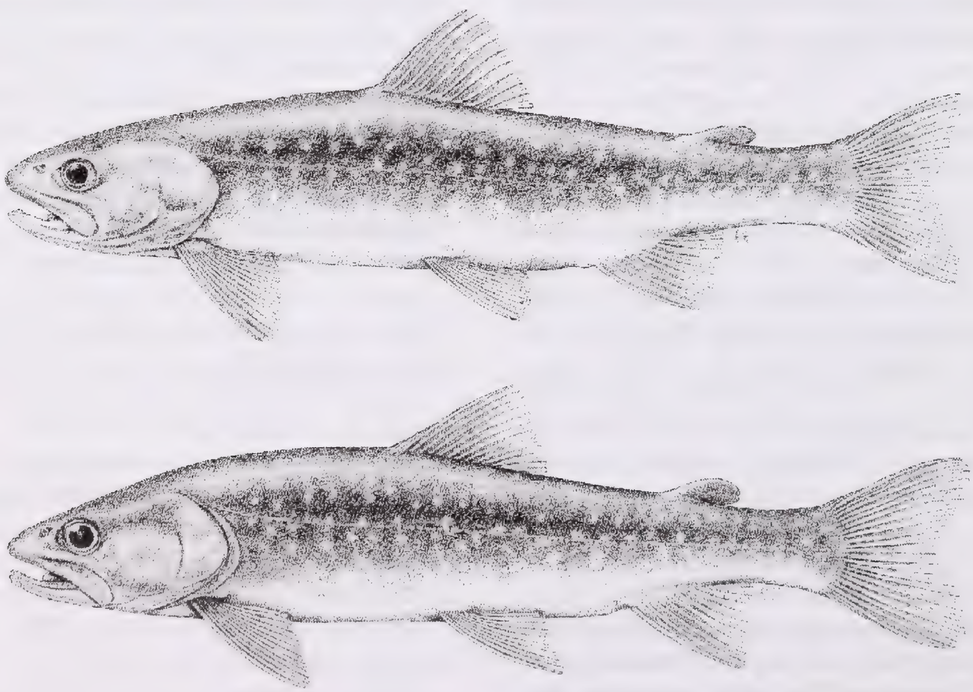

**Figure 1.** Composite drawings of Dolly Varden (top) and bull trout (bottom). Drawings were done by Karen Klitz. Extracted from Haas and McPhail (1991).

***2. Life History*** - There are three life history strategies expressed by bull trout in Alberta: stream resident, fluvial, and adfluvial (Berry 1994, Fitch 1997, James and Sexauer 1997, MBTRT 2000, McCart 1997, Rieman and Clayton 1997, Rieman and Myers 1997). Bull trout usually reach sexual maturity between five and seven years of age, with an extreme range of between three and eight years of age (Allan 1980, Berry 1994, Connor et al. 1997, Herman 1997, McCart 1997, Mushens et al. 2003, Mogen and Kaeding 2005, Ratcliff et al. 1996, Rieman and McIntyre 1996). In two fluvial populations, males were found to mature earlier than females (Allan 1980, McCart 1997). In contrast, Johnston and Post (2009) found that females matured first in an adfluvial population.

The body size of bull trout at maturity varies substantially among life history strategies. The average size at maturity for a resident population is 250 mm (fork length; reported throughout) with a range of 150 mm – 300 mm (Bellerud et al. 1997, Earle and McKenzie 2001). Migratory populations achieve greater sizes at maturity because they live as adults/subadults in more productive environments. The average length at maturity in a fluvial population is greater than 400 mm (1050 g), ranging from 240 mm to 730 mm (Allan 1980, Brewin 1994a, Clayton 1999, Hvenegaard and Thera 2001, Rhude and Rhem 1995). The body size of adfluvial bull trout is generally larger than that of fluvial bull trout. The average body length of adult fish in these populations is typically greater than 400 mm, with a range of 330 mm – $900^{+}$ mm (600 g – 7200 g) (Herman 1997, MBTSG 1998, Mushens et al. 2003, Ratcliff et al. 1996, Rieman and McIntyre 1996).

Fecundity (see glossary, Appendix 1) is proportional to body size, with small resident females producing 500 eggs, and large migratory females producing 2000 – 5000 eggs (Berry 1994, McPhail and Murray 1979). Egg size ranges from 4.8 mm – 6.2 mm in diameter (Allan 1980, McPhail and Murray 1979). Quantitative relationships between body size and fecundity are available in Goetz (1989) and Johnston and Post (2009).

The timing and extent of spawning migrations vary substantially among populations of bull trout. Timing is thought to be triggered by a hierarchy of environmental cues, including changes in river discharge and water temperature (Monnot et al. 2008, Mushens 2003, Popowich and Paul 2006). Monnot et al. (2008) found the downstream migration rate of bull trout was negatively related to stream discharge and more rapid and less variable for larger fish. Bull trout begin their migration between late May and August, depending on the distances to be travelled (Allan 1980, Bellerud et al. 1997, Burrows et al. 2001, Clayton 1998, Fontana et al. 2008, Hvenegaard and Fairless 1998, Hvenegaard and Thera 2001, McLeod and Clayton 1997, McPhail and Murray 1979, Westover 1999). Migratory movements generally occur at night (MBTSG 1998, McPhail and Murray 1979, Mushens et al. 2003, Ratcliff et al. 1996). Younger bull trout may enter the creek first, finish gamete development upstream, and spawn at the same time as older fish that entered the tributary at a later date but ready to spawn (Herman 1997, McPhail and Murray 1979, Mushens et al. 2003). Resident populations typically migrate only short distances for spawning, rearing, and overwintering habitat. In contrast, some populations of migratory adults must travel extensive distances (250 km) to their spawning grounds (Allan 1980, Burrows et al. 2001, MBTRT 2000, McLeod and Clayton 1997).

Spawning occurs from mid-August to late October (Allan 1980, Bellerud et al. 1997, Berry 1994, Brewin 1994b, Hvenegaard and Fairless 1998, MBTRT 2000, McPhail and Murray 1979, Mushens et al. 2003, Ratcliff et al. 1996, Rieman and McIntyre 1996, Rieman and Myers 1997, Westover 1999). In general, bull trout display a high fidelity to spawning areas; however, there is some evidence of switching locations, at least within localized areas (McPhail and Murray 1979, Mogen and Kaeding 2005, Rhude and Rhem 1995, Warnock 2008). There is also strong evidence that bull trout may display alternate-year spawning or resting periods between consecutive spawning events, with 20% or less of the population spawning annually (Hvenegaard and Fairless 1998, Hvenegaard and Thera 2001, Johnston and Post 2009, Popowich and Paul 2006, Rhude and Rhem 1995). Johnston and Post (2009) found that the proportion of bull trout in Lower Kananaskis Lake spawning annually declined with increasing density (i.e., density-dependent repeat spawning). Within a three-year interval, less than 20% of females and 60% of males were non-repetitive spawners when adult density was low (~500 fish or 0.8 fish/ha). Proportions of non-repeat spawners increased to greater than 40% of females and 80% of males, respectively, at high density (~1500 fish or 2.3 fish/ha). It is likely that in colder and less productive systems it takes more than one season to accumulate the energy necessary to produce gametes and migrate, leading to skipping of reproductive events. This behaviour may bias population estimates that are developed from surveys targeting spawning individuals that are performed on an annual basis.

Bull trout eggs incubate in the gravel and hatch from March to April (Allan 1980, Baxter and McPhail 1997, Berry 1994, MBTRT 2000). The incubation period is temperature dependent, varying between 100 and 200 days in the wild (Allan 1980, Berry 1994). Eggs require temperatures less than 8°C to survive, and have an inter-gravel incubation optimum of 2°C – 4°C (Berry 1994, Fairless et al. 1994, MBTSG 1998). Fredenberg et al. (1995) found that bull trout eggs incubated in a hatchery at an average of 3.1˚C achieved a 50% hatch rate in 126 days but took only 75 days to achieve a 50% hatch rate when average incubation temperature was increased to 6.4˚C. High temperatures (>8°C) and resulting low dissolved oxygen levels increase the rate of yolk absorption and decrease the size of fry. This suggests that bull trout have a cold-water adaptation (Giles and Van der Zweep 1996, McPhail and Murray 1979). The low temperatures typical of bull trout habitat may lead to lower growth rates when compared with other salmonids; however, lower temperatures do discourage the invasion of other species with higher temperature requirements and prevent competitive exclusion (MBTRT 2000).

While in the gravel, bull trout eggs and embryos are at risk from deposition and infiltration of fine sediment, changes in water quality, redd (see glossary, Appendix 1) superimposition, disturbance by wading mammals and stream bed scour and fill (DeVries 1997). Depth and location of egg burial influences their survival. Larger fish typically bury eggs deeper (DeVries 1997) and use larger substrates toward the centre of the channel when spawning, presumably reducing the impact of low flows (Berry 1994, MBTSG 1998) and freezing (Fairless et al. 1994) on the developing eggs. Successful incubation of bull trout eggs in some streams may be contingent upon the maintenance of relatively large female spawners in the population.

At emergence, fry range in length from 21 mm to 33 mm (Allan 1980, Ratcliff et al. 1996, Reiser et al. 1997). Fry grow rapidly, and in a favourable environment may gain 40 mm in their first summer (McPhail and Murray 1979). There appears to be a downstream migration of YOY shortly after emergence in the spring to lower velocity areas or lakes (Allan 1980, Bellerud et al. 1997, Connor et al. 1997, McPhail and Murray 1979, Reiser et al. 1997). Unfortunately, little is known about the movements of YOY and small juveniles, in part because they are too small to catch effectively with traditional sampling gear such as electrofishing and angling.

Migration of juvenile bull trout may be more extensive than commonly assumed. Through genetic analyses, Warnock (2008) estimated a mean movement of juvenile bull trout from their population-of-origin of 17.1 km (range 3.7 km – 35.6 km) in the upper Oldman River drainage. The timing of migration of juveniles to rivers and lakes appears to be highly variable among systems. Fish range from one to four years old (60 mm – 300 mm in length) when they migrate to these environments (Baxter and McPhail 1997, Brewin 1994b, MBTRT 2000, McPhail and Murray 1979, Mogen and Kaeding 2005, Mushens 2003, Ratcliff et al. 1996, Reiser et al. 1997, Rieman and Myers 1997, Sexauer and James 1997, Stelfox 1997). Often the migratory movement occurs in the fall (Bellerud et al. 1997, McPhail and Murray 1979, Mushens 2003, Reiser et al. 1997). This timing may reduce the risk of predation from adults migrating upstream, and provide a chance to exploit higher quality food resources at lower risk while adults are involved in their spawning migration (Mushens 2003). This information is important for industrial development timing windows, as in-stream construction activities may limit juvenile recruitment into adult cohorts.

***3. Growth and Feeding*** - Bull trout are opportunistic foragers that feed on a diversity of vertebrate and invertebrate prey (Boag 1987, Gunckel 2000, MBTSG 1998, Mushens et al. 2003, Popowich 2005, Wilhelm et al. 1999), selecting for larger-bodied prey items when available (Gunckel 2000, Wilhelm et al. 1999). The low productivity and temperatures common in rearing habitat often result in a low growth rate for juveniles on an insect diet (Berry 1994). Once juveniles reach 100 mm – 110 mm in length they may also eat small fish, including cannibalistic consumption of bull trout (Goetz 1997a, MBTSG 1998). Juvenile growth rates increase substantially when they enter rivers and lakes where prey fish are more abundant (MBTRT 2000, Mogen and Kaeding 2005, Mushens et al. 2003).

Prey availability, a function of the habitats occupied by different life histories, is one reason resident bull trout are substantially smaller than fluvial fish, which in turn typically experience lower growth rates than fish in adfluvial populations (Berry 1994, Ratcliff et al. 1996). Documentation of bull trout growth rate in Alberta is rare. Fish in the Kakwa River basin grew an estimated 30 mm per year (Hvenegaard and Fairless 1998). Growth of fish in Pinto Lake, where bull trout were the only fish species present, was 10 mm per year (Herman 1997). Johnston and Post (2009) found that growth of adult bull trout in Lower Kananaskis Lake was inversely related to abundance and fish length. Females also grew slower than males, and larger fish approached zero growth at high density (~2.3 fish/ha). Models describing these relationships are available in Johnston and Post (2009). Bull trout in Alberta streams appear to grow approximately 30 mm – 40 mm per year in the first several years of their life (Paul et al. 2000, Paul et al. 2003). The large difference in growth rates among life history types and populations has important implications for bull trout management.

Stream-dwelling bull trout feed primarily on invertebrates drifting in the water column (Gunckel 2000), but also forage at the water's surface and on the streambed (Berry 1994, Gunckel 2000, Nakano et al. 1992). Bull trout often maintain relatively fixed positions in low velocity (~10 cm/s) areas of the stream, with brief forays into faster water to forage. However, they have also been observed to move constantly along the streambed picking prey off the substrate (Nakano et al. 1992). Popowich (2005) found that adult bull trout in the Elbow River, Alberta fed almost exclusively on fish, including brook trout, cutthroat trout, mountain whitefish (*Prosopium williamsoni*) and rainbow trout (at similar proportions) and, to a lesser extent, on juvenile bull trout. Adfluvial populations are bottom-oriented, seeking cooler depths and making intermittent foraging trips into the littoral zone (Connor et al. 1997, MBTSG 1998). These fish are primarily piscivorous, although their diet may also include insect larvae and opossum shrimp (*Mysis relicta*) (Berry 1994, Connor et al. 1997, MBTSG 1998, Mushens et al. 2003). Smaller fish eat mostly benthos and amphipods from the littoral and pelagic areas, whereas larger bull trout specialize on fish (Connor et al. 1997, Mushens et al. 2003). Wilhelm et al. (1999) found that fish in Harrison Lake, a small alpine lake in Banff National Park containing only bull trout, fed primarily on chironomid pupae and amphipods. Recovery of some fluvial and adfluvial bull trout populations may be contingent upon the availability and abundance of prey fish species.

## DISTRIBUTION

***1. Alberta*** - Bull trout colonized Alberta after the last glaciation approximately 13 000 years ago (Nelson and Paetz 1992). This species appears to have originated from two to four glacial refugia, which were located in the east, west, and north (Nelson and Paetz 1992, McCart 1997, Thomas et al. 2001). Genetic data suggest that descendents from several ancestral populations can be found in Alberta's drainages, and that these fish interbred while recolonization was occurring (Thomas et al. 2001). These populations have become more isolated since then, resulting in the development of genetically distinct populations. Random amplified polymorphic DNA profiles indicate that populations in each Alberta drainage are distinct (Peace, Athabasca, North Saskatchewan, St. Mary, and South Saskatchewan [Oldman and Bow]), as are populations within each drainage (Thomas et al. 2001). In the South Saskatchewan drainage, populations were found to be distinct in the Belly, Waterton, Castle and Carbondale rivers. In the Peace system, populations were found to be less distinct (lower genetic distance between them) (Thomas et al. 2001).

Historically, bull trout were more widely distributed in Alberta than they are today (Figure 2). Most populations are currently found within the Rocky Mountain and Foothills natural regions, as well as a small portion of the Peace River Parkland and Dry Mixedwood subregions (Alberta Natural Heritage Information Centre 2005). Populations also historically occurred in the Parkland and Grassland natural regions (Berry 1994). Bull trout are thought to have once occurred as far downstream in the Peace River as the Slave River, as far east as Lethbridge in the Oldman River, as far east as Morrin in the Red Deer River, and were common in the Edmonton area of the North Saskatchewan River until the 1930s (Berry 1994, Brewin and Brewin 1997, Fitch 1997, McCart 1997, Nelson and Paetz 1992). Anecdotal information and limited historical records suggest a large decline in distribution and abundance in all systems since the early 1900s (see Appendix 3) (Allan 1980, Brewin 1994a and 1994b, Hvenegaard and Thera 2001, McCart 1997, Rhude and Stelfox 1997).

In the 1990s, bull trout were estimated to occupy some 20 000 km of stream habitat, and 12 000 ha of lake habitat in 24 lakes within Alberta (Berry 1994). They are generally confined to the upstream reaches of major river systems in the eastern slopes of Alberta (Peace, Athabasca, North Saskatchewan, Red Deer, Bow, and Oldman rivers). However, they do occur further from the mountains in the Peace and Athabasca drainages, but in lower abundance (Figure 2) (Berry 1994). Currently, the area within the bull trout range that is occupied by this species (i.e., area of occupancy), calculated using a 2-km x 2-km grid, is approximately 6636 $km^2$; this area is estimated to be 2288 $km^2$ when a 1-km x 1-km grid is used. Note that these estimates do not include national parks, as limited information on bull trout distribution is available for these areas.

***2. Other Areas*** - Globally, bull trout are distributed throughout the western mountains

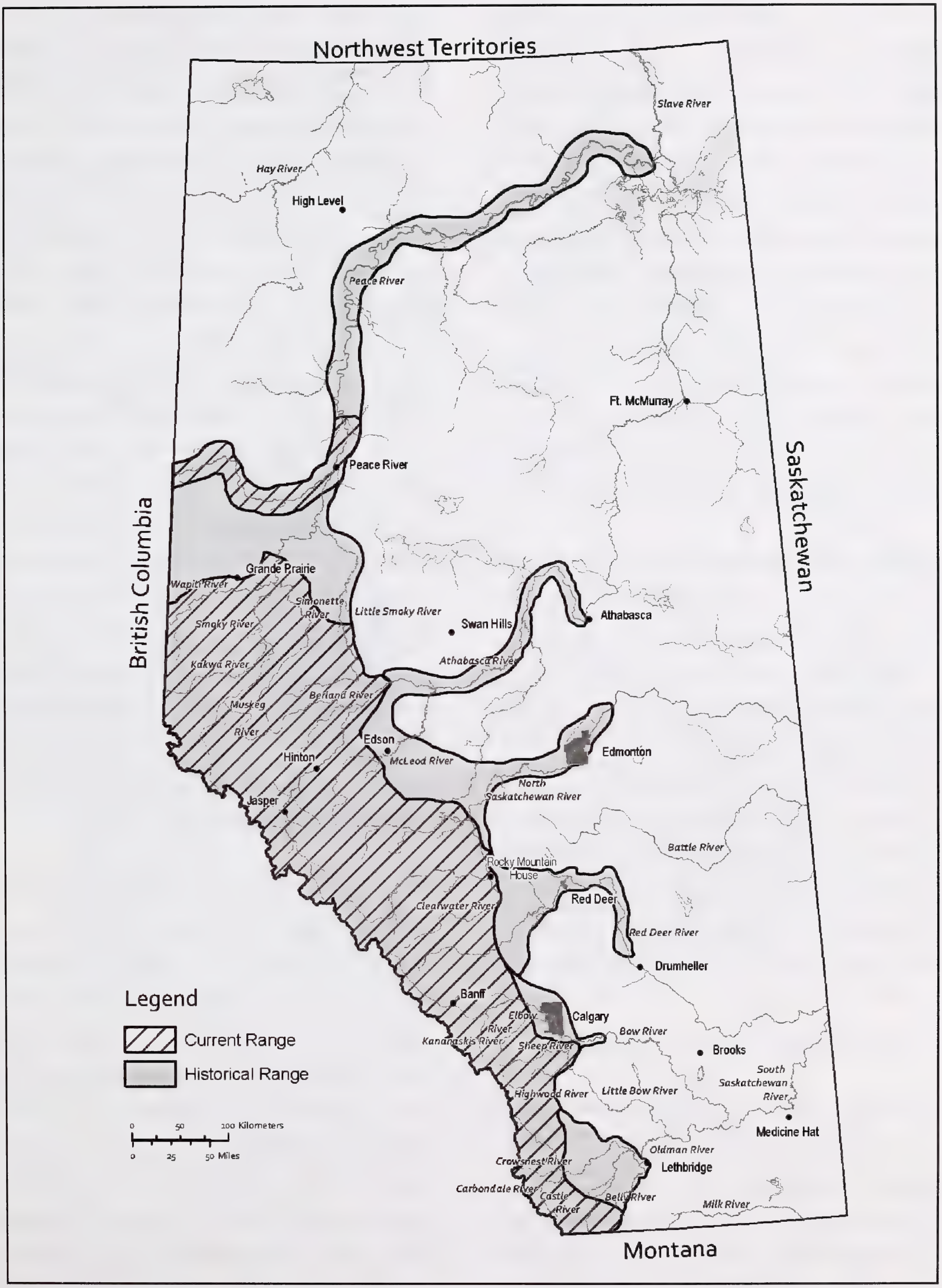


**Figure 2.** Historical and current distribution of bull trout in Alberta. Extracted from Brewin and Brewin (1997) and Alberta Sustainable Resource Development (in prep.).

and foothills of Canada and the United States (Figure 3). Historically, bull trout were distributed as far south as California (41°N) (Haas and McPhail 1991) but have been extirpated from California and Nevada, and the southern extent of their range is now the Oregon-California border (42°N) (Haas and McPhail 1991, MBTRT 2000, Rieman et al. 1997). The southern limit of bull trout distribution appears to be determined by temperature (Dunham et al. 2003b, MBTRT 2000), and populations appear to increase in abundance in northern parts of their range (Haas and McPhail 1991). Known to occur as far north as the Yukon River drainage (60-61°N) (Haas and McPhail 1991), bull trout were recently reported from the Mackenzie River (64°N) in the central Northwest Territories (Reist et al. 2002).

In northwestern British Columbia, the species does not extend to the coast; however, in the Puget Sound area, Washington, and the Fraser River, British Columbia, bull trout do reach the coast (Haas and McPhail 1991). Bull trout commonly occur as far east as western Montana and the headwaters of the South Saskatchewan River in western Alberta (Haas and McPhail 1991) and have been reported as far east as the Peace-Athabasca Delta (Nelson and Paetz 1992). Bull trout have been declining throughout their global native range during the last century, leading to local extinctions and the isolation of remnant populations (MBTRT 2000, Rieman and McIntyre 1995, Rieman et al. 1997).

## POPULATION SIZE AND TRENDS

***1. Alberta*** – Many bull trout populations have been declining in Alberta over the last century (Appendix 3). Most self-sustaining (see glossary, Appendix 1) bull trout populations persist only in less-accessible headwater areas. A number of populations have been extirpated in the last half century, including many populations in mountain lakes (Donald and Stelfox 1997). Only remnant (see glossary, Appendix 1) populations have been located in Jasper National Park and Waterton Lakes National Park, and few self-sustaining populations occur in Banff National Park (Brewin and Brewin 1997). Declines in population abundance have been more severe in southern areas of the province (Brewin and Brewin 1997). In the Bow River, large decreases in bull trout stocks were reported as early as the late 1930s, and more recent studies and creel surveys (see glossary, Appendix 1) have confirmed a continuing decline (Brewin 1994a). Today, bull trout are no longer present in large areas of the Oldman River drainage, and are self-sustaining in few rivers and streams in the Bow River system (Brewin and Brewin 1997). Bull trout are no longer found in most areas of the Red Deer River system (Brewin and Brewin 1997). Bull trout were once common in the North Saskatchewan River near Edmonton, but have not been recorded there since the late 1950s (Brewin 1994b). Declines in northern Alberta have been less drastic. Most major tributary systems in the Athabasca River drainage still support self-sustaining populations; however, several populations have been extirpated (Brewin and Brewin 1997). Further north in the Smoky and Peace river systems, self-sustaining populations are more common (Brewin and Brewin 1997).

The Fisheries Management Branch of Alberta Sustainable Resource Development has reviewed existing bull trout population data as part of its update of the species management plan. The review process was based upon a modification of the Natural Heritage Network ranking methodology using NatureServe Conservation Status Assessment Criteria. This model (described by Fredenberg et al. 2005) was first developed to assess bull trout status in the United States and includes ranking of individual core area (see glossary Appendix 1) population size, area of occupancy, short-term trend, and the severity, scope and immediacy of threats to the core area. Individual core area rankings are summarized in Appendix 3. A total of 51 core areas were identified; of those


**Figure 3.** Distribution of bull trout in North America. Extracted from Rieman et al. (1997).

50 were ranked and one remained unranked because of a lack of information. Of the 47 ranked core areas known to currently support bull trout, 38 (81%) were categorized as "High Risk" or "At Risk" of extirpation (see glossary Appendix 1; Figure 4). No core areas were ranked "Low Risk" (see glossary, Appendix 1; Alberta Sustainable Resource Development, in prep.). Bull trout were identified as being extirpated from three core areas: the Upper Crowsnest River and Willow Creek (Oldman River basin), and the Lower Bow River (Bow River basin). This is likely a conservative estimate, since many bull trout stocks were extirpated early in the last century before the relatively detailed information required to identify core areas was available. Insufficient information was available for ranking of the Upper Bow River core area (Alberta Sustainable Resource Development, in prep.). Only 18 of the 47 core areas in which population trend could be assessed were considered to have a stable or increasing bull trout population. In general, a preponderance of High Risk core areas was identified in southern Alberta (Figure 5). Without detailed genetic information, the total number of distinct bull trout populations in Alberta today is difficult to assess; however; it is not unreasonable to assume it is approximated by the number of core area subpopulations (n = 128) identified during the provincial review. Based on extrapolation of density estimates from specific habitats to the area of all occupied habitat within the province, approximately 30 000 adult bull trout were estimated to inhabit Alberta's lakes and streams (Alberta Sustainable Resource Development, in prep.).

Long-term trend data for Alberta bull trout populations are rare. The most comprehensive dataset was collected from the adfluvial population of Lower Kananaskis Lake and

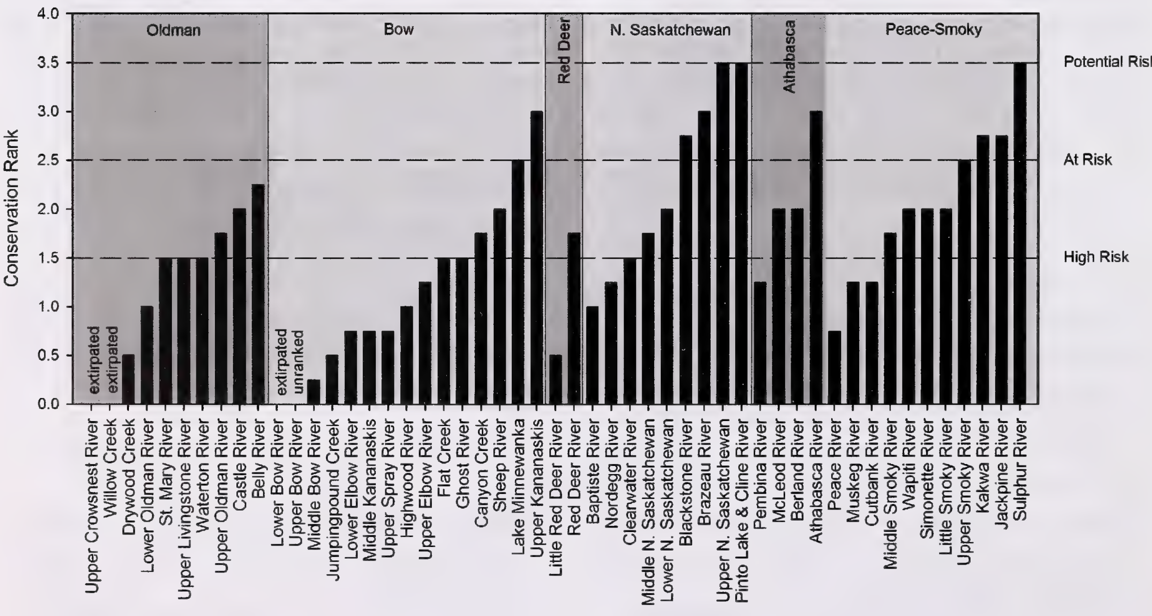


**Figure 4.** Conservation ranking of the 51 bull trout core areas identified in Alberta using a modification of the Natural Heritage Network ranking methodology and NatureServe Conservation Status Assessment Criteria. Core areas are arranged in ascending rank by river basin. Extracted from Alberta Sustainable Resource Development (in prep.). See Appendix 3 for a summary of the population size, stream occupancy, short-term trend, and threats to each core area.

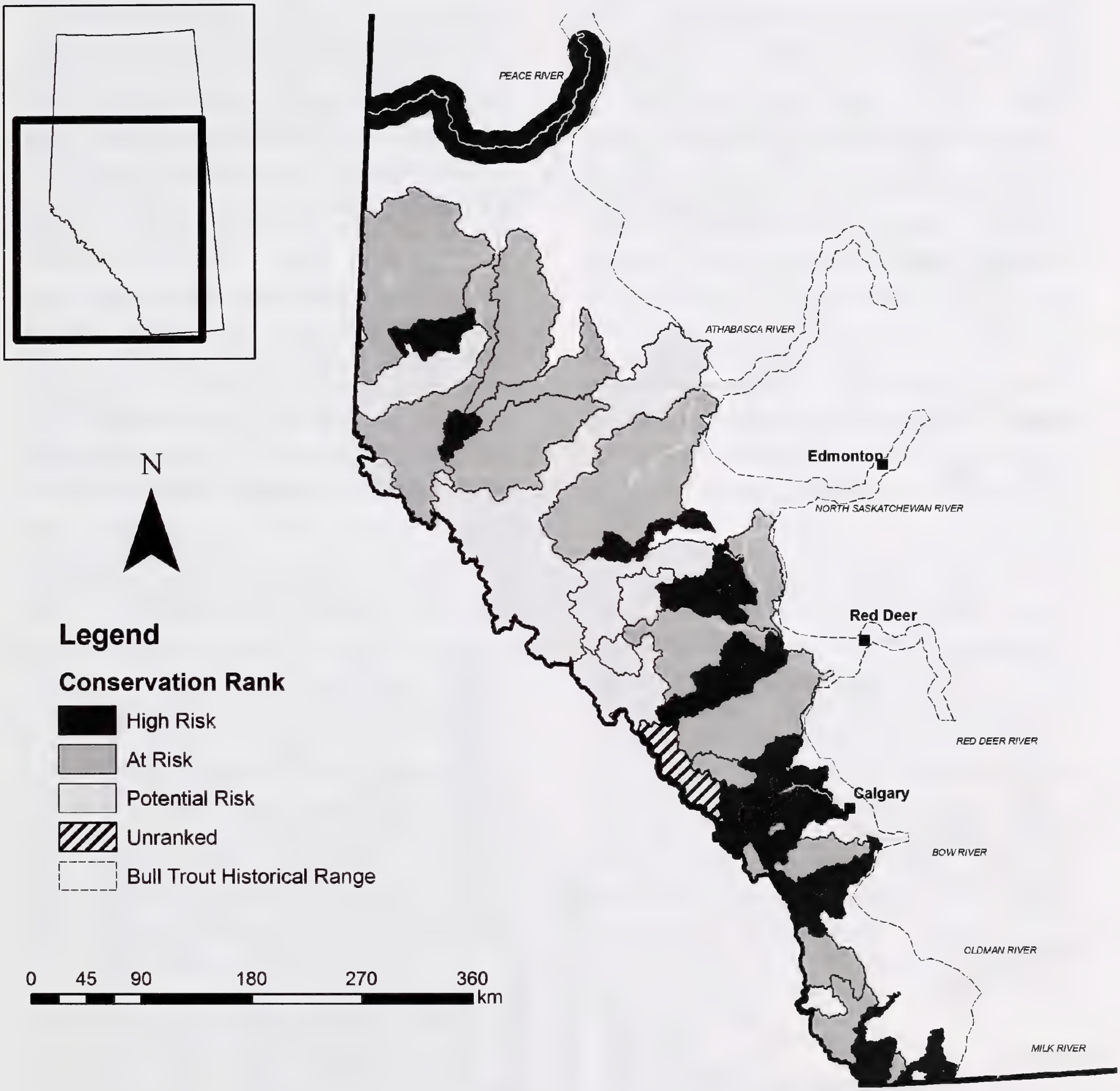


**Figure 5.** Spatial distribution of bull trout core areas in Alberta and their conservation ranking, based on a modification of the Natural Heritage Network ranking methodology and NatureServe Conservation Status Assessment Criteria. Extirpated core areas are not shown. Extracted from Alberta Sustainable Resource Development (ASRD) (in prep.). See Appendix 3 for a summary of the population size, stream occupancy, short-term trend, and threats to each core area.

documents the potential productivity of a heavily exploited bull trout population given adequate protection from angler harvest. Bull trout decreased from 11% of the reservoir's entire fish population in 1954 to 2% in 1986 (Stelfox 1997), and declined to only 60 spawning individuals by 1992 (Figure 6). Since restrictive angling regulations, including a zero-bag-limit, were implemented in 1992, the estimated adult population (based on number of adults caught in the trap) has increased almost 28-fold to over 1650 individuals by 2000 (Johnston et al. 2007). Increased density has resulted in delayed maturation and an increasing frequency of skipped reproductive events in adults and the population is believed to have reached its carrying capacity (Johnston and Post 2009).

Other adfluvial populations also appear to be increasing as a result of more restrictive angling regulations. In a 2004 survey, abundance of adult bull trout in Jacques Lake, a remote lake in Jasper National Park, was estimated at 10.5 fish/ha and the catch included fish of greater size than in any previous survey since 1942. Catch-and-release regulations for bull trout were implemented at Jacques Lake in 1995, and in 2003 the lake was closed to angling (Sullivan et al. 2005). Bull trout abundance in Pinto Lake, which was closed to angling in 1989, increased from 56 spawning adults in 1982, to 323 in 1993 (Herman 1997). Capture methods changed between assessments; however, the method was standardized from 1988 (n = 158) onward. A follow-up survey completed in 2004 indicated little change in bull

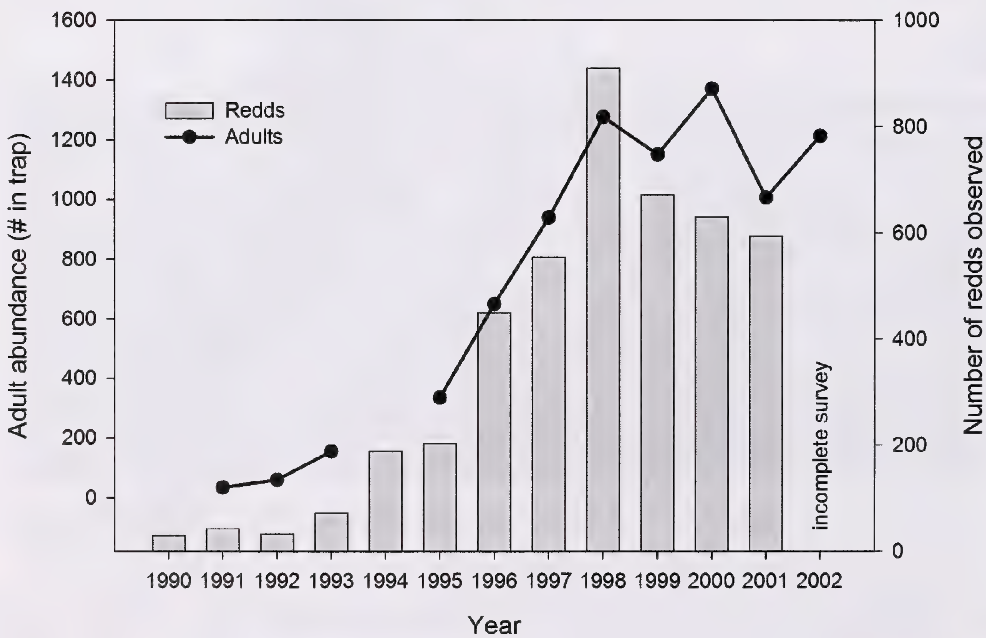


**Figure 6.** Bull trout population trend in Lower Kananaskis Lake, 1990-2002. A zero-bag-limit for bull trout was introduced in 1992. Bars indicate the number of redds observed in Smith-Dorrien Creek. Points indicate the number of spawning adults moving upstream that were caught in a trap. Trapping commenced May-August and ended in October of each year. Adult abundance in 2001 is estimated (see Johnston et al. 2007 for explanation; F. Johnston, unpubl. data).

trout abundance since the 1990s, although non-native cutthroat trout had become established in the lake in the interim and evidence of illegal angling activity was observed (S. Herman pers. comm.). Implementation of catch-and-release regulations and closure of an access road is thought to have resulted in a five-fold increase in bull trout abundance in Harrison Lake, a remote mountain lake in Banff National Park (Parker et al. 2007).

The impact of more restrictive angling regulations on fluvial and resident populations is less consistent. No change in bull trout abundance in the Kakwa River is apparent since the 1995 provincial zero-bag-limit and permanent closure of Lynx and Grizzly creeks in 1997 to protect spawning habitat. Bull trout abundance in a 32-kilometre study reach of the river does not appear to have changed significantly since 1997 (Johns 2006; Figure 7), and no consistent trend in juvenile abundance is evident from a monitoring site in Lynx Creek (Figure 8). Mean size of Kakwa River bull trout in the angling and electrofishing catch also does not appear to have changed since 1997 (Johns 2006; Figure 9). The number of large (≥400 mm) bull trout entering Lynx Creek to spawn since 1995 has varied considerably with no apparent trend, although periodic failure of the fence used for fish enumeration makes interpretation of these data problematic (Hvengaard and Thera 2001, Doran et al. 2003).

Studies performed in the 1970s, 1990s and 2004 indicate the fluvial bull trout population in the Clearwater River has likely increased, although changes to study design and the long interval between assessments (>10 years) limit their usefulness as a time-series (Rodtka 2005). Although too few bull trout were captured to calculate abundance estimates during previous assessments, estimated abundance of bull trout 350 mm or larger was between 2.2 and 3.6 fish/km in the upper reaches of the river in 2004 (Rodtka 2005). Maximum size of bull trout in the electrofishing catch also increased at these reaches. The number of bull trout redds in 2004 at previously identified spawning reaches was comparable to the maximum number of redds observed during past surveys. Renewed spawning was observed in Cutoff Creek, a Clearwater River tributary that received marginal use since the 1970s, but is believed to have supported a bull trout spawning run historically (Rodtka 2005). Nevertheless, bull trout were still incidental (see glossary, Appendix 1) in the catch at the lowermost river site and were not captured in tributary streams where they were known to occur historically (Rodtka 2005). Bull trout abundance in Elk Creek, a tributary to the Clearwater River, has fluctuated from an estimated 80 trout/km in 1966 to 13 trout/km in 1979 then increased following imposition of the zero-bag-limit in 1995 to 151 trout/km in 1998. The increase appears persistent as bull trout continue to be captured in comparable numbers at this index site a decade later (S. Herman pers. comm.). The apparent increase in bull trout abundance in Elk Creek is significant as the creek is paralleled by the Forestry Trunk Road for much of its length and is a popular destination for anglers; Elk Creek also contains populations of brook trout and brown trout. Periodic redd surveys of the Elbow and Highwood rivers near Calgary indicate little change in numbers of fluvial bull trout redds, while counts have increased substantially in the Sheep River from 51 in 1996 to 243 in 2006 (although the length of the survey reach was shorter in 1996) (Popowich and Eisler 2008).

Despite over a quarter-century of progressively restrictive angling regulations and nearly a decade of active suppression of the stream's non-native brook trout population, the bull trout population in Quirk Creek, a tributary to the Elbow River, does not appear to be recovering. Restrictive angling regulations pertaining to bull trout include the following: imposition of a daily bag limit for bull trout, originally five in 1974, reduced to two in 1984; introduction of a minimum size limit of 40 cm in 1987; the

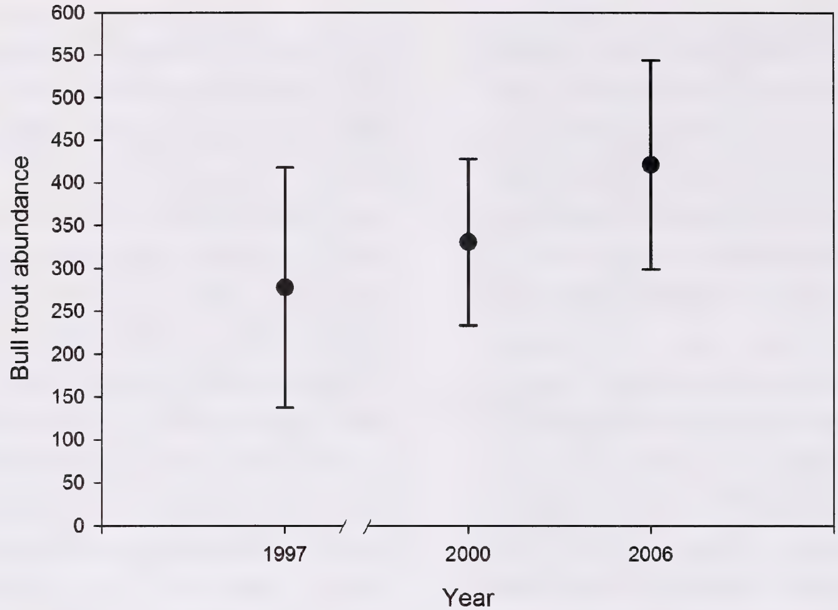


**Figure 7.** Estimated bull trout abundance (± 95% confidence limits) in a 32-kilometre reach of the upper Kakwa River in 1997, 2000, and 2006. Estimates were performed in late September using electrofishing and angling gear (Johns 2006).

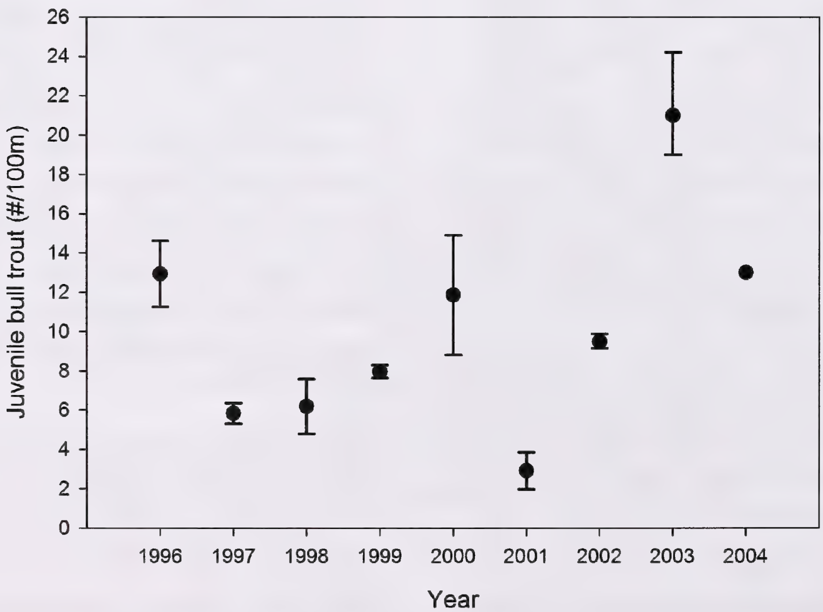


**Figure 8.** Estimated abundance of juvenile bull trout (#/100 m ± 95% confidence limits) at a permanent sample site established on Lynx Creek (Kakwa River drainage), between fall 1996 and fall 2004. Abundance in 2004 based on a single electrofishing pass corrected for estimated gear efficiency. Reach length ranged between 215 m and 634 m between years. Data from 1996-2003 extracted from Doran et al. (2003); 2004 data from T. Johns (unpubl.).

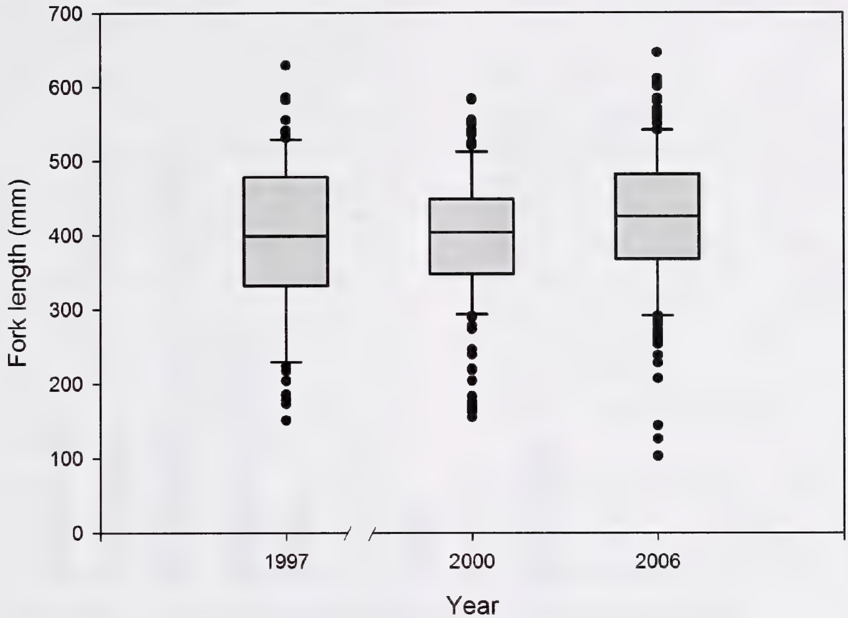


**Figure 9.** Box plot of median (line), 25th and 75th percentile (box), 10th and 90th percentile (whiskers), and outliers of bull trout fork length in the combined electrofishing and angling catch from a 32-kilometre reach of the Kakwa River in late September 1997, 2000, and 2006 (T. Johns, unpubl. data).

province-wide zero-harvest regulation in 1995; and finally, designation of the stream as catch-and-release only in 1998 (Paul et al. 2003). Commencing in 1998, brook trout removal involved selective harvest of brook trout by anglers in designated reaches, but has since expanded to allow harvest throughout the stream and includes capture using electrofishing gear (Earle et al. 2007). Since the 1990s, bull trout have composed 10% or less of the electrofishing catch at two study reaches in the stream and their relative abundance has fluctuated widely with no apparent trend (Figure 10). McCleary et al. (2003) found no significant difference in bull trout electrofishing catch rates following implementation of catch-and-release regulations in three upper Athabasca River drainage watersheds.

Quantitative information on the abundance and distribution of bull trout over decades is very limited, making it difficult to assess the extent of population declines, or even the current provincial population. Anecdotal evidence has traditionally been used to fill in the gaps; this approach may have sufficed in the last century but will undoubtedly fail to adequately inform bull trout conservation measures in the twenty-first century. Further complicating the matter are the broad natural fluctuations in abundance exhibited by bull trout populations. This variability makes assessment of population trends particularly difficult when monitoring studies are performed on a 5- or 10-year rotation, as often occurs in Alberta (Rodtka 2005). More than 10 years of consecutive data may be necessary to detect large population declines statistically (Al-Chokhachy et al. 2009, Maxwell 1999, Rieman and Myers 1997). Little is known about bull trout population dynamics under relatively unaltered conditions, although Eunice Creek in

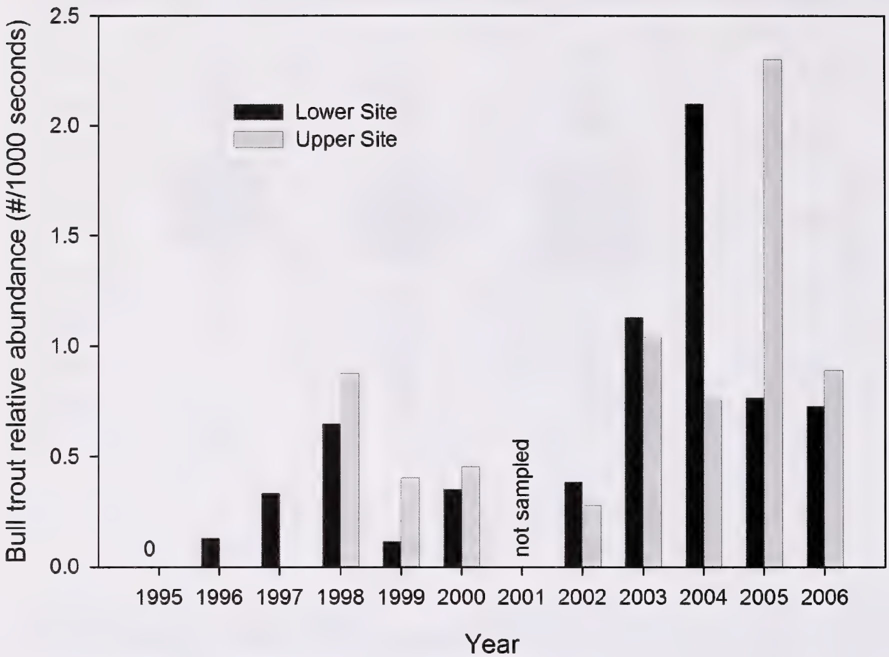


**Figure 10.** Relative abundance (#/1000 seconds) of bull trout in the electrofishing catch at two permanent sample sites established on Quirk Creek (Elbow River drainage), in August-September of 1995-2006. Upper site was not established until 1998; neither site was surveyed in 2001. Catch in 2005 at the upper site likely includes young brook trout x bull trout hybrids misidentified as bull trout. Extracted from Earle et al. (2007).

the Athabasca River drainage is an exception. Eunice Creek was closed to angling in 1966 and protected from most development until 1985 (Hunt et al. 1997). Abundance of bull trout in the creek fluctuated by two orders of magnitude in 15 years. The cyclical variation in juvenile abundance observed in the population was attributed to competitive interactions and cannibalistic behaviour (Paul et al. 2000). Quantitative information from a number of bull trout populations over a period of decades will be necessary for a comprehensive evaluation of current bull trout conservation measures, particularly in light of the array of factors implicated in their decline. However, the broad conservation status in Alberta is clearly that of populations at risk.

If long-term data exist, they typically incorporate non-standardized sampling techniques, making comparison difficult. Bull trout monitoring in Alberta has relied heavily on the use of electrofishing gear, trapping, and redd surveys to assess abundance at established index sites. Each capture method has its limitations. Electrofishing gear is size selective and its efficiency varies with stream habitat characteristics (Peterson et al. 2004). Trapping migratory populations can be effective, although it is labor intensive and trap avoidance and non-repetitive spawning behaviour of bull trout may be problematic (Mushens et al. 2003). Redd surveys have been criticized for their low power to detect bull trout population trends and should only be used for monitoring after a thorough evaluation of their potential limitations (Al-Chokhachy et al. 2005, Dunham et al. 2001, Maxwell 1999, Rieman and Myers 1997). Day and night snorkel counts, are a cost-effective approach commonly used in other jurisdictions (Al-Chokhachy et al. 2009), but are rarely used in Alberta. In many cases the effectiveness and sensitivity of bull trout monitoring index sites, established for assessment of population health, has not been determined. These relationships must be assessed, particularly as many of the factors limiting bull trout recovery are cumulative and scale-dependent. Ongoing and recently completed monitoring and baseline assessments that should provide useful data for future bull trout status updates include work performed on the Wapiti, Simonette and Muskeg rivers (Peace River drainage); McLeod River (Athabasca River drainage); North Saskatchewan River; Prairie, Canyon and Waiparous creeks (Bow River drainage); and the Oldman and North Belly rivers (South Saskatchewan River drainage).

***2. Other Areas*** - Bull trout populations have experienced declines in abundance in all areas of their native range (Brewin 1994a and 1994b, Brewin and Brewin 1997, Earle and McKenzie 2001, Fitch 1997, McCart 1997, Rhude and Stelfox 1997). Populations in British Columbia are considered vulnerable to declines because of their susceptibility to changes in habitat quality (Pollard and Down 2001). In the northwestern United States, more than 50% of populations have declined in abundance, and only 6% of the bull trout populations are considered stable or increasing (Lohr et al. 2001, MBTRT 2000, Rieman and Myers 1997). In the Columbia River basin, it is estimated that strong bull trout populations are present in only 6% of their potential range and 24% of potential spawning and rearing watersheds. Historical estimates are 12% and 44%, respectively, which suggests that it is unlikely the whole range was ever occupied at once (Rieman et al. 1997). Of 121 identified bull trout core areas in the conterminous United States, 43 (36%) were ranked highly vulnerable to extirpation, whereas only 4 (3%) were considered to have low risk of extirpation (Fredenberg et al. 2005).

## LIMITING FACTORS

Many factors, both natural and human-induced, limit the distribution and abundance of bull trout in Alberta (see Appendix 4 for an example). Although bull trout have evolved strategies to cope with many natural limiting factors, human activities resulting in barriers to migration, habitat fragmentation and degradation, overharvest and the introduction of non-native fish species are relatively new and have had a profound influence on bull trout distribution and abundance in the last century.

***1. Migratory Barriers*** - The construction of roads throughout Alberta to service mining, logging and fossil fuel industries has resulted in numerous blockages and hanging culverts, which act as barriers to the migration of bull trout (Brewin 1994b, Hunt et al. 1997, MBTSG 1998). For example, although road density in Alberta's Kakwa River watershed is relatively low (0.21 km/km$^2$) fully 57% of the culvert crossings in the watershed are hanging, blocking fish access to an estimated 98 km of stream (Johns and Ernst 2007). In the same watershed, bull trout occurrence was found to be negatively related to road density (Ripley et al. 2005). Scrimgeour et al. (2003) found a similar negative relationship between bull trout presence and cumulative density of stream crossings in the Simonette River watershed. Park et al. (2008) found that the occurrence of hanging culverts was positively associated with culvert age and reach slope, suggesting that even in the absence of new road construction, fragmentation of bull trout stream habitat will continue to increase where existing culverts are improperly maintained. Mining may also result in stream blockages from extraction of alluvial mineral deposits near streams (Earle and McKenzie 2001).

Dams block access to spawning and rearing habitat by isolating tributaries from spawning adults and juveniles, as well as isolating populations (Goetz 1997b, Hansen and

DosSantos 1997, MBTSG 1998). The Oldman Dam has no provision for fish passage and bull trout congregate below the dam to attempt spawning migration (Fernet and O'Neil 1997). Fish captured below and then released above the dam moved up the Castle River to spawn (Fernet and O'Neil 1997). Dams not only act as a physical barrier, but may also alter or withhold flows from areas that might otherwise have been accessible (Goetz 1997b, Hansen and DosSantos 1997, MBTSG 1998). Irrigation canals may also have the same effect (Clayton 1998, Hansen and DosSantos 1997, MBTSG 1998, McCart 1997). Twenty percent of mortality in the Belly and Waterton river drainages was attributed to entrainment (see glossary, Appendix 1) in irrigation canals or the blockage of upstream movement (Clayton 1998). Migratory movements may also be blocked by beavers, with their dams acting as physical barriers and withholding flow from otherwise suitable habitat (Brewin 1994b, McCart 1997, Rhude and Stelfox 1997).

***2. Habitat Degradation and Fragmentation*** - Human activities degrade bull trout habitat in numerous ways. Activities such as residential and industrial development, mining, grazing, agriculture, irrigation, dams, road construction, and recreational development may all decrease the stability and complexity of aquatic habitat (MBTSG 1998, McCart 1997).

Mining, logging, agriculture, irrigation, dams and recreational development often result in the alteration of surface and groundwater flows (MBTSG 1998). Logging can result in faster runoff events and flooding, as well as cause changes in the groundwater recharge and seasonal flows (Berry 1994, Cross and Everest 1997, MBTSG 1998, McCart 1997). Although artificial, reservoirs may provide habitat suitable for bull trout; however, where lake trout (*Salvelinus namaycush*) are sympatric, habitat changes associated with river impoundment typically lead to increased lake trout abundance and bull trout decline. For example, gill net surveys of Abraham Lake, a reservoir created in the 1970s after impoundment of the North Saskatchewan River, indicate a steady decline in bull trout abundance. Once dominant, bull trout are now rare in a catch dominated by lake trout (R. Konynenbelt pers. comm.). Large fluctuations in water flow may alter patterns of habitat use by bull trout. In Lower Kananaskis Lake, the surface area of the lake at draw-down is only 44% of the surface area when water levels are at bankfull level. This affects the presence and production of the littoral zone within the reservoir, and causes re-suspension of sediment during flooding (Golder Associates Ltd. 1995). Stabilization of water levels would likely increase bull trout production three-fold (J. Post unpubl. data). Similarly, flow alteration associated with the operation of dams and irrigation diversions has the potential to reduce the quantity and quality of downstream fish habitat and may have been a significant factor in the decline of bull trout stocks in several Alberta rivers including the Kananaskis and Highwood rivers (Bow River drainage), the North Saskatchewan River and the Peace River (A. Paul pers. comm.).

Logging, mining, road construction, grazing, agriculture, and recreational development may cause sediment accumulation in bull trout waters (Berry 1994, Cross and Everest 1997, MBTSG 1998, McCart 1997). A study conducted on managed and unmanaged watersheds suggests that sediment was carried from harvested forest areas with a high density of roads and deposited in the stream, thereby reducing the habitat complexity and carrying capacity of the stream (Cross and Everest 1997). Ripley et al. (2005) found that the distribution and abundance of bull trout in the Kakwa River watershed was negatively related to the percentage of fine substrate and sub-basin harvested, predicting the local extirpation of bull trout from 24% to 43% of stream reaches over the next 20 years as a result of forest harvesting. The construction of new, and destruction of old, beaver dams may also increase sediment loads (Fairless et al.

1994). Increased sedimentation may increase the mortality of incubating eggs and young, and alter the carrying capacity of the stream by destroying suitable habitat (Cross and Everest 1997, Fairless et al. 1994).

Road construction, timber harvest, grazing, agriculture and recreational development all potentially decrease canopy cover and cause increased thermal loading of streams (Berry 1994, MBTSG 1998, McCart 1997). Removal of water and containment in dams and irrigation structures also alters the thermal regime of bull trout habitat (Goetz 1997b, MBTSG 1998). The extirpation of bull trout in California is attributed to an increase in temperatures as a result of dam construction (California Department of Fish and Game 2007). Mining, irrigation, urban development, and agriculture also have impacts on water quality, either causing direct mortality or altering food supplies (MBTSG 1998, McCart 1997, McLeod and Clayton 1997). Coal mining in west-central Alberta has led to elevated levels of selenium in nearby streams containing bull trout. In high concentrations, selenium can increase rates of deformities during fish development thereby reducing recruitment, but its impact on bull trout specifically has not been assessed (Palace et al. 2004). Loss of habitat complexity, increased sediment load and increased temperatures may also occur during wildfires. However, fires tend to leave refugia, and may even enhance the habitat by increasing large woody debris and pools (MBTSG 1998, Ratcliff et al. 1996).

Climate change is projected to lead to global warming during this century, with annual mean warming of North America likely to exceed global means in most areas (Christensen et al. 2007). Although individual model predictions vary, mean projected warming ranges between 3°C and 5°C over most of the continent with a resulting increase in winter and decrease in summer precipitation in western regions (Christensen et al. 2007). Given their cold water requirements for spawning and rearing, bull trout may be especially vulnerable to climate change (Rieman et al. 2007). In one simulation, predicted warming resulted in a loss of 18% to 92% of thermally suitable habitat area over the next 50 years in the interior Columbia River basin (Rieman et al. 2007). Although no comparable assessment has been performed in Alberta, the thermal and hydrological effects of global warming are likely to interact with local or regional factors limiting bull trout abundance in the province, complicating recovery.

***3. Angling Pressure and Fisheries Management Practices*** - Historically, bull trout were considered a piscivorous, "junk" fish and active eradication plans were carried out in the 1920s (Colpitts 1997). Anglers would toss them in the bushes to rot (Van Tighem 1997), and during the depression they were overexploited as an easy food source (Allan 1980). In the late 1960s, four lakes in the Athabasca river drainage that contained bull trout were treated with a fish toxicant, rotenone (Hunt et al. 1997). Angler access to bull trout habitat in Alberta has also increased dramatically in the past 50 years, as access is developed to service the forestry, mining, and fossil fuel industries (Paul 2000, Post and Paul 2000, Rhude and Stelfox 1997, Walty and Smith 1997).

Attitudes, management practices, and regulations have changed; however, poaching and misidentification are still a problem. It is estimated that 5% of bull trout mortality in the Belly and Waterton rivers is a result of poaching (Clayton 1998). In Montana, poaching rates through the summer were estimated at 5 bull trout/day, and 22 fish/week (Long 1997), and in Idaho 0.006 – 0.007 fish/hour (Schill et al. 2001). Considerable effort made in the 1990s to educate Alberta anglers on the identifying characteristics of bull trout has had some success. In 1993, fully 29% and 68% of Trout Unlimited and licensed non-member anglers, respectively, were unable to describe any characteristics distinguishing brook trout from bull trout, whereas only 10% and 44%

of respondents failed in a survey completed in 2000 (Norris et al. 2001). Nevertheless, misidentification remains an issue, with 43% of anglers not knowing that the absence of spotting on the dorsal fin is a key feature distinguishing bull trout from other trout species in Alberta (Norris et al. 2001).

Bull trout are particularly susceptible to exploitation. Compared to other freshwater sport fish, they are slow-growing, late to mature, and more vulnerable to angling because of their opportunistic and aggressive foraging behaviour, especially when bait is used (Berry 1994, Brewin 1994a, Paul et al. 2003, Post and Paul 2000, Post et al. 2003, Van Tighem 1997). As a result of their high vulnerability, bull trout populations are susceptible to overharvest even at low levels of angling effort (Paul et al. 2003, Post and Paul 2000, Post et al. 2003). Spawning migrations may also involve staging periods at the mouths of tributaries, or aggregation beneath barriers to migratory movements (Bellerud et al. 1997, Fernet and O'Neil 1997, McCart 1997, Mushens et al. 2003, Ratcliff et al. 1996, Westover 1999). This behaviour, which can lead to concentrations of large bull trout in relatively shallow, clear water, increases their vulnerability.

In the 1950s, unrestricted anglers were catching 15 – 21 fish/day in the Clearwater drainage (Allan 1980). In a study done on the Athabasca River in 1992 and 1993, between17% and 22% of tagged fish were caught and killed by anglers (McLeod and Clayton 1997). Illegal angling activity is thought to have helped undermine recovery of bull trout in Osprey Lake in Jasper National Park (Parker et al. 2007). A decade after implementation of the province-wide zero-bag-limit, anglers in Alberta still reported keeping 255 bull trout (0.3% of the catch) in a 2005 recreational fishing survey, likely an under-representation of illegal harvest in the province (Park 2007).

Even catch-and-release fisheries can result in bull trout mortality. Mortality from hooking in the Belly and Waterton rivers was estimated to be 5% (Clayton 1998). In the Wigwam River, British Columbia, it was estimated that 64% of the bull trout spawning population was caught before or after the event, and that a minimum of 79% of these fish survived this catch-and-release (Westover 1999). Accounting for reasonable estimates of catch-and-release mortality, illegal harvest, and fishing effort, bull trout population and fisheries model simulations demonstrate that many populations can not be sustained without restrictive angling regulations (Post et al. 2003). Reliable predictions of sustainable fishing pressure are hampered by uncertainty in estimates of juvenile growth, survival and recruitment, bull trout catchability, rates of hooking mortality, and angler noncompliance in bull trout fisheries (Post et al. 2003, Thera et al. 2001). Nevertheless, although changes to these parameters may quantitatively change model predictions, qualitative patterns remain similar (Post et al. 2003). The presence of other introduced sport fish may increase the mortality of bull trout because of the incidental by-catch of bull trout by anglers targeting other trout species (McIntyre 1998, Paul et al. 2003, Post and Paul 2000).

***4. Fish Species Introduction*** - Introduction of sportfish species to bull trout waters, including non-native brown trout and brook trout, and transfer of native lake trout, has likely contributed to the decline and extirpation of bull trout populations in Alberta (Appendix 3) (Berry 1994, Fitch 1997, McCart 1997). Introduction of *Oncorhynchus* species (i.e., cutthroat and rainbow trout) is thought to have had less impact on bull trout populations. Competition may occur directly or indirectly, resulting in reduced growth and survival of bull trout or detrimental changes to the aquatic community. The relatively slow growth, late maturity and variable spawning frequency of bull trout make them susceptible to competition with non-native fish species, resulting in reductions in abundance and population viability (Berry 1994, Hunt et al. 1997, McCart 1997).

Brown trout spawn later than bull trout and may disturb redds (Rhude and Stelfox 1997). On the other hand, bull trout and brook trout have similar spawning requirements, which results in competition for spawning habitat, and the risk of hybridization (Berry 1994, Ratcliff et al. 1996). It is generally assumed that these hybrids are sterile (Berry 1994), although there has been some evidence that they are able to reproduce (Buktenica 1997). Brook trout also mature earlier than bull trout, allowing their populations to grow more rapidly and enabling brook trout sneaking (see glossary, Appendix 1) behaviour and hybridization, further limiting bull trout spawning success (Bellerud et al. 1997, Paul 2000, Post and Paul 2000, Ratcliff et al. 1996). Donald and Stelfox (1997) proposed that the introduction of other *Salvelinus* species results in the competitive exclusion of bull trout, while *Oncorhynchus* species allow for sympatry. Lake trout have displaced bull trout from low elevation (<1500 m) lakes to which they have been introduced in the Rocky Mountains (Donald and Alger 1993, Fredenberg 2002). In the areas in southwestern Alberta where brook trout have been introduced, approximately 70% of the native bull trout populations have been, or are thought to have been, extirpated (Fitch 1997). Brown trout did not cause extirpation in the one system where it was the sole introduced species present, but extirpation did occur when brown trout and brook trout were both present (Fitch 1997).

Invasion of bull trout habitats by brook trout may occur in pulses over a period of several decades (Adams et al. 2002). Invasion success is thought to be moderated by environmental factors, including landscape structure, habitat size, stream flow, human influences and temperature (Dunham et al. 2003a). In Alberta's foothill watersheds the probability of bull trout occurrence has been found to increase with elevation, but the probability of brook trout occurrence decreases (McCleary and Hassan 2008, Paul and Post 2001) and the brook trout have preferentially moved downstream of their original stocking locations (Paul and Post 2001). Elevation is highly correlated with temperature, and the low temperatures associated with bull trout habitat may limit the invasion of other species with higher temperature requirements, thereby preventing competitive exclusion (MBTRT 2000, Rodtka and Volpe 2007). Displacement of bull trout to these thermal refugia in headwater areas by competition with introduced fish species has likely occurred in Alberta (Donald and Alger 1993, Paul and Post 2001, Rodtka and Volpe 2007). However, water temperature alone is unable to fully account for the bull trout's apparent competitive advantage over brook trout in headwater streams. Maintenance of complex habitat structure and connectivity to nearby bull trout populations also appear to be vital for protecting remaining populations from invasion and displacement (McMahon et al. 2007).

***5. Genetics*** - Reproductive isolation of bull trout populations occurs because of their generally high fidelity to spawning areas (Allan 1980, Bellerud et al. 1997, Rieman and McIntyre 1996, Rieman and Myers 1997), resulting in relatively low genetic diversity within populations and high genetic divergence between populations (Bellerud et al. 1997, Costello et al. 2003, Taylor et al. 2001, Thomas et al. 2001, Warnock 2008). These genetically distinct units are stocks that result from evolutionary divergence because of local environments (Costello et al. 2003). Over time, the loss of genetic variability may result in a decrease in the population's viability. Therefore, exchange of genetic material between populations must occur (MBTSG 1996) and attempts to maintain population fragments without considering connectivity may not ensure their persistence (Bellerud et al. 1997, Rieman and McIntyre 1996).

Effective population size is related to the rate of loss of genetic diversity. Geneticists' estimates of the minimum population size required to maintain long-term genetic diversity vary with a population's level of isolation (Brewin 1994a, Ratcliff et al. 1996, Rieman and Allendorf 2001). The complex life history pattern of bull trout makes determination of effective population size difficult. Using model simulations, Rieman and Allendorf (2001) determined that a population size of at least 1000 breeding adult bull trout would maintain genetic diversity indefinitely, and at least 100 adults are necessary to minimize the risks of inbreeding. However, bull trout populations as large as 1000 breeding individuals are relatively uncommon; therefore, managers must recognize that more common, smaller populations are more at risk. The connection of multiple populations within a metapopulation (see glossary, Appendix 1) may enhance the maintenance of genetic diversity in more than an additive way, but the fragmentation of these populations may result in an accelerated loss of genetic diversity (Rieman and Allendorf 2001). Delimiting population size and range is difficult for migratory bull trout populations because their migrations may exceed hundreds of kilometres. Rieman and McIntyre (1996) found redd numbers or rate of change in redd numbers to be weakly correlated with distance, even within basins. This suggests that monitoring limited areas may not indicate trends in all local populations. The conservation of different life history strategies is critical to the persistence of viable populations on both a local and regional scale (Fitch 1997, MBTRT 2000, Rieman and Allendorf 2001, Rieman and Clayton 1997).

Factors that decrease the number of genetic sources within a metapopulation, such as local extinctions or the blockage of genetic exchange between populations, may increase the risk of extinction of the entire bull trout population (Haas and McPhail 2001, MBTRT 2000, McCart 1997, Rieman and McIntyre 1995, Rieman and Myers 1997). Unfortunately, little is known about the rate of genetic exchange within and between watersheds historically, although human-caused habitat fragmentation has restricted bull trout populations to smaller, more isolated areas making genetic exchange more difficult, if not impossible (Dunham and Rieman 1999, Rieman et al. 1997). Further habitat loss may result in an acceleration of extinction rates disproportionate to the rate of habitat loss (Rieman et al. 1997), and the high level of genetic divergence between bull trout populations suggests that human-induced reductions in population size will not likely be offset by immigration from nearby populations (Costello et al. 2003). More information is required to better define local populations and the population abundance required to produce viable populations. In a study of the genetic structure of bull trout populations in the Livingstone, Castle and Oldman rivers, Warnock (2008) found a gradient of overall migrant numbers that positively correlated with intrapopulation genetic diversity. Further description of genetic exchange between local populations in Alberta and its role in sustaining these populations and the larger metapopulations would be useful.

The genetic differentiation between bull trout populations also makes stocking and hatchery production for population recovery unattractive; the transfer of fish between drainages should be avoided (Berry 1994, McCart 1997), although transfers have occurred in the past. For example, bull trout populations in Ptarmigan and Marie lakes (Smoky River drainage) have been established, apparently through stocking, using fish from the Athabasca River drainage (M. Sullivan pers. comm.).

It is likely that a combination of these limiting factors has resulted in the large bull trout population declines over the last century. Current land use practices and fisheries management strategies have not been able to adequately maintain viable populations in Alberta and throughout the species' range. For effective conservation, bull trout monitoring in Alberta should include evaluation of these factors and their relative impact on populations in an adaptive management framework.

## STATUS DESIGNATIONS*

***1. Alberta*** - Bull trout are designated as a game fish under the *Fisheries (Alberta) Act*, and since 2002 have been considered a *Species of Special Concern* (Fish and Wildlife 2008). According to the 2000 and 2005 iterations of *The General Status of Alberta Wild Species*, bull trout are considered *Sensitive* in the province (Alberta Sustainable Resource Development 2001, 2007).

***2. Other Areas*** - The bull trout's Global Heritage Status rank is G3 (NatureServe 2009). Evaluation of the bull trout by the Committee On the Status of Endangered Wildlife in Canada (COSEWIC) is scheduled for November 2010 (A. Clarke pers. comm.). *The General Status of Species in Canada* lists the bull trout as *Sensitive* in British Columbia and the Yukon, and *May Be At Risk* in the Northwest Territories (Canadian Endangered Species Conservation Council 2006). The British Columbia Conservation Data Centre (2007) ranks the bull trout as S3, or "Blue-listed."

The United States Fish and Wildlife Service (USFWS) currently lists bull trout as *Threatened* throughout their range in the United States (lower 48 states), under the *Endangered Species Act* (USFWS 2003). After listing various populations of bull trout as *Threatened*, the USFWS listed the last population segments within their range in the United States as *Threatened* in 1999 (Lohr et al. 2001). A five-year review of the listing, initiated by the USFWS in 2004, recommended no change in the bull trout's classification (USFWS 2008). Bull trout are considered S2 and a candidate animal for listing in Washington (Washington Natural Heritage Program 2004), S2 and a *Critical* species in Oregon (Oregon Natural Heritage Information Centre 2007), and are ranked *Threatened* by the Nevada Natural Heritage Program (2007), the Montana Natural Heritage Program (2006), and the Idaho Fish and Game (2008). It is *Extirpated* in the State of California (California Department of Fish and Game 2007).

## RECENT MANAGEMENT IN ALBERTA

Angling regulations for bull trout became more restrictive in 1976, when some critical spawning and rearing habitats were closed to angling. Streams above and including Timber Creek, in the Clearwater drainage, were closed at this time (Rhude and Rhem 1995, Rhude and Stelfox 1997). In 1984, harvest limits were reduced from five bull trout/day to two bull trout/day, and in 1987 the minimum harvestable size of 40 cm was implemented province-wide (Rhude and Stelfox 1997). The large body size of fluvial and adfluvial bull trout at first maturity has important implications to minimum size for harvest regulations, since a 40-cm limit may allow for the capture of immature fish (Berry 1994). Migratory populations may not achieve maturity before they enter the vulnerable size category of the angling regulations. Stelfox (1997) found that 70% of the legal-sized fish caught during the winter of 1991 and 1992 in Lower Kananaskis Lake were immature. It was further estimated that one-half of the adult population was harvested during that single winter fishery. Bait bans were introduced to most flowing waters in the foothills of Alberta to decrease hooking mortality in the 1990s (Berry 1994). On April 1, 1995, a zero-bag-limit for bull trout was implemented throughout Alberta (Hvenegaard and Fairless 1998). Additionally, in response to increased information on bull trout life history strategies and migratory behaviour, the fall in-stream "no activity"

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* See Appendix 2 for definitions of selected status designations.

window was adjusted to include the month of August (Hvenegaard and Thera 2001).

In 1994, Alberta Fish and Wildlife produced *Alberta's Bull Trout Management and Recovery Plan* (Berry 1994). This document discusses angling regulations, public education, development of recovery plans, and enforcement, as well as management changes proposed for 1995 and aspirations for the year 2000. An internal review and update of the bull trout management plan by the Fisheries Management Branch of Alberta Sustainable Resource Development is ongoing (D. Christiansen pers. comm.). Brewin (2004) conducted an external review of the plan that included distribution of a questionnaire to stakeholders and active and retired resource managers to solicit feedback on bull trout recovery efforts in Alberta. Respondents generally agreed that there was insufficient information to indicate that there has been widespread recovery of Alberta's bull trout populations. Bull trout recovery successes were largely attributed to enactment of no-harvest regulations rather than implementation of actions to correct other factors impacting populations. Illegal harvest, insufficient funding and habitat degradation were identified by respondents as the primary factors limiting bull trout recovery in the province (Brewin 2004).

Although not specifically targeting bull trout, Fisheries Management Branch's ongoing review of bait ban and year-round and seasonal closures and implementation of a province-wide barbless hook regulation in 2004 have the potential to reduce bull trout hooking mortality. Tools developed to help anglers identify their salmonid catch include an interactive fish identification website, two styles of full colour pamphlet, and signage developed by Alberta Sustainable Resource Development in partnership with Trout Unlimited Canada and the Alberta Conservation Association. A major impetus for development of these tools was the prevalence of bull trout misidentification by anglers.

To minimize the potential for escapement of non-native brook trout and brown trout into bull trout waters, Fisheries Management's stocking locations for these species have been prioritized according to their potential for escapement and stocking has been discontinued at the majority of sites where escape into bull trout waters is a possibility. Development of sterile, triploid stocks of brook trout and brown trout is also underway, effectively eliminating the potential for naturalization of these species (D. Christiansen pers. comm.). The Quirk Creek brook trout suppression project, a study designed to determine if anglers could decrease brook trout abundance and therefore increase bull trout populations in the creek, is ongoing and was expanded in 2004 to include removal using electrofishing gear (Earle et al. 2007).

In contrast to the management of recreational anglers, a wide diversity of public and private interests needs to be considered when managing human activities with the potential to degrade and fragment bull trout habitat. To date, attempts to address human causes of habitat degradation and fragmentation that threaten the continued persistence of bull trout and other native fish species along the eastern slopes of Alberta have largely been piecemeal, and *ad hoc*. Those efforts that do occur typically focus on conservation of existing bull trout habitats rather than restoration of degraded habitats.

The *Northern Watershed Project*, a multi-stakeholder research initiative to evaluate the cumulative effects of watershed disturbance on stream fish communities (Scrimgeour et al. 2003), and related stream-crossing inventory work have catalyzed remediation efforts in some northwestern Alberta watersheds. Additional "Class A Areas" (i.e., areas where instream industrial activity is severely limited) have also been identified in the Codes of Practice under Alberta's *Water Act*, largely in an effort to protect bull trout spawning habitat (D. Christiansen pers. comm.). Although these and other habitat conservation measures likely affect local populations, it is nearly impossible to evaluate, or even document, their impact provincially. Furthermore, evaluation at the level of the population is complicated by a lack of suitable bull trout trend data from Alberta watersheds and the confounding of habitat and angler effects on bull trout persistence (Ripley et al. 2005).

In 2004, a provincial review of bull trout monitoring protocols was initiated jointly by the Alberta Conservation Association and Alberta Sustainable Resource Development. The review includes evaluation and development of monitoring methods in the context of ongoing monitoring and inventory activities. The initial focus includes evaluation of existing index monitoring sites, identification of optimal sampling design and intensity at the reach and watershed scale and estimation of electrofishing gear efficiency for the capture of bull trout. Although bull trout have been the focus of the review, results will be broadly applicable to other stream salmonids. Sustained recovery of bull trout stocks in Alberta will be contingent upon remediation of habitat degradation and fragmentation threats.

## SYNTHESIS

Bull trout populations in Alberta have been declining since the early 1900s. Although this decline has been more drastic in southern parts of the province, anecdotal evidence and limited historical records indicate that a decline has occurred throughout the bull trout's native Alberta range, leading to their extirpation from some drainages. Although data are limited, the restrictive angling regulations enacted in the 1990s appear to have led to increased bull trout abundance in some adfluvial populations. Results for fluvial and stream-resident populations are less clear; these populations occur over relatively broad geographic areas, are difficult to monitor, and are exposed to a complex array of limiting factors. To more clearly define bull trout status in the province, a coordinated, long-term monitoring program that follows standardized methods must be initiated. Not only would this information help refine our knowledge of the current status of bull trout in Alberta, but it would also assist in assessment and development of current and future bull trout conservation and management initiatives.

Our understanding of bull trout biology has increased substantially over the past decade. However, very little is yet known about why specific life history strategies are expressed, and about the migratory patterns of juveniles. Efforts to model sustainable fishing pressure are complicated by uncertainty in estimates of juvenile growth, survival and recruitment along with bull trout catchability, hooking mortality and angler noncompliance. Habitat requirements for each life history strategy at each life stage are still not fully understood, nor is the timing of these requirements. Much remains to be explained regarding adult fidelity to spawning streams and related spawning behaviour. Despite these uncertainties, the factors limiting bull trout recovery in the province are now well documented and need to be addressed in a comprehensive manner if the current trend of populations in decline is to be reversed.

Given the array of factors limiting bull trout production in the province and the diversity of life history strategies expressed by the species, bull trout management and recovery goals will likely need to be population specific. However, provincial coordination of monitoring and management activities is required to ensure consistency and promote efficiency. Furthermore, research is required to identify populations based upon genetic analyses, the rate of exchange of genetic material between populations, and the significance of this exchange to the overall viability of the species in

Alberta. The mechanisms by which non-native fish species interfere with bull trout population growth, including hybridization, need to be more clearly understood. Pilot studies that attempt to mitigate the factors limiting bull trout populations are being carried out. These studies should be examined for their feasibility within Alberta. Bull trout are not immediately at risk of extirpation in Alberta; however, 38 of 47 bull trout core areas are considered either High Risk or At Risk of extirpation, while at least three others are already extirpated. History has demonstrated that local populations are vulnerable to habitat disturbance, overfishing, and interactions with non-native fish species. If current trends continue, bull trout will only persist in the upper reaches of undeveloped watersheds, or will be completely extirpated if human activity eliminates these refuges.

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**Appendix 1.** Glossary of terms.

**Adfluvial** - Fish populations that spawn and rear in tributary streams, with adults residing downstream in lakes or reservoirs.

**Anadromous** - Fish populations that spawn and rear in freshwater streams, with adults residing in the ocean.

**Anchor Ice** - Ice formed on substrate or objects beneath freshwater surfaces when the water becomes supercooled.

**At Risk (C2)** – Bull trout population in the core area is vulnerable to extirpation because of very limited and/or declining numbers, range, and/or habitat.

**Core Area** - A combination of bull trout and the habitat that could supply all elements for the long-term security of the species. The basic unit on which to gauge recovery (Lohr et al. 2001). Core Areas are further subdivided into subpopulations.

**Creel Survey** - A creel is a container used to carry fish that have been kept by anglers. A creel census or survey is a record of the fish caught by anglers (Nelson and Paetz 1992).

**Diel** - Behaviour that occurs throughout the 24-hour period of one day.

**Entrainment** – The process by which fish are pulled through a water diversion device and trapped in water bodies such as irrigation canals.

**Extirpated (CX)** – The bull trout population is no longer viable in that core area; 0 bull trout/km or 0% of sportfish population

**Fecundity** - The number of eggs in the ovaries that are mature or will mature (Nelson and Paetz 1992).

**Fluvial** - Fish populations that spawn and rear in tributary streams, with adults residing downstream in mainstem rivers.

**Frazil Ice** - Slush formed in turbulent water.

**High Risk (C1)** – Bull trout population in the core area is highly vulnerable to extirpation because of extremely limited and/or rapidly declining numbers, range, and/or habitat.

**Incidental** - 1 bull trout/km or 1% of sportfish population.

**Littoral** - The zone around the perimeter of the lake that supports the growth of aquatic vegetation.

**Low Risk (C4)** – Bull trout are common or uncommon, but not rare, and usually widespread throughout the core area. Apparently not vulnerable at this time, but may be cause for long-term concern.

**Metapopulation** - Multiple populations (termed subpopulations in this context) connected by intermittent immigration and emigration.

**Pelagic** - The open water zone of a lake's water column, away from the bottom.

**Potential Risk (C3)** – Bull trout population in the core area is potentially at risk because of limited and/or declining numbers, range, and/or habitat, even though they may be locally abundant in some portions of the core area.

**Precocious** - Satellite male fish that are generally smaller in size and reach sexual maturity at an earlier age than the average male in the population. Because of their size, these males are unable to compete with the larger males for mates. Instead, these males achieve reproductive success by sneaking into redds, while other fish are spawning, and fertilizing some of the eggs.

**Appendix 1** continued:

**Redd** - The gravel nest of salmonids. The eggs are deposited in the redd and remain there until they hatch (Nelson and Paetz 1992).

**Resident** - Fish populations that reside in the tributary streams where they spawn and rear, with no adult migration to other water systems.

**Remnant** - 1-10 bull trout/km or 1-10% of the sportfish population; population is dependent upon immigration from other areas for maintenance.

**Self-Sustaining** - ≥10 bull trout/km or >10% of the sportfish population; population is not necessarily dependent upon immigration from other areas for maintenance.

**Sneaking/Satellite Male** - See precocious.

**Sympatry** - Two species living in the same geographic area.

**Unranked (CU)** – Core area currently unranked because of a lack of information or substantially conflicting information about status and trends.

**Appendix 2.** Definitions of status ranks and legal designations.

**A. The General Status of Alberta Wild Species 2005** (after Alberta Sustainable Resource Development 2007)

| **2005 Rank** | **1996 Rank** | **Definitions** |
|---|---|---|
| At Risk | Red | Any species known to be *At Risk* after formal detailed status assessment and designation as *Endangered* or *Threatened* in Alberta. |
| May Be At Risk | Blue | Any species that may be at risk of extinction or extirpation, and is therefore a candidate for detailed risk assessment. |
| Sensitive | Yellow | Any species that is not at risk of extinction or extirpation but may require special attention or protection to prevent it from becoming at risk. |
| Secure | Green | Any species that is not *At Risk, May Be At Risk* or *Sensitive.* |
| Undetermined | Status Undetermined | Any species for which insufficient information, knowledge or data is available to reliably evaluate its general status. |
| Not Assessed | n/a | Any species that has not been examined during this exercise. |
| Exotic/Alien | n/a | Any species that has been introduced as a result of human activities. |
| Extirpated/Extinct | n/a | Any species no longer thought to be present in Alberta (Extirpated) or no longer believed to be present anywhere in the world (Extinct). |
| Accidental/Vagrant | n/a | Any species occurring infrequently and unpredictably in Alberta, i.e., outside its usual range. |

**B. Alberta Species at Risk Formal Status Designations**
Species designated as *Endangered* under Alberta's *Wildlife Act* include those listed as *Endangered* or *Threatened* in the Wildlife Regulation (in bold).

| | |
|---|---|
| **Endangered** | **A species facing imminent extirpation or extinction.** |
| **Threatened** | **A species likely to become endangered if limiting factors are not reversed.** |
| Species of Special Concern | A species of special concern because of characteristics that make it particularly sensitive to human activities or natural events. |
| Data Deficient | A species for which there is insufficient scientific information to support status designation. |

**C. Committee on the Status of Endangered Wildlife in Canada** (after COSEWIC 2009)

| | |
|---|---|
| Extinct | A species that no longer exists. |
| Extirpated | A species that no longer exists in the wild in Canada, but occurs elsewhere. |
| Endangered | A species facing imminent extirpation or extinction. |
| Threatened | A species that is likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction. |
| Special Concern | A species that may become threatened or endangered because of a combination of biological characteristics and identified threats. |
| Not at Risk | A species that has been evaluated and found to be not at risk of extinction given the current circumstances. |
| Data Deficient | A category that applies when the available information is insufficient to (a) resolve a wildlife species' eligibility for assessment, or (b) permit an assessment of the wildlife species' risk of extinction. |

**Appendix 2** continued:

**D. Heritage Status Ranks: Global (G), National (N), Subnational (S)** (after Alberta Natural Heritage Information Centre 2007, NatureServe 2009)

| | |
|---|---|
| G1/N1/S1 | 5 or fewer occurrences or only a few remaining individuals. May be especially vulnerable to extirpation because of some factor of its biology. |
| G2/N2/S2 | 6 to 20 or fewer occurrences or with many individuals in fewer locations. May be especially vulnerable to extirpation because of some factor of its biology. |
| G3/N3/S3 | 21 to 100 occurrences; may be rare and local throughout its range, or in a restricted range (may be abundant in some locations). May be susceptible to extirpation because of large-scale disturbances. |
| G4/N4/S4 | Typically > 100 occurrences. Apparently secure. |
| G5/N5/S5 | Typically > 100 occurrences. Demonstrably secure. |
| GX/NX/SX | Believed to be extinct or extirpated; historical records only. |
| GH/NH/SH | Historically known; may be relocated in the future. |
| G?/N?/S? | Not yet ranked, or rank tentatively assigned. |

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

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

**Appendix 3.** Conservation rank, population size, stream occupancy (km), short-term trend, and the severity, scope and immediacy of threats to the 51 identified bull trout core areas in Alberta. Assessment was performed by the Fish and Wildlife Division of Alberta Sustainable Resource Development and is based upon a modification of the Natural Heritage Network ranking methodology using NatureServe Conservation Status Assessment Criteria. See the glossary in Appendix 1 for Conservation rank definitions. The focus of the review was on core areas currently occupied by bull trout, and therefore this is not a comprehensive list of extirpated core areas.

| Core Area | Conservation Rank | Population Size | Occupancy (stream km) | Short-term Trend | Threats |
|---|---|---|---|---|---|
| Oldman River Basin | | | | | |
| Belly River | At Risk | 250–1000 | 4–40 | Stable | Widespread, low-severity threat |
| St. Mary River | High Risk | 250–1000 | 40–200 | Stable | Substantial, imminent threat |
| Upper Crowsnest River | Extirpated | – | – | – | – |
| Castle River and Oldman Reservoir | At Risk | 250–1000 | 200–1000 | Stable | Moderate, imminent threat |
| Upper Oldman River | At Risk | 250–1000 | 40–200 | Stable | Moderate, imminent threat |
| Upper Livingstone River | High Risk | 250–1000 | 4–40 | Stable | Moderate, imminent threat |
| Lower Oldman River | High Risk | 50–250 | 40–200 | Declining | Substantial, imminent threat |
| Waterton River | High Risk | 1–50 | 4–40 | Declining | Localized, substantial threat |
| Drywood Creek | High Risk | 1–50 | 4–40 | Declining | Substantial, imminent threat |
| Willow Creek | Extirpated | — | — | — | — |
| Bow River Basin | | | | | |
| Lower Bow River | Extirpated | — | — | — | — |
| Highwood River | High Risk | 50–250 | 40–200 | Declining | Substantial, imminent threat |
| Flat Creek | High Risk | 1–50 | 4–40 | Declining | Widespread, low-severity threat |
| Sheep River | At Risk | 250–1000 | 40–200 | Increasing | Moderate, imminent threat |
| Lower Elbow River | High Risk | 50–250 | 40–200 | Rapidly declining | Substantial, imminent threat |
| Canyon Creek | At Risk | 1–50 | 4–40 | Stable | Widespread, low-severity threat |
| Upper Elbow River | High Risk | 50–250 | 40–200 | Declining | Moderate, imminent threat |
| Jumpingpound Creek | High Risk | 1–50 | 4–40 | Declining | Substantial, imminent threat |
| Ghost River | High Risk | 250–1000 | 40–200 | Declining | Moderate, imminent threat |
| Middle Bow River | High Risk | 1–50 | <4 | Declining | Substantial, imminent threat |
| Middle Kananaskis River | High Risk | Unranked | 4–40 | Severely declining | Substantial, imminent threat |
| Upper Kananaskis River | Potential Risk | 1000–2500 | 40–200 | Increasing | Widespread, low-severity threat |
| Upper Spray River | High Risk | 1–50 | 4–40 | Declining | Moderate, imminent threat |
| Lake Minnewanka | At Risk | 50–250 | 4–40 | Declining | Slightly threatened |
| Upper Bow River* | Unranked | Unknown | Unknown | Unknown | Unknown |

**Appendix 3** continued:

| Core Area | Conservation Rank | Population Size | Occupancy (stream km) | Short-term Trend | Threats |
|---|---|---|---|---|---|
| Red Deer River Basin | | | | | |
| Red Deer River | At Risk | 250–1000 | 200–1000 | Declining | Moderate, imminent threat |
| Little Red Deer River | High Risk | 1–50 | 4–40 | Declining | Substantial, imminent threat |
| North Saskatchewan River Basin | | | | | |
| Brazeau River | Potential Risk | 1000–2500 | 200–1000 | Stable | Widespread, low-severity threat |
| Blackstone River | Potential Risk | 250–1000 | 200–1000 | Stable | Widespread, low-severity threat |
| Nordegg River | High Risk | 50–250 | 40–200 | Declining | Moderate, imminent threat |
| Baptiste River | High Risk | 1–50 | 40–200 | Declining | Moderate, imminent threat |
| Upper North Saskatchewan River | Potential Risk | 250–1000 | 40–200 | Increasing | Slightly threatened |
| Pinto Lake and Cline River | Potential Risk | 1000–2500 | 40–200 | Stable | Slightly threatened |
| Middle North Saskatchewan River | At Risk | 250–1000 | 40–200 | Stable | Moderate, imminent threat |
| Lower North Saskatchewan River | At Risk | 50–250 | 40–200 | Stable | Moderate, non-imminent threat |
| Clearwater River | High Risk | 250–1000 | 40–200 | Declining | Moderate, imminent threat |
| Athabasca River Basin | | | | | |
| Pembina River | High Risk | 50–250 | 200-1000 | Declining | Substantial, imminent threat |
| McLeod River | At Risk | 1000–2500 | 1000–5000 | Declining | Substantial, imminent threat |
| Athabasca River | Potential Risk | 1000–2500 | 1000–5000 | Declining | Localized, substantial threat |
| Berland River | At Risk | 250–1000 | 1000–5000 | Declining | Moderate, imminent threat |
| Peace-Smoky River Basin | | | | | |
| Little Smoky River | At Risk | 250–1000 | 200–1,000 | Stable | Moderate, imminent threat |
| Upper Smoky River | At Risk | 2500–10 000 | 1000–5000 | Stable | Moderate, imminent threat |
| Muskeg River | High Risk | 50–250 | 200-1000 | Declining | Substantial, imminent threat |
| Jackpine River | Potential Risk | 250-1000 | 200-1000 | Stable | Widespread, low-severity threat |
| Sulphur River | Potential Risk | 250–1000 | 40-200 | Increasing | Slightly threatened |
| Middle Smoky River | At Risk | 250–1000 | 200–1000 | Declining | Moderate, imminent threat |
| Wapiti River | At Risk | 1000–2500 | 200–1000 | Declining | Moderate, imminent threat |
| Peace River | High Risk | 1–50 | 40–200 | Declining | Substantial, imminent threat |
| Cutbank River | High Risk | 50–250 | 200–1000 | Rapidly declining | Moderate, imminent threat |
| Kakwa River | Potential Risk | 2500–10 000 | 200–1000 | Declining | Localized, substantial threat |
| Simonette River | At Risk | 1000–2500 | 200–1000 | Declining | Moderate, imminent threat |

*Bull trout are known to occur within this core area; however, insufficient information was available to derive a conservation rank.

**Appendix 4.** Land-use events and bull trout declines in southwestern Alberta. Extracted from Fitch (1997).

| Drainage | Type of Habitat Disturbance (Watershed) | Date | Period of bull trout decline/ disappearance |
|---|---|---|---|
| St. Mary River and tributaries | Reservoir construction (St. Mary River)<br>Irrigation agriculture, irrigation diversion, timber harvest (Lee Creek) | 1946<br>1950s | 1960s |
| Belly River and tributaries | Three irrigation diversion weirs (Belly River)<br>Reservoir construction (Waterton River)<br>Reservoir construction (North Drywood Creek, Drywood Creek)<br>Gas exploration, development, and processing (Drywood drainage) | 1920s<br>1964<br>1960s<br><br>1950s | 1960s |
| Castle River and tributaries | Timber harvest (West Castle, South Castle, Carbondale drainages)<br>Road improvement (South Castle)<br>Timber harvest, road improvement (Carbondale drainage, South and West Castle drainages)<br>Gas exploration | 1940s<br><br>1953<br>1960s, 1970s<br><br>1960s, 1970s | 1960s – 1970s |
| Crowsnest River and tributaries | CPR construction<br>Coal mine developments<br>Timber harvest<br>Road improvements<br>Urban development | 1897 – 1898<br>1902 – 1970s<br>1902 – 1960s<br>1920s – 1970s<br>1902 – present | 1950s – 1960s |
| Oldman River and tributaries | Road improvement (Forestry Trunk Road) (Upper Oldman drainage)<br>Timber harvest (Upper Oldman drainage)<br>Reservoir construction (Willow Creek)<br>Irrigation diversion (Willow Creek drainage)<br>Gas exploration (Upper Oldman, Porcupine Hills) | 1953<br><br>1960s – present<br>1966<br>1960s<br>1960s – 1970s | 1960s – 1970s |

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