COSEWIC
Assessment and Status Report

on the

Westslope Cutthroat Trout
Oncorhynchus clarkii lewisi

Saskatchewan-Nelson River populations
Pacific populations

in Canada

Saskatchewan-Nelson River populations - THREATENED
Pacific populations - SPECIAL CONCERN
2016

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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Previous report(s):

COSEWIC 2006. COSEWIC assessment and update status report on the westslope cutthroat trout *Oncorhynchus clarkii lewisi* (British Columbia population and Alberta population) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 67 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

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Westslope Cutthroat Trout — Photo provided by author.

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COSEWIC
Assessment Summary

Assessment Summary – November 2016

Common name
Westslope Cutthroat Trout - Saskatchewan-Nelson River populations

Scientific name
Oncorhynchus clarkii lewisi

Status
Threatened

Reason for designation
This species inhabits cold streams and lakes in southwestern Alberta. It currently has a small and declining range and is severely fragmented. Over the last century, it has undergone substantial range contractions currently to less than 20% of that observed historically. Initially range contraction was due to overharvest and, more recently, due to a combination of hybridization with Rainbow Trout and habitat deterioration. The recent detection of Whirling Disease in Alberta presents an additional threat to this species.

Occurrence
Alberta

Status history
Designated Threatened in May 2005. Status re-examined and confirmed in November 2006 and November 2016.

Assessment Summary – November 2016

Common name
Westslope Cutthroat Trout - Pacific populations

Scientific name
Oncorhynchus clarkii lewisi

Status
Special Concern

Reason for designation
This species inhabits cold streams and lakes in southeastern British Columbia. Although some subpopulations appear to be stable, others are experiencing substantial hybridization with Rainbow Trout, most are susceptible to increasing water temperatures associated with climate change, and many are exposed to substantial recreational harvest. The recent discovery of Whirling Disease close to the range of these populations is an additional cause for concern.

Occurrence
British Columbia

Status history
Designated Special Concern in May 2005. Status re-examined and confirmed in November 2006 and November 2016.

COSEWIC
Executive Summary

Westslope Cutthroat Trout
Oncorhynchus clarkii lewisi

Saskatchewan-Nelson River populations
Pacific populations

Wildlife Species Description and Significance

The Cutthroat Trout, *Oncorhynchus clarkii* (formerly *Salmo clarkii*), is a polytypic species of salmonid native to western North America. Two subspecies occur naturally in Canada: the Coastal Cutthroat Trout (*O. c. clarkii*) and the Westslope Cutthroat Trout (*O. c. lewisi*). Cutthroat Trout is highly variable in terms of phenotypic traits and life history characteristics. The most conspicuous character distinguishing the Cutthroat Trout from similar species is the presence of bright orange-red slashes beneath the lower jaw.

Two designatable units of Westslope Cutthroat Trout are recognized based on genetic evidence for discreteness from other taxa and geographic separation as well as ecological adaptation: Saskatchewan-Nelson Rivers DU in Alberta and Pacific DU in British Columbia.

Westslope Cutthroat Trout (WCT) is a unique and important component of Canada's freshwater fish fauna and often the only native trout throughout much of its range. As such, it plays an important role in structuring many north temperate aquatic ecosystems. Because of its specific habitat requirements, WCT is viewed as an indicator species of general ecosystem health. Westslope Cutthroat Trout is a popular freshwater recreational fish species in western Canada.

Distribution

The distribution of Westslope Cutthroat Trout straddles the Continental Divide and includes drainages in Montana, Idaho, Washington, Oregon, and Wyoming in the United States. In Canada, it is restricted to southwestern Alberta (primarily the South Saskatchewan drainage) and southeastern British Columbia (primarily the Kootenay and Upper Columbia drainages). Its range has become extremely fragmented (in high elevation, isolated headwater areas) and the core of the distribution lies in the upper Kootenay River drainage in southeastern British Columbia.

Habitat

Westslope Cutthroat Trout has specific habitat requirements during various life history stages that are necessary to maintain its populations. They include cold clean water and varied forms of cover (undercut banks, pool-riffle habitat, and riparian vegetation). In Alberta, it is now largely restricted to the upper reaches of main stem rivers and the extreme headwaters of many tributaries. It occurs in large rivers and lakes in British Columbia, as well as many small higher elevation mountain streams. It often inhabits colder and less productive streams than other closely related species.

Biology

Westslope Cutthroat Trout possesses extensive phenotypic variation in size, colouration, and life history characteristics. Different life history types are present in many parts of the range of WCT with both resident and migratory subpopulations common throughout the Canadian range varying dramatically in size from ~20 cm to more than 40 cm, respectively. Adult WCT display a general pattern of upstream movement to spawning areas during peak spring flows with spawning occurring as peak flows diminish usually from May to July. Spawning occurs in both main stem and tributary habitats. The age and size at sexual maturity also varies across subpopulations and life history types, with some headwater subpopulations reaching maturity at age 2 but more generally by age 4 throughout the range. Water temperature measured at spawning varies from 6 to 15^{o}C. Cutthroat Trout is iteroparous and some fish may reproduce annually or every other year but post-mating mortality is high, especially for males. Lifespan varies widely with individuals verified as old as 16 years.

Population Sizes and Trends

A number of recent quantitative studies on WCT population trends in Canada have been completed. In Alberta, subpopulation sizes are generally small with the number of adult spawners typically in the order of hundreds, or fewer, per stream. British Columbia subpopulations are more robust averaging about 30 adults per stream km. They also exist in many lakes in British Columbia and in two lakes in Banff National Park. While most subpopulations in British Columbia appear to be relatively stable, subpopulations in Alberta are depressed relative to historical levels, and extirpations of large portions of watersheds have occurred. Habitat degradation makes subpopulations susceptible both to displacement by and hybridization with introduced species (Rainbow Trout, *Oncorhynchus mykiss*, and other Cutthroat Trout subspecies). As a result, subpopulations in degraded habitats are more likely in decline.

Threats and Limiting Factors

The greatest threats to Westslope Cutthroat Trout in both DUs are the anthropogenic manipulation, in particular hybridization with non-native Rainbow Trout, and degradation of the environment within the native range. Forestry, hydroelectric development, mining, urbanization and agriculture have all contributed to the loss and degradation of stream habitat in the range of WCT within both Alberta and British Columbia. Introgressive hybridization is widespread (particularly in Alberta), and continued stocking of non-native species could affect the genetic integrity of the remaining subpopulations. The number and distribution of pure subpopulations has steadily declined in Alberta but also in British Columbia in response to the cumulative effects of habitat loss and degradation, exploitation, and detrimental interactions with introduced species (i.e. competition, predation, hybridization).

Protection, Status and Ranks

Westslope Cutthroat Trout habitat is protected under both provincial and federal legislation. As a popular recreational fish species, WCT is subject to provincial and National Park recreational angling regulations. However, compliance with habitat protection and fishing regulations is a concern. The Alberta population of Westslope Cutthroat Trout is listed as Threatened under the *Species at Risk Act* (SARA) and provincially as Threatened under the *Alberta Wildlife Act*. The British Columbia population is currently listed as Special Concern under SARA and provincially blue-listed as ‘special concern’. Populations in the United States have been petitioned for listing under the *Endangered Species Act* but were found not to currently require such formal protection by the United States Fish and Wildlife Service. The species is critically imperilled in Wyoming and vulnerable in Oregon and Idaho. Globally, Westslope Cutthroat Trout is ranked by NatureServe as apparently secure (G4T4).

TECHNICAL SUMMARY – Saskatchewan-Nelson Rivers populations – DU1

Oncorhynchus clarkii lewisi

Westslope Cutthroat Trout
Saskatchewan-Nelson Rivers populations

Truite fardée versant de l'ouest
Populations de la rivière Saskatchewan et du fleuve Nelson

Range of occurrence in Canada: Alberta

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines(2011) is being used)	4-8 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, inferred decline in number of mature individuals
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline a clearly reversible and b.understood and c. ceased?	a. No (Some are possible, others not) b. Yes (hybridization, habitat loss, exploitation) c. No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence * based on minimum convex polygon within Canada's extent of jurisdiction	16,650 km²
Index of area of occupancy (IAO) * based on 2X2 km grids on continuous stretch of river/creek believed to contain native, genetically pure subpopulations within the historical distribution	844 km²

Is the population "severely fragmented" i.e. is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. Yes, most habitat patches are too small to support a viable population in the long term (100 years). b. Yes
Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	51, perhaps fewer given uncertainty in the extent of hybridization
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Yes, observed decline in extent of occurrence
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Yes, observed decline in the area of occupancy
Is there an [observed, inferred, or projected] decline in number of subpopulations	Yes, inferred decline in number of subpopulations
Is there an [observed, inferred, or projected] decline in number of "locations"*?	Yes, observed decline in the number of locations
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, inferred decline in the quality of habitat
Are there extreme fluctuations in number of subpopulations?	Unknown but unlikely
Are there extreme fluctuations in number of "locations"*?	Unknown but unlikely
Are there extreme fluctuations in extent of occurrence?	No, although range appears to be in decline
Are there extreme fluctuations in index of area of occupancy?	No, but area of occupancy is in decline due to hybridization

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
51 lakes/streams in Alberta outside National Parks	41,414 (21,968-60,777)
3 streams and 2 lakes in Banff National Park	Uncertain, but probably > 500
Total	> 41,414 (21,968-60,777)

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Unknown

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for this species? December 4, 2015.

i. Invasive & other problematic species & genes (very high to high)
ii. Climate change & severe weather (medium to low)

* See Definitions and Abbreviations on COSEWIC website and IUCN (Feb 2014) for more information on this term

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Declining
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada?	Unknown, but given genetic uniqueness and local adaptation seems unlikely
Is there sufficient habitat for immigrants in Canada?	Yes, suitable habitat exists, requires removal of other invasive trout
Are conditions deteriorating in Canada?[+]	Yes, ongoing development continues to impact available habitat
Are conditions for the source population deteriorating?[+]	Yes
Is the Canadian population considered to be a sink?[+]	No
Is rescue from outside populations likely?	No

Data Sensitive Species

Is this a data sensitive species? No

Current Status

COSEWIC: Threatened
Year Assessed: 2016
COSEWIC Status History: Designated Threatened in May 2005. Status re-examined and confirmed in November 2006 and November 2016.

Status and Reasons for Designation:

Status: Threatened	**Alpha-numeric codes:** B1ab(i,ii,iii,iv,v)+2ab(i,ii,iii,iv,v)
Reasons for designation: This species inhabits cold streams and lakes in southwestern Alberta. It currently has a small and declining range and is severely fragmented. Over the last century, it has undergone substantial range contractions currently to less than 20% of that observed historically. Initially range contraction was due to overharvest and, more recently, due to a combination of hybridization with Rainbow Trout and habitat deterioration. The recent detection of Whirling Disease in Alberta presents an additional threat to this species.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. Estimates of the rate of population decline are not available.

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect)

Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Threatened, B1ab(i,ii,iii,iv,v) +2ab(i,ii,iii,iv,v), because EOO is less than 20,000 km², the IAO is less than 2,000 km², the population is severely fragmented with more than 50% of patches too small to be viable and separated further than it would be expected to disperse, with continuing declines in EOO, IAO, extent and quality of habitat, number of locations and number of mature individuals.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable.
Criterion D (Very Small or Restricted Population): Not applicable.
Criterion E (Quantitative Analysis): No quantitative assessments are available.

TECHNICAL SUMMARY – Pacific populations – DU2

Oncorhynchus clarkii lewisi

Westslope Cutthroat Trout
Pacific populations

Truite fardée versant de l'ouest
Populations du Pacifique

Range of occurrence in Canada: British Columbia

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines(2011) is being used)	4-8 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, while many populations are stable others are projected to decline
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	unknown
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. No (Some are possible, others not) b. Yes (hybridization, habitat loss, exploitation) c. No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence * based on minimum convex polygon within Canada's extent of jurisdiction	85,183 km²
Index of area of occupancy (IAO) * IAO based on the standardized COSEWIC 2 x 2 km grid over each observation	6,824 km²

Is the population "severely fragmented" i.e. is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No, most habitat patches are adequate to support a viable population in the long term. b. No
Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	~928 (perhaps ~1319 including waterbodies with at least one report of WCT occurrence)
Is there an [observed, inferred, or projected] decline in extent of occurrence?	No, inferred that extent of occurrence is stable
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Yes, index of area of occupancy inferred to have declined due to hybridization
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Yes, inferred to have declined
Is there an [observed, inferred, or projected] decline in number of "locations"*?	Yes, inferred that number of locations has declined
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, inferred decline in the extent and quality of habitat
Are there extreme fluctuations in number of subpopulations?	Unknown but unlikely
Are there extreme fluctuations in number of "locations"∗?	Unknown but unlikely
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	N Mature Individuals
	unknown
Total	unknown

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Unknown, no quantitative analysis conducted

* See Definitions and Abbreviations on COSEWIC website and IUCN (Feb 2014) for more information on this term

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for this species? December 4, 2015. i. Invasive & other problematic species & genes (very high) ii. Climate change & severe weather (high) iii. Biological resource use (medium) iv. Human intrusions and disturbance (medium)

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Declining
Is immigration known or possible?	Unlikely
Would immigrants be adapted to survive in Canada?	Unknown, but given genetic uniqueness and local adaptation seems unlikely
Is there sufficient habitat for immigrants in Canada?	Yes, suitable habitat exists, but requires removal of other invasive trout
Are conditions deteriorating in Canada?[+]	Yes, ongoing development continues to impact available habitat
Are conditions for the source population deteriorating?[+]	Yes
Is the Canadian population considered to be a sink?[+]	No
Is rescue from outside populations likely?	No

Data Sensitive Species

Is this a data sensitive species? No

Current Status

COSEWIC: Special Concern
Year Assessed: 2016
COSEWIC Status History: Designated Special Concern in May 2005. Status re-examined and confirmed in November 2006 and November 2016.

Status and Reasons for Designation:

Status: Special Concern	**Alpha-numeric codes:** Not applicable
Reasons for designation: This species inhabits cold streams and lakes in southeastern British Columbia. Although some subpopulations appear to be stable, others are experiencing substantial hybridization with Rainbow Trout, most are susceptible to increasing water temperatures associated with climate change, and many are exposed to substantial recreational harvest. The recent discovery of Whirling Disease close to the range of these populations is an additional cause for concern.	

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect)

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable
Criterion C (Small and Declining Number of Mature Individuals): Not applicable
Criterion D (Very Small or Restricted Population): Not applicable
Criterion E (Quantitative Analysis): Not applicable

PREFACE

The Westslope Cutthroat Trout (WCT) populations in Alberta and British Columbia were previously assessed by COSEWIC in 2006. The main threats to the recovery of the species in Canada were habitat loss, overharvesting, and the introduction of non-native species and/or genotypes through inappropriate stocking practices. In the interim, these threats have continued. Regulations to prevent harvest have become more stringent but compliance is a concern. Habitat destruction associated with resource extraction is ongoing for both populations. Improvements to stocking practices are being implemented in both populations but hybridization resulting from past introductions is ongoing. The development of enhanced genetic techniques using single nucleotide sequence variation to detect the presence of Rainbow Trout or other Cutthroat Trout subspecies' genes has improved the detection of hybrids in what were previously believed to be pure WCT populations. These surveys are in early stages but indications are that more WCT populations have been compromised than was previously believed. As a result, the Saskatchewan-Nelson Rivers populations may be in a more desperate state than the available data indicate at this time. A similar situation exists in the British Columbia population but the impacts of hybridization appear to be less extensive.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2016)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment and Climate Change Canada
Canadian Wildlife Service
Environnement et Changement climatique Canada
Service canadien de la faune
Canada

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

COSEWIC Status Report

on the

Westslope Cutthroat Trout
Oncorhynchus clarkii lewisi

Saskatchewan-Nelson River populations
Pacific populations

in Canada

2016

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

The Cutthroat Trout (*Oncorhynchus clarkii*) is a polytypic species of salmonid native to western North America. It is widespread in both coastal and interior drainages in a variety of habitats, from lakes and headwater streams, to estuaries and large rivers. Taxonomists currently recognize 14 allopatrically occurring subspecies of Cutthroat Trout with four of these subspecies, including Westslope (*O. clarkii lewisi*), Coastal (*O. clarkii clarkii*), Lahontan (*O. clarkii henshawi*), and Yellowstone (*O. clarkii bouvieri*) showing substantial genetic divergence and broad distribution; the remaining 10 subspecies are of limited range (Allendorf and Leary 1988; Behnke 2002). Many historical records refer to Westslope Cutthroat Trout as the inland form of Yellowstone Cutthroat Trout. However, major genetic and chromosome differences have confirmed that these two forms are distinct subspecies (Behnke 1992; McPhail 2007). Yellowstone Cutthroat Trout is not native to Canada. The Coastal Cutthroat Trout and the Westslope Cutthroat Trout are resident in Canada and a third type, described by Dymond (1931) from the Revelstoke area in British Columbia as *O. c. alpestris,* is now considered to be synonymous with *O. c. lewisi*:

Family:	Salmonidae, subfamily Salmoninae (salmon, trout, charr)
Genus:	*Oncorhynchus* (formerly *Salmo*)
Species:	*Oncorhynchus clarkii* (formerly *Salmo clarkii*)
Subspecies:	Westslope Cutthroat Trout *O. clarkii lewisi* (Girard) formerly *Salmo clarkii lewisi*; considered synonymous with *S. clarkii alpestris* (Dymond)

Common name:

English:	Westslope Cutthroat Trout
French:	Truite fardée de l'ouest
Other:	cutthroat, interior cutthroat, westslope cutthroat, mountain cutthroat, cutty, spotted trout, (Montana) black-spotted trout, black spots, red-throated trout, Lewis' trout

The extensive phenotypic variation exhibited by this species (in terms of size, colouration, and life-history characteristics) has led to considerable confusion and disagreement among taxonomists in its description, particularly in the number of genuine types and of the proper taxonomic terminology used in describing them. At one time, up to 40 taxonomic designations existed for the species, and relationships within the group remain controversial. Many of the interior Cutthroat Trout subspecies appear to be of fairly recent origin (i.e. since the most recent glaciation) so that no one phenotypic or meristic character clearly differentiates them. Considerable overlap in morphological and meristic characters also exists between Cutthroat Trout and Rainbow Trout, *Oncorhynchus mykiss*. However, morphological (Behnke 1992), karyotypic (Thorgaard 1983), and genetic data (Gyllensten *et al.* 1985; Shedlock *et al.* 1992), confirm that while substantial overlap exists, all Cutthroat Trout subspecies are more closely related to each other than any is to Rainbow Trout, which supports the designation as a distinct species (Figure 1).

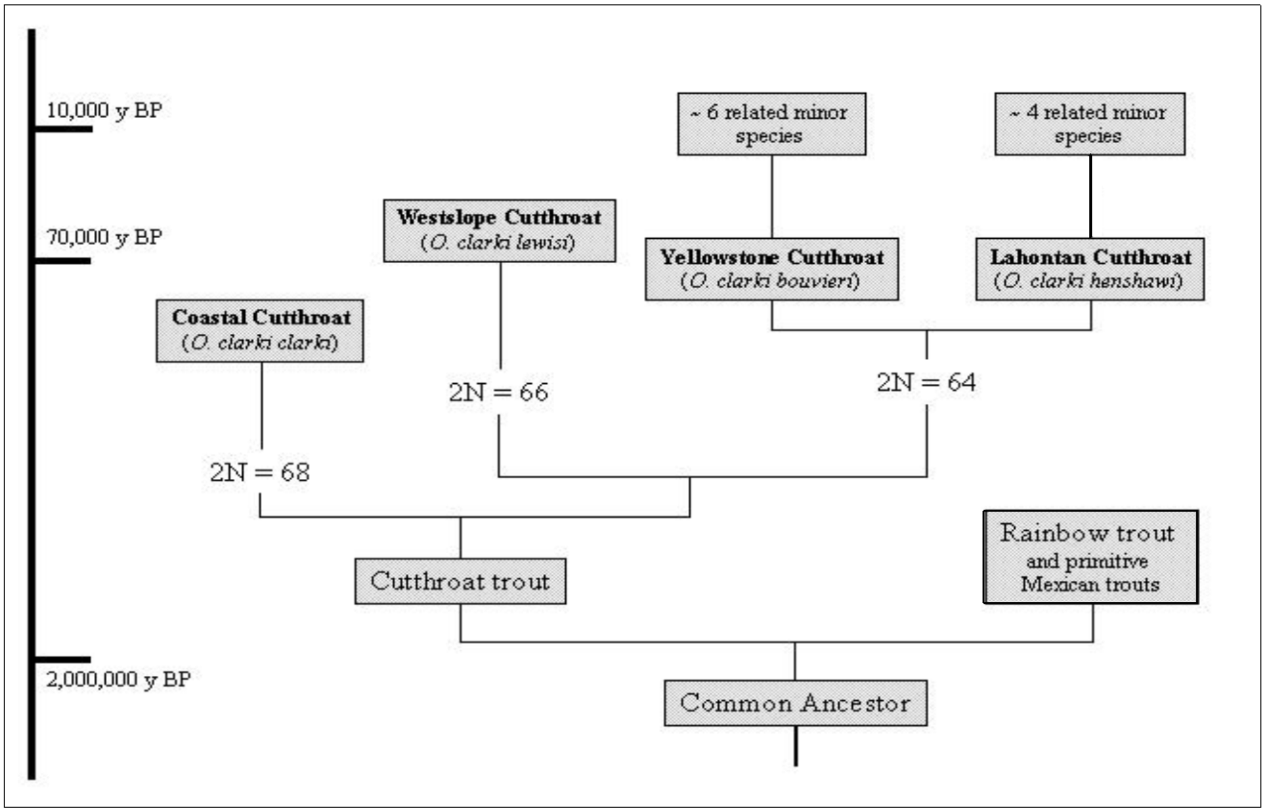

Figure 1. Phylogenetic relationships between the various Cutthroat Trout subspecies and Rainbow Trout. Diploid chromosome number (2N) is shown for Cutthroat Trout subspecies. Modified from Behnke (1997).

Morphological Description

Westslope Cutthroat Trout (hereafter referred to as WCT) has the streamlined body typical of salmonids (terminal mouth, small cycloid scales, and presence of an adipose fin) and is generally trout-like in appearance, with dark spots on a lighter background (Figure 2). Spots are small and irregularly shaped, forming a characteristic arc from the anterior base of the anal fin forward to the pectoral fin (more numerous posteriorly and concentrated above the lateral line). Body colouration ranges from silver to yellowish-green with red on the front and sides of the head. A narrow pink band may be present along the sides, but to a much lesser degree than in the closely related Rainbow Trout (hereafter referred to as RBT). Spawning fish often develop a bright red colouration over the entire body. WCT are typically small, generally 15-23 cm (28-142 g) (Behnke 2002), but some British Columbia subpopulations include larger specimens, 41-46 cm (~1.5 kg), tending to come from lakes.

Figure 2. Westslope Cutthroat Trout from the Wigwam River (Upper Kootenay drainage) in the Pacific DU. Photo courtesy of Ernest Keeley, Idaho State University.

The most conspicuous character distinguishing Cutthroat Trout throughout its range in Canada is the presence of orange-red slashes beneath the lower jaw. The slashes, however, may be faint or absent in juveniles or hybrids, making the field identification of WCT and RBT difficult. While field guides and taxonomic keys are available (McPhail and Carveth 1993; Pollard *et al.* 1997; Joynt and Sullivan 2003), considerable phenotypic variation exists between individual subpopulations in the size, colouration and degree of spotting. WCT tend to have a larger mouth than RBT with a longer maxillary, which extends past the hind portion of the eye. As well, a series of small basibranchial teeth at the back of the throat are considered to be diagnostic of pure WCT throughout much of its range (Behnke 1992; Leary *et al.* 1996; Weigel *et al.* 2002). Hybridization with RBT leads to a host of alternate spotting patterns and to the appearance of spots on the top of the head and anterior portion of the body. Hybrids may also lack the basibranchial teeth and the slash beneath the lower jaw, and have a larger head-tail length ratio (Behnke 1992; Weigel *et al.* 2002).

The meristic overlap between variants has been exacerbated by indiscriminate stocking of non-native species and a variety of hybrids in the past. While diagnostic testing now exists to identify the genetic composition of introgressed subpopulations (McKay *et al.* 1997; Baker *et al.* 2002; Ostberg and Rodriguez 2002), the ecological and taxonomic status of hybridized subpopulations remains largely unresolved (United States Federal Register 1996; Allendorf *et al.* 2004).

Genetic Population Spatial Structure and Variability

Relatively few studies have investigated subpopulation genetic structure in the Westslope Cutthroat Trout subspecies. Early genetic assays of WCT using allozymes suggested that subpopulation subdivision was substantial, with F_{st} values (a widely used measure of genetic subdivision) ranging from 0.08 to 0.45 (Loudenslager & Gall 1980; Leary *et al.* 1987; Allendorf and Leary 1988). Subpopulations appeared well differentiated and were often characterized by unique alleles or those that, while locally abundant, were uncommon over a larger geographic area. In Alberta, Potvin *et al.* (2003) examined the levels and partitioning of genetic diversity in 24 lakes from Banff and Waterton Lakes National Parks. Based on microsatellite data, they found populations with low to moderate levels of genetic variation (average heterozygosity ranging from ~0.1–0.5). Heterozygosity is a measure of the amount of genetic variability in the subpopulation and a low value (0.05) suggests an isolated and possibly inbred subpopulation whereas higher values indicate a greater level of genetic mixing. Habitat heterogeneity, in terms of migration barriers, appears to be a significant factor in structuring this variation. The number of alleles per locus was also significantly lower in Banff National Park (BNP) than in Waterton Lakes National Park (WLNP; 2.5 vs. 3.5, respectively; $p = 0.004$). Factorial correspondence analysis found native subpopulations clustering closely with low levels of variation (H_e=0.17) while subpopulations stocked into previously fishless habitat were more widely scattered having the highest levels of genetic variation ($H_e = 0.43$). Lakes containing both native and introduced stocks appear intermediate ($H_e = 0.29$). While levels of variation were lower in native subpopulations, the amount of genetic divergence between them was significant with genetic subdivision in BNP exceeding that in WLNP (F_{st} 0.45 vs. 0.19, respectively).

Janowicz (2004) reported the results of a study addressing rates of hybridization among WCT subpopulations over a larger area in Alberta that found levels of genetic variation at six microsatellite loci were consistent with those from other portions of the range (Leary *et al.* 1987; Taylor *et al.* 2003). Variability was generally low in the reference WCT subpopulations (Job Lake, Picklejar Lakes #2 and #4, and Marvel Lake), averaging 3.3 alleles per locus and heterozygosity of 0.36. Including a larger subset of subpopulations identified as “pure WCT” as part of the hybridization assay found a larger number of alleles per locus ranging from 4–21, with marginally higher heterozygosity. The presence of barriers appeared to be a significant factor influencing levels of genetic diversity and genetic divergence.

Two microsatellite loci (Omy77 and Ssa85) were shared between these three studies (Table 1) and allowed for some comparison between the two DUs. The allelic size range is smaller for Omy77 and slightly larger for Ssa85 in Alberta. However, for both loci, there are fewer alleles across the allelic size range in Alberta than in British Columbia.

Table 1. Microsatellite loci (Omy77 and Ssa85) allelic size range for Pacific and Saskatchewan-Nelson Rivers designatable units in southeast British Columbia (SE BC), Banff national Park (BNP) and Alberta (AB). The most common allele is in parentheses.

Source	**Area**	**Omy77**	**Ssa85**
Taylor *et al.* 2003	SE BC	80 - 140 bp (110 bp)	100 - 164 bp (136 bp*)
Potvin *et al.* 2003	BNP, WLNP	85 - 141 bp (85 bp)	91 - 191 bp (137 bp*)
Janowicz 2004	AB	79 - 107 bp (81 bp)	137 - 155 bp (141 bp)

*likely same allele; different scoring systems

The reduced subset of alleles in Alberta is not unexpected considering that WCT likely recolonized the area through headwater transfers across low-lying mountain passes from British Columbia (McPhail and Lindsey 1986). Serial founder events associated with recolonization of Alberta early during the deglaciation process could have led to such a pattern and have been observed in other species in the region (Costello *et al.* 2003). Allele frequencies at the shared loci cannot be compared directly because allele scoring differed between studies, but there was a difference in the most common allele at these two loci in the two DUs. In British Columbia, Omy77*110 and Ssa85*136 are the most common alleles while over a wide range in Alberta, Omy77*81 and Ssa85*141 predominate. The lack of recent dispersal opportunities between the two regions and increased isolation of subpopulations in headwater stream reaches suggests that most subpopulations in Alberta may have even greater reproductive isolation and demographic independence than seen in the Pacific DU.

In British Columbia, Taylor *et al.* (2003) examined population structure in 32 WCT subpopulations (including sites in the upper Kootenay, upper Columbia, and upper Fraser drainages). The total number of alleles per microsatellite locus ranged from 5–20 across the study area, the average number of alleles per microsatellite locus in any one subpopulation was low, averaging ~3.9, consistent with previous studies. Expected heterozygosities averaged 0.56 but varied widely among subpopulations (from 0.05-0.61). Subpopulations above impassable migration barriers consistently showed significantly reduced variation and increased differentiation compared to those not similarly isolated {allelic richness (2.1 vs. 2.9), expected heterozygosity (0.303 vs. 0.463), F_{st} (0.45 vs. 0.18); $p < 0.005$ for all tests}.

Subpopulation subdivision appears extensive throughout the region (overall F_{st} value of 0.32) and a large proportion of the total genetic variation (32%) is partitioned among subpopulations (i.e. certain subpopulations have a high frequency of alleles that are uncommon over the larger region). Based on the distribution of this allelic variation, Taylor *et al.* (2003) suggested the existence of four main groups of WCT in southeastern British Columbia, corresponding to geographic proximity (Figure 3). Subpopulations isolated above migration barriers had significantly lower levels of genetic variation and were generally more divergent from one another than was observed between below-barrier subpopulations. However, the significant divergence among subpopulations lacking any obvious migration barriers (e.g., Kootenay mainstem subpopulations with F_{st} of 0.12) suggests significant reproductive isolation and a high degree of demographic independence among even main stem subpopulations. Each individual subpopulation appears to act as a distinct biological entity and conservation of genetic diversity in the DU's WCT population will require maintenance of many such subpopulations throughout the region.

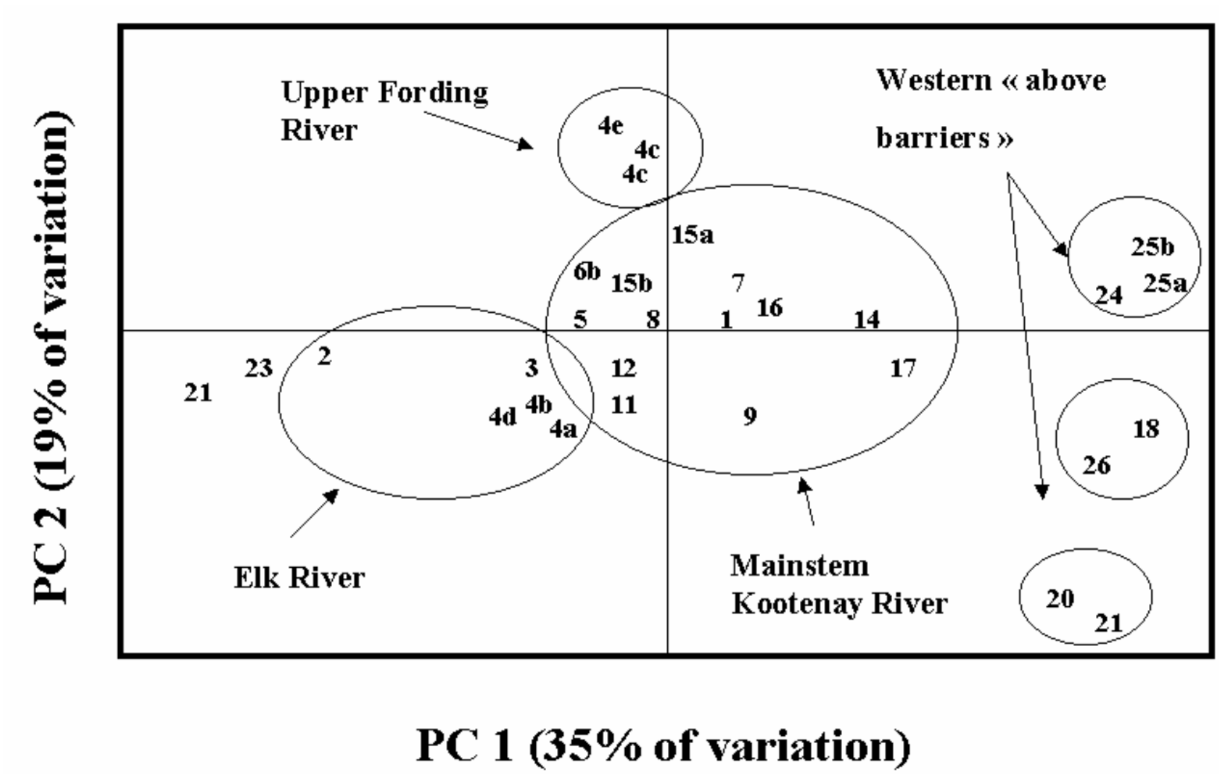

Figure 3. Principal Components Analysis (PCA) of the genetic relationships between southeastern British Columbia WCT populations. Modified from Taylor *et al.* (2003).

A more complete analysis of genetic population structure across the entire native range of WCT using genome-wide DNA sequence data and single nucleotide polymorphism (SNP) markers is warranted. It would provide an improved understanding of the origin and relatedness of populations in the three major river drainages the species occurs in

(Columbia, South Saskatchewan, and Missouri) as well as at the finer scale of local subpopulations. As highlighted in a study using microsatellite markers to assess genetic population structure of WCT populations in the United States (Drinan *et al.* 2011), these markers are not well suited for describing genetic differences among populations that have been separated for a long time and are very different from each other. Since this is the case for many WCT populations, genetic differences between isolated populations may be underestimated or estimated with considerable uncertainty when microsatellite markers are used (Drinan *et al.* 2011). As Canadian and United States biologists collaborate on range-wide WCT genetic analysis, an improved understanding of genetic population structure will be available. This will be key information when assessing the risks to unique genetic diversity and local adaptations associated with recovery stocking and translocation of stocks from one drainage to another. It will also better inform the number of discrete subpopulations of WCT that exist.

Designatable Units

A designatable unit (DU) refers to an evolutionarily significant component of the species where "significant" implies that the unit is important to the evolutionary legacy of the species as a whole. If the DU were lost it would likely not be replaced through natural dispersion.

The disjunct distribution of subpopulations of WCT across the Rocky Mountain divide and evident genetic differentiation between regions (Table 1) provides support for the existence of two DUs for WCT in Canada:

1. Saskatchewan-Nelson Rivers DU – in Alberta
2. Pacific DU – in British Columbia

Recognition of the two DUs is supported by the biogeographic ecozones inhabited by the two groups: Alberta subpopulations inhabit National Freshwater Ecological Area 4 (Saskatchewan-Nelson) while subpopulations in British Columbia inhabit National Freshwater Ecological Area 11 (Pacific); while these ecozones are adjacent, they are separated by the Rocky Mountains. The WCT populations in these two DUs represent the most northerly inland distribution of the species in a unique ecological setting that has given rise to local adaption (Bear 2007, Muhlfeld *et al.* 2009, Seiler and Keeley 2009, Rasmussen *et al.* 2010, 2012; Corsi *et al.* 2013, Yau and Taylor 2013, 2014). It is also likely that the two groups originated from separate glacial refugia (Columbia and Missouri).

Manipulated Populations

COSEWIC guidelines for manipulated populations provide direction on how the existing information on WCT is to be interpreted. In general, only native, genetically pure subpopulations within the historical WCT distribution are included in the assessment of remaining WCT populations at this time. The assessment includes subpopulations from a 'pure' source (from within the native range of the original DU) that is introduced to a new site. Similarly, naturally reproducing subpopulations within the DUs that have been stocked with WCT at least once but that were not originally WCT-free or have been genetically altered by introductions are included. Studies have used the threshold of <1% introgression to identify "pure" populations (COSEWIC 2006; The Alberta Westslope Cutthroat Trout Recovery Team 2013). This threshold was adopted here and therefore this assessment is restricted to subpopulations within a DU showing evidence of <1% introgression with RBT or other Cutthroat Trout subspecies. At this level of introgression, the subpopulation is assumed to be non-hybridized because it is difficult, if not impossible, to distinguish between intra-specific polymorphism and a slight amount of introgression (*see* Allendorf *et al.* 2001, 2004, 2005).

Special Significance

Westslope Cutthroat Trout is a unique and important component of Canada's freshwater fish fauna. As one of the first salmonids to recolonize western Canada following deglaciation, it is often the only native trout throughout much of the Canadian range. As such, it plays an important role in structuring many north temperate aquatic ecosystems (McPhail and Carveth 1992). Its small size at maturity allows it to exist in smaller streams than most other salmonids, where it contributes to riparian vegetation and forests in terms of nutrient recovery (Willson and Halupka 1995). Furthermore, rigid habitat requirements make WCT an indicator species for the health of many ecosystems. Canadian populations inhabit a variety of extreme habitats (in terms of elevation, temperature, and other physiogeographic factors). Populations of WCT in Alberta and British Columbia, for example, exist on the northern periphery of the subspecies' historical range and possess a number of unique specializations for colder, less productive ecosystems typical of the area (Rasmussen *et al.* 2012, Yau and Taylor 2013, 2014). Adaptations to these habitats might be necessary for reintroduction to extirpated areas and, as such, constitute an important component of species biodiversity. WCT is of traditional importance to several First Nations and is a popular freshwater recreational fishery species in western Canada. Revenues from recreational fisheries provide a substantial contribution to many local economies. While historically widespread, WCT has shown dramatic global declines in the number and distribution of subpopulations so that the core distribution of both DUs now occurs in Canada. The maintenance of genetically pure subpopulations in Canada may be required for attempts to re-establish extirpated subpopulations, and the future preservation of the species as a whole.

DISTRIBUTION

Global Range

With the exception of Lake Trout (*Salvelinus namaycush*), the historical distribution of Cutthroat Trout was likely greater than any other form of North American trout or salmon (Behnke 2002). The historical distribution of WCT is not known with certainty (Behnke 1992; McPhail 2007) but includes the upper Missouri and Columbia River basins and the Kootenay River and headwaters of the South Thompson in British Columbia westward to the Cascade Mountains where it occurs as disjunct subpopulations including those described as Mountain Cutthroat (Dymond 1931; Behnke 1992). It includes the Salmon, Clearwater, Coeur d'Alene, St. Joe, and Spokane river drainages in Idaho, and the Clark Fork and Kootenai drainages in Idaho and Montana (downstream to the falls on the Pend d'Oreille River near the Washington-Idaho border (Spahr *et al.* 1991)). It also includes Lake Chelan in Washington, the John Day drainage in Oregon, and the middle-Columbia River tributaries of Methow, Entiat, and Wenatchee rivers in Washington (McIntyre and Rieman 1995). These disjunct subpopulations likely resulted from catastrophic flood events from Glacial Lake Missoula (Behnke 1992), although some may be of hatchery origin (Shepard *et al.* 2003). On the eastern slopes of the Rocky Mountains, WCT is native to the upper South Saskatchewan River drainage in Alberta (Bow and Oldman rivers), and the upper Missouri River drainage in southern Alberta, northwestern Wyoming, and Montana (including the headwaters of the Judith, Milk and Marias rivers) to approximately 60 km downstream of Great Falls, Montana (Willock 1969; Behnke 1992).

WCT is thought to be one of the first post-glacial colonizers in many areas that were later extirpated except above barriers as RBT were introduced into these systems (McPhail 2007). The current global distribution of WCT populations has become extremely fragmented in Canada and throughout its range in the United States, where WCT now occupy ~59% of the 91,000 river kilometres estimated historically circa 1800 (Shepard *et al.* 2003). Genetic testing in the United States suggests that WCT subpopulations may be genetically unaltered in as little as 8% of this historical range (Shepard *et al.* 2003).

<u>Saskatchewan-Nelson Rivers DU</u>

The native range of WCT in Alberta was likely limited to the Bow and Oldman drainages of the South Saskatchewan River and possibly the headwaters of the Milk River on the eastern slopes of the Rocky Mountains (Sisley 1911; Prince *et al.* 1912; Willock 1969). In the Bow drainage, WCT was found from the extreme headwaters near Bow Lake (Helen and Mosquito Creek) in Banff National Park, downstream to the plains below Calgary and Lethbridge and in all of its major tributaries: the Spray, Cascade, Kananaskis, Ghost, Elbow, and Highwood rivers as well as Jumpingpound and Fish creeks (Prince and McGuire 1912; Behnke 1992; Mayhood 2000). At present, it has been estimated that native WCT occupies less than five percent of the native range in the Bow drainage, where it is restricted to a few lakes and the extreme headwaters of a few of the major tributaries and the upper main stem (Figure 5; Mayhood 1995, 2000).

Since the 2006 Status Report the extent of hybridization in various subpopulations in Alberta has been under investigation using a set of microsatellite loci that have largely stayed the same (Taylor and Gow 2007, 2009;, Yau and Taylor 2013; Mee *et al.* 2013; Allen *et al.* 2014; Allen *et al.* 2015; Allen and Rogers 2015; S. Humphries pers. comm. 2015). The microsatellite loci used in these studies have, for the most part, been polymorphic between WCT and RBT, and differed from the predominantly diagnostic loci used in comparable studies in the United States (e.g., Boyer *et al. 20*08). As such, methods for estimating hybridization using microsatellite loci between RBT and WCT have differed in Canada and the United States. Over approximately the last 5 years, the United States has transitioned to estimating hybridization using single nucleotide polymorphism (SNP) loci and assessing hybridization with Yellowstone Cutthroat Trout as well as with RBT. Alberta is transitioning to using the same technique, although no data are available at this time.

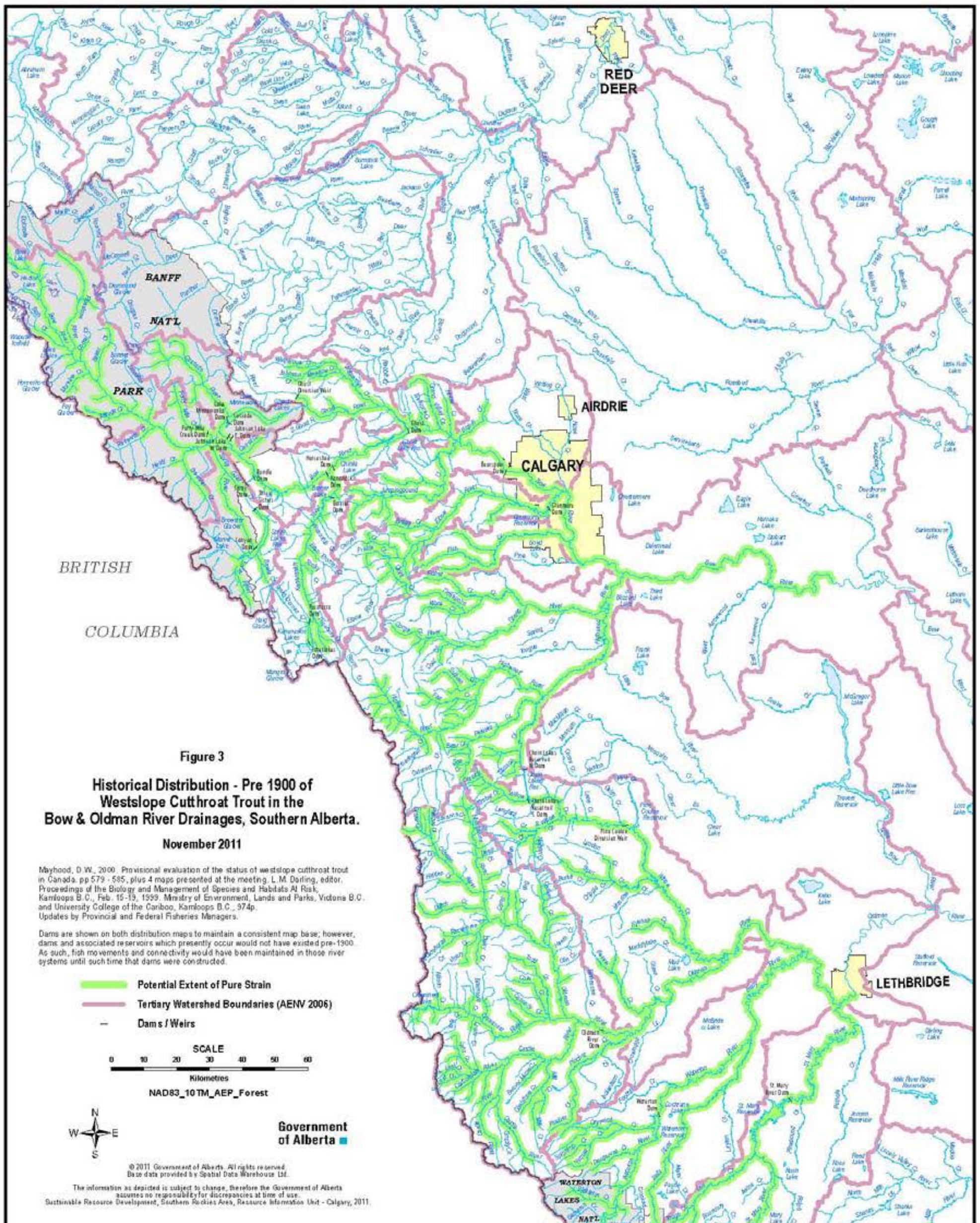

Figure 4. Historical distribution pre-1900 of Westslope Cutthroat Trout in the Bow and Oldman River drainages, southern Alberta in the Saskatchewan-Nelson Rivers DU (taken from The Alberta Westslope Cutthroat Trout Recovery Team 2013).

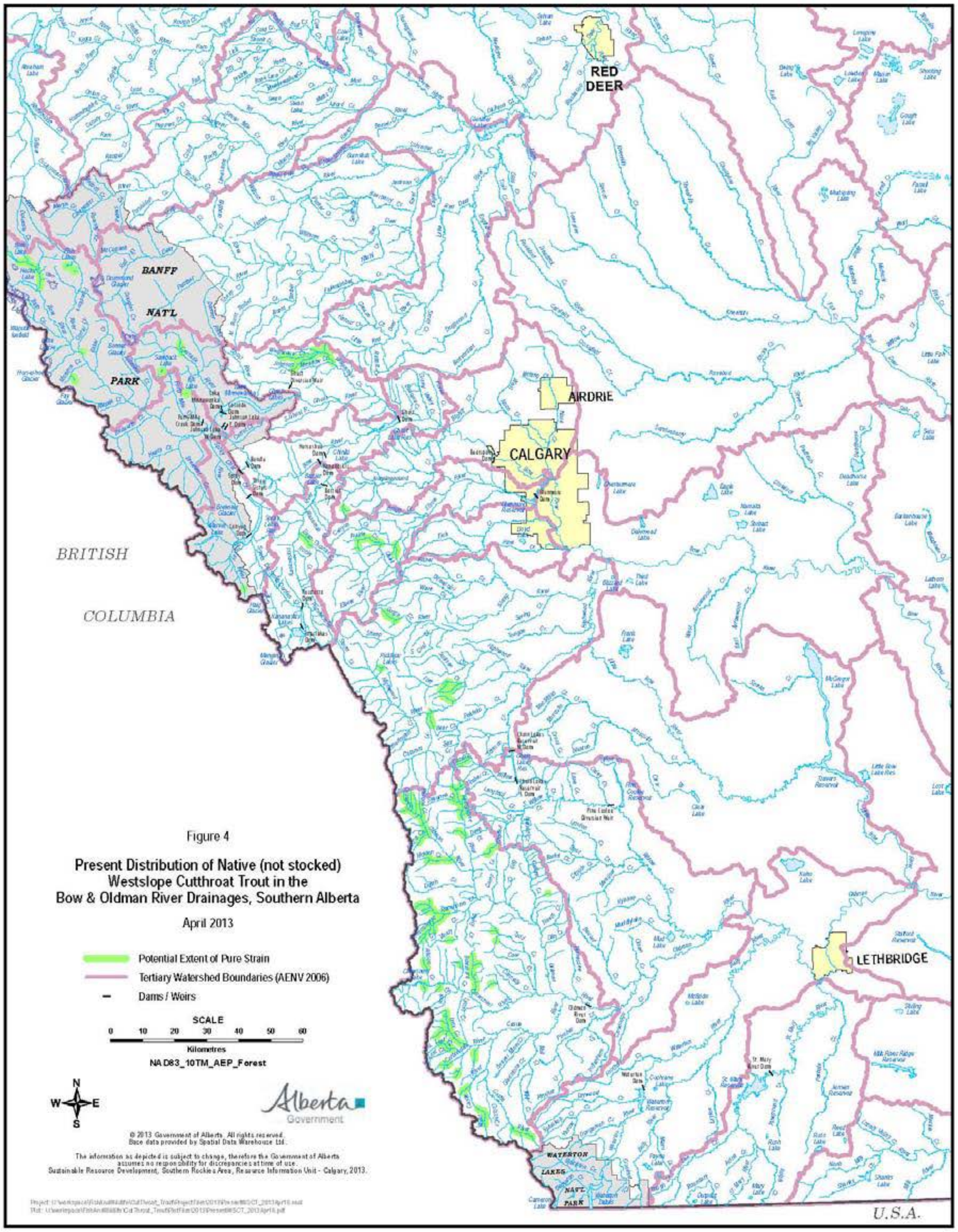

Figure 5. Present distribution of native (not stocked) Westslope Cutthroat Trout in the Bow and Oldman River drainages, southern Alberta in the Saskatchewan-Nelson Rivers DU (taken from The Alberta Westslope Cutthroat Trout Recovery Team 2013).

Within the native range many Bow River drainage subpopulations are hybridized (McAllister *et al.* 1981; Carl and Stelfox 1989; Strobeck 1994; Bernatchez 1999; Janowicz 2005; Taylor and Gow 2007, 2009; Robinson 2008, Yau and Taylor 2013). Nearly all remnant subpopulations are small and isolated (Mayhood 2000).

WCT still occupies much of the native range in the upper Oldman basin (Figure 5), but has been lost from native waters in the main stem east of the mountain front and most of the accessible tributaries (Radford 1975, 1977; Fitch 1977 –80; Mayhood *et al.* 1997). WCT is rare in the St. Mary and Belly River drainages and may occur only as hybrids even in the headwaters of these drainages, and it is nearly extirpated from the Crowsnest River drainage (Fitch 1977–80; Mayhood *et al.* 1997).

Alberta Environment and Parks (AEP) maintains a WCT genetic database linked to a geographic information system, in which there are currently 209 genetic sampling sites outside National Parks with an average sample size of 22 individuals (2006 to 2014, sample size range: 1-53). Genetic results from the 209 sites are summarized in a series of technical reports and peer reviewed publications from the labs that completed the analysis (Taylor and Gow 2007, 2009; Yau and Taylor 2013; Mee *et al.* 2013; Allen *et al.* 2014; Allen and Rogers 2015; Allen *et al.* 2015; Allen *et al.* 2016). To date, only analyses conducted by Dr. Eric Taylor from the University of British Columbia and Dr. Sean Rogers from the University of Calgary are included in Alberta's database due to inconsistencies in methods used in earlier studies (Janowicz 2004, Robinson 2008). Of the 209 sites, 78 (37%) have an average WCT genetic purity >99%, 51 (24%) have an average genetic purity of 95-99%, and 80 (38%) have an average genetic purity <95%. Sampling has been biased to locations were WCT are known to occur, so the distribution of sites in these three genetic categories is not representative of the actual proportion of WCT populations in Alberta that are pure, near-pure, or hybridized. Many populations have been sampled multiple times and at multiple locations, so the 209 sample sites are also not representative of the number of WCT populations in Alberta. However, AEP has developed a ruleset for extrapolating the genetic status of all streams within the entire WCT native range from these genetic sampling points (AEP 2016). The Westslope Cutthroat Trout Genetic Delineation Project maps the inferred genetic status of all WCT streams in Alberta from the headwaters (excluding National Parks) downstream to the historical extent of the species on the Bow and Oldman rivers near Calgary and Lethbridge respectively. The product assigns all streams a genetic status, including the smallest, first order streams, even though the fish bearing status of these streams is not always known. This product has also been used to identify data gaps, especially where inferences have been made over large geographic areas with limited or no genetic information. This information will be used to direct and inform future work in order to fill data gaps and improve certainty.

This GDP product has been used to evaluate the genetic status of WCT at the HUC10 watershed scale. Out of 37 HUC10 watersheds in the Oldman basin that originally had native WCT populations, 13 watersheds (35%) still contain at least one genetically pure population, some having near-pure populations as well. An additional 4 watersheds (11%) only contain near-pure populations. Combining these, a total of 17 of 37 HUC10 watersheds (46%) still have at least one pure or near-pure WCT population in the Oldman drainage. In the Bow drainage, out of 36 watersheds that originally had native WCT populations, 8 watersheds (22%) still contain at least one genetically pure population. An additional two watersheds are suspected to have a pure population, although neither of these has been confirmed through genetic testing. Six of those with at least one pure population also have at least one near-pure population. An additional two watersheds contain a near-pure population in only a segment of stream. Combining these, a total of 10 of 36 watersheds (28%) in the Bow drainage still have at least one pure or near-pure WCT population. Combining the Oldman and Bow drainages, out of 73 HUC10 watersheds that originally had native WCT populations, 27 (37%) have at least one pure or near-pure population. It is worth noting that in the majority of the watersheds, the pure or near-pure populations exist in only one or two streams or portions of streams.

Water bodies within the native range of WCT in Alberta that are believed to contain pure subpopulations have been identified as critical habitat and are detailed in the recovery strategy (Fisheries and Oceans Canada 2014). Of the 307 km of stream identified, 70% of this occurs in the Oldman drainage and 30% in the Bow drainage.

Distribution of WCT in the National Parks in the Saskatchewan-Nelson Rivers DU is variable. Pure subpopulations occur only in Banff National Park (Figure 5). Other subpopulations in Banff National Park exhibit a range of hybridization or have been extirpated. WCT within the historical range of the species in Waterton Lakes National Park is hybridized with either stocked RBT or Yellowstone Cutthroat Trout (McAllister *et al.* 1981; Potvin *et al.* 2003). In Jasper National Park two pure stocked WCT subpopulations occur outside the historical range for the species and now potentially threaten Athabasca Rainbow Trout (The Alberta Westslope Cutthroat Trout Recovery Team 2013).

Pacific DU

The core WCT range in British Columbia occurs in the Kootenay, Flathead, and Pend d'Oreille systems, where WCT inhabits most major tributaries as well as smaller creeks and lakes. However, disjunct subpopulations also occur in headwater streams and lakes of the upper Columbia River as well as a few tributaries of the South Thompson River and the Kettle River (Prince 2001; McPhail 2007). Dymond (1931) described some isolated subpopulations of Cutthroat Trout in the Revelstoke area (from both Columbia and Fraser tributaries) as a distinct subspecies: the Mountain Cutthroat Trout (*Oncorhynchus clarki alpestris)* but these are believed to be WCT (Behnke 1992). The origin of these disjunct subpopulations is unclear but they may have originated by movement from nearby headwater Columbia tributaries (McPhail 2007). However, genetic data from Fraser and Columbia WCT subpopulations in close physical proximity suggest they are distinct (Taylor *et al.* 2003). The alternative hypothesis is that WCT was once much more broadly distributed in the Fraser watershed but was displaced by naturally recolonizing Rainbow Trout (Dymond 1931). Similarly, WCT is only present above barriers in a few small tributaries of the Kettle River (McPhail 2007). Native WCT does not occur in the Okanagan River drainage. WCT has been stocked into many additional lakes and some streams, mainly in the British Columbia Southern Interior within core and peripheral areas of the native range of the species.

More specifically, the British Columbia Ministry of Environment (2014) describes the core and peripheral distributions of WCT in British Columbia (Figure 6) as:

Core Range:

- Elk - Elk lakes to Elko Dam including all tributaries,
- Flathead - Flathead from headwaters to the United States border,
- Upper Kootenay - Kootenay River and tributaries from headwaters to Kookanusa Reservoir. This set excludes the Elk River except for the very lowest portion below the natural barrier at Elko Dam; Wigwam River and Kootenay National Park included,
- West Kootenay - Kootenay Lake and tributaries including inlet (to border) and outlet (to Brilliant Dam).

Peripheral Range:

- Columbia - entire Columbia River mainstem from headwaters to border including Pend d'Oreille. Includes Glacier and Yoho National Parks.
- Kettle - entire watershed,
- South Thompson - upper portion of South Thompson watershed.

The core range subpopulations represent the centre of distribution for WCT in British Columbia while the other three peripheral drainages contain fairly disjunct, sparsely distributed subpopulations considered as the edge of the native range.

The Fisheries Information Summary System (FISS) is a database of individual observations of fish species maintained by the Province of British Columbia. As of 2010, a total of 1,319 unique waterbodies (including both lakes and streams) were found to contain at least one WCT observation (Table 2). However, the number of observations that are truly representative of original native subpopulations versus introduced subpopulations via hatchery releases is difficult to determine given the extensive hatchery history for WCT in British Columbia (British Columbia Ministry of Environment 2014). Most water bodies with records of WCT, approximately 928, have no hatchery release records so there are an estimated 928 to 1,319 water bodies that may contain pure WCT subpopulations. Also, it includes only sites where WCT has been reported and so is likely conservative because many small headwaters and lakes capable of supporting WCT have not been surveyed.

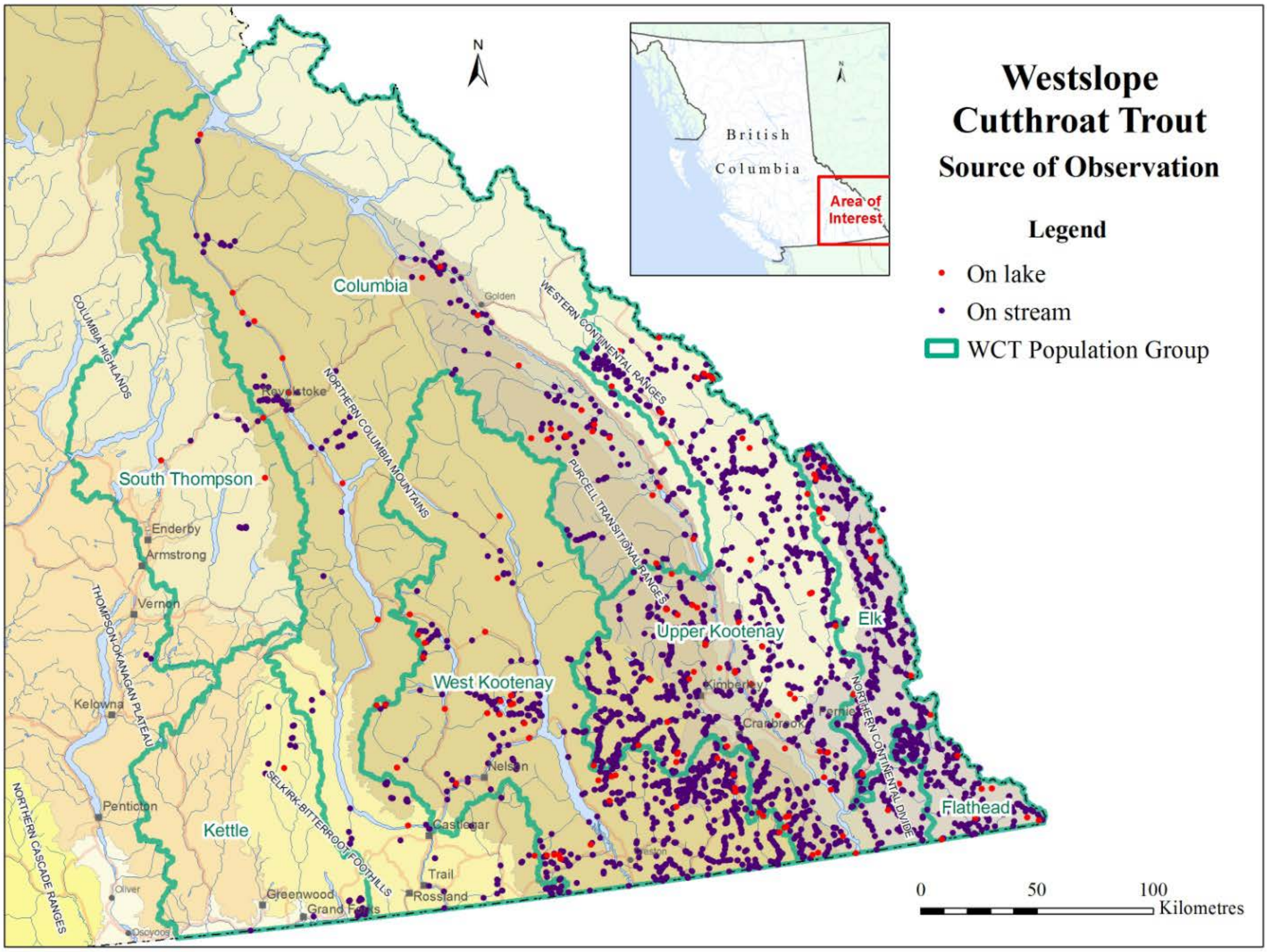

Figure 6. Distribution of WCT observation data collected from lakes and streams within each population group in the Pacific DU (taken from BC Ministry of Environment 2014).

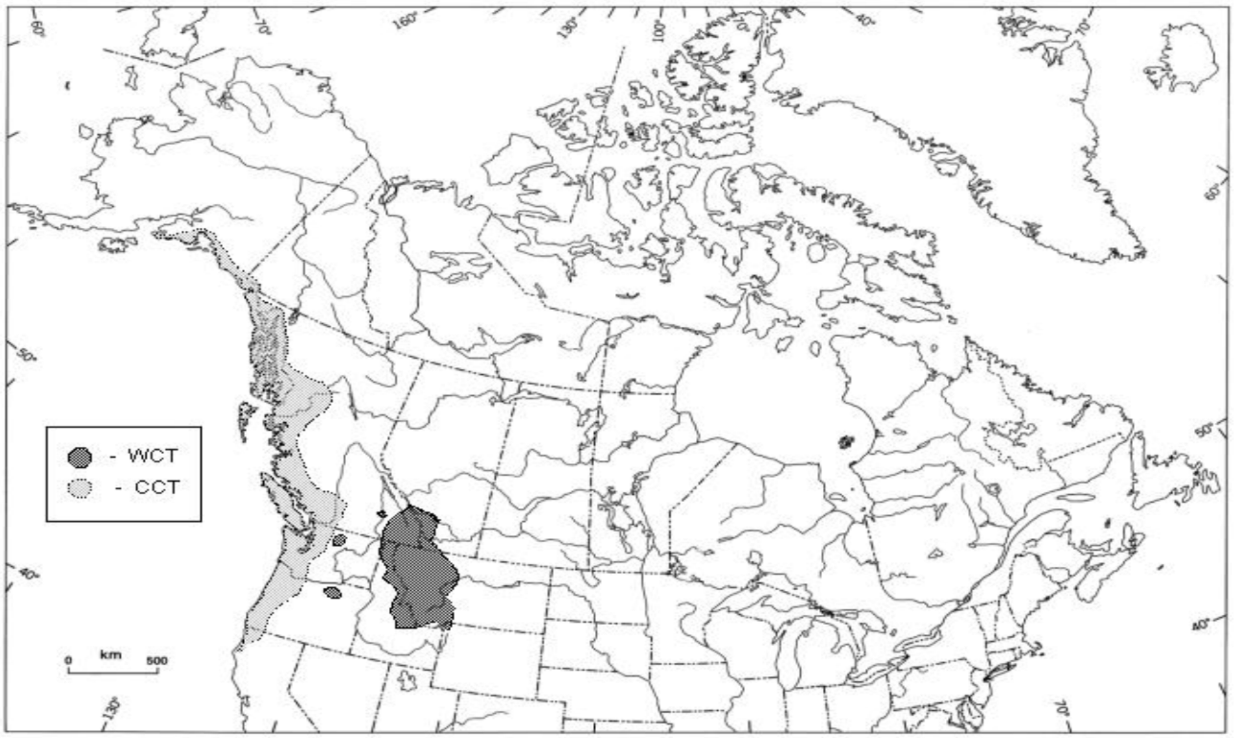

Figure 7. Global/Canadian ranges of native Coastal (CCT) and Westslope Cutthroat Trout (WCT). Modified from Behnke (2002).

Table 2. Comparison of the number of streams and lakes in the Pacific DU (as defined by blueline coding in 1:20,000 stream network data) in which WCT have been observed, as of June 2010, across population groups. Overall, most WCT observations occur in stream environments (taken from BC Ministry of Environment 2014).

Population Group	Streams	Lakes	Total	% Streams
Elk	134	36	170	78.8
Flathead	85	17	102	83.3
Upper Kootenay	406	114	520	78.1
West Kootenay	246	81	327	75.2
Columbia	117	54	171	68.4
Kettle	12	7	19	63.2
South Thompson	6	4	10	60.0
Total	1006	313	1319	76.3

Introduced Subpopulations in Canada

Westslope Cutthroat Trout has been widely introduced both within and outside its native range. Most stocking has been done to enhance or replace extirpated native subpopulations, or to populate previously fishless areas. In Canada, stocking has been used to enhance recreational angling opportunities rather than to rebuild populations. Rarely has WCT become established much beyond the original distribution (Behnke 1992). Introductions were made from non-local source subpopulations and in some cases WCT X RBT hybrid subpopulations have been knowingly propagated. The scope and nature of these introductions makes it difficult to assess the status of wild subpopulations because they often obscure trends in native production and may contribute to the decline of these subpopulations (Scribner *et al.* 2001; Docker *et al.* 2003).

The stocking of RBT, other subspecies of Cutthroat Trout, and RBT x WCT hybrids into native WCT habitat has resulted in hybridization and introgression in many native WCT subpopulations. These subpopulations are not included in the assessment of remaining pure WCT subpopulations but are considered a threat for the purposes of this document. The Canadian native range of RBT overlaps that of WCT only in the Upper Columbia, South Thompson and Lower Kootenay (most upstream extent of range is between Libby and Troy in Montana where Kootenai Falls prevented further upstream movement). No RBT occurred in the Flathead or Upper Kootenay systems naturally (Behnke 1992), which is the core of WCT native range in Canada. However, RBT has been stocked into a number of water bodies in this region known to contain WCT.

The following section identifies systems stocked with WCT both within and outside the native range of WCT in Canada.

<u>Saskatchewan-Nelson Rivers DU</u>

In Alberta, WCT has been widely introduced in several major drainages, both within and outside the native range, most commonly into previously fishless headwater lakes located above impassable barriers. It has been introduced into several streams in the Oldman and Bow river systems (Mayhood 2000) and into many naturally fishless lakes in Waterton Lakes National Park (Landry *et al.* 2000). In the upper North Saskatchewan River, a system in which it did not occur naturally (Sisley 1911; Prince *et al.* 1912), it has been stocked into Watchman Lake, Banff National Park, and small headwater lakes above the Clearwater junction and the upper half of Brazeau River (Lake of the Falls, Landslide Lake and some tributaries of the Nordegg River). Recently, WCT has been introduced into the Bighorn and Ram Rivers above David Thompson Canyon, to the Athabasca River, Mowitch Creek (Jasper National Park), and into tributaries of the Peace River (Smoky, Wapiti, Simonette, Little Smoky, Pine and the Narraway watersheds) (Nelson and Paetz 1992). While transplanted WCT in Alberta is widespread, individual subpopulations appear to be small and localized with the exception of the Ram River subpopulation in the North Saskatchewan River drainage (Mayhood 2000). Many of the early introductions were made with eggs and fry imported from the United States (particularly in Waterton Lakes National Park). For several years, eggs were taken from a native subpopulation in the Spray Lakes

(Alberta), but when that subpopulation was no longer available, fish were obtained from a variety of sources including Coastal Cutthroat Trout stock from Washington State, and a Yellowstone Cutthroat Trout variety from the Cranbrook hatchery in British Columbia (Ward 1974).

The majority of recent (since 1998) WCT stocking in Alberta has come from Job Lake, a high elevation lake in the North Saskatchewan River basin which was established as a brood lake for stocking streams in the 1970s. Approximately 200,000-300,000 WCT eggs are taken from Job Lake every other year for rearing at the Sam Livingstone Hatchery and later transfer as fingerlings to various lakes and streams in Alberta (Carl and Stelfox 1989). Job Lake was barren of fish until 1965 when it was stocked with WCT from Marvel Lake (Banff National Park; McAllister *et al.* 1981). These fish originally came from a native subpopulation in Spray Lakes that was extirpated by the construction of the Spray Lakes Reservoir (Ward 1974, Mayhood 2000). The Job Lake hatchery stock is considered wild WCT from within the native range but most plantings have been done in lakes, and rarely in streams and rivers (COSEWIC 2006).

It is evident that past introductions have affected the genetic integrity of pure subpopulations. However, there are only few instances in the Saskatchewan-Nelson Rivers DU since 1997 where RBT have been introduced into waters where pure WCT is still present. In all cases where RBT continue to be stocked in Alberta, there is no longer a pure WCT subpopulation present and a self-sustaining population of RBT has been established from past introduction (The Alberta Westslope Cutthroat Trout Recovery Team. 2013).

Pacific DU

Many naturally fishless systems in southeastern British Columbia have probably been stocked with WCT since the 1920s. These include high elevation headwater lakes and streams, as well as small lakes near urban centres. In addition, WCT has been stocked into a variety of lakes, streams and rivers likely already containing native WCT subpopulations. Within the native range of WCT, a total of 313 streams or lakes have been reportedly stocked with WCT at least once since 1923 (British Columbia stocking records, Fisheries Inventory Summary System (FISS) http://srmwww.gov.bc.cba/fish/fiss/index.html, summarized in Table 3). Unfortunately, it is impossible to determine for many of these water bodies which ones originally contained native WCT subpopulations prior to stocking. It is also very likely that introduction of WCT into new water bodies prior to record keeping occurred because early settlers were known to move fish around through the southeastern British Columbia region in hopes of establishing fishable populations.

Table 3. Number of streams and lakes in the Pacific DU where WCT has been observed at least once for which at least one stocking event has also occurred for CS (Cutthroat x Rainbow Trout cross), CT (Cutthroat Trout, probably coastal), EBT (Eastern Brook Trout), RBT (Rainbow Trout), and WCT. Total WCT = the total number of streams and lakes where WCT have been observed (taken from BC Ministry of Environment 2014).

Subpopulation	Waterbody type	Total WCT	CS	CT	EBT	RBT	WCT	Total stocked
Elk	Stream	134	0	0	4	3	22	29
	Lake	36	0	0	0	5	20	25
Flathead	Stream	85	0	0	0	1	6	7
	Lake	17	0	0	0	1	12	13
Upper Kootenay	Stream	406	0	3	5	15	43	66
	Lake	114	0	1	7	21	53	82
West Kootenay	Stream	246	1	2	4	21	30	58
	lake	81	0	0	2	16	47	65
Columbia	Stream	117	0	0	2	9	19	30
	Lake	54	0	1	0	11	29	41
Kettle	Stream	12	0	0	0	0	3	3
	Lake	7	0	0	0	0	7	7
South Thompson	Stream	6	0	0	0	1	5	6
	Lake	4	0	0	0	3	1	4
Total	Stream	1006	1	5	15	40	128	189
	Lake	313	0	2	9	54	169	234

A number of WCT introductions into lakes and streams have also occurred outside the native range including the lower Fraser River basin, the Okanagan/Kettle/Similkameen basin, coastal systems and the Peace River basin. WCT has been planted in the tributary systems of the Similkameen River including the Ashnola River, Ladyslipper Lake, Quinesco Lake, Lake of the Woods and Pyramid lake in Cathedral Park. Limited stocking has occurred at two sites in the coastal Bella Coola River system (Blue and Octopus lakes) but was discontinued in 1995 (COSEWIC 2006). Approximately 70 such water bodies outside the native range of WCT have been stocked at least once.

Early stocking records do not consistently list the origin of the hatchery stocks used for these introductions. In at least one case (Seton River), the Cutthroat Trout stocked was of coastal origin from the Cowichan River on Vancouver Island. A variety known as ‘Cranbrook Trout’ (an intentionally crossed RBT X WCT hybrid produced by the Cranbrook Hatchery) was stocked throughout Alberta and to a more limited extent in British Columbia until 1964 when the hatchery closed. Other WCT X RBT hybrid stocks were also introduced for a period (1923 -1945) into small lakes and creeks in the upper Kootenay River drainage. Since 1971, all stocked WCT has been derived from Connor Lakes broodstock, considered to be pure WCT from within the native range of the DU (Taylor *et al.* 2003).

It is evident that the stocking of RBT and other Cutthroat Trout subspecies has affected the genetic integrity of WCT subpopulations in the Pacific DU. In recent years, almost all RBT stocking within the native range of WCT has been limited to releases into small lakes. Furthermore, many of these fish are triploid and/or all-female stocks. The extent to which these lakes can be considered ‘closed’ is uncertain, and over 100 water bodies have been stocked since 2000. Furthermore, reproductively viable juvenile Gerrard strain RBT was stocked multiple times into a tributary of Kookanusa Reservoir from 1986 to 1998 (FISS stocking records). During this period, the Montana government also stocked large numbers of reproductively viable RBT from Murray Springs Hatchery into the reservoir and they could access all connected tributaries and outlets of the reservoir. They continue to stock triploid fish into the system.

Extent of Occurrence and Area of Occupancy

Saskatchewan-Nelson Rivers DU

It is estimated that only 51 pure subpopulations of WCT remain in the documented native range in Alberta (The Alberta Westslope Cutthroat Trout Recovery Team 2013). This number is subject to change pending further field surveys and genetic analysis. These subpopulations occupy only a small portion of the former range in streams and lakes. In the Bow River basin a minimum of 63 subpopulations have been lost from a combination of factors including habitat degradation, competition, and hybridization (Mahood 2009). It includes apparent eradication of the species from the Bow River below Lake Louise and the lower main stems of the Highwood, Elbow, Spray, Jumpingpound, Sheep, and Kananaskis rivers and extensive hybridization in the upper reaches of most of the main stems (The Alberta Westslope Cutthroat Trout Recovery Team 2013). Pure WCT are restricted to small habitats in the extreme headwaters in all systems implying that any migratory fluvial and adfluvial life history forms are extirpated. Only small stream-resident populations are likely to remain. A similar situation exists in the Oldman River basin where an estimated 49 WCT subpopulations have been lost, primarily due to hybridization, habitat changes, and competition. The subspecies appears extirpated from the Crowsnest River main stem existing only as heavily introgressed subpopulations in the mid- to lower Oldman, Belly and Castle river main stems. The fluvial and adfluvial life-history forms have been lost from the Oldman River basin with small stream-resident subpopulations continuing to exist in the upper headwaters (The Alberta Westslope Cutthroat Trout Recovery Team 2013).

The estimated extent of occurrence and index of area of occupancy are 16650 km^2 and 844 km^2, respectively.

Pacific DU

The native range of WCT in British Columbia is concentrated along the western slope of the Rocky Mountains, but limited to the southeastern portion of the province. Indications of the extent to which WCT still occupy their native range within British Columbia are limited to the data captured in the provincial FISS database and subpopulation-specific studies where available. WCT appears to persist throughout its historical range in all core and peripheral area watersheds. The status is complicated by the extensive stocking history of WCT in the province, making it difficult to determine whether occurrences represent historical distribution or introductions (particularly in the peripheral range) and hybridization with introduced RBT that reduces the distribution of genetically pure WCT subpopulations (British Columbia Ministry of Environment 2014).

A total of 114 sites representing 88 waterbodies (both streams and lakes) have been assessed for the presence of hybrids (British Columbia Ministry of Environment 2014). The WCT subpopulations in the Elk and Upper Kootenay watersheds are extensively hybridized and any waters accessible from the Kookanusa Reservoir (i.e. in the lower portions of tributaries below barriers) contain significant levels of RBT genes (British Columbia Ministry of Environment 2014). Additional "hotspots" for hybrids include (1) lower and mid-sections of tributaries in the lower Elk River above Elko Dam (i.e. Michel Creek area); (2) streams (e.g., White River) near Whiteswan Lake in the Upper Kootenay watershed; and (3), to a lesser degree, upstream tributaries of Kootenay National Park in the Upper Kootenay. The Canadian portion of the Flathead watershed contains mostly pure WCT but south of the international border, hybridized subpopulations are scattered throughout the lower portions of the Flathead River and its tributaries (Boyer *et al. 20*08). Across all 88 sites surveyed only 61.4% contained pure WCT subpopulations (British Columbia Ministry of Environment 2014). More recently, SNP (single nucleotide polymorphism) chips have been used to resample a number of these subpopulations in an effort to confirm the degree of hybridization in the systems. Preliminary results mostly confirm earlier findings with higher levels of hybridization in a number of systems.

The estimated extent of occurrence and index of area of occupancy are 85183 km^2 and 6824 km^2, respectively.

Search Effort

The WCT populations in both the Alberta and Pacific DUs reside in remote, often difficult to access headwater regions of rivers and streams. Data on distribution accumulate mostly from collections associated with other studies (e.g. fish bearing status for forestry, sampling for development projects, etc.). Surveys to assess abundance and distribution have been limited with some recent exceptions. In Alberta, since recommended as Threatened (COSEWIC 2006), genetic sampling has occurred in the Bow and Oldman River drainages in conjunction with habitat data collection on degraded riparian areas and water quality (The Alberta Westslope Cutthroat Trout Recovery Team 2013). As well, surveys have been conducted at a subset of streams to locate barriers to upstream fish passage, particularly for preventing upstream migration of non-native species. In British Columbia, a series of multi-year mark recapture and telemetry studies have been conducted on large systems to determine trends in abundance, seasonal habitat choice and migration timing (Moore and Prince 2004; Baxter 2006; D'Angelo *et al.* 2013; Cope *et al.* 2014; Heidt 2015). Sampling has continued to assess abundance and distribution at the watershed level in 2014-2016. In addition, British Columbia maintains records of observations by GPS coordinate of samples of all species in the Fisheries Information

Summary System (FISS). Similarly, in Alberta the Fisheries and Wildlife Management Information System (FWMIS) maintains records of observations by species in an accessible database.

HABITAT

Habitat Requirements

Information on habitat requirements comes primarily from the Pacific DU but is assumed to also apply to the Saskatchewan-Nelson Rivers populations. The WCT exists as one of three life history forms in British Columbia (Oliver 2009):

- stream-resident – headwater stream subpopulations above barriers, completing their life cycle within a very restricted distribution; remaining relatively small (i.e. < 200 mm in length) due to nutrient-poor nature of these small cold streams;
- fluvial – migratory subpopulations that move between small spawning/rearing tributaries and larger, more productive adult-rearing rivers; generally larger as adults (i.e. > 400 mm in length); and
- adfluvial – subpopulations that migrate between spawning/rearing tributaries and adult rearing lakes often exceeding 500 mm in length in productive lakes.

Resident and fluvial subpopulations frequently co-occur in the same watersheds in British Columbia although barriers may separate them (Oliver 2009). Adfluvial subpopulations may occur in headwater lakes with inlets and outlets, as well as larger downstream lakes like Kookanusa Reservoir and Kootenay Lake. As a consequence they have a range of habitat requirements inhabiting large rivers and lakes in British Columbia, as well as many small mountain streams. In Alberta, genetically pure native subpopulations are now largely restricted to the upper reaches of main stem rivers and the headwaters of a few major tributaries. The extent and distribution of these phenotypes between the two designatable units is not known but the subspecies as a whole seems to thrive in streams with abundant pool habitat and cover. As with other salmonids, four types of habitat are required to complete the life cycle (Behnke 1992):

- <u>Spawning</u> – Small, low-gradient streams with cold well-oxygenated water and clean unsilted gravels; spawning often occurs in the tailouts of deep pools at moderate to high-flow events, which are often of short duration (Brown and McKay 1995b; Schmetterling 2001). Proximity to cover is important for spawning fish that seek out areas of large woody debris (LWD), boulders or bedrock while residing in spawning tributaries. The in-stream structure creates the necessary pool habitat to catch and retain spawning gravels as well as providing cover from predation. High mortality may result when suitable cover is lacking (Behnke 1992; Brown and Mackay 1995b). Shoal spawning has been noted but is not common (Carl and Stelfox 1989).

- Rearing – Small streams that remain permanently wetted during low flows and have a diversity of cover are required juvenile rearing habitat (McIntyre and Rieman 1995). Young-of-the-year fry migrate to low energy lateral habitat (i.e. shallow riffle or backwater habitat) with protective cover and low water velocities (some populations may rear in lakes). Larger juveniles move into pools where they establish social dominance based on size. Parr require large territories and the availability of pool habitat often limits productivity (Schmetterling 2001).
- Maintenance – The resident component of subpopulations may remain in the natal stream their entire lives. Migratory forms undergo a niche shift and leave small natal streams for larger systems or main stem habitat where the potential for increased growth exists. Fluvial (riverine) forms require slow pools formed by boulders or LWD with faster adjacent water and plenty of cover (undercut banks, riparian vegetation, in-stream structure). Adfluvial adults (migrating between lakes and rivers) spend summer months feeding in lakes and reservoirs with temperatures less than 16°C (McIntyre and Rieman 1995).
- Overwintering – Overwintering habitat suitability is largely determined by groundwater influx and the absence of anchor ice (Brown and Mackay 1995a). During winter months, fluvial adults congregate in slow deep pools sheltered from high flows (Cope *et al.* 2014). Juveniles often utilize cover provided by boulders and other large in-stream structures, or off-channel habitat such as sloughs or beaver ponds. Adfluvial fish will often overwinter in lakes.

Essential Habitat Parameters

The wide range of environmental conditions encountered by WCT suggests some flexibility in habitat utilization. However, it is apparent that subpopulations have very strict habitat requirements during various life history stages and generally do well only in unaltered lotic environments with cold clean water and varied forms of cover (i.e. undercut banks, pool-riffle habitat, and riparian vegetation) to maintain their numbers.

Temperature

Stream temperature is an important habitat parameter affecting cold-water salmonids like WCT. Water temperature influences a host of biological processes including growth rate, swimming ability, and capacity to survive disease and capture food (Reiser and Bjornn 1979). WCT are sensitive to changes in water temperature and are not found in waters where maximum stream temperature repeatedly exceeds 22°C (Behnke and Zarn 1976). Exposure to temperatures as high as 28-30°C quickly leads to loss of equilibrium, swimming difficulty, and ultimately death (Heath 1963). Preferred temperatures range from 9-12°C. Spawning generally occurs from 6-17°C (Hunter 1973). Optimum stream temperature for incubation of eggs is ~10-11°C and ~15°C for juvenile rearing (Merriman 1935; Snyder and Turner 1960). Preference for cooler water temperatures appears to make

WCT a superior competitor in higher elevation stream reaches (Griffith 1988; Fausch 1989; Paul and Post 2001). The current distribution of WCT populations in many headwater areas supports the idea of a “temperature/elevation refugia” for WCT where populations are most able to resist invasion by non-native species (Paul and Post 2001; Rasmussen *et al.* 2010, 2012; Yau and Taylor 2013, 2014).

Current Velocity / Stream Flow

While WCT occupy a wide range of habitats, they generally inhabit smaller but steep streams with lower volume discharges. Spawning occurs at water depths of 20-50 cm and average water velocity from 0.3-0.4 m/sec (Liknes 1984; Shepard *et al.* 1984). Young-of-the-year fry prefer lower energy habitat with flow ~0.06 m/s and depth over 3 cm (Bozek and Rahel 1991). Platts (1974) found that WCT density peaked at a channel gradient of about 10%, which exceeded that for peak densities of Bull Trout (*Salvelinus confluentus*), Brook Trout (*Salvelinus fontinalis*), or RBT. Changes to natural flow regimes and inadequate base flows have a significant impact on stream-dwelling salmonids (Spence *et al.* 1996). Eggs and alevins are sensitive to the infiltration of fine sediments into spawning gravels with embryo survival less than 50% when the concentration of fine sediments exceeded 20% of the substrate in laboratory studies (Shepard *et al.* 1984). Adequate riffle coverage and flow velocity is required to maintain levels of habitat diversity and insect production to feed parr in pools. Reduction in the annual mean flow can lead to substantial loss of marginal rearing habitat, elevated stream temperature and may inhibit normal patterns of migration when populations become isolated to pockets of water (Slaney *et al.* 1996; Rosenau and Angelo 2003). WCT has evolved to move with the rising limb and peak of the hydrograph, allowing it to negotiate seasonal barriers within streams where increased flows may be necessary to gain access to these habitats.

Riparian and In-stream Cover

Riparian cover and varied in-stream structure are essential elements of WCT habitat, contributing greatly to stream complexity and creation of refugia. Riparian vegetation (alders, salmonberry, willow, poplar, etc.) serves to stabilize stream banks, reduces predation, and maintains low stream temperatures by reducing insolation (Reeves *et al.* 1997; Rosenfeld 2001). The riparian input of terrestrial insects is a significant food source for stream resident WCT during summer months (Behnke 1992). Undercut banks, root wads and boulders are also important in partitioning habitat and as areas of refuge. Bedrock outcroppings may be more important where trees are smaller, and debris jams are less frequent. The abundance of larger juveniles in streams is limited by the availability of pools and LWD (Schmetterling 2001). Riparian logging and the removal of LWD adversely affects pool habitat, and leads to the loss of stream complexity, bank instability, sedimentation and the infilling of pools resulting in reduced egg-to-fry survival, availability of rearing habitat and future production of aquatic invertebrates (Reeves *et al.* 1997; Rosenfeld 2001).

Habitat Trends

The native range of WCT is limited to the western provinces of Alberta and British Columbia, where economies are driven by land use and resource extraction. Available data indicate significant habitat loss and degradation throughout the range of both DUs in Canada over the last century. The greatest losses have occurred as a result of resource extraction and associated road construction. Habitat loss and alteration due to water impoundment for hydroelectric projects and agricultural irrigation are also factors in some declines although they may be more prevalent at lower elevations than WCT prefer. Protected areas exist for WCT within the National Parks.

<u>Saskatchewan-Nelson Rivers DU</u>

Urbanization, water diversion, and agricultural practices have all impacted WCT habitat in Alberta. Cumulative impact assessments on 98 fourth order or higher watersheds in the upper Oldman, Crowsnest, and Carbondale (Castle River drainage) basins found that approximately two-thirds of the watersheds are at moderate risk of degradation, potentially resulting in further loss of WCT habitat. Of the rest, all but three are at high risk of degradation from increased peak flows and surface erosion resulting from extensive clear cutting and road development (Mayhood *et al.* 1997; Mayhood 2000). Resource exploration has led to a dramatic increase in road density in Alberta, translating into an explosion of wilderness access points (e.g., roads, cut-lines). Off-road vehicle traffic has increased stream bank erosion and sedimentation, as well as increased angling pressure. For example, in the Ghost-Waiparous area, there are 189 km of designated trails, but on long weekends up to 2000 km of largely undesignated trails are being used by nearly 15,000 people (COSEWIC 2006). Habitat degradation along the Bow River is severe; the city of Calgary is built around its banks and major transportation thoroughfares run along much of its course.

The human population in the South Saskatchewan River basin is expected to grow to ~2 million by 2021 (from 1.3 million in 1996; Alberta Environment 2003a) resulting in a projected increase in domestic water demand of 29-66%. Alberta has limited groundwater supplies that can be accessed with 97.5% of its water coming from surface runoff (Alberta Environment 2003b). Much of the Bow River valley watershed (41.5%) in Banff has been regulated, obstructed, or otherwise impounded (Schindler and Pacas 1996). The Bow River main stem has four TransAlta hydroelectric plants (11 in total on the Kananaskis/Bow River system) and the downstream aquatic environment on the Bow and Oldman rivers is in decline (Golder Associates Ltd. 2003). In 2001, the quantity of water flowing down the Bow and Oldman rivers as they merge into the South Saskatchewan River (near Medicine Hat) was at a 31-year low. Much of the natural flow in the Oldman (>70%) and Bow Rivers (> 68%) is allocated for industrial and domestic purposes (COSEWIC 2006). Irrigation licences account for about 75% of the total volume of South Saskatchewan River basin allocations (Alberta Environment 2003b). Alteration of discharge and flow regimes may have long-term impacts on WCT sustainability (Al-Chokhachy *et al.* 2014; Muhlfeld *et al.* 2014).

Although water withdrawal is focused in the lower reaches of these systems below existing WCT subpopulations, they have likely contributed to extirpation of WCT in the Highwood, Bow, and Oldman rivers. WCT disappeared following development of the dams and stocking of RBT into the reservoirs (Nelson 1965). Dams have been a major factor in the decline of the Kananaskis, lower Spray and Cascade WCT subpopulations. WCT was abundant in lower Kananaskis and Spray lakes before they were dammed, but are now virtually absent (Stelfox 1987a,b). Prior to dam construction in 1913, WCT also existed throughout the Kananaskis River system below Twin Falls (between the Upper and Lower Kananaskis lakes, in Lower Kananaskis Lake, and in the Kananaskis River). WCT is now virtually absent from Lower Kananaskis Lake, the Kananaskis River main stem and the upper reaches of all but three of its small tributaries (Rocky, Evan-Thomas and Porcupine). Similarly, no WCT was found between the Ghost Dam on the Bow River and the Bearspaw Reservoir (RL & L Environmental 1998) or from the TransAlta Pocaterra Power plant to Pocaterra Creek (Kananaskis River drainage; Golder and Associates Ltd. 1999). Both areas historically supported WCT subpopulations.

<u>Pacific DU</u>

The major threats to WCT habitat in British Columbia include logging, mining and urbanization. Logging remains an important resource industry in British Columbia. Loss of forest cover is known to adversely affect fish populations by changing temperature and hydrological regimes within streams. Poor and outdated harvest practices contributed to habitat loss in Canada, and until recently, the numerous small streams and tributaries associated with logging activities often received little formal protection. Improperly placed culverts or outdated logging practices may still occur. Urbanization and local development have impacted some populations. In the East Kootenay region, which contains ~65,000 people, the city of Cranbrook has grown extensively around Joseph Creek (St. Mary River drainage). Traditional First Nations knowledge indicates that the creek used to be a very important spawning area for WCT (Prince and Morris 2002). Extensive habitat degradation and alteration (e.g.*,* impassable culverts, storm-drain runoff, siltation) and extremely low flows during summer months have severely impacted juvenile rearing in the system (COSEWIC 2006). Changes to the spring flow regime during snow melt due to reservoir filling or other diversions have impacted adult upstream migration. In addition to the high levels of water withdrawal in many systems, changes induced in the annual hydrograph are impacting the spawn timing for WCT such that hatching success and fry survival may have declined.

Currently eleven operating mines exist in the East Kootenay region of British Columbia. Six of these are industrial mineral mines, and five are coal mines. Impacts include the construction of rock drains on creeks (typically the infilling of valley bottoms and related habitat destruction), chemical loading (e.g., selenium) and stream diversion. Recent telemetry studies demonstrate the localized occurrence of overwintering habitat for WCT (Cope *et al.* 2013, 2014) that may have been lost due to infilling or re-channelization within watersheds. However, the most detrimental impact of the mining industry on freshwater habitat is water contamination. Levels of selenium have increased 13% per year between 2004-2009 in the Fording River (Minnow *et al.* 2009). Elevated levels of selenium exceeding acceptable standards were detected throughout the food chain of WCT. WCT collected throughout the Fording River also had high concentrations of selenium in muscle and gonad tissues. Elevated selenium levels are known to increase the overall mortality to the swim-up stage and increase the incidence of spinal deformities and edema in fry (Holm *et al.* 2003; Lemly 2014). Accompanying these primary industries is an increase in road density that promotes habitat fragmentation, degradation, and the opening of new access points for angling and non-native introductions (Reeves *et al.* 1997).

BIOLOGY

Behnke (1992, 2002) provides comprehensive synopses of current knowledge of all the Cutthroat Trout subspecies' biology and ecology that are key sources for this report. WCT displays a remarkable diversity in phenotypic traits and life history characteristics throughout its range. However, the extent of this diversity and its underlying biology remains poorly understood relative to other salmonid species. It is evident that WCT inhabits smaller, less productive streams, preferring colder water temperatures than other closely related species. Subpopulations are generally small (~100 adults/stream) but show strongly developed natal homing and well-defined population structure. WCT is sensitive to habitat perturbation and the introduction of non-native fishes. Habitat degradation increases susceptibility to displacement and hybridization with introduced species. The number of WCT subpopulations in degraded habitats is likely in decline, and their demographic independence suggests that losses are unlikely to be offset by immigration from nearby sources.

Life Cycle

WCT demonstrates extensive phenotypic variation in size, colouration, and life history characteristics (Trotter 1987; Behnke 2002). The extensive diversity is adaptive having evolved in response to local environmental conditions (Taylor 1991). Different life history types are present throughout the range of WCT with both migratory and resident subpopulations common throughout the Canadian range and often present within the same watercourse. The relationship between these life history types and their interaction is unclear, particularly with regard to sharing resources and habitat. However, within an area different life history types are more closely related to each other than to those from other areas (Johnson *et al.* 1999). Different life history components of a subpopulation may share certain habitats (e.g., the same overwintering or summer habitat) while exploiting different spawning habitat. The size differences between life history strategies appears to provide an opportunity for spatial or temporal isolation on spawning grounds because stream resident WCT seldom exceed 25 – 30 cm fork length, while fluvial and adfluvial fish can attain sizes of >50 cm FL and 0.9-1.5 kg in weight (Shepard *et al.* 1984; McIntyre and Rieman 1995; Cope *et al.* 2014).

Reproduction

Adult WCT display a general pattern of upstream movement to spawning areas during peak spring flows in the Flathead River (D'Angelo *et al* 2013). Spawning occurred during and as peak flows diminished usually May to July. Spawning occurs in both main stem and tributary habitats (usually in the tailouts of deep pools) and males compete for access to females (Fleming 1998). Brown and Mackay (1995b) found fluvial WCT in the Ram River, Alberta maintained territories of ~400 m^2 in the natal creek. Females dug several nests (redds) within this territory and males attempted to mate with all females they encountered. Sex ratios on the spawning grounds vary considerably and may partly correspond with life history type. Downs *et al.* (1997) found that the sex ratio favoured males in headwater resident subpopulations (1.3:1) while ratios for migratory subpopulations ranged between 0.2 and 0.9 males per female. Males appear to be more susceptible to angling due to aggressive territorial behaviour and may be removed from larger systems prior to spawning. Headwater resident subpopulations, which are less accessible, likely receive less angling pressure.

The age and size at sexual maturity also varies across subpopulations and life history types. Downs *et al.* (1997) found that males in isolated headwater subpopulations from Montana reach maturity at age 2 and all are mature by 4 years of age. The youngest mature female was 3 years old while most were mature by age 5. Length was a better predictor of sexual maturity than age; males matured at 110-160 mm fork length (FL) and females at 150 – 180 mm FL. Mean fecundity (±SD) was estimated at 227 eggs (±41.1) for fish 150 – 174 mm, 346 (±85.6) for 175 – 199 mm fish, and 459 (±150.8) for fish 200 mm and longer. Migratory forms maturing at a larger size have correspondingly higher fecundities. Migratory females with a fork length of 350 mm may produce 1000-1500 eggs (Liknes and Graham 1988).

Spawning has been observed generally towards the end of the spring freshet and decline of the hydrograph and rising water temperature in the Bull River (Cope *et al.* 2014). Timing makes WCT prone to impaired survival where habitat degradation leads to increased erosion and sedimentation near redds. Water temperature at spawning varied from 5.2^{o} to 11.6^{o} C in the Flathead River (D'Angelo *et al.* 2013) and Cope *et al.* (2014) report spawning for the Elk and St. Mary Rivers at 7^{o} C. Similar temperatures for spawning have been observed in Alberta (The Alberta Westslope Cutthroat Trout Recovery Team 2013). Fluvial WCT occupied tributaries of the Blackfoot River, Montana from 4 to 63 days but spawning occurred over only 1 to 3 days (Downs *et al.* 1997). Eggs generally incubate in the spawning gravels for 6-7 weeks, depending on water temperature. Eggs spawned in the Flathead River drainage (south of the British Columbia/Montana border) required ~310 temperature units (degree days) for full development. Once hatched, alevins remained in the substrate until their yolk sac was absorbed (a further 100-150 temperature units; Shepard *et al.* 1984). Fry emerge from the streambed at ~20 mm in early July to late August and quickly migrate to low energy lateral habitats.

WCT is iteroparous and some fish may reproduce annually or every other year but post-mating mortality may be high, especially for males. Very few repeat spawners were found in one study (0.7–2.9%; Schmetterling 2001) but higher values have also been reported (Shepard *et al.* 1984; McIntyre and Rieman 1995). Fecundity increases with size (Giger 1972; Downs *et al.* 1997), so maintaining the repeat spawners is particularly important for small subpopulations subject to habitat degradation. Eggs produced by larger females are bigger and produce larger alevins, increasing their chances for survival.

Physiology and Adaptability

Throughout much of its native range in both DUs, the WCT subpopulations have been impacted or displaced by hybridization and introgression with RBT (Rubidge and Taylor 2005). As a result, in many sites WCT have become restricted to small high elevation headwater streams leading to speculation that the species is better adapted to colder waters explaining the cline in hybridization with RBT in many watersheds (Hitt *et al.* 2003; Rubidge and Taylor 2005; Muhlfeld *et al.* 2009; Rasmussen *et al.* 2010; Yau and Taylor 2013). A recent study confirms the superior performance of WCT relative to RBT in controlled experiments for fish acclimated to 15^{o} C (Yau and Taylor 2014). Rasmussen *et al.* (2012) provide additional evidence of superior metabolic performance of WCT at higher elevations.

A number of studies suggest that WCT is highly susceptible to habitat perturbation, particularly factors affecting water quality, temperature, or the amount of in-stream structure (Liknes and Graham 1988; Reeves *et al.* 1997; Porter *et al.* 2000). Several long-term studies also demonstrate that the loss of riparian buffer integrity leads to a decline in trout biomass, and populations remain depressed for 5-20 years as the riparian zone regenerates (Hartman *et al.* 1996; Reeves *et al.* 1997). These perturbations involve complex changes disrupting growth within subpopulations and causing increased mortality of certain age classes (Hartman *et al.* 1996). As a result, habitat partitioning is disrupted leading to increased competition for resources. WCT may be particularly sensitive to changes in natural flow regimes (Brown and MacKay 1995a; Downs *et al.* 1997). In agricultural or urbanized areas where water has been appropriated for irrigation or domestic use, WCT subpopulations suffer dramatic declines as all life history stages are affected.

Dispersal and Migration

The WCT exhibits a broad and variable spectrum of migratory behaviours perhaps resulting from the diversity of life history types and habitats it occupies (Northcote 1997; Hilderbrand and Kershner 2000a; D'Angelo *et al.* 2013; Cope *et al.* 2014). WCT undergo a suite of movements during their lifetime including seasonal movements (feeding, overwintering, spawning) as well as those associated with life history shifts. Mixed migratory strategies for different life history types may also be an adaptation to buffer periodic environmental disturbances (Rieman and Clayton 1997).

During their first year of life, fry disperse from areas of high density to low density; generally into lower velocity habitats with sufficient cover. Juveniles reside in natal streams from 1 to 4 years depending on stream productivity and their life history type. During this time, individuals may be relatively sedentary, remaining in the vicinity of the same stream reach or pool. Older juveniles and sub-adults may range further in response to changing water levels, stream temperatures, or the availability of food. Individuals from headwater streams in Montana, for example, have been observed to move less than 1 km (Jakober *et al.* 1998) while fluvial and adfluvial WCT may migrate over large distances (in excess of 100 km) to find suitable feeding grounds or overwintering habitat (Schmetterling 2001; D'Angelo *et al.* 2013). Telemetric studies report varying home ranges for WCT: 7.6 km, range 0.7 - 27.9 km for the upper Bull River (Cope and Prince 2012); 11.2 km, range 1.8 km – 35.9 km for the Elk River above the Elko Dam (Prince and Morris 2003); 8.9 km, range 1.5 – 24.9 km for the upper St. Mary River; 19.6 km, range 2.1 – 55.5 km for the lower St. Mary River (Morris and Prince 2004); and 13.3 km, range 0.7 – 31.6 km for the upper Fording River (Cope *et al.* 2014) indicating extensive movement of individuals throughout the available habitat as conditions change throughout the year. The age of outmigration for migratory forms typically appears to be 2-3 years old (95-170 mm FL; McIntyre and Rieman 1995). Timing depends on local conditions, but peaks early to mid-summer with migrants leaving natal streams at night. However, movement will often cease once suitable feeding habitat has been found.

Recent telemetry studies primarily on a few British Columbia systems provide more detailed insight into the seasonal use of habitat by WCT (Moore and Prince 2004; Cope and Prince 2012; D'Angelo *et al.* 2013; Cope *et al.* 2014). In the Fording River, the average home range of WCT was 13 km with a range of <1 km to 32 km. Ice conditions, presence of surface water, groundwater influences, water temperature and depth, availability of spawning habitat and number of large pools all influenced seasonal distribution of sub-adult and adult WCT (Cope *et al.* 2014). An earlier study on the Bull River found spring migrations from overwintering pools to spawning areas of 1.5 to 27.2 km (Cope and Prince 2012). Spawning habitat consisted of gravels associated with pool tail-outs, large woody debris and side-channels or stream margins. D'Angelo *et al.* (2013) found that most WCT (81%) on the Flathead River travelled upstream to spawning grounds; about half spawned in tributaries, with the other half in main stem or side channel habitats. Spring movements of adult WCT were related to stream flow and water temperature. Fish consistently moved upriver or downriver towards spawning sites as flows increased in the spring and spawned following peak runoff as water temperatures approached 7–9 C in late May through to mid-June. Post-spawning fish tended to move downstream although some also went upstream. Sub-adults also made short upstream and downstream movements but many fish stayed within 2 km of their tagging site (D'Angelo *et al.* 2013). Some sub-adults and most post-spawning WCT made rapid or incremental downriver movements (up to 177 km) to lower portions of the river system and to Flathead Lake during high spring flows and as temperatures declined in the fall and winter. Temperature declines in the fall may cause WCT to make extensive movements to suitable overwintering habitat. Temperatures below 4–6 C stimulate winter concealment because as water temperatures approach freezing, metabolic rate is reduced, food requirements are lowered, and less energy is available for activity. During these relatively inactive periods WCT often use deep, low-velocity areas (i.e. pools and deep runs) to maximize energy conservation (D'Angelo *et al.* 2013). Sub-adult and adult WCT used deep, slow pool habitats with relatively abundant cover throughout the main stem North Fork Flathead during all seasons. Water temperature is an important factor in the seasonal distribution of WCT. D'Angelo *et al.* (2013) found that radio-tagged WCT consistently selected cold-water fluvial habitats (< 12^o C), regardless of their location in the watershed, and that the seasonal distribution of temperatures occupied by adults and sub-adults were remarkably similar. The mean summer temperature occupied by radio-tagged individuals was less than 12^o C, consistent with laboratory studies that suggest an upper thermal suitability limit of 13-15^o C (Bear *et al.* 2007) for long-term persistence of WCT.

In late summer and early fall, WCT seek suitable overwintering sites in response to decreasing water temperatures and ice formation. Individuals may travel considerable distances to find suitable habitat but remain relatively sedentary through winter months (see D'Angelo *et al.* 2013). In streams with dynamic ice conditions, movement can continue throughout the winter (Brown and Mackay 1995b; Schmetterling 2001; Prince and Morris 2002). In response to lengthening days and increasing water temperatures in late winter-early spring, WCT leave overwintering habitat returning to small natal tributaries to spawn (D'Angelo *et al.* 2013, Cope *et al.* 2014). Once in the natal system, numerous small movements occur within a section of stream associated with breeding territory and following spawning, a return to summer feeding habitat occurs (depending on its location/availability).

Interspecific Interactions

Interaction with other species occurs throughout the life history but sensitivity is greatest from the egg to juvenile stage. Eggs and newly hatched alevins are highly sensitive to environmental degradation, particularly sedimentation and dewatering. Physical injury and competition for rearing habitat is significant where such habitat is limited. For fry and larger juveniles, competition with each other and sympatric species for food and areas of refuge may be significant. Predation by piscivorous fishes (e.g., Cottids, Bull Trout (*Salvelinus confluentus*), Brook Trout (*Salvelinus fontinalis*), Northern Pikeminnow (*Ptychocheilus oregonensis*) and other salmonids) is also most intensive at this life stage (COSEWIC 2006). Adults are susceptible to a number of terrestrial predators (raptors, mustelids, etc.*)* where sufficient cover is lacking. In the past, recreational harvesting played an important role in the survival of adult WCT, but the only angling now permitted is catch and release although hooking mortality and poaching are concerns (Heidt 2014).

Cutthroat Trout tend to be highly opportunistic in terms of their diet, often feeding voraciously on whatever prey item is seasonally abundant. Unlike the coastal variety, WCT is not highly piscivorous and tends to be an invertebrate specialist, even where forage fish are abundant (Shepard *et al.* 1984). It may be a result of sympatric evolution with the Bull Trout and the Northern Pikeminnow, two highly piscivorous species (Behnke 1992). For young-of-the-year WCT, Chironomid larvae are an important food source. Older juveniles and adults feed both on terrestrial insects and invertebrates; Dipterans (true flies, other than Chironomidae such as crane flies, fruit flies, etc.) and Ephemeropterans (mayflies) are the most important dietary components. Trichopterans (caddisflies) are important for fish

110 mm long or longer (Liknes and Graham 1988). Winged insects are not important in the diets of smaller fish, but the diversity of food items increases with increasing size. For adfluvial forms, zooplankton is an important food source, particularly during winter months (Shepard *et al.* 1984).

The native range of WCT in both DUs has been impacted by invasions of other salmonids, particularly RBT. The impacts have been most significant in Alberta and included hybridization, introgression, competition, predation, and perhaps as vectors and reservoirs of parasites and agents of disease. RBT is the single greatest threat to the continued existence of native WCT populations in Alberta. Trout hatcheries were established as early as 1913 in Banff, Jasper in the early 1920s and Waterton Lakes in 1928. In 1936, the first trout hatchery outside the National Parks was established in Calgary (Nelson and Paetz 1992). All of these hatcheries contributed trout for introduction into the native range of WCT in Alberta (Department of Marine and Fisheries 1914; Nelson and Paetz 1992). When native WCT was unavailable hatchery stocks of RBT were widely distributed onto the depleted WCT subpopulations (The Alberta Westslope Cutthroat Trout Recovery Team 2013). RBT readily hybridize with WCT producing fertile offspring that interbreed with either parental species or themselves. Often this has resulted in a fully introgressed hybrid population called a hybrid swarm.

While genetically pure WCT appears to be competitively superior in colder headwaters (Rasmussen *et al.* 2010, 2012; Yau and Taylor 2013, 2014), it appears to be an inferior competitor to RBT and RBT x WCT hybrids in warmer waters, where RBT and hybrids dominate (Paul and Post 2001; Hitt *et al.* 2003; Rubidge and Taylor 2005; Muhlfeld *et al.* 2009; Rasmussen *et al.* 2010; Yau and Taylor 2013). Preference for colder water temperatures appears to make WCT a superior competitor at higher elevation stream reaches (Griffith 1988; Fausch 1989; Paul and Post 2001). As a result, pure WCT subpopulations are now almost exclusively confined to small, higher elevation headwater streams. The populations are small and isolated from each other, making recolonization unlikely and increasing susceptibility to extirpation from the effects of inbreeding and stochastic events (The Alberta Westslope Cutthroat Trout Recovery Team 2013). In National Parks, most of the native WCT populations only exist in headwater lakes and above barriers or in tributary streams above barriers (The Alberta Westslope Cutthroat Trout Recovery Team 2013). However, Platts (1974) found that WCT densities peaked at a channel gradient of about 10%, which was higher than that for peak densities of Bull Trout, RBT or Brook Trout and may explain WCT persistence in some lower elevation systems.

Yellowstone Cutthroat Trout (YCT-*Oncorhynchus clarkii bouvieri*) also introgressively hybridize with WCT but appear to be less effective in competition with WCT suggesting that the hybrids would be similarly ineffective. In Glacier National Park, Montana, introduced Yellowstone Cutthroat Trout have been unable to replace or significantly hybridize with native WCT in any lake where they are indigenous (The Alberta Westslope Cutthroat Trout Recovery Team 2013). Hybrid subpopulations of WCT and Yellowstone Cutthroat Trout subspecies are primarily found in Banff and Waterton Lakes National Park waters with limited sampling. Outside National Parks Alberta's populations have not been tested to YCT hybridization and therefore the degree to which YCT may be invasive is unknown (Taylor and Gow 2007). To date, no evidence of Yellowstone alleles has been detected in the upper Kootenay or Elk Rivers in British Columbia (G. Wilson, 2016, pers. comm.).

Brook Trout is a non-native invasive species. Some populations have greatly expanded their range in certain watersheds over time, while others have not (Adams *et al.* 2000; Dunham *et al.* 2002; Peterson and Fausch 2003). Brook Trout may displace and often replace, native salmonids especially various subspecies of Cutthroat Trout (Behnke 1992; Stelfox *et al.* 2001; Dunham *et al.* 2002; Peterson *et al.* 2004; Peterson *et al.* 2008). In the past, the mechanism was often related to differential susceptibility of native WCT to harvest as they are particularly catchable by anglers (Stelfox *et al.* 2001; Dunham *et al.* 2002, Paul *et al.* 2003). Displacement mechanisms involve competition effects from Brook Trout on survival of WCT at early life-history stages, and high immigration from established Brook Trout populations, typically situated downstream (Adams *et al.* 2000; Dunham *et al.* 2002; Shepard *et al.* 2002; Peterson *et al.* 2004), but also from populations stocked into headwater lakes (Adams *et al.* 2001). Brook Trout has a competitive advantage over WCT at warmer temperatures and matures earlier in life (De Staso and Rahel 1994). Brook Trout can be very difficult to eradicate, but where successful has resulted in greatly increased numbers of native WCT (Shepard *et al.* 2002; Dunham *et al.* 2002). Brook Trout populations are a serious threat to the long-term viability of WCT within its native range in both DUs.

Brown Trout (*Salmo trutta*) is another invasive species that has replaced WCT in certain native habitats, primarily in Alberta's lower gradient, larger, and warmer main stem rivers where they are mostly established (The Alberta Westslope Cutthroat Trout Recovery Team 2013). The mechanism for displacement is not clear but it has been proposed that competition between early life stages for habitat (Griffith and Smith 1993) and aggressive behaviour by juvenile Brown Trout during interactions with juvenile WCT are factors (Wang and White 1994). WCT is also much more susceptible to angling than Brown Trout where they co-exist (Behnke 1992).

Lake Trout (*Salvelinus namaycush*) is native to parts of both Saskatchewan-Nelson Rivers and Pacific DUs but has also been introduced into lakes and reservoirs in native WCT range. Lake Trout is believed to be native in headwater lakes of the South Saskatchewan River drainage including Waterton Lake and Lake Minnewanka (Donald and Alger 1993). It has migrated down the Bow River and colonized the Ghost and Bearspaw Reservoirs and was stocked into the Ghost Reservoir between 1948 and 1952 (The Alberta Westslope Cutthroat Trout Recovery Team 2013). Lake Trout was also introduced into Bow, Hector and Crowsnest Lakes and Spray Lakes Reservoir between 1951 and 1987. Bow and Hector lakes are important headwater systems in Banff National Park that previously supported robust adfluvial WCT populations (S. Humphries pers. comm. 2016). Lake Trout are now spreading further in the Oldman watershed into the Castle and Carbondale rivers. In lakes and reservoirs where Lake Trout has been introduced, native species including WCT have declined substantially or been extirpated (The Alberta Westslope Cutthroat Trout Recovery Team 2013). In British Columbia, Lake Trout is a serious threat to WCT in the Flathead River where it exists as an introduced population in Flathead Lake (H. Lamson 2016 pers. comm.). Once a WCT population is replaced by another salmonid species, it appears unlikely that it is able to repopulate its niche (Moyle and Vondracek 1985).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

WCT subpopulations in Alberta now exist primarily in small, fragmented and widely distributed streams that are often difficult to access. As a consequence, few standardized monitoring programs have been conducted to determine population abundance. Distribution data are primarily available from observed instances of the species in a specific system. However, since the recommendation for a Threatened listing in 2006, genetic sampling has been conducted in the Bow and Oldman River drainages to delineate the distribution and genetic status of WCT subpopulations; catch-per-unit-effort statistics have been generated for some sampled subpopulations; abundance estimates have been conducted at several sites using removal-depletion or mark-recapture methods; and surveys have been conducted at a subset of streams to locate barriers to upstream fish passage, particularly where they prevent upstream migration of non-native species (The Alberta Westslope Cutthroat Trout Recovery Team 2013). More recent sampling in 2014-2016 will provide more detailed estimates when the information is fully analyzed.

Population abundance data for WCT is more broadly available in British Columbia. Abundance estimates for some high priority streams have been collected in the East Kootenays, specifically streams in the Upper Kootenay and Elk River watersheds including the Elk main stem, Wigwam, Michel, St. Mary, White, Skookumchuck, and Bull Rivers (British Columbia Ministry of Environment 2014). Higher abundance and densities were evident in the warmer, more productive sections of the rivers as well as larger fish. Hagen and Baxter (2009) used catch data to infer an unfished equilibrium of about 45 fish/km (> 30 cm), from systems that are almost entirely catch and release. Obtaining estimates of abundance is costly and requires knowledge of subpopulation structure. As a result, British Columbia has focused more effort on estimators of abundance (e.g., fish per kilometre) or alternatives like mortality (i.e. catch and release related mortality) to assess abundance trends (British Columbia Ministry of Environment 2014). However, snorkel mark-recapture surveys have been conducted at a number of index sites for several popular WCT streams to estimate abundance and densities and these are fairly efficient (snorkellers are able to observe most fish) for adult and sub-adult WCT (Baxter, 2006; Hagen and Baxter 2009; Cope and Prince 2012; Cope *et al.* 2013; Heidt 2015) and standard error estimates are low (~10%). Estimates of fish/km are more variable and lower (~30 fish/km) than those based on catch data alone (Cope *et al.* 2013).

Abundance Fluctuation and Trends

<u>Saskatchewan-Nelson Rivers DU</u>

In Alberta, outside the National Parks, a total of 274 streams are believed historically to have contained native subpopulations of WCT and only 51 (19%) remain with apparently pure strains (Figure 5, The Alberta WCT Recovery Team 2013). Population estimates are available for 38 of these 51 streams (Table 4). These stream sections containing pure strain Westslope Cutthroat Trout range in length from a few hundred metre tributaries to 45 km of the upper Oldman River. The sum of the individual population estimates for these streams is approximately 40,000 mature individuals (Table 4). In addition, Banff National Park contains three stream sections and two lakes containing WCT, with crude population estimates in the order of hundreds each (Table 5). Recent rates of decline of WCT in the Saskatchewan-Nelson Rivers DU (since 2000, i.e. within the last three generations) are not known, but they have been in decline since the early decades of the twentieth century. The declines were initially largely due to exploitation, but more recently are a result of competition and introgressive hybridization with introduced species, primarily RBT.

Table 4. Summary of estimated numbers of mature Westslope Cutthroat Trout (>153 mm Fork Length)[1] for a subset of pure populations in Alberta outside National Parks in the Saskatchewan-Nelson Rivers DU. The estimates are based on first pass electrofishing data from 2006-2012 and a mean catchability correction of 44% from Alberta Conservation Association electrofishing of WCT streams. The estimates only include fish in occupied "Critical Habitat" reaches designated under the Federal Recovery Strategy. In summary, 28 of 38 (74%) subpopulations are estimated to be smaller than the 470 adults minimum viable population estimate from Mayhood and Taylor (2011). This is unpublished data provided by Jennifer Earle, Alberta Environment and Parks, Canmore, Alberta.

Subpopulation	Critical Habitat Length (m)	Number of Sites (~ 300 m)	Estimate of Number of Mature WSCT[1]	Bootstrapped Confidence Interval
Unnamed trib to Flat Creek	5,166	1	0	n/a
Unnamed trib to Gardiner Creek	250	1	6	n/a
South Todd Creek	234	1	11	n/a
Unnamed trib to Blairmore Creek	259	1	18	n/a
Mockingbird Creek	3,000	3	36	0-85
Unnamed trib to Jumping Pound	1,615	1	37	n/a
Girardi Creek	2,044	4	43	12-80
Syncline Brook	2,862	2	54	n/a
Star Creek	1,282	2	58	n/a
Silvester Creek	4,084	3	81	0-150
Allison Creek	3,110	1	94	n/a
Carbondale River	3,846	3	94	n/a
Vicary Creek	1,127	1	101	n/a
Speers Creek	3,437	3	104	0-208
Deep Creek	4,156	3	121	0-236
Sharples Creek	251	1	121	n/a
O'Haggen Creek	2,808	2	128	n/a
Rock Creek	776	1	135	n/a
North Lost Creek	5,549	2	143	n/a

Subpopulation	Critical Habitat Length (m)	Number of Sites (~ 300 m)	Estimate of Number of Mature WSCT[1]	Bootstrapped Confidence Interval
Gardiner Creek	1,586	3	156	132-191
Zephyr Creek	4,264	1	174	n/a
Beaver Creek	1,755	1	186	n/a
Corral Creek	2,890	1	266	n/a
Evan-Thomas Creek	4,002	2	268	n/a
Unnamed 'Cutthroat' Creek	4,127	2	318	n/a
Unnamed Trib To Todd Creek	1,288	1	374	n/a
South Castle River	8,858	2	463	n/a
Hidden Creek	12,344	16	723	399-1,086
Prairie and Trail Creeks	14,076	18	625	527-970
Waiparous Creek	38,872	51	783	491-1,103
West Castle River	8,257	2	1,157	n/a
Gorge Creek	6,871	2	1,197	n/a
Gold Creek	16,741	9	1,818	788-3,257
Livingstone River	22,479	15	2,031	1,196-3,069
White Creek	5,320	3	3,070	2,273-3,869
Lynx Creek	25,078	15	4,638	1,959-7,166
Racehorse Creek	37,560	7	6,749	2,729-11,428
Oldman River	44,984	26	14,033	6,059-22,476
Total			40,414	21,968-60,777

[1] the fork length (>153 mm) used to estimate number of mature fish is taken from the Government of Alberta's Fish Sustainability Index for WSCT and is most applicable to stream-resident populations. It would therefore result in an overestimate of the number of mature fish, especially in the larger riverine populations such as in the Oldman River drainage.

Table 5. Estimated population sizes of mature Westslope Cutthroat Trout in Banff National Park (Banff-Lake Louise unit) in the Saskatchewan-Nelson Rivers DU. Data provided by Shelley Humphries, Aquatics Specialist - Banff, Yoho and Kootenay National Parks, and represents subpopulations in the Banff-Lake Louise portion of WCT range.

Subpopulation	Stream Length (m) or Lake Area (ha)	Estimate of Number of Mature WCT
Upper Bow River	14,500 m	< 100
Outlet Creek	1,500 m	125
Babel Creek	1,500 m	< 125

Subpopulation	Stream Length (m) or Lake Area (ha)	Estimate of Number of Mature WCT
Little Fish Lake	3.7 ha	> 100
Big Fish Lake	13.7 ha	> 100

Habitat degradation and the stocking of non-native species in Alberta has led to the displacement of WCT from many areas and hybridization of several remaining native subpopulations (Carl and Stelfox 1989; Strobeck 1994). Westslope Cutthroat Trout has disappeared from an estimated 30% of its historical range in Banff National Park (Schindler and Pacas 1996) and now occupies less than 5% of the native range in the Bow River drainage. Several WCT subpopulations are severely depressed or extirpated: Quirk, Bragg, Lesueur, Meadow, Sullivan, Loomis, Flat, Odlum, McPhail, Carnarvon, Pekisko, Ware, Threepoint, Fisher, Fish, and Jumpingpound creeks (COSEWIC 2006).

Quirk Creek is in the Elbow River drainage (Bow River drainage) in southwestern Alberta and the focus of a WCT population study between 1995 and 2002. It supported only native Bull Trout and WCT prior to the introduction of Brook Trout to the Elbow River watershed in 1940 (Stelfox *et al.* 2001). A 1948 fisheries survey found no Brook Trout in Quirk Creek, but by 1978, it had colonized the lower 3 km of the creek and comprised 35% of the fish population (Tripp *et al.* 1979). Electrofishing surveys in 1987 were still dominated by native WCT and Bull Trout, but by 1995, Brook Trout had spread throughout the creek and comprised ~92% of the fish population. Despite the selective harvest of Brook Trout since 1998 (Stelfox *et al.* 2001) the composition of fish in Quirk Creek remained fairly stable from 1995 to 2002 with an average of 83% Brook Trout, 15% WCT and 2% Bull Trout (Paul 2003). A similar trend is evident in Fish Creek (also in the Bow River drainage), which historically supported a significant WCT fishery. In 1915, the Department of Naval Science reported that the value of Fish Creek's native trout fishery was nearly eight times that of the Bow River (Baayens and Brewin 1999). Recent surveys found that the WCT subpopulation has declined greatly since with estimates for introduced Brook Trout at 211 fish/km, introduced RBT at 59 fish/km and native WCT at only 4 fish/km in the spring of 1993 (Baayens and Brewin 1999). It is a pattern common throughout the region.

In areas stocked with RBT, WCT are more subject to hybridization than to displacement. For example, population estimates of the Gorge Creek WCT population (Sheep River drainage) were approximately 800 fish/mile (1287 fish/km) in 1949 (Andrekson 1949). RBT were introduced into Gorge Creek in 1941 and hybrids are now present in that population (Janowicz 2004). Introduced Brook Trout and RBT appear to prefer lower elevation main stem stream reaches (Paul and Post 2001; Hitt *et al.* 2003; Rasmussen *et al.* 2010). For this reason, many remaining genetically pure WCT populations are present in small, isolated headwater populations (Donald 1987; Hilderbrand and Kershner 2000b; Dunham *et al.* 2002).

The status of many WCT populations in Banff National Park is unclear. Early in the last century, WCT was plentiful in Banff National Park and recorded in a number of systems. However, surveys of the Bow River main stem through Banff National Park during the 1990s found very few WCT between Redearth Creek and Forty Mile Creek. Brook Trout are now common in the area and the few WCT observed appeared to be WCT x RBT hybrids (COSEWIC 2006). Hybridization of WCT and RBT is also evident in several lakes (Landry *et al.* 2000; Potvin *et al.* 2003). More recent survey and genetic analysis indicates that fewer populations exist than previously believed (COSEWIC 2006) and that introgression is widespread (Taylor and Gow 2009). It appears that only 10 sites with pure WCT populations now exist in Banff (4 lakes and 6 streams or small river segments approximately 30 km in combined length). Ongoing research to resolve historical presence includes coring of some lakes, use of SNPs to better resolve genetic issues, and four restoration projects (Sawback Creek, Cascade Creek, Rainbow Lake and Hidden Lake) (S. Humphries pers. comm. 2016).

Pacific DU

At present, an estimated 928 to 1319 (if stocked systems included) streams and lakes in the native range may contain WCT populations (British Columbia Ministry of Environment 2014). As in Alberta, the situation is complicated by the extent of introgression by RBT genes because a significant portion of the observed individuals may be progeny of introduced fish from adjacent locations. Of the 928 waterbodies where no stocking records for WCT exist, 94 have received hatchery RBT at least once, and seven have received hatchery Cutthroat Trout. Another 297 streams or lakes within the native range of WCT were stocked with WCT at least once since 1923, although many may have originally contained native WCT populations as well (British Columbia Ministry of Environment 2014, Table 3). Estimating abundance and trends over time for the DU as a whole is difficult. Applying the Alberta estimate of 100 fish/stream (~12 fish/km) is very conservative for British Columbia where abundance averaged ~30 fish/km for WCT >30 cm from snorkel surveys in some Kootenay systems (Cope *et al.* 2013; also see British Columbia Ministry of Environment 2014, Appendix 5). Estimates of adult WCT (>30 cm) for the upper Bull River using mark-recapture methods indicated a stable population of about 1000 fish during 2003-2005 in a 17.7 km segment (Baxter 2006). A similar snorkel-based mark-recapture study of a 50 km stretch of the upper Fording River during 2012-2013 estimated about 3000 WCT >20 cm (Cope *et al.* 2014). Additionally, snorkel surveys of sections of Michel Creek, Wigwam and St. Mary Rivers were conducted in 2008 and were comparable to previous estimates in 2001/2002 for Wigwam and to the early 1980s for St. Mary (Hagen and Baxter 2009). Indications from these studies suggest that adult populations of WCT are stable. More recent surveys have also been conducted on the upper St. Mary, White, and Skookumchuck systems (Heidt 2015). Applying the Alberta estimate of 100 fish/subpopulation to British Columbia systems indicates the presence of a minimum of 92,800 WCT.

Fluvial populations in large rivers also appear to be stable based on creel surveys but were being subjected to increasing fishing pressure and hybridization (Rubidge *et al.* 2001; COSEWIC 2006). Many WCT subpopulations were overexploited in British Columbia from the 1960s to the 1980s leading to dramatic declines (Heidt 2002). River closures and more restrictive recreational fishing regulations were implemented in the 1980s and by the 1990s many systems had recovered resulting in renewed increase in angling pressure. In response, a new river classification system was adopted in 2004 and seven East Kootenay quality waters and their tributaries (Bull River, Elk River, Skookumchuck Creek, St. Mary River, Upper Kootenay River, White River and Wigwam River) were listed as Class II waters in April of 2005 requiring additional licensing (Heidt 2014). The result has been an increased angler catch per unit effort and general satisfaction in the fishing experience (Heidt 2014). Concerns remain regarding incidental hooking mortality and a modest level of non-compliance and illegal fishing.

In the upper Kootenay River watershed, many subpopulations have been adversely impacted by hybridization with RBT introduced to supply recreational fishing demand. Hybridization with introduced RBT was reported in 78% of the 23 streams genetically tested in the area (Rubidge 2003). The Lodgepole Creek subpopulation (tributary of the Wigwam River in the Elk River drainage) has experienced advanced hybridization (37.5% heterospecific alleles) and may have formed a hybrid swarm. Hybrid swarms have been shown to occur between WCT and RBT in as little as five generations (Hitt 2002) and pose a critical risk to the remaining WCT populations throughout their range. Introgression appears to be spreading throughout the lower reaches of systems nearest the Koocanusa Reservoir, where an RBT stocking program existed in British Columbia from 1986 to 1998 but continues in the United States (Rubidge *et al.* 2001; Rubidge and Taylor 2004, 2005). Indications are that many of the remaining WCT subpopulations are increasingly restricted to isolated headwater streams above barriers where they are susceptible to stochastic extinction events such as rockslides or drought (Dunham *et al.* 2002; Peterson *et al.* 2013). Finally, ongoing genetic surveys of watersheds in the Kootenay River using new genetic techniques are being conducted to assess the prevalence of RBT genes in these populations (G. Wilson 2016, pers. comm.).

Rescue Effect

The impacts of hybridization and introgression of WCT with RBT in many of the mainstem reaches of watersheds throughout the native range in both DUs has led to the fragmentation of WCT habitat and largely restricted the remaining subpopulations to the headwater streams and tributaries (Hitt *et al.* 2003; Taylor *et al.* 2003; Rubidge and Taylor 2005; Rasmussen *et al.* 2010). The fragmentation of much of the remaining WCT habitat makes it very unlikely that extirpated subpopulations could be recolonized from other systems. WCT is also subject to predation and negative interactions with other salmonids. Its well-developed natal homing suggests high levels of demographic independence among adjacent subpopulations so that declining or extirpated subpopulations are unlikely to be recolonized over the short term. In fact, experience has demonstrated that once WCT are removed from a system they rarely reclaim the niche that has become dominated by another salmonid invader (Dunham *et al.* 2002; The Alberta Westslope Cutthroat Trout Recovery Team 2013).

Severe Fragmentation

Subpopulations of Westslope Cutthroat Trout in the Saskatchewan-Nelson River DU are severely fragmented with more than 50% of patches too small to be viable in the long term and separated further than the species would be expected to disperse. The majority of the 51 subpopulations, 28 out of 38 (74 %) of the populations for which we have data, have lower confidence intervals of the population estimates below the abundance that has been calculated to provide minimum viable populations for persistence, estimated to be 470 individuals (Mahood and Taylor 2011). To attain a density likely to result in a high probability of long term persistence, an MVP of 4600 mature individuals (Mahood and Taylor 2011) is observed in only a single Alberta subpopulation, the Oldman River (Table 4). It is likely that small subpopulations of Cutthroat Trout can persist naturally for the long term only if they are connected through migratory pathways. This is not likely the case in the present day in the East Slopes of the Rocky Mountains in Alberta due to the extreme extent of anthropogenically fragmented stream network. The subpopulations of Westslope Cutthroat Trout in the Pacific DU are not considered to be severely fragmented because abundance is on average much greater than in Alberta, and there are many more subpopulations distributed across southeastern British Columbia.

THREATS AND LIMITING FACTORS

A number of factors appear to be limiting the abundance of WCT in Canada: these are primarily habitat alteration and fragmentation, past overharvesting, and the introduction of non-native species and genotypes through inappropriate stocking practices (**Appendix 1, 2**). Dramatic declines in WCT subpopulations over the last century indicate that the greatest threat to WCT has been the anthropogenic manipulation and degradation of its environment (Allendorf and Leary 1988; Liknes and Graham 1988; Slaney *et al.* 1996; Johnson *et al.* 1999; Shepard *et al.* 2003). WCT possesses biological characteristics that make it susceptible to a variety of threats. It typically inhabits cold waters with limited productivity, making it historically subject to thermal and physical isolation (Behnke 2002). Subpopulations are typically small rendering them vulnerable to stochastic events such as epizootics or catastrophic environmental change (e.g., drought, earthquakes, landslides). The small effective population sizes typical of the species may predispose it to inbreeding and loss of genetic diversity (Amos and Harwood 1998; Vucetich and Waite 2001).

Introductions, Hybridization, Introgression, and Outbreeding

Hybridization is the interbreeding of individuals from genetically distinct stocks of the same taxon. Possibly the greatest threat facing native populations of WCT in Canada is the harmful effect of introductions of hatchery-origin salmonids. The hatchery production of salmonids has been a common response to declining fish populations and the desire to provide fishing opportunities. However, it is evident that hatchery fish have been routinely stocked without an assessment of the effectiveness of the transfer, or the impacts on wild populations. In the United States, introduction of non-native species is the primary cause of decline in several inland subspecies of Cutthroat Trout (Dunham *et al.* 2002). Depending on the species, introduction of hatchery-origin salmonids results in both genetic (e.g., hybridization, outbreeding depression), and ecological impacts (e.g., displacement, competition, disease) on native WCT populations.

WCT is subject to introgressive hybridization when closely related species (RBT, other Cutthroat Trout subspecies) are introduced into their range. Several factors contribute to the breakdown in species barriers. RBT and the various interior subspecies of Cutthroat Trout have evolved in relative isolation from one another (Behnke 2002). Therefore, only weak behavioural isolating mechanisms have evolved to separate the different species and the similarity in chromosome number allows for fertile crosses between species (Thorgaard 1983; Allendorf and Leary 1988).

Of the non-native salmonids in these DUs, RBT and Yellowstone Cutthroat Trout are a threat to WCT because of their ability to freely hybridize producing offspring that themselves can successfully interbreed with the parental groups and among themselves. This type of hybridization is termed introgression. It eventually results in the complete mixing of the genetic material of the two distinct organisms (Mayhood 2009). In fish, hybridization between distinct species and subspecies often produces inter-fertile offspring, leading in many cases to complete introgression and the formation of hybrid swarms. The effect of introgressive hybridization is to create a single new taxon where once there were two, while the parental forms become extinct (Leary *et al.* 1995). For WCT in both DUs hybridization occurs only because a nonnative form (generally hatchery RBT) has been introduced into the habitat of native WCT. The loss of the non-native hatchery stock in any habitat is not critical, but the loss of the limited native subpopulations is catastrophic.

Each individual subpopulation of WCT tends to be unique, with genetic characteristics not present even in nearby populations. It is the result of fish living in the highly subdivided habitats provided by stream networks that isolate subpopulations allowing them to diverge. In small subpopulations random genetic drift, accompanied by inbreeding, produces differences among isolated subpopulations (Mayhood 2009). WCT subpopulations have become uniquely adapted to the environments they occupy, evolving co-adapted gene complexes in the process (Allendorf and Leary 1988). Genetically based local adaptation is typical of salmonids including Cutthroat Trout (Bowler 1975). Indirect evidence of local adaptation is reflected by superior growth and survival of WCT relative to introduced species. Repeated introductions of non-native Yellowstone Cutthroat Trout into native WCT range in Glacier National Park, Montana, consistently failed over a period of many decades (Mayhood 2009). In the West Kootenay area WCT subpopulations above waterfalls, possess a strong upstream swimming response as fry and young juveniles, an adaptation that maintains WCT above impassable barriers (Mayhood 2009). Introgressive hybridization disrupts local adaptations and co-adapted gene complexes, reducing population fitness. When genetically divergent genomes such as WCT and either RBT or Yellowstone Cutthroat Trout hybridize, intermediate or reduced fitness (outbreeding depression) is the expected result (Leary *et al.* 1995). Although artificially produced hybrids of RBT and WCT had higher fertilization and hatching success than pure WCT parents, hybrids had reduced fitness showing poorer growth and post-hatching survival (Leary *et al.* 1995). Similarly, Muhlfeld *et al.* (2009) found that even a 20 percent introduction of RBT alleles reduced reproductive success of WCT trout males and females by about 50 percent. Bear *et al.* (2007) found evidence of selection against WCT X RBT hybrids during development, with only 3% survival. However, hybrids are clearly fit and able to survive under a range of conditions (Ferguson *et al.* 1985, 1988; Rubidge and Taylor 2004).

RBT and Yellowstone Cutthroat Trout introductions have resulted in significant levels of introgressive hybridization throughout the historical range of WCT (Leary *et al.* 1984; Leary *et al.* 1987; Allendorf and Leary 1988, Hitt *et al.* 2003). Less than 29% of occupied habitats in the United States now support subpopulations at or near the habitat's potential capacity. Genetic studies indicate that WCT subpopulations are genetically pure in less than 8% of the United States historical range (Shepard *et al.* 2003). Hybrid swarms between RBT and WCT have been documented in both the Saskatchewan-Nelson Rivers and Pacific DUs (Rubidge 2003; Janowicz 2004, Boyer *et al.* 2008) and levels of introgression appear to be spreading rapidly upstream from mainstem rivers (Hitt *et al.* 2003; Rubidge 2003; Weigel *et al.* 2002; Janowicz 2004, Boyer *et al.* 2008). However, spread of hybridization into higher elevation sites may be impeded by natural physical or ecological barriers including temperature and elevation (Paul and Post 2001; Weigel *et al.* 2002; Hitt *et al.* 2003; Rubidge and Taylor 2005; Rasmussen *et al.* 2010, 2012; Corsi *et al.* 2013; Yau and Taylor 2013, 2014). Given the expected long-term increase in climate warming, genetically pure WCT subpopulations will likely increasingly be restricted to isolated headwater streams and susceptible to extirpation.

Outbreeding depression refers to the reduced fitness of progeny produced from individuals from different populations. WCT produced in hatcheries in both British Columbia and Saskatchewan-Nelson Rivers DUs to 'supplement' native production have not considered impacts on locally adapted biodiversity and little effort has been made to use local stocks. British Columbia has relied on a single source (Connor Lake) of WCT for all stockings in the past three decades. Most of the hatchery production in Alberta uses eggs from Job Lake. In other salmonid species, such programs have resulted in increased straying and homogenization of genetic population structure, as well as genetic swamping, outbreeding depression and resulting reduced fitness (Rhymer and Simberloff 1996, Allendorf *et al.* 2001). Because significant genetic substructure exists within WCT, even greater impacts in genetic homogenization and outbreeding depression are occurring. Limited evaluation of this effect has occurred for WCT (but see Seiler and Keeley 2007a, b, 2009), and information available to determine how many native subpopulations have been supplemented with hatchery WCT is incomplete. The long-term impact of ongoing and historical stocking on viability of WCT remains an ongoing threat.

Saskatchewan-Nelson Rivers DU

McAllister *et al.* (1981) conducted an early study of morphological and biochemical variation in WCT from Banff National Park (10 lakes), Kootenay National Park (Floe Lake), Waterton Lakes National Park (Sofa Creek), and Connor Lakes in British Columbia. Ten of the 13 sites contained pure WCT while two sites contained WCT x Yellowstone Cutthroat Trout hybrids (Baker Lake (BNP) and Sofa Lake (WLNP)) and a third, Taylor Lake (BNP), contained a pure introduced subpopulation of Yellowstone Cutthroat Trout. Hybridization with RBT was not evident from morphological and allozyme markers but they had limited resolution to detect RBT introgression and all samples were collected from alpine systems (elevation > 2000m) that were expected to contain pure WCT subpopulations. Stocking of non-native species in the sampled subpopulations was assumed minimal or non-existent.

Recent genetic testing indicates that hybridization is widespread in the eastern slopes of the Rocky Mountains. Janowicz (2004) detected hybridized subpopulations in 13 of 14 watersheds sampled. Hybridization within watersheds ranged from 100% of sampled creeks in Ram River (North Saskatchewan drainage) and Sheep River (South Saskatchewan drainage) to 22% in the Kananaskis River. The Elbow River watershed was the only system where hybridization was not detected. Extent of hybridization within streams varied from one or a few hybrid individuals to those where more than 80% were of hybrid origin. Many subpopulations exhibited highly mixed genotypes (more than 50% with heterospecific alleles) indicating that hybridization was moving towards hybrid swarms in these creeks.

Pacific DU

A recent survey of some watersheds in the DU indicates that the Flathead, west Kootenay, south Thompson, and much of the Columbia are largely pure subpopulations of WCT (British Columbia Ministry of Environment. 2014). Of the 88 waterbodies assessed, those in the upper Kootenay River drainage, the Elk drainage, and the Kettle River were found to be extensively introgressed with introduced RBT. Earlier, Leary *et al.* (1987) had detected approximately 5% hybridization within the White River watershed (tributary of the upper Kootenay River). It has spread to the lower reaches of seven other tributaries including Wild Horse, Mather, Skookumchuk, and Gold creeks, as well as the Elk, St. Mary and Lussier Rivers (Rubidge 2003). In the United States, Hitt *et al.* (2003) reported increases in the number of introgressed subpopulations in the upper Flathead drainage (24 of 42 sites (57%), seven more than a 1984 study). Hybridization appeared to be spreading upstream from the site of most RBT introductions: Lake Koocanusa and Flathead Lake, respectively. Evidence from these and other areas indicates that the spread of hybridization is largely a function of the distance from the nearest stocking site (Hitt *et al.* 2003; Taylor *et al.* 2003; Rubidge *et al.* 2005; Boyer *et al.* 2008; Muhlfeld *et al.* 2009) and may not be prevented by ecological gradients (except impassible upstream barriers).

Habitat Loss

Timber extraction (Elk, Flathead, White, Upper St. Mary rivers), mining (Upper Fording and Elk rivers), and hydroelectric developments are ongoing threats to WCT habitat in the Pacific DU. In Alberta, they have been responsible for loss and degradation of WCT habitat and the decline of numerous subpopulations (e.g., Bow, Oldman, , Spray and Kananaskis Rivers). Road networks associated with primary resource extraction have encroached upon a multitude of streams requiring culverts or other alteration such as stream-bed redirection in both DUs. Easier road access has also led to an explosion of angling and recreational activities (e.g. ATV use) that further degrade sensitive habitats.

Oliver (2009) evaluated logging impacts in the upper Kootenay and Columbia Rivers in British Columbia concluding that harvest effects are variable in terms of changes to peak flow but have largely occurred within acceptable levels without producing large imbalances in hydrologic stability. Any effects may be most evident at the sub-basin scale but evidently where riparian buffers were provided, summer temperatures were not elevated. Impacts to riparian habitats are mostly residual based on practices prior to 1996 when the Forest Practices Code was instituted in British Columbia (British Columbia Ministry of Environment 2014). Some ongoing concerns persist related to small WCT streams where salvage logging, ongoing sedimentation, and inadequate riparian buffers are issues in the lower Columbia. Similar impacts have been recorded in Alberta (Mayhood 2009).

In the Pacific DU, coal mining is a major concern while mineral mines within the WCT range are small-scale operations and relatively benign (Oliver 2009). Impacts are primarily physical and chemical impacting upstream fish passage, resulting in habitat loss, and increasing water nutrification and contamination. Coal extraction and selenium introduction into the aquatic environment is a concern in the Elk Valley (British Columbia Ministry of Environment 2014). Selenium has been linked to defects in reproduction and growth, and mortality and deformity in WCT (summarized in Oliver 2009; also see Lemly 2014). However, studies in the Elk Valley have been inconclusive in terms of population-level impacts to WCT although selenium levels throughout the ecosystem exceed safe guidelines in the upper Fording River (Cope *et al.* 2014). In some tributaries of the Elk River entire headwater reaches have been disrupted and the subpopulations fragmented by rock drains. It is probable that these headwater reaches contain valuable genetically pure subpopulations. The Elk Valley Water Quality Plan has been developed to address some of these issues (Teck 2014). Large areas of the Flathead River and Elk River basins, two of the main WCT river systems in British Columbia, are also under consideration for future coal bed methane development and negative impacts on WCT (Campbell and Rutherford 2006).

Agriculture in the Pacific DU is focused on hay production and cattle, and follows irrigation water licence distribution along the valley bottoms in the Elk, Kootenay, Upper Columbia, Slocan, Kettle, and Shuswap Rivers (Oliver 2009). Water extraction for irrigation during the summer months is a significant issue within the native range of WCT as storage facilities are limited or non-existent, so water removal is on an as-needed basis (Oliver 2009). Smaller streams with naturally low summer base flows are most vulnerable during July and August, particularly in the dry southern interior sections of the Upper Kootenay. Riparian habitat damage is another significant concern in much of the core range where cattle are able to access small (possibly important spawning) streams, leading to sedimentation and increased water temperatures. Nutrient loading associated with feedlot runoff may occur in some instances (Oliver 2009) and it is possible that increased nutrient levels may benefit introduced RBT in the area. Habitat degradation and sedimentation due to cattle grazing is also a concern in the Saskatchewan-Nelson Rivers DU (Mayhood 2009).

Road construction can impact fish passage at stream crossings and increases access to vulnerable subpopulations. While new road development is sensitive to fish passage and standards now minimize impacts, a number of railway crossings (e.g., in the Elk Valley) that have been in place for years are a concern (Oliver 2009). A recent analysis indicates that 50% or more of culverts would likely present a fish barrier (British Columbia Ministry of Environment 2014). Road density, perhaps reflecting development activity appears to be an indicator of WCT abundance. A significant negative relationship was observed between WCT density and cumulative effects of forestry-related activities as measured by road density, roads on erodible soils, roads within near-stream zones, and two measures of logging to the stream bank (Valdal and Quinn 2011). The study examined fish abundance data collected between 1996 and 2000 via electroshocking for six river basins within the upper Kootenay River. Proximity of roads to streams (i.e. within 100 m of streams) was a significant predictor of abundance, and logging of non-fish bearing perennial and ephemeral streams appears to affect downstream WCT abundance.

Protected areas exist within the range of WCT in Canada, but they are often small and do not encompass all the habitats needed by various life history types such as migratory forms. Although exact movements are unknown for many subpopulations, WCT are adapted to move during moderate to high flow events. Movements often coincide with the rising limb and peak of the hydrograph, allowing passage of seasonal barriers within streams where increased flows are needed to allow access (Brown and MacKay 1995a; Schmetterling 2001). WCT move significant distances to find desired habitat but migration is dependent on the preservation of suitable migration corridors between habitat types. The associated road culverts produce an additional limitation on stream carrying capacity for WCT. Improperly placed and obstructed culverts are common, preventing upstream access to the stream network (Mayhood 2009). The lost habitat is potentially very large if impassable culverts prevent completion of WCT life history. Many culverts are not designed to accommodate fish passage at high flows. The dramatic decline of fluvial WCT subpopulations throughout parts of Alberta is evidence of the importance of migration barriers on those systems (e.g. Mayhood 2009). Loss of the migratory forms is particularly significant, limiting recolonization potential for areas with locally extirpated resident subpopulations. A partial survey of 167 culverts in Banff National Park found that 55 percent were full barriers, 33 percent were partial barriers, and only 12 percent were passable to salmonids (Mayhood 2009). However, in come cases barrier culverts protect remnant stocks from non-native RBT, Brook and Brown Trout.

Urban Development

Urban development affects physical, chemical, and biological aspects of watersheds through encroachment into floodplains, contamination by urban runoff and habitat degradation in both DUs. Stream function is affected by anthropogenic activities resulting in loss of riparian area and in-stream cover elements, stream channelization and modification in runoff pattern (Oliver 2009). The extent of impervious area from the urban footprint contributes to hydrological imbalance from loss of groundwater storage and surface runoff in storm sewer networks. Water quality can be degraded by storm sewer inputs or point source discharges from sewage treatment plants. Effluent discharges increase nutrient levels but may include a variety of natural products, pesticides, pharmaceuticals and industrial chemicals that are found in the effluent of sewage treatment plants and can affect endocrine function in fish and other vertebrates (Oliver 2009). Many of these chemicals mimicking the activities of hormones such as estrogen may adversely affect fish and wildlife reproductive fitness.

Water Use: Permanent Water Withdrawal

Community water use consists of domestic and irrigation licences that allocate water rights to user groups including public utilities and private licences for surface and groundwater supplies (Oliver 2009). Community water supply development that supports storage facilities has profound impacts on in-stream flow and water temperature in downstream areas. For example, Joseph Creek is influenced by water storage in Phillips Reservoir that causes a discontinuity in the natural flow pattern both above and below the reservoir and delays the timing of peak flow, which affects spawning cues and may even prevent upstream migration. In 1998, WCT spawner entry was delayed as much as one month, probably affecting egg development, fry emergence, and winter survival in the following year (Oliver 2009). In addition, lower reaches experienced summer temperatures that exceeded optimum juvenile WCT rearing temperatures, causing stress and potentially reducing survival. Water withdrawal is a serious threat for both DUs.

Hydroelectric Development

Numerous large- and small-scale hydroelectric facilities operate on rivers within the native WCT range in the Saskatchewan-Nelson Rivers and Pacific DUs. Dams block movements of fish both upstream and downstream, transform upstream habitats from running water to standing water, substantially transform flow regimes in downstream habitats, and reduce downstream flows (in the case of irrigation dams and diversion weirs), among many other effects (Mayhood 2009). Reservoirs are often heavily stocked with non-native fishes to replace loss of native stocks and the lower productivity of most such waterbodies (Schindler and Pacas 1996). These effects can severely disrupt fish populations such as native WCT in Alberta. Ten major dam projects now modify native WCT habitat in the Bow River basin with another four in the Oldman (Mayhood 2009). Many smaller dams occur on tributaries in the Oldman and Bow river basins, plus numerous impassible road crossings of streams with similar effects.

In the Pacific DU, the large dams along the Columbia River downstream of Mica Dam impacted historical WCT populations that used main stem or lower tributary habitats while the majority of remaining stocks occur above barrier falls in a number of tributaries that now constitute discrete subpopulations (Oliver 2009). In the East Kootenay, dams are constructed on natural barriers that determined WCT distribution and any downstream effects are minimized. Dams along the lower Kootenay River below Nelson and the Walter Hardman and Whatshan facilities do not overlap WCT distribution. The greatest impact to WCT subpopulations in British Columbia resulted from the building of the Libby Dam in the upper Kootenay River. Prior to establishment of the Koocanusa reservoir, WCT were widely distributed between Wardner and the international border. Following completion of the dam in 1972, WCT have been displaced from much of the historical range (Oliver 2009). Despite stocking efforts on behalf of the Montana Department of Fish, Wildlife and Parks through the 1980s, the accidental introduction of Kokanee to the reservoir altered fish dynamics to the detriment of WCT given competitive interactions with pelagic species (both RBT and Kokanee) dependent upon zooplankton as their principal food supply. Independent Power Producer (IPP) operations tend to be fairly small due to the size and location of the streams used (upper reaches with high gradients) but may pose a threat where fluvial populations occur (Oliver 2009). The most vulnerable season for WCT associated with IPPs may be during overwintering if water is diverted when flows are naturally low at this time (Oliver 2009). Diversion flows reducing residual pool volumes may change temperature regimes leading to icing conditions that restrict already limited habitat. Future dams and diversions within the native WCT habitat pose an ongoing threat in both DUs.

Fishery Harvesting

Early overexploitation was a major factor in the decline and extinction of many local WCT subpopulations in southwestern Alberta (Mayhood 1995, 2000, 2009). Beginning with the arrival of the Canadian Pacific Railway and its construction crews in the early 1880s (Bow River basin) and early 1890s (Oldman River basin), native salmonids were taken in large numbers by every conceivable method, including trapping, netting, liming, explosives and angling; this was in addition to losses from industrial pollution, damming and water diversions. The removal and depletion of stocks and destruction of their habitat in the early decades of European settlement facilitated the establishment of the Yellowstone Cutthroat Trout, RBT, Brook and Brown Trout that were introduced at the time (Mayhood 2009).

The WCT is a popular species targeted by recreational fisheries in western Canada perhaps because they are more easily caught than other species (MacPhee 1966: Paul and Post 2001; Paul 2003). Voracious feeding habits and accessibility in small streams make WCT susceptible to angling (Giger 1972; Varley and Gresswell 1988). Heidt (2002) reports that in a creel survey in the Elk River, WCT made up 94.5% of the estimated total catch of 98,031 fish. Although possibly due to greater relative abundance, it appears that fish may be caught numerous times in a season and often more than once on the same day. In Yellowstone National Park, studies have shown that WCT were caught an average of 9.7 times in a heavily fished catch-and-release section of the Yellowstone River during one 3.5 month fishing season (Schill *et al.* 1986).

Recreational fishing regulations in the Saskatchewan-Nelson Rivers DU for WCT in lakes and streams within the native range are now highly restrictive and confined to catch and release. In addition, catch and release only is permitted in Banff National Park, but it should be noted that release mortality does occur although its magnitude is uncertain.

In British Columbia, recreational fishing for WCT is also now catch and release and no harvest is permitted in Yoho, Kootenay, Mount Revelstoke or Glacier National Parks. Significant guided and tourist recreational fishing occurs in the DU placing ongoing stress on a number of WCT populations (Heidt 2014). The main threat related to angling is catch and release post-hooking mortality and incidental catches in winter fisheries as well as compliance with regulations and poaching. Catch and release is believed to result in low mortality (i.e. < 5%) but cumulative effects of multiple catch and release incidents for individual fish can be significant over a summer season with some WCT in the Elk River being caught 11 times (Mayhood 2009). Hooking mortality associated with a fly and lure caught fish range from 4 to 6% (Wydoski 1979). Significantly higher mortality may occur with warm water temperatures and poor handling by some anglers. Where fishing pressure on WCT populations continues to increase, the risk associated with catch and release mortality may become a greater concern.

The potential for both legal and illegal angling is greater in highly developed watersheds with extensive road and trail development. While this problem is well known (Radford 1977) attempts to have roads decommissioned have been unsuccessful (Mayhood 2009). Roads, trails and other habitat incursions contribute to exploitation and other threats to salmonids. It is believed that many of the threats for WCT in Alberta (overharvest, habitat damage and loss, and their interactions with climate change and species invasions) could be reduced by removing unneeded roads and restoring the right of way to natural conditions (Mayhood 2009).

Ecological Impacts

While it is unclear whether other species of introduced salmonids actively displace or simply replace WCT subpopulations depressed by other factors, introductions of non-native Brook Trout have typically resulted in range constriction or elimination of WCT from large portions of their native habitat (Donald 1987; Fausch 1989; Griffith 1988). Non-native Brook Trout have been stocked throughout much of the WCT native range in British Columbia and Alberta. Brook Trout effectively displaced or replaced WCT in a wide variety of systems (Adams *et al.* 2001, Paul and Post 2001, Dunham *et al.* 2002, Peterson *et al.* 2004), contributing to the present restriction of WCT to mainly isolated higher elevation headwaters (Peterson *et al.* 2013).

Other non-salmonid species have been introduced both by authorized and unauthorized methods in both DUs. In particular, Walleye (*Sander vitreus*), Smallmouth (*Micropterus dolomieui*) and Largemouth Bass (*M. salmoides*), Yellow Perch (*Perca flavescens*), and Northern Pike (*Esox lucius*) have been documented in a number of systems within the native WCT range (COSEWIC 2006). These species are all predatory and have been implicated in salmonid declines in inland waters of the United States (Fuller *et al.* 1999) and pose an ongoing threat to WCT in both DUs.

Whirling Disease

Myxobolus cerebralis is a myxosporean parasite of salmonids (salmon, trout, and charr) that causes whirling disease in farmed salmon and trout and also in wild fish populations. It was first described in Rainbow Trout in Germany a century ago, but its range has spread throughout Europe, and much of the United States particularly in the west. In the 1980s, *M. cerebralis* was found to require a tubificid oligochaete (a kind of segmented worm) to complete its life cycle. The parasite infects its hosts with its cells by piercing them with filaments ejected from nematocyst-like capsules. Whirling disease affects juvenile fish (fingerlings and fry) and causes skeletal deformation and neurological damage. Fish “whirl” forward in a corkscrew-like pattern instead of swimming normally, find feeding difficult, and are more vulnerable to predators. The mortality rate is high for fingerlings, up to 90% of infected populations, and those that do survive are deformed by the parasites residing in their cartilage and bone. They act as a reservoir for the parasite, which is released into water following the fish's death. *M. cerebralis* is one of the most economically important myxozoans in fish, as well as one of the most pathogenic. At this time, there have been 41 reported detections of whirling disease in Alberta: in Banff National Park, in the Bow River watershed in Alberta downstream of BNP, and in several commercial aquaculture facilities (CFIA 2016). This represents a significant threat to WCT populations.

Climate Change

A number of trends associated with a changing climate are relevant to WCT in both DUs. Snowmelt-driven systems are experiencing earlier runoff followed by longer and drier summers that are resulting in reductions of summer baseflows as a percentage of the mean annual discharge in both southern British Columbia and Alberta drainages (Oliver 2009, Mayhood 2009). Together with increasing water demands this could be catastrophic for WCT in small streams where naturally dry conditions already exist. Accompanying the lower flows is increased water temperature, reduced oxygen level, reduced riffle habitat, and in winter, conditions that produce increased physiological stress and mortalities. The flow-sensitive streams impacted by summer water diversions (irrigation demand) exist in a few key areas: the Central Columbia Mountains, Southern Columbia Mountains, Selkirk Foothills, Southern Purcell Mountains, McGillivray Range, East Kootenay Trench, Eastern Purcell Mountains, Flathead Valley, and Elk Valley (R. Ptolemy pers. comm. 2016).

WCT usually occur at water temperatures less than 16°C for all life history stages (Behnke 1992; McIntyre and Rieman 1995) and the 'critical thermal maximum' for WCT of 27°C is lower than those estimated for Brook Trout and RBT: 29.8°C and 31.6°C, respectively (Feldmuth and Eriksen 1978 cited in McIntyre and Rieman 1995; also see Rasmussen *et al.* 2012; Yau and Taylor 2014). Therefore, increasing water temperatures may give non-native fish a competitive advantage over WCT in marginal habitats (Muhlfeld *et al.* 2014). Analysis of daily average temperatures between 1895 to 1995 found that the Southern Interior Mountain region (containing core WCT distribution in British Columbia) has increased average summer temperatures of 1.2°C (British Columbia Ministry of Environment 2006). Climate change models suggest that mean air temperatures in the Columbia Basin could increase by 1.8-2.7°C or more by 2050 (Murdock and Sobie 2013). In the Rocky Mountain region, it has been estimated that an increase of as little as 1°C in mean July air temperatures would reduce the geographic area of suitable salmonid habitat by 16.8%, and a 5°C increase in mean air temperature would reduce the amount of habitat by 71.8% (Keleher and Rahel 1996).

Increasing temperatures are partly responsible for the extensive infestations of Mountain Pine Beetle (*Dendroctonus ponderosae*) in British Columbia that are expected to affect streambed substrate composition (including sedimentation), channel morphology, LWD presence and water temperatures thereby impacting some WCT habitat. Longer term changes to precipitation pattern, hydrology, stream morphology, and glaciers which provide summer flows in many important WCT streams such as the Bow, Bull, White and Upper Kootenay Rivers are also expected (Oliver 2009; Murdock and Sobie 2013).

Warming climate is expected to increase the frequency, intensity and extent of wildfires, increase drought frequency, and enable outbreaks of Mountain Pine Beetle infestations in Alberta (Mayhood 2009). Increased runoff and soil erosion from affected watersheds superimposed on forest management practices are already contributing to these effects. The salvage log policy to pre-emptively remove beetle-infested lodgepole pine on Alberta's east slopes will likely result in increased peak runoffs and erosion from the killed forests (Mayhood 2009). Higher and more frequent extreme runoff events resulting from projected higher winter and spring temperatures will add to these effects. On logged, burned and beetle-killed watersheds, channel adjustment and riparian zone disturbances will be especially severe, as will increased fine-sediment deposition in WCT critical habitat in those basins (Mayhood 2009).

Number of Locations

Saskatchewan-Nelson Rivers DU

The recovery strategy for the DU identifies 51 (19% of historical) remaining subpopulations of the 274 native pure subpopulations that existed within the historical distribution of WCT (Fisheries and Oceans Canada 2014; The Alberta Westslope Cutthroat Trout Recovery Team 2013). The main threats to all locations within the DU remain ongoing hybridization with introduced species, primarily RBT and climate change (see **Appendix 1**).

Pacific DU

In British Columbia, an estimated 928 streams and lakes (or 1319 including stocked systems) in the native range may contain pure WCT subpopulations (British Columbia Ministry of Environment 2014). Uncertainty exists with respect to the purity of some of the populations. The main threats to all locations within the DU remain hybridization with introduced species, primarily RBT, destruction of habitat as a function of resource extraction activities and climate change (see **Appendix 2**).

PROTECTION, STATUS AND RANKS

Legal Protection and Status

The Saskatchewan-Nelson Rivers DU for WCT was listed as Threatened in 2006 and the Pacific DU as Special Concern in 2006 under the *Species at Risk Act* (SARA). A species listed under SARA is eligible for Government of Canada SARA program funding and benefits from immediate protection, recovery planning, and development of management plan or recovery strategy and action plan. A recovery potential assessment was conducted for the Saskatchewan-Nelson Rivers DU in 2009 and discussed critical habitat, recovery targets and allowable harm for the species (Cleator *et al.* 2009). The federal recovery strategy document (Fisheries and Oceans Canada 2014) adopted the provincial recovery plans for WCT (The Alberta Westslope Cutthroat Trout Recovery Team 2013) and added supplementary material including an identification of critical habitat. The Alberta recovery plan also identifies a number of conservation and management initiatives. Activities include extensive genetic sampling, collection of habitat and riparian data, barrier surveys, population estimates, angling regulations, Brook Trout suppression, and testing for the diatom, *Didymosphenia geminata*. The Parks Canada Agency is also developing action plans for Banff and Waterton Lakes National Parks that include measures to be taken to implement the recovery strategy within the parks. A species listed as Special Concern requires the development of a management plan to protect it from further decline. The province of British Columbia has prepared a management plan for the Pacific DU (British Columbia Ministry of Environment 2014) that is available for federal adoption under SARA to meet this obligation. The objectives of the plan are to maintain the native distribution and genetic diversity of the populations at abundance levels that exceed at-risk assessments and provide societal benefits. In addition, the plan includes maintenance and rehabilitation of habitats to meet abundance targets and to optimize sustainable recreational benefits (British Columbia Ministry of Environment 2014).

The responsibility for the conservation and protection of all fishes lies with the Fisheries and Oceans Canada (DFO) under the federal *Fisheries Act* (http://laws.justice.gc.ca/en/F-14/). The federal *Fisheries Act* delegates authority to the provinces to establish and enforce regulations under respective recreational fishing regulations. The regulations in both DUs are now catch and release opportunities for all waters containing pure WCT populations within the native range. But pure WCT can still be harvested in mainstem rivers downstream of pure populations where trout are primarily Rainbow Trout (for example the Crowsnest River in Alberta). Additionally, WCT subpopulations within the native range within National Parks receive protection under the *National Parks Act*, and measures such as a zero-possession limit in Banff, Yoho, Kootenay, Mount Revelstoke, and Glacier National Parks are in place for the conservation of the species.

In Alberta, WCT is protected under the provincial *Wildlife Act*, the provincial *Forest Act*, the provincial *Water Act*, and the federal *Fisheries Act.* The *Wildlife Act* enables provincial authorities to license anglers and angling guides, and to supply scientific fish collection permits. It also addresses species at risk but these are governed by policy and discretionary legislative power and so are limited to federal protections. The *Forest Act* provides for operating ground rules that specify procedures that are utilized during harvesting to ensure protections of rivers, streams, and lakes from environmental damage. The *Water Act* ensures sustainability of Alberta's water by requiring the development of a provincial water management planning framework (watercourse codes of practice). It provides a licensing and approval process for water-related activities and diversions. It allows for flexible water management in areas where available water is already allocated, by providing the ability to transfer water licences. Additionally, there are protections provided under the Alberta Energy Regulator, Integrated Standards and Guidelines, which identifies desired outcomes and approval standards for the energy industry near watercourses and waterbodies. These include maintaining: 1) natural drainage; 2) riparian habitat structure that contributes to water quality; 3) aquatic function; 4) preventing soil and deleterious substances/materials from entering watercourses; 5) the integrity of the bed and shore, and 6) aquatic and terrestrial habitat and fish passage. The approval standards provide siting, timing and site related requirements (http://esrd.alberta.ca/forms-maps-services/enhanced-approval-process/eap-manuals-guides/documents/EAP-IntegratedStandardsGuide-Dec01-2013.pdf).

In British Columbia, WCT is protected under the provincial *Wildlife Act*, the provincial *Fish Protection Act*, the *Water Sustainability Act*, and the federal *Fisheries Act*. The *Wildlife Act* enables provincial authorities to license anglers and angling guides, and to supply scientific fish collection permits and the *Fish Protection Act* provides the legislative authority for water managers to consider impacts on fish and fish habitats before approving new water licences or amendments to existing licences, or issuing approvals for works in and about streams. New legislation controlling the use of water is embodied in the *British Columbia Water Sustainability Act* that came into force in 2015 and replaces the *British Columbia Water Act*. The Act ensures that environmental flow needs are considered in new water allocation decisions and extends water licensing to groundwater for anything other than domestic use. It should address concerns that habitat requirements for fish such as ensuring adequate stream flows and issuance and control of water withdrawal licences have been conducted without proper hydrological budgeting (Rosenau and Angelo 2003). The introduction of the *British Columbia Fish Protection Act* in 1997 (http://www.qp.gov.bc.ca/statreg/stat - /F/97021_01.htm) also provided government agencies the means to more adequately protect critical stream flows for fish populations.

Non-Legal Status and Ranks

WSCT are currently listed as Threatened in the Province of Alberta. In December 2007, Alberta's Minister of Environment and Sustainable Resource Development approved listing the Westslope Cutthroat Trout as Threatened under Alberta's *Wildlife Act* based on the recommendations from the Alberta Endangered Species Conservation Committee. The species was listed under Schedule 6 of the Alberta Wildlife Regulation in 2009. In British Columbia WCT are ranked as S3Vulnerable and placed on the provincial blue-list (British Columbia Conservation Data Centre 2004). Nationally in the United States, WCT are assessed Vulnerable in Idaho and Oregon (S3), Imperilled in Montana (S2), Critically Imperilled in Wyoming (S1), and not yet ranked in Washington (SNR). Globally, WCT is ranked by the Nature Conservancy as G4T4. The G4 ranking is defined as 'apparently secure, uncommon but not rare'. The T-ranking refers to a taxonomic subunit (in this case, subspecies). The American Fisheries Society ranked WCT as Threatened in 2008.

Westslope Cutthroat Trout was petitioned for protection under the United States *Endangered Species Act* in 1997 (USFWS 1999). In 2000, that listing was deemed unwarranted by the United States Fish and Wildlife Service (USFWS) but the ruling was appealed by conservation groups on the basis that the threat of hybridization to this subspecies had not been sufficiently determined. After re-examination of the available genetic data (Allendorf *et al.* 2001, 2004, 2005; Shepard *et al.* 2003; Campton and Kaeding 2005), the USFWS decided in July 2003, not to list WCT as "endangered" under the act at that time because of the uncertainties regarding the entity to be listed. The situation remains unchanged.

Habitat Protection and Ownership

The federal *Fisheries Act* in Canada was amended in 2013 to focus on protecting the productivity of commercial, recreational and Aboriginal fisheries. DFO developed a Fisheries Protection Policy Statement that applies to proponents of existing or proposed works, undertakings or activities (i.e. projects) that are likely to result in impacts to fish or fish habitat that are part of or support commercial, recreational or Aboriginal fisheries, including projects that have the potential to affect the passage of fish or modify the flow of watercourses (DFO 2013). The policy provides guidelines for the approval process to mitigate against habitat impacts. In addition, WCT occurs within Waterton, Jasper and Banff National Parks are regulated by the *National Parks Act*. Under the *Species at Risk Act* if a species is listed as Threatened, a recovery strategy must be prepared including the determination of 'critical habitat' or habitat necessary for the survival or recovery of a listed species. In the SARA, habitat includes "spawning grounds and nursery, rearing, food supply, migration and any other areas on which aquatic species depend directly or indirectly in order to carry out their life processes, or areas where aquatic species formerly occurred and have the potential to be reintroduced" (Fisheries and Oceans Canada 2014). A Critical Habitat Order will subsequently enact the prohibitions in SARA section 58(1) against the destruction of any part of the critical habitat identified in a species final recovery strategy or action plan, i.e. 'no person shall destroy any part of the critical habitat of any listed endangered species or of any listed threatened species'.

Various park systems and protected areas also exist throughout the range of WCT in Canada. However, much of their range remains subject to development and various types of resource extraction, particularly in British Columbia. A number of higher level land use planning processes have been undertaken (e.g. Elk Valley Water Quality Plan). However, in the East Kootenay region of British Columbia, less than 16% of the land base is formally protected; 9% is privately owned and the remaining 75% is subject to resource extraction, recreational use, and environmental stewardship (Owen 1994). In October 2002, the British Columbia government implemented the Kootenay Boundary higher-level plan, which addresses habitat rehabilitation and ongoing operations of the forest industry (http://www.env.gov.bc.ca/kootenay/hlp/main.htm).

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BIOGRAPHICAL SUMMARY OF REPORT WRITER

Jacob (Jake) Schweigert received his B.Sc. (Honours) from the University of Toronto in 1974 and his M.Sc. (Zoology) from the University of Manitoba in 1976. Mr. Schweigert is Scientist Emeritus with Fisheries and Oceans Canada at the Pacific Biological Station (PBS), Nanaimo, British Columbia. Prior to his retirement in 2013, Mr. Schweigert was employed as a scientist with DFO since 1981 most recently as Section Head for Conservation Biology at PBS. Jake spent the majority of his career conducting research and stock assessment of Pacific herring and other forage species. Mr. Schweigert has authored or co-authored more than 30 publications in peer-reviewed scientific journals and over 70 other publications including the COSEWIC stock status reports for Pacific Sardine, Interior Fraser Coho and Sakinaw Lake Sockeye Salmon.

Appendix 1. Threats assessment for Westslope Cutthroat Trout – Saskatchewan-Nelson River populations

Species or Ecosystem Scientific Name	Westslope Cutthroat Trout – Saskatchewan-Nelson River populations			
Element ID			**Elcode**	
Date (Ctrl + ";" for today's date):	10/12/2015			
Assessor(s):	Jake Schweigert (writer), Dwayne Lepitzki (facilitator), John Post (co-chair), Rick Cunjak (SSC member), Greg Wilson (COSEWIC - BC), Heather Lamson (BC MoE), Jennifer Earle (AB Environment and Parks), Shelley Humphries (Parcs).			
References:	threats telecon, 10 Dec 2015; draft report and threats calculator			

Overall Threat Impact Calculation Help:			**Level 1 Threat Impact Counts**	
	Threat Impact		**high range**	**low range**
	A	Very High	1	0
	B	High	0	1
	C	Medium	1	0
	D	Low	7	8
		Calculated Overall Threat Impact:	Very High	High
		Assigned Overall Threat Impact:	**B = High**	
		Impact Adjustment Reasons:		
		Overall Threat Comments	**only 51 streams/lakes now have pure, native fish; hybridization from stocking a past threat?; no stocking in waterbodies containing the remaining pure, native fish. "Very high" means 50-100% decline in next 3 generations (~15 yrs) based on these threats occurring in the next 10 years.**	

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development						
1.1	Housing & urban areas						historical range? Looking forward on current range, housing and urban development is negligible if applicable at all. Along the stream are ranching activities. Habitat alteration from human intrusion accounted for under threat 8.3 and 9.1 or 9.4.
1.2	Commercial & industrial areas						not applicable
1.3	Tourism & recreation areas						marinas or docks? Associated with head waters. Manuer is accounted for under 8.3 and 9.1 or 9.4. no marina or docks expected to be developped. Not applicable

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2	Agriculture & aquaculture	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	
2.1	Annual & perennial non-timber crops						not applicable
2.2	Wood & pulp plantations						not applicable
2.3	Livestock farming & ranching	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	cattle trampoling on the fish or eggs? Most remaining individuals in the head waters. Of 51 sites, more than 30% may be affected or more than 15 of the 51. 31-70% of the sites are affected by cattle trampoling (excluding National Parks). Bison re-introductions in Banff National Park. Unsure whether this will overlap with WSCT range will be affected. maybe one site. needs to be verified. juveniles maturing at age 3 (rather quickly) coupled with low spawning in extreme headwaters. Generation time is considered 4 - 8 years for 3 generation projection. eggs do not overwinter in the streams. May to October cows in stream so two month overlap for trampoling. Riparian damage is observed but direct mortality is unknown and estimated. small streams in BC more affected. more towards lower end of scope.
2.4	Marine & freshwater aquaculture						not applicable
3	Energy production & mining	D	Low	Small (1-10%)	Serious (31-70%)	Moderate (Possibly in the short term, < 10 yrs)	
3.1	Oil & gas drilling						roads accounted for under 4.1. pipelines accounted for under 4.2. not applicable except for Blairmoor Creek. One stream expected to be dug up.
3.2	Mining & quarrying	D	Low	Small (1-10%)	Serious (31-70%)	Moderate (Possibly in the short term, < 10 yrs)	Fracking further east. Jenny to look into this. Severity is likely extreme for the one stream.
3.3	Renewable energy						not applicable. windfarms in the southern range but no direct impact.
4	Transportation & service corridors	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	
4.1	Roads & railroads	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	not applicable. New bridges, new roads, or railroad development unlikely overtop of WSCT habitat. Road side expansion is likely. Sedimentation is accounted for under 6.3.
4.2	Utility & service lines		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	mitigation preventing in stream work for any drilling however most gas pipe lines are in the north of Alberta. Some farcking fluid comes out from the ground and into the stream.
4.3	Shipping lanes						not applicable for the park range
4.4	Flight paths						not applicable
5	Biological resource use	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals						not applicable

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.2	Gathering terrestrial plants						not applicable
5.3	Logging & wood harvesting	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	not huge direct impact. Some of the range has logging but Jenny will check this.
5.4	Fishing & harvesting aquatic resources	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	catch and release only so possibility of post release mortality. Only two sites in the parks subject to this threat. Some pressure from fishers and anglers in the park. Pervasive threat. Bate fishing mortality is slightly higher post release compared to fly fishing. and catch and keep happening as well.
6	Human intrusions & disturbance	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	
6.1	Recreational activities	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	camping, horse back riding, trails, ATV with trucks in the winter,
6.2	War, civil unrest & military exercises						DND facility on Whitebress Creek (Cadet camp). Outside of critical habitat.
6.3	Work & other activities		Negligible	Large (31-70%)	Negligible (<1%)	High (Continuing)	some research resulting in direct mortality.
7	Natural system modifications		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	
7.1	Fire & fire suppression		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	prescribed burns. Evan Thomas. Wildfire in southern Alberta (in the past and therefore not accounted for) in areas that are heavily logged. Effects are still being researched. Some mitigation on effects of prescribed burns. Post burn water chemistry is high in ammonia. extreme temperature caused by burn sometimes eradicate the species from the stream. stream sterilization. One stream was designated as emergency water source but resulted in refusal.
7.2	Dams & water management/use		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	sites for snow making arent in range. Flow diversion at one location. No water pumping. Historically this threat was devastating but future threat is minimal. No permit approval for water diversion in main population ranges but some temporary diversion requests approved.
7.3	Other ecosystem modifications		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	clearing of riparian areas not known of. Some riprap.
8	Invasive & other problematic species & genes	AB	Very High - High	Pervasive (71-100%)	Extreme - Serious (31-100%)	High (Continuing)	
8.1	Invasive non-native/alien species	AB	Very High - High	Pervasive (71-100%)	Extreme - Serious (31-100%)	High (Continuing)	Brook Trout, Rainbow Trout displacing WSCT. In the Oldman and Bow. Some efforts to move Brook Trout but results leaning towards angling to control population size. Invasion results in high mortality for WSCT.
8.2	Problematic native species						not as a future threat. Lake Trout and WSCT coexist well. Little overlap. Some stocking of WSCT accounted for under 8.3. Bull Trout recovery does not impact WSCT
8.3	Introduced genetic material	AB	Very High - High	Pervasive (71-100%)	Extreme - Serious (31-100%)	High (Continuing)	introduced stocked CTT hybridization (Yellow Stone) continuing to reproduce. Brook Trout not considered under this threat.
9	Pollution	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.1	Household sewage & urban waste water	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	road salt not a problem in the parks. Outhouses. Sediment off roads. Eutrophication is somewhat beneficial to Brook Trout and Lake Trout so perhaps negligible to WSCT.
9.2	Industrial & military effluents	D	Low	Small (1-10%)	Serious - Slight (1-70%)	Moderate - Low	effects of railcrossings not applicable in the park. Some pipelines in nonpark range. Scope depends on product that is spilled. Some are detrimental and some arent.
9.3	Agricultural & forestry effluents	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	agriculture not applicable in terms in nutrient runoff but manuer from free ranging cattle is applicable.
9.4	Garbage & solid waste						not applicable
9.5	Air-borne pollutants						acidification is not an issue. PCB's occur but no data to suggest population effects. Mercury and Selenium that are competing. Unknown effect at present. Mike Sullivan research on Selenium to be looked into.
9.6	Excess energy						not applicable
10	Geological events	D	Low	Large (31-70%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs)	
10.1	Volcanoes						not applicable
10.2	Earthquakes/tsunamis						some occasional earthquakes in the province but unknown effect on population
10.3	Avalanches/landslides	D	Low	Large (31-70%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs)	one of 10 sites affected by landslide and this is very likely to reoccur. Direct mortality is high but number of individuals affected is unknown. 3 generation hit is still unknown. Spawning area was affected which was also the best spawning habitat in the creek. new spawning area establishment is unknown.
11	Climate change & severe weather	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	
11.1	Habitat shifting & alteration						not applicable
11.2	Droughts						not applicable.
11.3	Temperature extremes						some cases earlier snow melt and dryier summers as well as increases in water consumption. Winter reduced refugia areas.
11.4	Storms & flooding						not applicable.
Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).							

Appendix 2. Threats assessment for Westslope Cutthroat Trout – Pacific populations

Species or Ecosystem Scientific Name	Westslope Cutthroat Trout - Pacific populations			
Element ID			**Elcode**	
Date (Ctrl + ";" for today's date):	10/12/2015			
Assessor(s):	Jake Schweigert (writer), Dwayne Lepitzki (facilitator), John Post (co-chair), Rick Cunjak (SSC member), Greg Wilson (COSEWIC - BC), Heather Lamson (BC MoE), Jennifer Earle (AB Environment and Parks), Shelley Humphries (Parcs).			
References:	threats telecon, 10 Dec 2015; draft report and threats calculator			

Overall Threat Impact Calculation Help:

Threat Impact		Level 1 Threat Impact Counts: high range	Level 1 Threat Impact Counts: low range
A	Very High	1	0
B	High	0	1
C	Medium	4	1
D	Low	5	8
	Calculated Overall Threat Impact:	Very High	High

Assigned Overall Threat Impact:	**B = High**
Impact Adjustment Reasons:	
Overall Threat Comments	**only 51 streams/lakes now have pure, native fish; hybridization from stocking a past threat?; no stocking in waterbodies containing the remaining pure, native fish. "Very high" means 50-100% decline in next 3 generations (~15 yrs) based on these threats occurring in the next 10 years.**

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development						
1.1	Housing & urban areas						Kaslo and Cranbrook (streams within) mentioned in management plan for urban expansion. Filling in part of the stream (past not future). Habitat alteration from human intrusion or pollution accounted for under threat 8.3 and 9.1 or 9.4.
1.2	Commercial & industrial areas						not applicable
1.3	Tourism & recreation areas						marinas or docks? Ski area plans are unknown. Most large body lakes are reservoirs. Dock development may affect WSCT but none planned for reservoirs. maybe Kootenay area. sewage is accounted for under 8.3 and 9.1 or 9.4. no marina or docks expected to be developped. Not applicable. Greg or Heather to look into this.
2	Agriculture & aquaculture	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.1	Annual & perennial non-timber crops		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	hay fields in the trench. Management plan explains hay field as a larger problem but not direct impact. Accounted for under threat 7.3.physical expansion of hay field may not go into stream but mowing right up to stream causes increase in water temperature of the stream. negligible. actual sedimentation accounted for under 7.3. severity is higher in smaller streams.
2.2	Wood & pulp plantations						not applicable
2.3	Livestock farming & ranching	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	less ranching in this unit compared to AB unit.
2.4	Marine & freshwater aquaculture						not applicable
3	Energy production & mining	C	Medium	Restricted (11-30%)	Serious (31-70%)	High (Continuing)	
3.1	Oil & gas drilling						not applicable. roads accounted for under 4.1. pipelines accounted for under 4.2.
3.2	Mining & quarrying	C	Medium	Restricted (11-30%)	Serious (31-70%)	High (Continuing)	Fracking? Herb Tepper to comment on this threat quantification as it relates to mine expansion. One kill this week. 30% of one creek overwintering range completely filled in.
3.3	Renewable energy						run of the river suspected in one research project on WSCT. IPP proposed at one site. Cold bed methane development mentioned in the last COSEWIC report. Elk Valley rich in coal but unknown ongoing threat in the next 10 years.
4	Transportation & service corridors	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	
4.1	Roads & railroads	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	not applicable. New bridges, new roads, or railroad development unlikely overtop of WSCT habitat. Road side expansion is likely. Sedimentation is accounted for under 6.3.
4.2	Utility & service lines		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	pipelines. Siltation from increases in road density and crossings. In BC, species is not pushed up into the head waters as in AB.
4.3	Shipping lanes						not applicable
4.4	Flight paths						not applicable
5	Biological resource use	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals						not applicable
5.2	Gathering terrestrial plants						not applicable
5.3	Logging & wood harvesting	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Loggging applicable at many sites.
5.4	Fishing & harvesting aquatic resources	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	Pervasive threat. Population is open to fishing and angling at some point. Recapture is common. Theyre surviving but management plan suggests that population increasing since restriction on angling regulations. Some poaching as well.
6	Human intrusions & disturbance	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	
6.1	Recreational activities	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	camping, horse back riding, trails, ATV through steams, all recreational activities considered = small threat.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6.2	War, civil unrest & military exercises						not applicable
6.3	Work & other activities		Negligible	Restricted (11-30%)	Negligible (<1%)	High (Continuing)	some research. No direct mortality. Some egg takes. Introgression research. 2 in Kootenay done and plans for expansion on this research. A lot of research in the Elk and the Flathead.
7	Natural system modifications	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	High (Continuing)	
7.1	Fire & fire suppression		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	prescribed burns and wildfire in BC about the same as AB. Some mitigation on effects of prescribed burns. Effects are still being researched in terms of fire suppression (toxins fire retardants spilling into streams) or succession that many be beneficial. Post burn water chemistry is high in ammonia. extreme temperature caused by burn sometimes eradicate the species from the stream. stream sterilization.
7.2	Dams & water management/use	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	High (Continuing)	agriculture water extractions. Bow River dam. Ikookanoosa. Many big dams in BC. Causing floods or changes in water flow patterns and/or temperatures. WSCT is close to dams in BC whereas theyre farther away from dams in BC. Water withdrawal also common, run of the river as well. perhaps to confirm?
7.3	Other ecosystem modifications	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	clearing of riparian areas not known of. Some riprap. Siltation from new roads coming in. Channelization?
8	Invasive & other problematic species & genes	AB	Very High - High	Pervasive (71-100%)	Extreme - Serious (31-100%)	High (Continuing)	
8.1	Invasive non-native/alien species	AB	Very High - High	Pervasive (71-100%)	Extreme - Serious (31-100%)	High (Continuing)	Brook Trout, Rainbow Trout affecting the habitat and displacing WSCT. Some pike as well. Walleye as well in the Columbia. Some efforts to move Brook Trout but results leaning towards angling to control population size. Invasion results in high mortality for WSCT.
8.2	Problematic native species						not as a future threat. Lake Trout and WSCT coexist well. Little overlap. Some stocking of WSCT accounted for under 8.3. Bull Trout recovery efforts (stocking) does not impact WSCT since most stock are sterile but publication to suggest some are fertile and reproducing. Burbot not causing problem to WSCT. Kokanee as well.
8.3	Introduced genetic material	AB	Very High - High	Pervasive (71-100%)	Extreme - Serious (31-100%)	High (Continuing)	introduced stocked CTT hybridization (Yellow Stone Rainbow hybrids from original AB hatchery) in BC. Brook Trout not considered under this threat. Rainbow stocked in the Elk are coming back as pure strain. Same with Brook Trout. Some of Elk individuals experiencing hybridization though.
9	Pollution	CD	Medium - Low	Restricted (11-30%)	Serious - Slight (1-70%)	High (Continuing)	
9.1	Household sewage & urban waste water	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	household sewage and waste water. Eutrophication is somewhat beneficial to Brook Trout and Lake Trout so perhaps negligible to WSCT. No runoff.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.2	Industrial & military effluents	CD	Medium - Low	Restricted (11-30%)	Serious - Slight (1-70%)	High (Continuing)	pulp mill at Skookumchuk. Coal from the mine. Pipeline in northern range. Train derailment or pipeline spills may occur.
9.3	Agricultural & forestry effluents	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	agriculture not applicable in terms in nutrient runoff but manuer from free ranging cattle is applicable. Pollution from forestry activities, road building indirect impact, nutrient loading and sedimentation accounted for.
9.4	Garbage & solid waste						not applicable
9.5	Air-borne pollutants						not applicable.
9.6	Excess energy						not applicable
10	Geological events	D	Low	Small (1-10%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs)	
10.1	Volcanoes						not applicable
10.2	Earthquakes/tsunamis						not applicable.
10.3	Avalanches/landslides	D	Low	Small (1-10%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs)	debrie events. Landslides occur in WSCT range.
11	Climate change & severe weather	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	
11.1	Habitat shifting & alteration						
11.2	Droughts						
11.3	Temperature extremes						some cases earlier snow melt and dryier summers as well as increases in water consumption. Winter reduced refugia areas.
11.4	Storms & flooding						
Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).							