COSEWIC
Assessment and Status Report

on the

Coastal Giant Salamander
Dicamptodon tenebrosus

in Canada

THREATENED
2014

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:

COSEWIC. 2014. COSEWIC assessment and status report on the Coastal Giant Salamander *Dicamptodon tenebrosus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xii + 53 pp. (www.registrelep-sararegistry.gc.ca/default_e.cfm).

Previous report(s):

COSEWIC. 2000. COSEWIC assessment and update status report on the Coastal Giant Salamander *Dicamptodon tenebrosus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 41 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Ferguson, H.M. and B.E. Johnston. 2000. Update COSEWIC status report on the Coastal Giant Salamander *Dicamptodon tenebrosus in* COSEWIC assessment and update status report on the Coastal Giant Salamander *Dicamptodon tenebrosus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-41 pp.

Farr, A.C.M. 1989. COSEWIC status report on the Pacific Giant Salamander *Dicamptodon tenebrosus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 30 pp.

Production note:
COSEWIC would like to acknowledge Elke Wind for writing the status report on the Coastal Giant Salamander (*Dicamptodon tenebrosus*) in Canada. This report was prepared under contract with Environment Canada and was overseen by Kristiina Ovaska, Co-chair of the COSEWIC Amphibians and Reptiles Specialist Subcommittee.

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Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur la Grande salamandre du Nord (*Dicamptodon tenebrosus*) au Canada.

Cover illustration/photo:
Coastal Giant Salamander — Cover photo taken by Elke Wind.

Catalogue No. CW69-14/690-2014E-PDF
ISBN 978-1-100-23924-8

Recycled paper

COSEWIC
Assessment Summary

Assessment Summary – May 2014

Common name
Coastal Giant Salamander

Scientific name
Dicamptodon tenebrosus

Status
Threatened

Reason for designation
The Canadian distribution of this salamander is restricted to the Chilliwack drainage system in southwestern British Columbia, where it occurs mainly in cool, clear mountain streams and surrounding riparian forest. Major threats include habitat loss, degradation and fragmentation due to forest harvest, road building, and encroaching residential development. These threats may be exacerbated by droughts and flooding events that are predicted to increase with climate change. Poor dispersal ability, low reproductive rate, late maturity, and long generation time increase the vulnerability of the species.

Occurrence
British Columbia

Status history
Designated Special Concern in April 1989. Status re-examined and designated Threatened in November 2000 and May 2014.

COSEWIC
Executive Summary

Coastal Giant Salamander
Dicamptodon tenebrosus

Wildlife Species Description and Significance

The Coastal Giant Salamander (*Dicamptodon tenebrosus*), formerly known as the Pacific Giant Salamander, is a large stream-dwelling salamander. The genus *Dicamptodon* consists of four species in the Pacific Northwest; only the Coastal Giant Salamander is found in Canada. The salamanders can attain a total length of 35 cm (including tail).

Coastal Giant Salamanders have an aquatic and a terrestrial life stage. Aquatic larvae have a dark back with light underbelly, shovel-shaped head, external gills, and tail fin. Larvae can attain sexual maturity and remain aquatic (neotenic) or transform into terrestrial adults; neotenic adults remain obligate stream-dwellers. Terrestrial adults are robust and broad-headed; the colour is dark brown to black on the back usually with tan or copper marbling. This species is the largest semi-aquatic salamander in North America and the only salamander capable of true vocalizations with adults emitting bark-like cries when disturbed.

Distribution

The distribution of the Coastal Giant Salamander extends along the west coast of North America from southwestern British Columbia, through the Cascade and Coast mountain ranges, to northwestern California. In Canada, the Coastal Giant Salamander occurs only in extreme southwestern British Columbia south of the Fraser River in the Chilliwack and adjacent small drainages.

Habitat

The Coastal Giant Salamander has been found at elevations from sea level to 2160 m in a variety of lotic environments ranging from small seepages and mountain streams to large rivers and lakes. They breed mostly in mountain streams, where larvae spend multiple years developing. A number of factors influence the species' occurrence in streams, including elevation, stand age of surrounding forest, gradient, substrate, wetted width, and riparian forest cover. Transformed juveniles and adults inhabit surrounding riparian and upland forests. Terrestrial Coastal Giant Salamanders are usually found in close proximity (within 50 m) to streams, where they utilize a variety of refuge sites such as root channels, spaces under logs and rocks, and small mammal burrows. Studies have shown that larvae and adults move relatively little, and individual salamanders may spend their entire life cycle in one stream. Connectivity among populations is likely maintained through dispersing adults moving along streams or across upland forest.

Biology

The reproductive biology of the Coastal Giant Salamander in British Columbia is poorly known. The female deposits a clutch of 135-200 eggs on the underside of a rock in an aquatic nest chamber within a creek or stream, probably once every 2 years. Larvae may take up to 6 years to reach metamorphosis. The best approximation of life span comes from studies of similarly sized aquatic salamanders, which may live up to 25 years in captivity. The generation time is thought to be 10 – 15 years.

Coastal Giant Salamanders are highly dependent on moisture, the availability of which constrains their activity and movements. Chilliwack Valley is the northern limit of the Coastal Giant Salamander's distribution, and low temperatures and short growing season may limit its occurrence both northwards and upwards in elevation. In British Columbia, larvae are rarely detected in streams until water temperatures rise above 5°C, and they become sluggish at temperatures >20°C, suggesting these temperatures approximate the limit of their thermal tolerance.

Population Sizes and Trends

Population size and trends are poorly known. Survey results from the Chilliwack Valley reflect a lower density of Coastal Giant Salamanders in British Columbia than in the United States, as might be expected for a species along the limits of its geographic range. The previous COSEWIC update for the species reported the Canadian population as roughly 13,400 terrestrial adults and 9,000 aquatic neotenic adults; there are no new estimates.

Threats and Limiting Factors

Main threats to Coastal Giant Salamanders are from logging that continues to degrade habitats across the species' Canadian range and from siltation of breeding streams resulting from erosion and surface run-off associated with roads and forestry activities. Urban development and run-of-river energy projects pose additional threats to local populations. The Coastal Giant Salamander occurs mainly in and around mid-elevation streams, and its occurrence and breeding activity, in particular in main stems at lower elevations, are curtailed by introduced predatory fish. Thus, even if forested stream buffers are left in otherwise deforested terrain, overland dispersal can be expected to be severely restricted, accentuating inter-stream isolation and population fragmentation. More frequent and severe droughts and flooding events are expected to accentuate impacts of human activities on these salamanders.

Protection, Status, and Ranks

Globally, the Coastal Giant Salamander is ranked as G5 (Secure). Nationally, it is ranked as N2 (Imperilled) in Canada. The species has been assessed as Threatened by COSEWIC and is on the official list of species at risk under the *Species at Risk Act*. In British Columbia, it is ranked as S2 (Imperilled). The majority of the species' range in Canada is on provincial land managed for forestry. As of 2010, 25% of the total known occupied stream length is within designated Wildlife Habitat Areas established for the species under the Identified Wildlife Management Strategy and receives a degree of protection through associated General Wildlife Measures.

TECHNICAL SUMMARY

Dicamptodon tenebrosus
Coastal Giant Salamander — Grande salamandre du Nord
Range of occurrence in Canada (province/territory/ocean): 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 (2008) is being used). *Larvae take up to 6 years to metamorphose. Dudaniec* et al. *(2012) used a "conservative" generation time of 12.5 years for their genetics study based on an estimated maximum life span of approximately 20 years (Nussbaum 1976).*	10 – 15 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? *Inferred decline based on habitat trends*	Yes
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].	Suspected decline of ≥30%
[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.	Suspected decline of ≥30%
Are the causes of the decline clearly reversible and understood and ceased? *Partially understood, not clearly reversible, and not ceased*	No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence *Originally calculated as 850 km² – discrepancy is likely due to differences in calculation method*	760 km²
Index of area of occupancy (IAO) *IAO based on 2x2 km grid cells superimposed on the Canadian distribution (BC Conservation Data Centre 2010) is 332 km²; however, IAO is here estimated to be 608 km², based on grid cells placed along the entire linear length of occupied streams (152 km)*	608 km²
Is the population severely fragmented?	Possibly but cannot be demonstrated

Number of locations∗ *Threats are from stream siltation associated with forestry activities and road building/deactivation, and from housing developments. If each cutblock and development is considered a single threatening event, then there are >10 locations, even accounting for downstream effects through siltation.*	>10
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	No
Is there an inferred continuing decline in index of area of occupancy? *Inferred decline based on habitat loss and degradation from continuing forestry, residential development, and other human activities.*	Yes
Is there an [observed, inferred, or projected] continuing decline in number of populations?	Unknown
Is there an [observed, inferred, or projected] continuing decline in number of locations*?	Unknown
Is there an inferred continuing decline in area, extent and quality of habitat?	Yes
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations∗?	No
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 population)

Population	**N Mature Individuals**
Number of populations unknown; *each occupied 4th order watershed may correspond to a population with limited amount of gene flow among other such units, which would result in 15 known populations.*	Unknown
Total population: *Ferguson and Johnston (2000) provide a gross estimate of 13,400 terrestrial adults and an upward estimate of 9000 neotenic adults for a total estimate of 22,400 sexually mature salamanders. However, no accurate estimates are available.*	Unknown; probably >10,000

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Not done due to lack of data

*See Definitions and Abbreviations on the COSEWIC website and IUCN 2010 for more information on this term.

Threats (actual or imminent, to populations or habitats)

Main threats: Forestry (widespread) and siltation of breeding streams from logging and other resource extraction and associated roads; residential developments (localized) and associated infrastructures that continue to degrade and fragment habitats. Other threats: Introduced fish; micro-hydro developments; disease, particularly chytridiomycosis due to both *Batrachochytrium dendrobatidis,* which threatens numerous amphibian populations worldwide, and newly discovered *B. salamandrivorans*, but to date neither has been reported from the Coastal Giant Salamander in BC; climate change and severe weather through droughts and flooding events, and changes to hydrology.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? *Washington: S5 (secure); Oregon: S4 (apparently secure); California: SNR (unranked)*	
Is immigration known or possible? *Possible through a few mountain passes, but high elevations generally prohibit dispersal across the border.*	Possible but unlikely
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Probably not
Is rescue from outside populations likely?	No

Data-Sensitive Species

Is this a data-sensitive species? *Listed as Data-Sensitive by BC Conservation Data Centre, and therefore exact observation locations are not to be released. Screening assessment by Amphibians & Reptiles SSC using COSEWIC guidelines determined the species not to be data-0* *sensitive*	Yes

COSEWIC Status History

Designated Special Concern in April 1989. Status re-examined and designated Threatened in November 2000 and May 2014.

Reasons for Designation:

Status: Threatened	**Alpha-numeric Code:** A3c+4c
Reasons for designation: The Canadian distribution of this salamander is restricted to the Chilliwack drainage system in southwestern British Columbia, where it occurs mainly in cool, clear mountain streams and surrounding riparian forest. Major threats include habitat loss, degradation and fragmentation due to forest harvest, road building, and encroaching residential development. These threats may be exacerbated by droughts and flooding events that are predicted to increase with climate change. Poor dispersal ability, low reproductive rate, late maturity, and long generation time increase the vulnerability of the species.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Threatened A3c+4c because the number of mature individuals is suspected to decline by 30% or more within the next 30-45 years (3 generations) based on a decline in the index of area of occupancy and quality of habitat from logging, residential development and other sources. A4c also applies because similar reductions are suspected in both the past and future over a 30-45 year time span.
Criterion B (Small Distribution Range and Decline or Fluctuation): Does not meet criteria. Comes close to meeting Endangered because the EO is below thresholds and there is a continuing decline in the area, extent, and quality of habitat, but does not meet any of the other subcriteria.
Criterion C (Small and Declining Number of Mature Individuals): Does not meet criteria; the estimated number of mature individuals is above the threshold of 10,000 adults.
Criterion D (Very Small or Restricted Population): Does not meet criteria.
Criterion E (Quantitative Analysis): Insufficient information is available for quantitative population viability analyses.

PREFACE

Since the previous status report (Ferguson and Johnston 2000), a number of studies have been conducted of the Coastal Giant Salamander in the Chilliwack Valley, British Columbia (BC), focusing on habitat use, genetics, and demography. In addition, there have been several inventories to clarify the species' distribution. Although several new occurrence records have been documented, the species has not been found outside the previously known range, which remains small. A provincial recovery strategy has been prepared (Pacific Giant Salamander Recovery Team 2010), and a federal recovery strategy, including Critical Habitat description, has been drafted.

The threats identified in the previous status report continue with logging and associated forestry activities considered the greatest threat. The recently described chytrid fungus, *Batrachochytrium salamandrivorans*, poses a new but at present unknown threat to the Coastal Giant Salamander. The new chytrid, isolated from *Salamandra salamandra* in Europe, is closely related to *B. dendrobatidis*, which causes a skin disease in amphibians and has been linked to amphibian declines globally. Low temperatures in mountain streams are thought to protect stream-dwelling amphibians, including the Coastal Giant Salamander, from *B. dendrobatidis*. However, the thermal growth preference range of the new chytrid is lower than that of *B. dendrobatidis* (Martel *et al*. 2013), increasing the vulnerability of stream-dwelling amphibians to infection. The new chytrid is yet to be reported from North America.

As of 2013, 20 Wildlife Habitat Areas (WHAs) have been approved for the Coastal Giant Salamander under the Identified Wildlife Strategy associated with the provincial *Forest and Range Practices Act*. These areas encompass a total of 771 ha of occupied sections of streams within the Chilliwack Forest District. The combined linear length of occupied streamside habitat within WHAs is approximately 38 km or 25% of the total known occupied stream length. As of 2013, the provincial government is working on 16 new WHAs for the Coastal Giant Salamander covering 1396 ha (George pers. comm. 2013). The effectiveness of the WHAs in protecting Coastal Giant Salamander populations is currently unknown.

No Aboriginal Traditional Knowledge was available at the time this report was prepared.

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
(2014)

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 Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune

Canada

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

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Dicamptodon tenebrosus

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2014

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific name: *Dicamptodon tenebrosus* (Baird and Girard, 1852)

English name: Coastal Giant Salamander (Crother 2012); formerly known as Pacific Giant Salamander

French name: Grande salamandre du Nord (Green 2012)

The Coastal Giant Salamander, *Dicamptodon tenebrosus* (Figure 1) belongs to a group of large, semi-aquatic salamanders endemic to Western North America (Good 1989). This group was originally considered to be a subfamily of the Ambystomatidae. However, taxonomic analysis by Edwards (1976) and Estes (1981) found several unique morphological and neurological traits in *Dicamptodon* that warrant distinct family status.

A) Adult B) Larva

Figure 1. Coastal Giant Salamander, A) terrestrial adult and B) aquatic larva. Photos by Elke Wind.

Using allozymes, Good (1989) recognized four species: *Dicamptodon aterrimus* (Idaho Giant Salamander) *D. copei* (Cope's Giant Salamander), *D. ensatus* (California Giant Salamander) and *D. tenebrosus*. Prior to this analysis, *D. tenebrosus* and *D. ensatus* were considered to be one species: *D. ensatus*. *Dicamptodon ensatus* and *D. tenebrosus* are similar in appearance and life history but disjunct geographically (Figure 2). *Dicamptodon tenebrosus* is the only species of this genus in Canada.

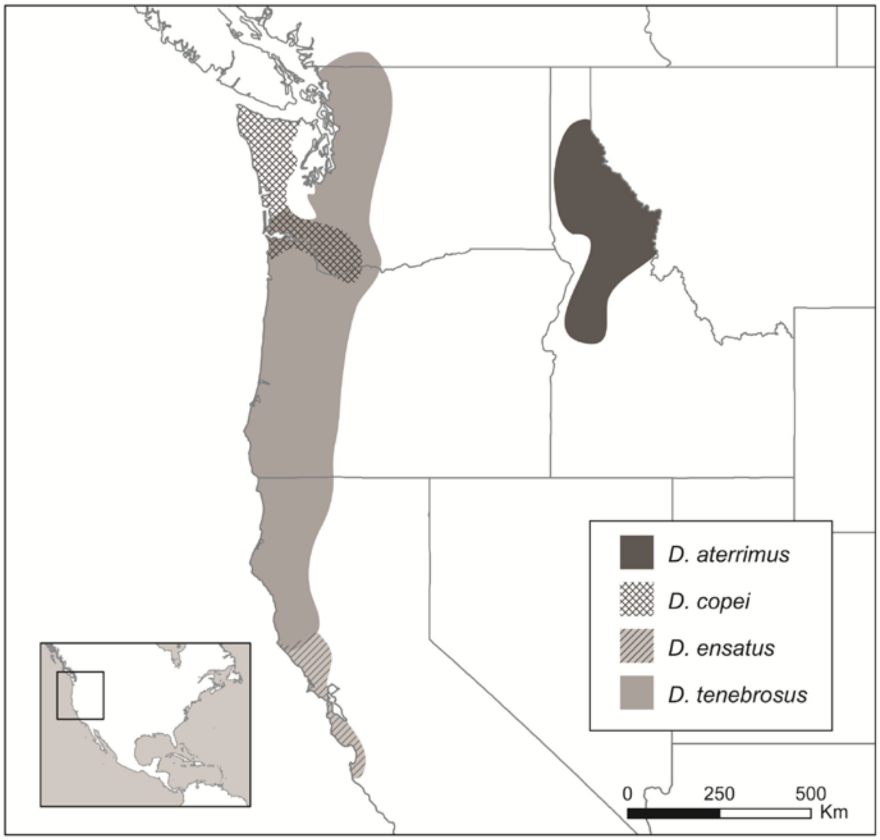


Figure 2. Global distribution of *Dicamptodon* species, including Coastal Giant Salamander (*D. tenebrosus*), in western North America (adapted with permission from Fessler 2012).

Morphological Description

Larvae of Coastal Giant Salamander are approximately 33-35 mm in total length at hatching (Nussbaum and Clothier 1973). Larvae are dark dorsally with light underbellies, have gills and tail fins, and shovel-shaped heads (Figure 1B). If larvae transform into terrestrial adults, they usually do so at 92-166 mm in total length, reaching a maximum length of 340 mm (Nussbaum *et al.* 1983). Some adults do not transform and remain obligate stream dwellers. These neotenes can grow up to 350 mm (Nussbaum *et al.* 1983). Terrestrial adults are heavy-bodied and broad-headed (Figure 1A). They are dark brown to black dorsally and usually marbled with tan or copper (Farr 1989). Larger adults are significantly less marbled than small individuals, suggesting these markings fade with age (Johnston pers. obs. 2000).

Population Spatial Structure and Variability

Studies have shown that Coastal Giant Salamander populations in the Chilliwack Valley, BC, are genetically differentiated from and have less genetic diversity than populations in southern Washington (Dudaniec *et al.* 2010, 2012). The low genetic diversity within BC populations was attributed to historical factors, such as small founding population during post-glacial range expansion northwards, and topographic factors that limit dispersal, including slope and elevation. Observations of Coastal Giant Salamanders have been recorded from the majority of larger watersheds within the Chilliwack drainage, but the degree of connectivity between sites is unknown. Habitat connectivity through upland is disrupted by extensive logging and other habitat disturbance, while presence of predatory fish probably curtails dispersal along larger streams to other sub-drainages.

Designatable Units

The species in Canada is limited to one small area in the Chilliwack Valley. There is no evidence that any subpopulations of Coastal Giant Salamander in Canada are affected by distinct trends or factors, or that there are biological differences between subpopulations that would reflect historical or genetic distinctions. Therefore, the Canadian population is treated as one designatable unit.

Special Significance

In Canada, the Coastal Giant Salamander is found in only one major watershed. It is endemic to the temperate rainforests of the Pacific Northwest and is emblematic of the unique fauna these ecosystems support (Nussbaum *et al*. 1983). The northern limit of the species' range is near the southern border of Canada. Peripheral populations often exhibit a high degree of genetic divergence (Lesica and Allendorf 1995) and are potentially important sources of new adaptations. Coastal Giant Salamanders in Chilliwack Valley are genetically differentiated from populations near the core of the range in Washington (Dudaniec *et al.* 2010). This population may play an important role in the species' persistence in the face of climate change

Coastal Giant Salamander plays an important role as a top predator in streams, particularly in systems lacking large predatory fish. This species is the largest semi-aquatic salamander in North America and the only salamander capable of true vocalizations with adults emitting bark-like cries when disturbed (Nussbaum *et al*. 1983). The terrestrial form of the species is poorly known to the public due to its secretive nature; aquatic larvae and neotenic adults are occasionally captured by anglers.

DISTRIBUTION

Global Range

The range of Coastal Giant Salamander extends along the west coast of North America from southwestern BC, through the Cascade and Coast ranges, to northwestern California (Figure 2). Less than 1% of the global range of the species is in Canada.

Canadian Range

In Canada, the Coastal Giant Salamander is restricted to the Chilliwack River Valley in BC (Figure 3). No Coastal Giant Salamanders have been detected in the watersheds east of Chilliwack Lake (i.e., the Skagit and Silverhope watersheds), or north of the Fraser River. Although Coastal Giant Salamanders have been detected at new sites in the Chilliwack Valley since the previous status report (Ferguson and Johnston 2000), the overall range remains similar, extending from the west side of Vedder Mountain to the slopes east of Chilliwack Lake. The population on the west side of Vedder Mountain, especially at lower elevations, may be isolated due to modifications to the drainage system (Farr 1989). Populations in the Promontory area around Ryder Lake and north of Elk Mountain are increasingly fragmented due to habitat loss and degradation from rural development (Welstead pers. comm. 2012).

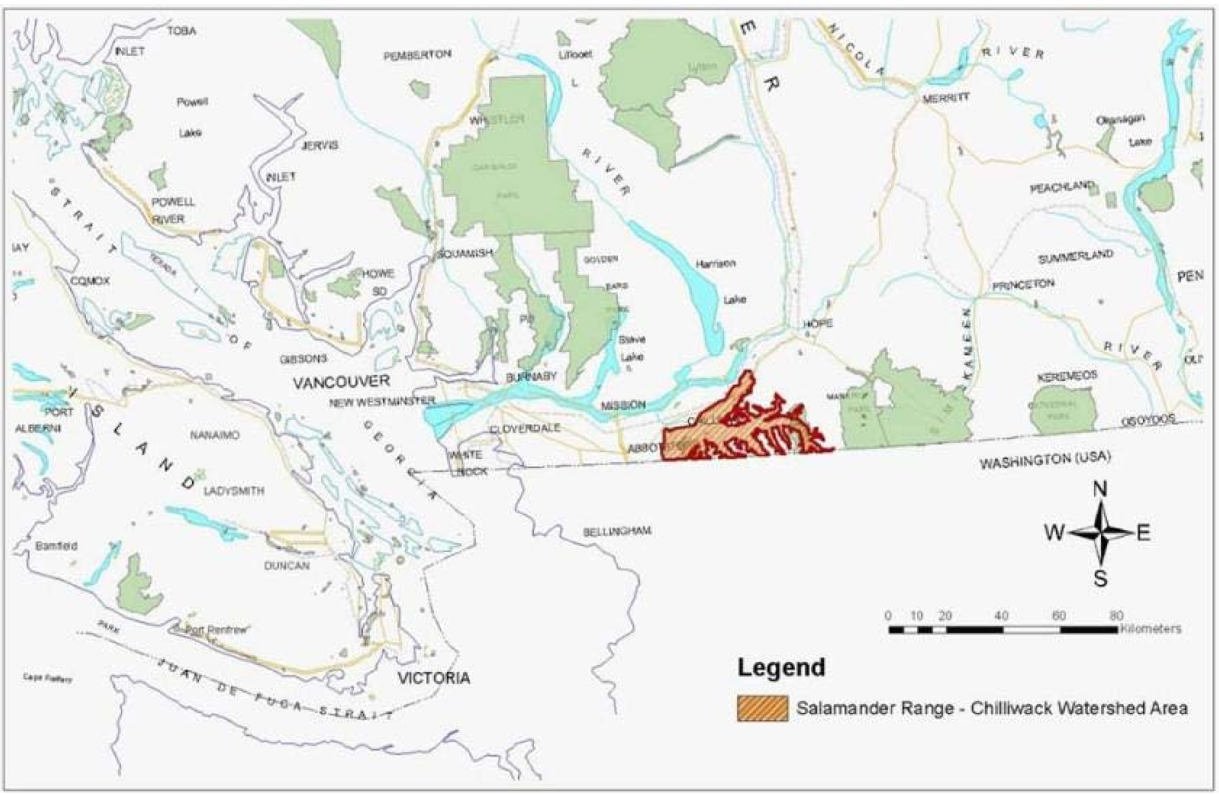


Figure 3. Distribution of the Coastal Giant Salamander, *Dicamptodon tenebrosus*, in Canada. Map prepared by K. Welstead based on data compiled by Ferguson and Johnston (2000) and L. Sopuck, and additional data from the B.C. Ministry of Environment data files. [Taken with permission from: Pacific Giant Salamander Recovery Team 2010].

The overall distribution of the Coastal Giant Salamander in Canada has probably changed little in recent history, aside from the possible historical loss of populations in the Sumas Lake and Vedder Creek areas. In the 1920s, Sumas Lake was drained for agricultural purposes and Vedder Creek was channelled north, becoming the Vedder Canal.

Extent of Occurrence and Area of Occupancy

The estimated extent of occurrence in Canada is 760 km^2. The estimated index of area of occupancy (IAO) is 332 km^2, based on 2 x 2 km grid cells, based solely on known sites (discrete IAO, calculated by A. Filion, Environment Canada). This value is most likely an underestimate. The continuous IAO is estimated to be 608 km^2, based on grid cells placed along the linear length of occupied streams (152 km; Pacific Giant Salamander Recovery Team 2010). The continuous IAO joins known occurrences along occupied streams, accounting for unsearched stream stretches that are likely to be occupied, and is therefore a more accurate representation of the IAO.

The combined linear length of known occupied stream habitat was estimated to be 80 km in 1999 (Ferguson and Johnston 2000) and 152 km in 2009 (Pacific Giant Salamander Recovery Team 2010). The latter value reflects increased knowledge of the species' distribution, rather than an increase in the area of occupancy, which remains small. It is likely that the actual area of occupancy has decreased over the past decade due to habitat loss and degradation (see **Habitat Trends**).

Search Effort

A number of studies on the Coastal Giant Salamander related to habitat use, genetics, and demography have been conducted in the Chilliwack Valley. In addition, there have been several inventories to determine the species' distribution (Appendix 1).

The most recent surveys for the Coastal Giant Salamander in the Chilliwack Valley occurred in summer 2012. Visual surveys were conducted in August 2012 in forested areas within six sub-basins of the Chilliwack River and in the Silverhope Creek drainage to the east (Lynch and Hobbs 2012). In total, 37-person days of searching (based on 8-hour field days) yielded 50 Coastal Giant Salamander in nine streams where the species had not been detected before. In addition, 34 larvae and one terrestrial adult were detected at the survey training site at Elk Mountain.

Students from the BC Institute of Technology (BCIT) conducted surveys of nine streams in 2011 [Vedder Mtn (3), Elk Mtn (4), and on Foley Creek (2)], five streams within existing Wildlife Habitat Areas, and four on streams with some level of deforestation within 30 m of the bank (Currie pers. comm. 2012). In total, 38 individual Coastal Giant Salamander larvae or neotenic adults were observed at seven streams.

As part of her PhD dissertation at the University of British Columbia, Rachael Dudaniec surveyed 48 streams across the Chilliwack Valley for aquatic and / or terrestrial Coastal Giant Salamanders in streams in 2008 and 2009 (from approximately 70 km^2 of the species' Canadian range) using visual encounter surveys for genetics work and analysis of habitat associations (Dudaniec *et al*. 2010; Dudaniec and Richardson 2012; Dudaniec *et al*. 2012). All sites and streams surveyed were previously known localities for the species within the Chilliwack Valley (individuals were detected in 34 of 48 streams).

Curtis and Taylor (2003) collected tissue from larvae in streams flowing through forest stand of various ages for genetic analyses. They searched 25 streams in 1998 and used tissue collected from eight. Sites were situated immediately west of Cultus Lake (Vedder Mountain), east to the upper end of Foley Creek, and from the upper ends of Tamihi Creek and Nesakwatch Creek. All sites and streams surveyed were previously known localities for the species within the Chilliwack Valley.

Unpublished data exist for 66 Coastal Giant Salamanders captured incidentally during fish surveys from 16 localities along the Chilliwack River from 1985 – 2001 (Ptolemy, unpubl. data 1984 – 2001). BC Timber Sales has conducted surveys for salamanders in streams within cutblocks prior to harvesting throughout the Chilliwack Valley, but detailed information on the survey effort was not available.

The main studies and surveys conducted prior to the above studies were included in the previous update (see Ferguson and Johnston 2000). The majority were conducted by students and staff from the University of British Columbia.

HABITAT

Habitat Requirements

The Coastal Giant Salamander requires both aquatic and upland terrestrial habitat to meet all its life history needs. The species has been found from sea level to 1790 m in Oregon (Leonard *et al*. 1993) and to 2160 m in northwest California (Welsh 2005) but appears to reach an altitudinal limit of 1200 m in the Chilliwack Valley (Welstead pers. comm. 2012). Although it has been reported to inhabit a wide range of habitats throughout its range, the species appears to be more restricted in its habitat requirements in BC than elsewhere.

Over its global range, the Coastal Giant Salamander has been reported from all types of lotic environments, from small seepages and mountain streams to large rivers, as well as from some lakes and ponds (Stebbins 1951; Nussbaum and Clothier 1973; Nussbaum 1976; Johnston 1998). Suitable nesting sites may be the most important habitat attribute for Coastal Giant Salamander (Farr 1989), but only four known nest sites have been described from the field, all from montane streams (Jones *et al.* 1990). Two of these were from western Oregon, as described by Nussbaum (1969): 1) in a stable talus and earth bank adjacent to a stream, and 2) within a rock pile at the base of a waterfall. A third was found on a submerged piece of lumber from a bridge that crossed a fast-flowing stream (Henry and Twitty 1940). The fourth nest was discovered on a partly rotted log in a riffle at the edge of a small stream in southwest Oregon (Jones *et al.* 1990).

Within the stream environment, larval Coastal Giant Salamanders utilize various microhabitats but are predominantly found in stream pools (Haycock 1991; Mallory 1996), although this could reflect a sampling bias (larvae are harder to detect in riffles). Hatziantoniou (1999) found giant salamander abundance to be strongly associated with a high percentage of small “pocket” pools (pools of small size). Larval abundance tends to decrease with increasing wetted width (Richardson and Neill 1995; Adams and Bury 2002) and with increasing depth (Southerland 1986; Tumlinson *et al*. 1990). However, Coastal Giant Salamanders have been observed regularly in large river systems, such as the Chilliwack River. A total of 66 Coastal Giant Salamanders were caught at 17 sites along the river during 16 sampling sessions between 1985 – 2000 during fish surveys using an electrofisher (average river width was 5 m (Ptolemy, unpubl. data 1984 – 2001). As well, Coastal Giant Salamanders use the hyporheic zone of streams (area where surface and shallow groundwater mix beneath and lateral to streambeds). Feral *et al.* (2005) captured 15 larval Coastal Giant Salamander in invertebrate traps, buried up to 60 cm deep, in northern California. All captures were when flows were less than 4 cm deep, but the majority were from streams that had no surface flow.

As with other stream amphibians (e.g., Coastal Tailed Frog, *Ascaphus truei*), the presence and relative abundance of Coastal Giant Salamander are influenced by surficial geology. In streams in western Washington and Oregon, the abundance of Coastal Giant Salamander was positively correlated with the number of substrate crevices and cover objects (Hall *et al.* 1978; Murphy and Hall 1981; Connor *et al.* 1988). The availability and density of rocks (> 7.5 cm) strongly influenced the abundance and distribution of larval Coastal Giant Salamander both within and among pools (Parker 1991) with larvae selecting substrate objects that covered their entire bodies (Haycock 1991). In the Chilliwack Valley, the relative abundance of larvae was positively associated with the percentage of boulders within streams (Dudaniec and Richardson 2010). Leuthold *et al*. (2012) estimated that peak larval densities occur in intermediate-sized streams, which contain most suitable substrates with large cover objects. Hatziantoniou (1999) found Coastal Giant Salamander abundance increased with increasing percentage of rock coverage and decreasing water velocity. The type of rock available may also be important. In the unharvested landscape of the Olympic National Park, Adams and Bury (2002) only found the Cope’s Giant Salamander in streams flowing over unconsolidated surface geology (e.g., marine sediments that erode easily) compared to the Coastal Tailed Frog, which were more abundant in streams on consolidated rock types. The authors point out that previous studies have generally found a scarcity of stream amphibians on unconsolidated rock types, leading to less forest protection of these habitat types. However, no studies have examined the interaction of surface geology with timber harvest, and the Adams and Bury (2002) study is the only one to examine surface geology in unlogged forests.

The riparian zone of streams is important for terrestrial Coastal Giant Salamanders. Eighty-four percent of terrestrial Coastal Giant Salamanders captured in unmanaged forests in Oregon were found within 10 m of a stream (Vesely 1996). On average, 67% of recorded sites from 18 radio-tracked Coastal Giant Salamander in BC and Washington were within 5 m of the water's edge, but the results were highly variable; some individuals were always found close to the water, while others were never observed closer than 5 m from the stream margin (Johnston 1998). Based on more extensive telemetry work carried out across two active seasons in central Washington, Fessler (2012) found that Coastal Giant Salamander movements were generally restricted to within 30 m of a stream bank and no more than 50 m from a water source (seep or stream). Although some individuals moved over 100 m from a stream into upland habitat, all individuals were tracked to sites in and around seeps (Fessler 2012). Coastal Giant Salamander were found in terrestrial and aquatic locations almost equally throughout the active season (terrestrial: 49%; stream bank: 18%; stream: 21%; seep: 12%; Fessler 2012).

Coastal Giant Salamanders use a variety of terrestrial refuge sites. The most common refuges were within or under coarse woody debris, usually in advanced stages of decay, underground (small mammal burrows and root channels), or under rocks (Johnston 1998). Fessler (2012) used two techniques to observe Coastal Giant Salamander microhabitat use, radio telemetry and remote cameras aimed at known refuge sites, and found evidence of site fidelity. Most revisits to refuges were within 50 days and with individuals having moved less than 50 m during that time. The longest time and distance observed between revisits to a refuge were 381 days and 259 m, respectively (Fessler 2012). Any moist microsites may be a suitable resting site for terrestrial *Dicamptodon*. In northern California, large aggregations of metamorphosed California Giant Salamanders were found under two old, rusted culverts that were removed from streams (Fellers *et al.* 2010).

Terrestrial Coastal Giant Salamanders tend to overwinter in the same types of refuges that they use throughout the active season, most commonly in underground burrows and seeps (Johnston pers. obs. 2000). All nine Coastal Giant Salamander overwintering sites to which individuals were tracked in central Washington were in locations associated with aquatic features (below the surface in the path of a seep; in a stream; in a stream bank with flowing water; Fessler 2012). Dethlefsen (1948) published an account of numerous *D. ensatus* adults unearthed 6.1 m underground during drilling into a sandstone and mud hillside by a spring in California that was likely an overwintering site (Nussbaum 1969).

Coastal Giant Salamanders have been found in a variety of forest stand ages, including clearcuts and mature and old forest. Dudaniec and Richardson (2012) found that the presence and relative abundance of Coastal Giant Salamander in 32 streams sampled across the Chilliwack Valley were positively associated with stream elevation and forest age. Previous studies in the area have found the presence or density of larvae similar or higher in clearcuts than in forests (Pollock *et al.* 1990; Richardson and Neill 1998; Neill, unpubl. data 2000), and higher densities in streams in second-growth versus clearcuts or old-growth stands (Hatziontoniou 1999). In contrast to studies comparing relative abundance, Curtis and Taylor (2003) found that larval Coastal Giant Salamander in streams in recent clearcuts had lower genetic variation and heterozygosity compared to those in old-growth and second-growth forests, suggesting bottlenecks in population size either due to reduced survivorship or restricted dispersal. Ferguson (1998) found that larval growth rates at one clearcut site (< 5 years old) in the Chilliwack Valley were nearly twice as fast as in closed canopy sites (N = 3). This is consistent with observations in fisheries research, where growth is frequently found to increase in clearcut streams due to increased productivity (e.g., Hartman and Scrivener 1990). The recovery of Coastal Tailed Frogs in the Mount St. Helens area, which has seen some of the highest densities of larvae anywhere in the Pacific Northwest, has also been attributed to increased productivity in local streams post-eruption (Crisafulli *et al*. 2005).

In contrast to aquatic forms, the catch per unit effort of terrestrial Coastal Giant Salamander was lower in clearcuts than in forested habitat, and salamanders in clearcuts altered their behaviour in ways consistent with a moisture stress hypothesis (Johnston 1998; Johnston and Frid, unpubl. data 2000). In the Chilliwack region, terrestrial adults have been observed crossing from forested habitat into clearcuts (< 10 years since cut; Johnston 1998). However, this behaviour was observed infrequently and on every occasion, the salamander returned to forested habitat within 8 days. When salamanders were placed at the habitat interface between forest and clearcut, they avoided the clearcut in favour of the forest with the former acting as a barrier to movement (Johnston 1998). In comparison to salamanders at forested sites (>25 years since last cut), animals in clearcuts (< 10 years since last cut) remained closer to the stream, spent longer in subterranean refuges, had smaller summer and fall home ranges, and were more dependent on precipitation for their movements during the summer (Johnston 1998). These changes in behaviour could reduce the fitness of animals in clearcuts by influencing their ability to find food and mates (Johnston 1998), and curtail overland dispersal. Dudaniec and Richardson (2012) found evidence that heat-load index (measure of solar intercept) could influence the genetic structure in Chilliwack Valley populations of the Coastal Giant Salamander. These findings are consistent with results of a study in Oregon, where fewer terrestrial Coastal Giant Salamanders were found along streams where forest was cut to the stream edge (7%, one of 13 sites) than at sites that had forested riparian buffers (42%, five of 12 sites) (Vesely 1996).

Habitat Trends

In Canada, much of the Coastal Giant Salamander's historical habitat has become fragmented by forest harvesting, residential development, and wild fires. Residential development has led to the permanent loss of forest cover and streams: for example, three steams were completely drained in the community of Yarrow approximately 20 years ago as a result of development (Knopp pers. comm. 2012). Logging activities throughout the valley reduce habitat quality due to changes in microclimatic conditions in riparian and terrestrial environments (Chen *et al.* 1993, 1995; Brosofske *et al.* 1997), and increased stream temperatures in young stands (Beschta *et al.* 1987), which may exceed thermal tolerance limits of stream amphibians. Road building associated with urban development and forest harvesting can degrade stream habitat by altering flows, fragmenting populations, and increasing sedimentation. Sedimentation of streams, in turn, can reduce aquatic insect populations, clog the gills of aquatic salamanders (Toews and Brownlee 1981), and reduce available cover by filling interstitial spaces among rocks and pebbles (Waters 1995).

Approximately 9% of the Canadian range of Coastal Giant Salamander has been developed (Pacific Giant Salamander Recovery Team 2010), largely in the western sections of the range. Urban development is slowly progressing eastward into the Chilliwack Valley, as well as onto surrounding hillsides, isolating populations within forest fragments and streams. In 1996 there were approximately 1400 residential dwellings on the hillsides surrounding Chilliwack (Promontory, Chilliwack Mountain, Ryder Lake and Eastern Hillside areas; Ferguson and Johnston 2000). As of 2012, that figure rose to 4022 (City of Chilliwack Official Community Plan, OCP 2013). According to the plan, "the urban corridor has to be favoured over the hillside option which has a limited capacity (in relation to the City's long term growth needs) and a high development cost. The City's future thus lies in densification." The plan outlines a new development proposed in the southwest part of the Coastal Giant Salamander's range northwest of Vedder Mountain. It will include medium-density residential, general industrial areas, and general commercial areas. As well, the OCP proposes approximately 21 km of trail way through the neighbourhoods of Promontory, Ryder Lake, and Eastern Hillsides, and seven new, expanded, or redeveloped neighbourhood parks and one new, expanded, or redeveloped community park. A relatively high proportion of development has occurred on Vedder Mountain in the area of one of the largest known occurrences of Coastal Giant Salamander in BC (BC CDC Element Occurrence #5). This site has detection records from 1927 to 2011 and over 50 Feature IDs (i.e., unique geographic sites or streams where individuals have been found within an EO; Table 1). The next nearest observations of the species are approximately 3 km away on the other side of the Chilliwack River (in EOs #25 and #10, the latter of which did not have Coastal Giant Salamander detections in 2006), which also faces threats from increasing development, and across the developed Cultus Lake Valley (in EO #23 in the Liumchen Creek watershed over 4 km to the east).

Table 1. Summary of occurrences of Coastal Giant Salamander in British Columbia grouped by element occurrences. Data are from BC Conservation Data Centre database (up to and including 2011).

EO No. / ID[a]	General Locality of the EO	# Sites per EO (Source Feature Ids)	# Detection Yrs per EO	Yrs when detected per EO	Notes on threats	Protection[b]	Estimated viability[c]
3 / 5627	Chilliwack River; northeast of Mount Pierce	8	9	1983, 1985, 1994, 1999-2001, 2008, 2009, 2011			AC - Excellent, good, or fair estimated viability
4 / 2563	Foley Creek	18	7	1985, 1994, 1995, 2000, 2004, 2008, 2009	Partly clearcut in 1994	Partly within WHA	BC - Good or fair estimated viability
5 / 1819	Cultus Lake; west side	63	24	1927, 1935, 1942, 1947, 1981, 1984, 1985, 1990, 1991, 1993, 1994, 1996, 1998-2000, 2002-2009, 2011	Portions of the occurrence subject to some development; however, small stream and wet areas remain		AB - Excellent or good estimated viability
6 / 5094	Centre Creek	13	8	1984, 1985, 1994, 1995, 2000, 2001, 2008, 2009		Within WHA	BC - Good or fair estimated viability
7 / 902	Nesakwatch Creek	16	6	1994, 1995, 2000, 2007-2009		Partly within WHA	BC - Good or fair estimated viability
8 / 4468	Slesse Creek	5	5	1994, 2000, 2001, 2008, 2009	Clearcut around stream (Knopp and Larkin 1995), now younger age (immature) forest.		BC - Good or fair estimated viability
9 / 3244	Seedling Creek	2	3	1995, 2000, 2011		WHA within lower reaches of creek	E - Verified extant (viability not assessed)
10 / 3248	Promontory Heights / Mount Tom	4	5	1986, 1990, 1991, 1995, 2000; not detected at 4 sites in 2006	Much housing development in area		F - Failed to find
11 / 5422	Church Mountain; north side	8	7	1986, 1993, 1994, 2000, 2008, 2009, 2011		Within WHA	CD - Fair or poor estimated viability
12 / 3918	Wingfield Creek	1	1	1990			E - Verified extant (viability not assessed)
13 / 1357	Tamihi Creek	13	6	1934, 1980, 1986, 1995, 2000, 2008	Development encroaching to portion of area	Partly within WHA	BC - Good or fair estimated viability
14 / 4357	Elk Mountain; south slope	31	11	1987, 1989, 1994, 1996, 1999, 2000, 2006-2009, 2011	Private land fragments this site somewhat; habitat quality deteriorates downstream	Partly within WHAs for this & other species	BC - Good or fair estimated viability
15 / 2424	Bridal Veil Creek	5	3	1990, 1993, 1994; in 2006 - no salamanders found within 1 km to the north and east of 1994 sightings		Provincial Park	F - Failed to find
16 / 1431	Chipmunk Creek	4	3	1990, 2000, 2011		Extensive logging	E - Verified extant (viability not assessed)
17 / 158	Post Creek	3	3	1988, 1996, 2001			E - Verified extant (viability not assessed)

EO No. / ID[a]	General Locality of the EO	# Sites per EO (Source Feature Ids)	# Detection Yrs per EO	Yrs when detected per EO	Notes on threats	Protection[b]	Estimated viability[c]
18 / 2845	Chilliwack Lake; northeast shore	12	6	1985, 1986, 1988, 1989, 1994, 2009		Provincial Park	B - Good estimated viability
20 / 4182	Chilliwack Lake; creek west of inlet river	2	2	1990, 1996		Provincial Park & Ecological Reserve	E - Verified extant (viability not assessed)
21 / 2282	Chilliwack Lake; west shore	2	5	detected before 1960; 1977-1979, 1985		Provincial Park	H? - Possibly historical
22 / 5404	Paleface Creek; Chilliwack Lake Park	1	1	1976	Valley logged	Provincial Park	H - Historical
23 / 1027	Liumchen Creek	5	4	1934, 1988, 1995, 2012		Ecological Reserve	E - Verified extant (viability not assessed)
24 / 7497	Calkins Creek	5	4	1993, 2000, 2006, 2007	New access road (2006); possibly to be developed		E - Verified extant (viability not assessed)
25 / 7498	Ryder Lake / Mount Tom	3	4	1992, 1994, 2006, 2007	Habitat described as fair-poor with many disturbances		BD - Good, fair, or poor estimated viability
26 / 7535	Tamihi Creek	6	6	2000, 2005, 2007-2009, 2011	Portions clearcut		E - Verified extant (viability not assessed)
27 / 7669	Elk Crk; Rosedale	1	1	2001		Partially within WHA	E - Verified extant (viability not assessed)
28 / 7671	Midgley Creek	1	2	1998, 2004	Roads		E - Verified extant (viability not assessed)
29 / 8969	Chipmunk Creek	2	1	2011	Heavy recreational use; area to the north has recently been logged		C - Fair estimated viability
26 (total # EOs)		234 (total # sites / Source Feature IDs)	5.27	average # detection years			
			4.5	median # detection years			
			24	max # detection years			
			1	min # detection years			

[a] BC Conservation Data Centre Element Occurrence (EO).

EO is: "An area of land and/or water in which a species or ecological community is, or was present. An Element Occurrence (EO) should have practical conservation value for the Element as evidenced by potential continued (or historic) presence and/or regular recurrence at a given location. For species Elements, the EO often corresponds with the local population, but when appropriate may be a portion of a population (e.g., long distance dispersers) or a group of nearby populations (e.g., metapopulation)."

[b] WHA – Wildlife Habitat Area

[c] Viability assessment ratings by BC Conservation Data Centre

In BC, there has been a trend for logging activities to progress uphill, starting in the valley bottoms and gradually moving to higher elevations, as easily accessible timber in most productive areas are depleted. In the Chilliwack Valley, the lower elevations have already been logged, leaving most of the remaining old-growth habitat in scattered fragments and above the altitudinal limit of the Coastal Giant Salamander. Of the approximately 64,300 ha of land that was under forest cover within the range of the

Canadian population of Coastal Giant Salamander, and below the 1,200 m elevation limit for the species in the Chilliwack Valley, less than 10% was over 120 years old and approximately 51% was ≤ 60 years old as of 2003 (unpubl. data, Pacific Giant Salamander Recovery Team 2010). According to the 5-year cut plan for the area submitted for 1998-2002, an additional 970 ha were proposed for clearcut harvesting and partial harvesting by 2002 (including selective logging and commercial thinning; Ferguson and Johnston 2000). Following an 80-year harvest rotation, it was projected that much of the remaining mature second-growth would likely be subject to second rotation cutting beginning around 2013. Future harvest plans were not accessible for this update due to the shift in 2004 from the Forest Practices Code to the *Forest and Range Practices Act*, which no longer requires licensees to submit 5-year harvesting plans to the provincial government. Instead, 5-year forest stewardship plans are prepared, which show areas designated for stewardship and where required land use objectives are addressed. These include old-growth management areas and Wildlife Habitat Areas. Estimations from data extracted from iMapBC suggest that from 2006 to 2013 approximately 3800 ha of forest blocks: 1) were or will be harvested (gross area = 690 ha), 2) are / were pending (gross area = 69 ha), or 3) have been retired (cutting completed but may be re-harvested in the future) within the range of the Coastal Giant Salamander (gross area = 3037 ha; Table 2; Figure 4). Projections for the next 5 years (2012 – 2017) were obtained from the three main licensees / companies (i.e., Dorman Group, BC Timber Sales – a branch of the BC provincial government, and Ts'elxwéyeqw Tribe Management Limited) that have an agreement to treat the Chilliwack Valley as an area-based licence project (Wealick pers. comm. 2013). From that, a projected total volume of 376,259 m^3 will be harvested during that 5 years from their licences in the valley, and approximately 577 ha will be logged by the latter two companies (no data were available from Dorman Group).

Table 2. Number of cutblocks and area harvested within the range of the Coastal Giant Salamander in the Chilliwack Valley from 2006 to 2013 as summarized from the provincial iMAPBC online mapping tool (http://www.data.gov.bc.ca/dbc/geographic/view_and_analyze/imapbc/index.page).

Cutblock Status*	# Cutblocks	Database Years	Planned Gross Block Area (ha)	Planned Net Block Area (ha)
Active	57	2006-2013	690.26	582.17
Pending	3	2010-2013	69.08	47.90
Retired	190	2006-2012	3037.76	2582.15
		Total	3797.10	3212.22

*Logging plans are no longer required, and hence information on future logging could not be obtained.

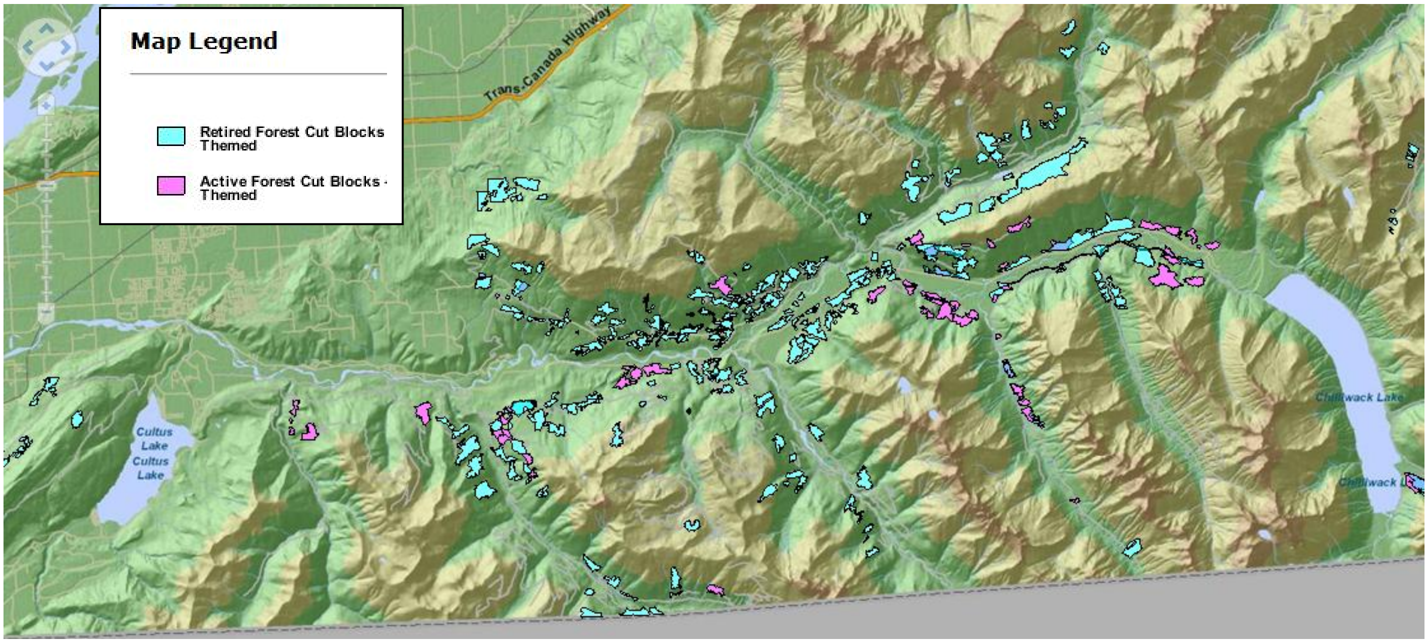


Figure 4. Retired, pending, and active forest cutblocks in the Chilliwack Valley. (Source: iMAPBC online mapping tool (http://www.data.gov.bc.ca/dbc/geographic/view_and_analyze/imapbc/index.page; accessed March 2013).

There has been an increase in the number of power generation development projects in the Chilliwack Valley since the previous status report update in 2000 (i.e., run-of-river projects). Based on iMapBC, there are 18 licences for water diversion for power generation within the range of Coastal Giant Salamander in BC (Figure 5; Appendix 2), 10 of which are new. Of the 18 licences 13 are categorized as "active" and the remainder as "abandoned" or "refused". The average amount of water diverted is 2.3 cubic metres per second (m^3/s; 3.38 m^3/s for active licences only), and average penstock length is 2615 m (2824 m for "active" licences only; no penstock length was provided for five active licences). Numerous watersheds south of the Chilliwack River that contain Coastal Giant Salamander populations overlap with power generation licences (Tamihi, Nesakwatch, Slesse, Pierce, and Centre Creeks). The importance of main stem channels that are often the target of run-of-river projects to the population dynamics of Coastal Giant Salamander is not well understood, but individuals are found in larger systems (Ptolemy, unpubl. data 1984 – 2001). The effects of altered and reduced flow regimes associated with power generation on Coastal Giant Salamanders living in diversion channels has not been studied but is currently the focus of research for another stream amphibian, the Coastal Tailed Frog (Malt pers. comm. 2012). Power projects that impact mid-elevation, forested streams via the construction of roads, power houses, transmission lines, pipelines, and weirs, as well as changing in-stream water flows may contribute to greater habitat fragmentation for Coastal Giant Salamander in the Chilliwack Valley.

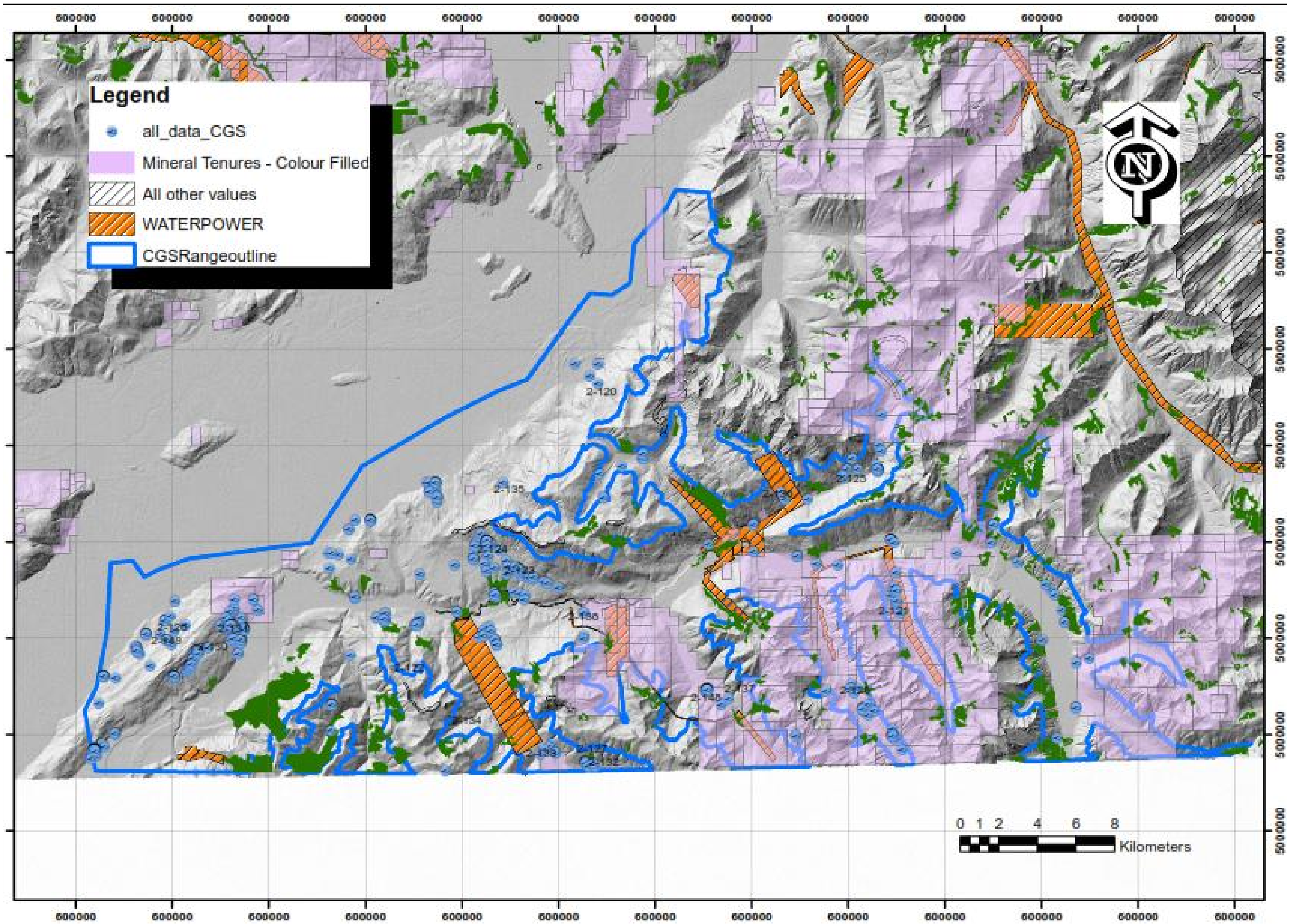


Figure 5. Locality of proposed renewable energy production development projects and mineral tenures within the range of Coastal Giant Salamander (developed by K. Welstead, MFLNRO 2012).

BIOLOGY

Life Cycle and Reproduction

Coastal Giant Salamanders probably breed once every second year (Nussbaum 1976) in or adjacent to montane streams (Haycock 1991); only four nest sites have been described from the field and all have been from the US (Henry and Twitty 1940; Nussbaum 1969; Jones *et al.* 1990). Egg clutches in three of the described nests found in Oregon were estimated to have been laid in May. The fourth nest was found in July with larvae observed in September (Jones *et al*. 1990). In California and Oregon, breeding can occur either in spring or fall (Nussbaum *et al.* 1983). Similarly, breeding in BC may occur throughout the May – October active season (Haycock 1991). Ferguson (1998) monitored changes in larval abundance at four streams over 2 years within the Chilliwack Valley. She observed a sudden influx of hatchlings (< 50 mm total body length) at two of four sites during August. Larvae of this length are likely 11 months old, and their appearance in August suggests they were the product of breeding the previous September (Ferguson 1998). As not all sites experienced a similar pulse of hatchlings, it remains uncertain whether breeding is seasonal in BC.

Age at first reproduction is unknown but is over 5 – 6 years, which is the length of the larval period. Nothing is known about the sex ratio in Coastal Giant Salamander populations. Fertilization is internal but indirect and accomplished by means of spermatophores. Females pick up spermatophores deposited by males with their cloaca and subsequently deposit a clutch of 135 – 200 eggs in a nest chamber (Nussbaum *et al.* 1983). Nussbaum *et al.* (1983) reported that the female will stay in the nest until the eggs hatch and the young abandon the nest chamber, a period of up to 200 days.

Coastal Giant Salamanders take approximately 35 days to develop to tail bud stage (Nussbaum 1969) and a further 5 months until hatching (Henry and Twitty 1940). Newly hatched larvae remain buried in the substrate and attached to their yolk sac for a further 3-4 months before appearing in streams at 45-51 mm in total length (Nussbaum and Clothier 1973). Combining these developmental periods, Ferguson (1998) assumed larvae are first detectable 9-11 months after egg-laying. The larval period is believed to last between 2 – 4 years in the US (Duellman and Trueb 1986), but preliminary data from four streams within the Chilliwack Valley suggest larvae may take up to six years to reach a total length of 130 mm (Ferguson 1998), the midpoint of the 92-166 mm range for transformation suggested by Nussbaum and Clothier (1973).

At the end of the larval period, Coastal Giant Salamanders either transform into terrestrial salamanders or remain in their natal habitat as neotenes. The frequency of neoteny varies between populations and appears to be facultative. Adults can grow up to 350 mm in total length, making this species the largest semi-aquatic salamander in North America (Nussbaum *et al.* 1983). The best approximation of life span comes from studies of similar-sized aquatic salamanders, which may live up to 25 years in captivity (Duellman and Trueb 1986). The generation time is probably 10 – 15 years, based on maturity at >6 or more years and maximum lifespan of two decades or more. Dudaniec *et al*. (2012) used a “conservative” generation time of 12.5 years for their genetics study based on an estimated maximum life span of approximately 20 years (Nussbaum 1976).

Physiology and Adaptability

Coastal Giant Salamanders evolved within the temperate rainforests of the Coastal Northwest (Welsh 1991). They are highly dependent on moisture for cutaneous respiration. Although they have lungs, transformed adults receive approximately 66% of their oxygen through the skin (Clothier 1971). This moisture dependence restricts their activity and limits the habitats they can exploit.

Streams within the Chilliwack Valley experience moderate to high snowfall in winter. Larvae are rarely detected in streams until the water temperature rises above 5°C (Ferguson 1998). At water temperatures below 5°C, larvae are thought to burrow into crevices within the stream substrate. This strategy may allow them to avoid freezing in winter surface waters. Larvae in Chilliwack streams become sluggish and easy to catch at water temperatures >20°C, suggesting this temperature approximates the upper limit of their thermal tolerance in this area. From a single population from Oregon, Bury (2008) determined the Critical Thermal Maxima for larval Coastal Giant Salamander acclimated at a water temperature of 14°C to be 28.9°C – 29.3°C. Johnston (1998) found terrestrial Coastal Giant Salamanders had a minimum air temperature threshold of 0°C for movement.

Movements and Home Range

Johnston (1998) calculated the home range size of 20 radio-tracked terrestrial Coastal Giant Salamander in the Chilliwack Valley using the Minimum Convex Polygon (MCP) and Adaptive Kernel (AK) methods of home range estimation. The mean home range size was estimated as 3074 m^2 (ranging from 381 m^2 to 21,600 m^2, median = 1223 m^2) using the MCP method, and 5196 m^2 (with a range of 403 m^2 to 35,321 m^2, median = 3075 m^2) when the 95% AK method was used. These results do not conform to the classic concept of a restricted home range as the size of each animal's range continued to increase as new telemetry detections were added with time. Johnston (1998) concluded that for the time scale of the study (2 – 4 months), adults had an indefinite home range and that a telemetry study conducted over a longer period of time (i.e., years) may be able to recognize distinct home ranges. In contrast, Fessler (2012) tracked adult Coastal Giant Salamander through two active seasons / years in central Washington and found that almost all individuals returned to previously occupied areas and refuges (activity centres) within and among seasons. He determined that the mean home range size for multi-season animals was 1,282 ± 547 m^2 MCP (837 ± 228 m^2 95% KDE and 205 ± 59 m^2 50% KDE) for the entirety of tracking. He also found for multi-season tracked individuals that range size varied between years. Four of the five individuals he tracked had a substantial decrease in range size in the second year, differences between years ranging from 74 m^2 to 2,733 m^2 MCP (252 m^2 to 1,600 m^2 95% KDE). Fessler (2012) speculated that reduced precipitation from June to September 2011 curtailed movements and thus home range size in that year. However, the amount of precipitation in 2011 was closer to climate norms for the area, suggesting that Coastal Giant Salamander home ranges that year may have been closer to normal than in wetter 2010. The results from these studies may reflect that terrestrial Coastal Giant Salamander may not have distinct home ranges, in the traditional sense. However, they do have sites that they return to on a regular basis but still roam quite widely.

Farr (1989) speculated that Coastal Giant Salamanders spend their entire life cycle in one creek. This claim was based on the observation that many apparently isolated creeks had viable populations. This assertion has been strengthened by studies within the Chilliwack Valley showing low movement distances for both larvae and adults. A mark-recapture study conducted from 1996 – 1998 found that 73% of marked larvae (N > 2500) remain within 10 m of their initial capture site (mean annual movements were estimated at less than 2 m from the site of first capture), and fewer than 2% travelled greater than 50 m annually (Neill 1998; Neill unpubl. data 2000). Similarly, Ferguson (1998) found that 90% of marked larvae moved less than 20 m (cumulative distance) over the course of one year, and only 10% of larvae moved further than 20 m over two successive summers.

Terrestrial adults move further than larvae but rarely travel between streams (Johnston 1998). In a radio-telemetry study of 20 individuals in BC, Johnston (1998) found that terrestrial adults were primarily active at night, with 70% of all movements between dusk and dawn. In that study, the average movement length of a terrestrial adult, once initiated, was 10.2 ±1.1 m, similar to movements in central Washington (14.4 ± 1.8 m; Fessler 2012). However, the longest movements in the two studies differed markedly. Johnston (1998) reported a maximum movement of 67 m in BC; in contrast, Fessler (2012) recorded a maximum of 271 m in Washington, with more than 10 movements greater than 67 m. Terrestrial adults in both studies moved more often and greater distances when it was raining (Johnston 1998; Fessler 2012).

The speed at which Coastal Giant Salamanders can recolonize unoccupied habitats is unknown. Survey work in the Chilliwack Valley detected Coastal Giant Salamanders in only 22 of 59 seemingly habitable streams (Richardson and Neill 1995); 53 larvae experimentally introduced into an unoccupied stream suggested that at least some of these uninhabited streams could sustain larval populations (Neill unpubl. data 2000). It is possible that many of these currently unoccupied streams experienced local extirpation in the recent past. Coastal Giant Salamander larvae reappeared in one Washington stream two years after a severe drought (Nussbaum and Clothier 1973). It is unknown whether these animals had dispersed from nearby areas or had survived in refuges in subsurface waters during the drought (Feral *et al.* 2005).

Ferguson (1998) found no difference in the frequency or lengths of movements by larvae in the early active season (May – June) and the late active season (August – September). Larvae caught in subsequent years were frequently found in the same site (within ± 2 m), providing no evidence of seasonal migration. Radio-telemetry of terrestrial adult Coastal Giant Salamander in BC and Washington found no evidence of seasonal differences in movements up and down streams, or towards and away from the streams (Johnston 1998; Fessler 2012).

Dispersal

Results of studies conducted in the Chilliwack Valley suggest that both larval and terrestrial Coastal Giant Salamanders are poor dispersers. In 1996 and 1997, Ferguson (1998) experimentally depleted 25 m – 40 m reaches of four streams and marked larvae in reaches surrounding the depletion zone to assess recolonization rates. One year after depletion, only 4 – 5% of the marked larvae from neighbouring reaches had colonized the depleted area. One of four sites was fully re-colonized by recruits as a result of breeding (i.e., no marked individuals colonized the area), and only 29 – 77% of removed individuals had been replaced at the other three sites by recruits and marked individuals combined. If larvae were lost as a result of forest harvesting, Ferguson (1998) estimated that full recolonization of a 400 m reach in an average-sized clearcut in the Chilliwack Valley would require 8 – 55 years. Limited movements and dispersal abilities could be exacerbated by roads and culverts. Sagar (2004) found that larval Coastal Giant Salamander making long-distance movements moved less frequently through stream reaches with culverts than stream reaches without culverts, suggesting a barrier effect. The author also found larval Coastal Giant Salamander using habitat found in arch culverts (i.e., which provides a presence and heterogeneity of substrate) more than pipe culverts.

It is likely that adult dispersal and reproduction are a more effective mode of colonization than is in-stream dispersal of larvae. In Ferguson's (1998) colonization experiment, larval dispersal never contributed more than 13 individuals to any removal zone. In contrast, adult females can carry between 85 – 200 eggs (Nussbaum 1969). Egg-to-larva survival in Coastal Giant Salamanders is unknown, but if higher than 10 – 15%, one reproductive event could increase local density in depopulated areas much more effectively than larval immigration from adjacent reaches. Although their movements are difficult to study directly, terrestrial Coastal Giant Salamanders appear to be poor dispersers. Johnston (1998) fit the distribution of displacement distances of 20 terrestrial adults to a negative exponential model to predict the probability of an animal dispersing various distances over a 2-month period. The distance between neighbouring streams in the Chilliwack Valley is variable, but on average is approximately 0.5 km (Johnston, pers. obs. 2000). Results of the model suggested that likelihood of a salamander travelling this distance in a 2-month period was one in 1000. This estimate is undoubtedly an overestimation as it assumes no mortality during dispersal (Johnston 1998). In addition, this probability is based upon movements made in all directions (rather than simply orthogonal to the stream of origin). If movement distances were weighted by the angle to a neighbouring stream, the probability of an animal dispersing to a stream 0.5 km away would be significantly lower. Thus even if the terrestrial adult population in an area is high, very little long-range dispersal will occur over a few months (Johnston 1998). Based on tissue collected from larvae, it was estimated that gene flow among populations was 1.7 – 4.5 effective migrants per generation, which is considered a moderate level of gene flow among subpopulations (Curtis and Taylor 2003). Populations within the Chilliwack Valley had lower genetic diversity compared to populations in more central range locations, attributed to historical landscape-driven factors, and show evidence of recent bottlenecks for 10% of populations sampled (Dudaniec *et al*. 2012). Poor dispersal ability is of particular concern in the Chilliwack Valley where potential salamander habitat has been extensively fragmented as a result of logging over the past 70 years. Logging roads and culverts do not appear to be a dispersal barrier to terrestrial Coastal Giant Salamander (Knopp pers. comm. 2012). Terrestrial Coastal Giant Salamanders have been tracked in very steep terrain, such as up rock and cliff walls and up waterfalls, and thus they may be able to climb up and around culverts (Johnston pers. obs. 2000).

The volcanic eruption of Mount St. Helens in 1980 offered a unique opportunity to observe the dispersal and recolonization of Coastal Giant Salamanders and other amphibians. Stream amphibians recovered at a slower rate than lake and pond species 20 years post-eruption, which the authors attributed to lower dispersal capabilities in the former group (Crisafulli *et al*. 2005). Stream amphibian recovery rates within the blow-down and scorch zone were species-specific, with Coastal Tailed Frogs recovering faster and occurring at higher densities compared to *Dicamptodon* species. The authors believed that individuals in streams and in terrestrial habitats did not survive the blast, and that recovery of *Dicamptodon* species within the blow-down and scorch zones likely came from neotenic individuals occurring in ice-protected lakes in the headwaters of some streams (Crisafulli *et al*. 2005). No stream amphibians had been detected in the debris-avalanche and pyroclastic-flow zones 20 years post-eruption, probably due to poor dispersal capabilities (the closest source population containing terrestrial *Dicamptodon* adults is 15 km away; Crisafulli *et al*. 2005).

Intraspecific Interactions

Dicamptodon are considered highly predaceous and cannibalistic, and as such tend to be solitary. Nussbaum *et al.* (1983) commented that bite marks are frequently found on Coastal Giant Salamanders; many larvae caught within the Chilliwack region had bite marks on their tails that were likely delivered by conspecifics (Ferguson pers. obs. 2000). In central Washington, Fessler (2012) never observed more than one Coastal Giant Salamander adult in the same refuge. He suggested that territorial behaviour influences the distribution of animals within a given area.

Interspecific Interactions

Coastal Giant Salamanders can be the most abundant vertebrate species in headwater assemblages (Hawkins *et al*. 1983; Olson and Weaver 2007), playing a dominant role as top predators (Feminella and Hawkins1994; Parker 1994; Rundio and Olson 2001). In aquatic sites containing predatory fish, Coastal Giant Salamander are both prey and predator. Young-of-the-year Coastal Giant Salamanders are palatable to fish, such as Cutthroat Trout (*Oncorhynchus clarki*; Rundio *et al*. 2003) but become predators of fish themselves as they grow larger (Parker 1993). Other *Dicamptodon* species commonly co-occur with salmonid fish throughout the Pacific Northwest (Hawkins *et al*. 1983; Roni 2002; Olson and Weaver 2007) and may in some cases benefit through coexistence. Sepulveda and Lowe (2011) found no difference in the survival, recruitment, or population growth rate between upstream (fishless) and downstream (fish bearing, containing salmonids) populations of California Giant Salamander, and downstream populations did not appear to act as reproductive sinks. Leuthold *et al*. (2012) found a small, positive effect of fish density (Cutthroat Trout and/or Steelhead Trout (*Oncorhynhus mykiss*) on the density of Coastal Giant Salamander larvae (a factor of 1.01 times for every 0.01 individuals / m^2 increase in fish density), based on 100 study sites in southwest Oregon. Co-existence may result from numerous factors, including gape limitations of fish once Coastal Giant Salamander obtain adult size (Parker 1993), predator release dynamics (fish may preferentially feed upon macroinvertebrates that prey on larval amphibians; Adams *et al*. 2003), and/or habitat segregation (Roni 2002) or behavioural adaptations. Coastal Giant Salamander larvae alter their behaviour when exposed to chemical cues of Cutthroat Trout, spending more time under cover objects, so potentially minimizing encounters with fish (Rundio *et al*. 2003).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

The majority of studies of the Coastal Giant Salamander in Canada have used visual encounter surveys in both aquatic and terrestrial environments (RISC 2000). Within pools, cascades, and riffles, rocks are overturned to detect larvae and neotenic adults. Hand nets held downstream of overturned rocks capture aquatic salamanders, where currents facilitate downstream drift. Effort is recorded as person minutes spent searching; a search of approximately 120-person minutes is considered standard for a given stream stretch. More recently, the technique has been adjusted to a “light touch” approach to avoid disturbing habitat or inadvertently killing individuals. Surveyors visually search appropriate micro-habitats to maximize the probability of detecting both larvae and adults, using sticks to gently poke and prod crevasses and recesses in the stream and along stream edges. This technique effectively flushes out concealed larvae and adults. Under light touch, surveyors do not move rocks or debris. In addition to targeted surveys, some incidental observations of Coastal Giant Salamander have also come from anglers and fish surveys using electrofishing or baited minnow traps.

Compared to some amphibian species, a relatively high number of detailed studies have focused on Coastal Giant Salamander in the Chilliwack Valley over the past 15 years. The results show high variability in relative abundance of salamanders across sites. One of the most extensive and most recent surveys captured 0.09 – 4.20 individuals/hour from 48 streams across the species’ Canadian range (Dudaniec *et al*. 2012). Others conducting surveys in the Chilliwack Valley have found 0 – 0.127 individuals/metre (nine streams stretches; BCIT, unpubl. data 2011) and 0.03 individuals/metre or 1.4 individuals/ hour (two main stem streams and 20 tributaries; Lynch and Hobbs 2012). A density of 0.16 – 0.49 larva/m^2 was estimated from eight streams surveyed in 1998 (Curtis and Taylor 2003). Based on mark-recapture methods, Ferguson (1998) determined a mean larval abundance of 69 – 174 larvae/120 m^2 of stream surveyed (734 total captures at four streams). On the Chilliwack River, 0.25 individuals/metre were detected through electrofishing at 16 localities (Ptolemy, unpubl. data 1984 – 2001). During surveys for terrestrial adults, Johnston (1998) found 7.4 terrestrial individuals in clearcuts and 13 in old growth per 100 hours of searching.

Abundance

No population census has been completed in the Chilliwack Valley for the Coastal Giant Salamander. Survey results indicate a lower density of Coastal Giant

Salamanders than reported for other localities within the species' range (Ferguson 1998). This suggestion is supported by recent genetics work that estimated that the current effective population size of the Coastal Giant Salamander in BC is 33% lower than that near the core of the species' range in Washington (Dudaniec *et al.* 2012). The effective population size is an index of genetic diversity among breeding individuals and cannot be directly related to the total population size due to various factors such as fluctuating population size, breeding sex ratio, and spatial dispersion of the population (Dudaniec *et al.* 2012). The previous COSEWIC update for Coastal Giant Salamander (Ferguson and Johnston 2000) estimated the Canadian population as roughly 13,400 terrestrial adults and 9,000 aquatic, neotenic adults; no estimates have been made since.

Fluctuations and Trends

No new information, based on local mark-recapture or demographic studies, is available on population sizes or trends since the previous report (Ferguson and Johnston 2000). Survey information has increased, but efforts have focused on detecting the species' presence rather than estimating population parameters or trends (Pacific Giant Salamander Recovery Team 2010). Based on recent genetics work, the Coastal Giant Salamander appears to exhibit a 'stable' population signature in BC, which originates from a historically small founding population with reduced genetic variability and limited opportunity for range expansion; approximately 10% of sites had evidence of historical genetic bottlenecks (Dudaniec *et al.* 2012).

Repeat sampling in the Chilliwack Valley has confirmed continued occurrence of the species within the majority of Element Occurrences (EO) defined within the BC CDC database. An EO is an area of land and/or water in which a species or ecological community is or was present, that has practical conservation value for the species, and that often corresponds with the local population or portion of a population (BC CDC). Of the 26 EOs in the database, 18 have had one or more years with salamander detections since the previous status report in 2000 (Table 1). Two EOs within the database (i.e., EOs #10 and #15), where larvae were detected prior to 2000, yielded no detections when last sampled in 2006. Coastal Giant Salamanders were found in 56% of formerly occupied streams in 2006 (N = 18 streams searched; unpubl. data collected by B.C. Conservation Corps; B.C. Ministry of Environment data files). Two new EOs were added to the database since the previous update (post 2000). Four new datasets, not yet in the provincial database as of 2012, are included in this report, producing nine "new" streams or tributaries with salamander observations (e.g., Pierce Creek).

Based on the species' specific habitat requirements, habitat fragmentation, and continuing threats, a declining population trend that may exceed 30% is suspected, unless threats are adequately mitigated.The Coastal Giant Salamander occurs mainly in and around mid-elevation streams in forested habitats but is absent or occurs only occasionally both in slow-moving main stems at low elevations and in high elevation portions of streams. Thus, even if forested stream buffers are left in otherwise deforested terrain, overland dispersal can be expected to be severely restricted, thus accentuating inter-stream isolation and population fragmentation. The BC Conservation Data Centre assessed the viability of each element occurrence in their database, based on threats, habitat condition, and occupancy history (Table 1). Of the 26 EOs in the database, 38.4% included sites with “excellent or good” viability (including those EOs rated as ranging from “good to fair”). Four (15.5%) were rated as historical or their persistence could not be confirmed. Ten of the EOs (38.5%) could not be rated due to scarcity of observations, and were simply recorded as extant, based on the detection of one or more salamanders since 1990. Examining these data in another way, ten EOs contained sites with excellent or good viability (ratings A or B), ten contained sites with fair, poor occurrences or were not found during resurveys (ratings C, D, or F), and 12 were either historical or they could rated only as extant due to insufficient information (ratings H or E). Employing the precautionary principle, EOs in the last two categories cannot be considered secure given the threats facing the species from logging and other sources.

Habitat and Population Fragmentation

The Canadian populations of Coastal Giant Salamander occur within a landscape that has been significantly altered by forest harvesting and development. Approximately 9% of the landscape has been developed (Pacific Giant Salamander Recovery Team 2010), largely in the western sections of the range. Of the approximately 6,300 ha of forest within the Canadian range of Coastal Giant Salamander that was over 120 years old as of 2003, much occurred at higher elevations deemed unsuitable or low quality for the species (Pacific Giant Salamander Recovery Team 2010). The largest remaining mature to old forest areas occurred in the upper watersheds of Liumchen Creek and Post Creeks, and along the east-facing slopes of Chilliwack Lake. Coastal Giant Salamanders have not been observed in the upper watersheds of Liumchen or Post creeks despite targeted surveys conducted in Post Creek. Only one creek on the west side of Chilliwack Lake has confirmed Coastal Giant Salamander. Based on projected 80-year rotations, much of the mature second-growth in the valley is to be subjected to second rotation cutting beginning in 2013 (Ferguson and Johnston 2000; George, pers. comm. 2013). All the above factors contribute to habitat fragmentation and increasing isolation of subpopulations.

Based on what we know of the species’ movement and dispersal capabilities, especially in recently harvested stands (Ferguson and Johnston 2000; Curtis and Taylor 2003), the majority of the Canadian subpopulations have likely been isolated from other subpopulations to some degree over their recent history. Genetic studies from Dudaniec *et al*. (2012) found high variability in the genetic composition of Coastal Giant Salamander populations across streams, but this was related to historical and topographic influences rather than recent landscape alterations such as logging. It is unknown at what point within the harvest rotation, if any, stands become permeable to dispersing Coastal Giant Salamanders and under what additional habitat, climatic, or topographic conditions; cooler east or north-facing slopes might facilitate dispersal, while warmer, drier south-facing slopes might be impermeable to salamander movements. Curtis and Taylor (2003) documented lower genetic diversity and heterozygosity among populations in clearcut sites (2 – 3 years since harvest) in the Chilliwack Valley compared to second-growth (30 – 60 years since harvest) and old-growth sites (>250 years old), but the differences were less pronounced between the latter two stand ages. This suggests some genetic recovery through immigration from surrounding populations occurring as stands age, possibly as soon as 30 years after harvest. Although larvae persist and in some cases do well in streams in recently harvested stands due to increased stream productivity, the abundance of terrestrial Coastal Giant Salamander is relatively low in cutblocks compared to mature and old-growth forest. These smaller populations are likely at greater risk of becoming locally extirpated due to stochastic events, especially in BC where both densities (Ferguson and Johnston 200) and genetic diversity are relatively low (Dudaniec *et al*. 2012). Information on population sizes and viability within different stream systems are largely lacking for Coastal Giant Salamander populations in BC (Pacific Giant Salamander Recovery Team 2010).

Based on habitat fragmentation, threats, and limited movement capabilities of the salamanders across upland habitats and among stream systems, it is possible that a large proportion of the population is in habitat fragments that do not support viable subpopulations. However, quantifying the extent of habitat fragmentation is extremely challenging for a population living in a dynamic landscape, which is managed for forestry and due to lack of systematic surveys.

Rescue Effect

A rescue effect is possible but not likely for the Coastal Giant Salamander in BC. Given the limited dispersal of both larvae and adults, it is unlikely that dispersal from populations in the U.S. is frequent, if it occurs at all. In northwestern Washington, Coastal Giant Salamander occurs within the Nooksack and Skagit drainages (McAllister 1995; Washington Herp Atlas 2005). The closest locality records to the Chilliwack Valley population are from the North Fork drainage of the Nooksack River, about 10 km south of the Canadian border. Five Coastal Giant Salamanders were captured at Nooksack Falls on the North Fork of the Nooksack River in August 2003 (Saltzer pers. comm. 2014). Streams that extend from Canada into the U.S. approach within 1 – 2 km of occupied headwater streams of the Washington Nooksack and Skagit drainages, but high-elevation alpine passes between them probably pose a barrier to movements. Salamanders could possibly access one headwater tributary of Tamihi Creek from the Nooksack drainage, provided they were able to cross a narrow, forested saddle between the two drainages. Human settlements and agricultural activity within the Columbia Valley and along the Sumas River probably pose barriers to dispersal of salamanders into Canada along more western routes (Pacific Giant Salamander Recovery Team 2010). No distribution records exist from the upstream portions of the Chilliwack River or its tributary streams immediately south of the Canadian border, but this area is isolated, and the extent of surveys is unknown.

This hypothesis of little to no possibility of connectivity or rescue from Washington populations was corroborated by results from genetic studies by Dudaniec *et al*. (2012). Their data indicate that Coastal Giant Salamanders in BC have less genetic diversity than those from Washington, a condition that emerged post-glacially and pre-dates human settlement, suggesting that populations have been isolated for a long time.

THREATS AND LIMITING FACTORS

The IUCN Threats Calculator assessment (Master *et al.* 2009) was applied for the Coastal Giant Salamander on 27 June 2012 (Table 4; full version, with notes, is available from COSEWIC Secretariat). The greatest impacts were estimated to be from biological resource use (i.e., logging and wood harvesting; considered a Medium threat) and pollution (i.e., agriculture and forestry effluents; considered a Medium - Low threat). Other impacts identified as a Low threat included: residential and commercial development, energy production and mining, transportation and service corridors, human intrusions and disturbance, invasive and other problematic species and genes, and climate change and severe weather. The most important threats, from highest to lowest impacts, are discussed below.

Table 3. Conservation Status (from NatureServe 2013, B.C. Conservation Data Centre 2013, B.C. Conservation Framework 2013, and Wild Species General Status Ranks web site http://www.wildspecies.ca/home.cfm?lang=e).

Global Status	National Status	Canada General Status Rank (Canada rank)	Sub-national Status	COSEWIC	IUCN Red List Category	Conservation Framework
G5* – Secure (2001) *Rationale:* Common in many areas and still well distributed throughout the historical range from southwestern British Columbia to northwestern California.	Canada – N2 (1998) United States – N5	CA = 1 – At Risk BC = 1 – At Risk	British Columbia (S2), California (SNR), Oregon (S4), Washington (S5)	Threatened (2000)	Least Concern	Highest Priority: 1** Goal 1: 5 Goal 2: 6 Goal 3: 1***

* Rank 1– critically imperilled; 2– imperiled; 3– vulnerable to extirpation or extinction; 4– apparently secure; 5– secure; H– possibly extirpated; NR – status not ranked

** 1 is the highest of the 6 ratings.

***The three goals of the B.C. Conservation Framework are: 1. Contribute to global efforts for species and ecosystem conservation; 2. Prevent species and ecosystems from becoming at risk; 3. Maintain the diversity of native species and ecosystems.

Table 4. Summary of the IUCN Threats Calculator assessment for the Coastal Giant Salamander (full results with notes available from COSEWIC Secretariat).

Threat categories that do not apply are excluded (hence consecutive threat numbers). Assessed via conference call on 27 June 2012.

Threat Impact		high range	low range
A	Very High	0	0
B	High	0	0
C	Medium	2	1
D	Low	6	7
Calculated Overall Threat Impact:		High	High

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing
1	Residential & commercial development	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)
1.1	Housing & urban areas	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)
1.2	Commercial & industrial areas		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)
1.3	Tourism & recreation areas	D	Low	Small (1-10%)	Moderate - Slight (1-30%)	High (Continuing)
2	Agriculture & aquaculture		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)
2.1	Annual & perennial non-timber crops		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)
2.3	Livestock farming & ranching		Negligible	Negligible (<1%)	Moderate (11-30%)	High (Continuing)
3	Energy production & mining	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)
3.2	Mining & quarrying	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)
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)
4.2	Utility & service lines	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)
5	Biological resource use	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)
5.1	Hunting & collecting terrestrial animals		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)
5.3	Logging & wood harvesting	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)
5.4	Fishing & harvesting aquatic resources		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)
6	Human intrusions & disturbance	D	Low	Small (1-10%)	Moderate (11-30%)	High (Continuing)
6.1	Recreational activities	D	Low	Small (1-10%)	Moderate (11-30%)	High (Continuing)

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing
7	Natural system modifications		Low	Small (1-10%)	Extreme to Moderate (11-100%)	High (Continuing)
7.1	Fire & fire suppression		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)
7.2	Dams & water management/use		Low	Small (1-10%)	Extreme - Moderate (11-100%)	High (Continuing)
8	Invasive & other problematic species & genes	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)
8.1	Invasive non-native/alien species	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)
9	Pollution	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	High (Continuing)
9.1	Household sewage & urban waste water	D	Low	Small (1-10%)	Moderate - Slight (1-30%)	High (Continuing)
9.2	Industrial & military effluents					
9.3	Agricultural & forestry effluents	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	High (Continuing)
11	Climate change & severe weather	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)
11.1	Habitat shifting & alteration	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)
11.2	Droughts	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)
11.3	Temperature extremes	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)
11.4	Storms & flooding	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)

Logging and Wood Harvesting

Logging occurs throughout the Chilliwack River Valley and, as such, has the greatest scope of all threats to Coastal Giant Salamander populations. However, forest harvesting does not necessarily result in permanent loss or fragmentation of habitat compared to other threats. Canopy removal results in microclimatic changes (Chen *et al.* 1993, 1995; Brosofske *et al.* 1997). Although these changes can lead to increased productivity in creeks, they also increase physiological stress for terrestrial Coastal Giant Salamanders. Logging and associated road building degrades stream habitat by increasing sedimentation and causing increases in summer stream temperatures (Newbold *et al.* 1980; Beschta *et al.* 1987; Hartman and Scrivener 1990).

Studies designed to assess the effects of logging on the aquatic stages of this species have yielded mixed results (see **Habitat Requirements**). Studies conducted in the Chilliwack Valley have found a higher relative abundance and growth rate of larvae in streams in clearcut and/or second-growth stands compared to mature and old-growth stands (Pollock *et al.* 1990; Ferguson 1998; Richardson and Neill 1998; Hatziontoniou 1999; Neill, unpubl. data 2000). Studies in BC have also found reduced genetic diversity of Coastal Giant Salamanders in clearcut sites (Curtis and Taylor 2003), restricted dispersal from streams in clearcuts (Richardson and Neill 1998; Johnston and Frid, unpubl. data 2000), and greater relative abundance in streams in older forest stands and at higher elevations (Dudaniec and Richardson 2012). Higher elevation sites have higher relative abundance of larvae but reduced genetic diversity among Coastal Giant Salamander populations, suggesting greater resource availability but a low density of breeding adults (reduced gene flow; Curtis and Taylor 2003; Dudaniec and Richardson 2012). Effects of stand age on the abundance of terrestrial Coastal Giant Salamander are poorly known, due to difficulties in detecting salamanders in terrestrial habitats and resulting low sample sizes (Kelsey 1995; Vesely 1996). Based on catch per unit effort from night searches in northern Washington, Johnston (1998) found that terrestrial Coastal Giant Salamanders were less abundant in clearcut habitat than in old-growth forest. It is likely that the life stages of Coastal Giant Salamander respond differently to forest harvesting, with aquatic stages benefiting from increased productivity in streams and terrestrial stages suffering adverse effects through loss of habitat and moist microclimates, at least in the short term. The duration, extent, and overall net effects of forest harvesting on populations of Coastal Giant Salamander remain poorly understood, but likely have their greatest effect on dispersing terrestrial adults. Clearcuts probably limit connectivity among populations and reduce the potential for recolonization where populations have declined or been lost (e.g., during harvesting or from debris slides).

Pollution

Roads and trails can be a source of pollutants from sediments and chemical use. Sediments may also enter the system via slope failures from forestry operations, clearcutting activities upstream, or development projects, such as run-of-river power projects.Numerous studies in the United States have found that stream sedimentation is detrimental to Coastal Giant Salamanders (Hall *et al*. 1978; Hawkins *et al*. 1983; Corn and Bury 1989; Welsh and Ollivier 1998; Ashton *et al*. 2006). Fine sediments fill in interstitial spaces among rocks with the stream substrate, so reducing or eliminating refuges that are critical for salamander larvae. In the Chilliwack Valley, preliminary results from data collected by BCIT students’ studies suggest that logging can result in sedimentation of stream stretches occupied by Coastal Salamanders, even where forested riparian buffers of 30 – 50 m are left within Wildlife Habitat Areas for the species (Welstead pers. comm. 2013). Anecdotally, fewer salamanders have been observed in streams and pools with relatively high silt content in the Chilliwack area (Knopp pers. comm. 2012).

Roads are also a source of chemical inputs into streams. For example, chemicals used to reduce road dust and to de-ice roads may impact Coastal Giant Salamanders. Impacts from chemical use depend on how much the chemicals are diluted within the system, for example through rain, and the extent of their use at any given time.

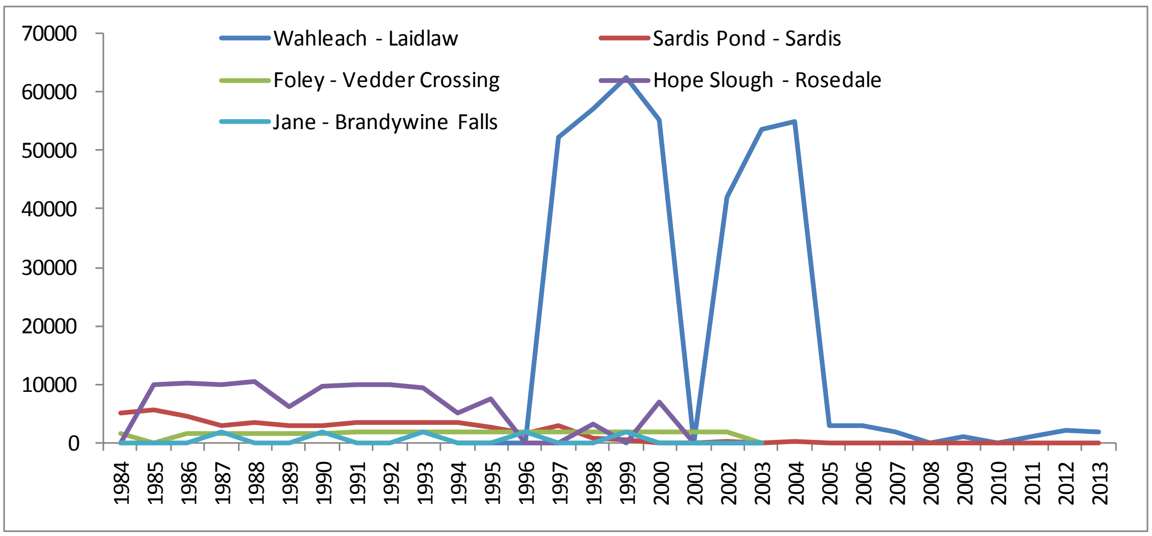
Herbicides used in housing developments, commercial areas, and in forestry may pose a threat to Coastal Giant Salamanders. Ninety percent of the herbicide used in the Chilliwack Valley is glyphosate (Vision®); Triclopyr (Release®) and 2-4-D are also used on a limited basis to control the growth of maple and alder (Stad pers. comm. 2000). In most years, these chemical treatments account for less than 1% of the total site-preparation activity in BC, and far less is used in southern versus northern parts of the province (Govindarajulu 2008). Little is known about the effects of herbicides on stream-dwelling salamanders. Studies conducted on anurans have found malformations and mortalities associated with exposure to herbicides (e.g., Dial and Bauer 1984; Ouellet *et al.* 1997). The LC_{10} value (estimated dose at which 10% mortality occurs) for amphibians tested using Vision® has been found to be at or below the expected environmental concentration for that herbicide (Govindarajulu 2008). In 2004, Howe *et al*. (2004) concluded that the toxicity of glyphosate-based pesticides was due to the surfactant present in the preparations rather than to the active herbicidal ingredients. Formulations that do not contain the harmful surfactant have been found to be less toxic to amphibians (Govindarajulu 2008).

Residential and Commercial Development

Residential and commercial development has a relatively small scope but is considered extreme in severity as the effects result in permanent habitat loss and fragmentation. The scope of housing and urban areas and commercial and industrial areas lies largely within the boundaries of the City of Chilliwack, which encompasses an estimated 10 – 15% of the Canadian range of the Coastal Giant Salamander. Residential development is ongoing (see **Habitat Trends**). Developments occur in productive, lower elevation areas, and as a result their impact on salamander habitat is greater than indicated by the proportion of range affected.

Invasive Non-native / Alien Species

The threat to Coastal Giant Salamander populations in the Chilliwack Valley posed by non-native species comes from the introduction of sport fish into waterways that historically lacked large predatory fish. While Coastal Giant Salamanders can co-occur with fish, as indicated by the presence of neotenic salamanders in larger lakes and their occasional captures in main stems of rivers, the salamanders may not be able to breed successfully in these situations. Predation of smaller larvae by salmonids (e.g., Cutthoat Trout; Rundio *et al.* 2003) is of concern where fish and salamanders co-occur, and predation is likely to curtail dispersal of salamanders among sub-drainages connected by larger streams or lakes. Salmonids are routinely stocked within the Chilliwack drainage. Since 1984, over four million trout have been released into six sites near or within the range of Coastal Giant Salamander in BC (GoFishBC 2013; Figure 6). Some salmonids have the capability to disperse widely from points of stocking and to persist in mountain streams occupied by salamanders. The GOFishBC stocking reports only contain trout stocking records, and far more salmon (*Oncorhynchus* species) have been stocked into the Chilliwack watershed; for example, a total of 4.9 million juvenile Chinook (*O. tshawytscha*), Coho (*O. kisutch*), and Chum (*O. keta*) were stocked in 2005 (http://www.pac.dfo-mpo.gc.ca/sep-pmvs/projects-projets/chilliwack/chilliwack-eng.html). Some of the off-channel habitat along the Chilliwack River has been modified to facilitate fish access and increase wetted area to benefit Coho.



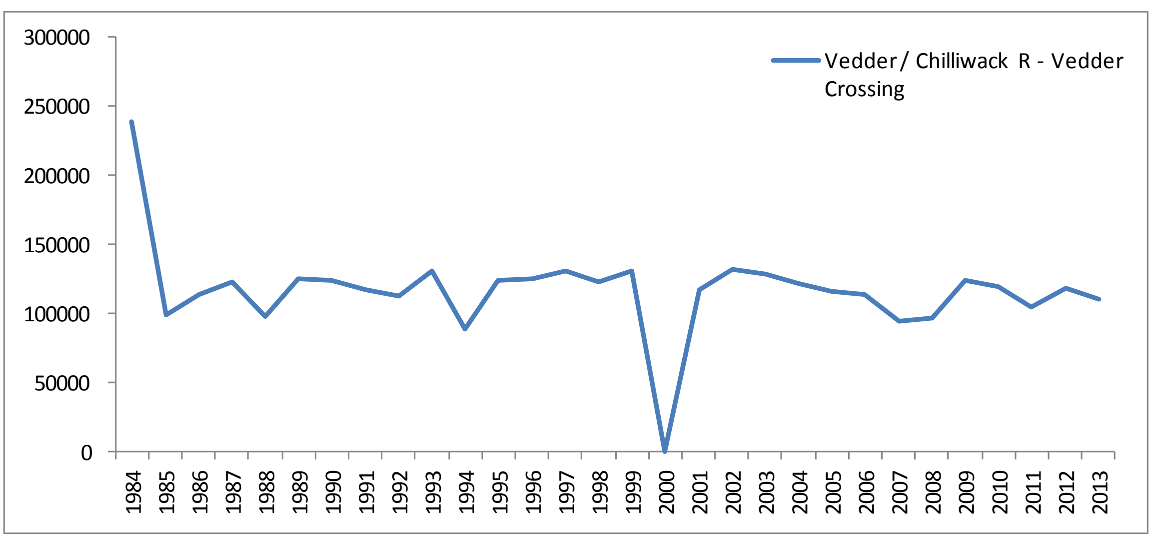


Figure 6. Localities and numbers of trout stocked into sites in and near the range of the Coastal Giant Salamander in Canada from 1984 to 2013. Salmon (*Oncorhynchus* species) stocking records are not included. Source: GoFishBC.

Little is known about the vulnerability of Coastal Giant Salamanders to epidemic diseases. Hossack *et al.* (2010) sampled 304 stream salamanders from five mountainous areas of the US for the chytrid fungus (*Batrachochytrium dendrobatidis*), which is a proximate cause for declines and disappearances of amphibian populations worldwide. A total of 60 Coastal Giant Salamander larvae from three streams in northern California and 57 *D. atterimus* larvae from three streams in Montana and Idaho were tested for *B. dendrobatidis*, but only one larva (*D. atterimus* from Montana) tested positive. The authors cite one previous study where the fungus was isolated from a dead *D. atterimus*. The authors hypothesized that low water temperatures may limit the establishment of the fungus in these stream-dwelling amphibians. The recently described chytrid fungus, *Batrachochytrium salamandrivorans*, from the salamander *Salamandra salamandra* in Europe (Martel *et al*. 2013), poses a new, potentially grave threat to the Coastal Giant Salamander. Similar to *B. dendrobatidis*, *B. salamandrivorans* erodes the skin of infected amphibians with fatal results, and it has been linked to precipitous population declines in *S. salamandra*. The new chytrid operates at lower ambient temperatures than *B. dendrobatidis* (Martel *et al*. 2013), and salamanders in cool stream habitats would not be protected by low temperatures. The new chytrid is yet to be reported from North America, but given the rapid global spread of *B. dendrobatidis* around the world, its introduction and spread is possible.

Climate Change and Severe Weather

Potential future effects of climate change on Coastal Giant Salamanders are difficult to estimate, but negative effects could occur through stream drying and reduced availability of moisture on the forest floor, leading to shorter seasonal activity periods as a result of more frequent or prolonged droughts in spring – summer. Wetter and warmer winters could possibly counteract these effects to some degree. Higher frequency and intensity of flooding events could lead to flash floods and debris flows, and increased siltation of streams, resulting in direct mortality and reduced habitat quality for larvae. Stream amphibian surveys conducted in an unharvested landscape in Washington, found that *D. copei* had the strongest relationship to variables related to climate of the three species of giant salamanders studied, and the authors suggested that climatic factors (precipitation) could already be limiting that species' range on the Olympic Peninsula (Adams and Bury 2002). Predicting the effects of climate change on stream amphibians is confounded by the fact that we have a poor understanding of their use of subsurface habitats that could serve as important refugia (e.g., subterranean chambers for nesting: Dethlefsen 1948; caves: BC CDC database; hyporheic zone of streams: Feral *et al.* 2005). As well, under a scenario where a permanent stream becomes intermittent due to climatic extremes, some Coastal Giant Salamanders within the population (e.g., large larvae) may be able to transform (Knopp pers. comm. 2012).

To estimate what the environmental conditions may be like under a climate change scenario, historical and projected data were summarized from the ClimateBC website for a random locality centred within the Coastal Giant Salamander range within BC (Latitude: 49° 04' 40"N, Longitude: -121° 52' 36"W, elevation 500 m; Spittlehouse 2006). Climate-normal data for this random BC locality for two time periods from 1961 – 2000 were compared to climate projections based on three different models for three time periods: 2020s, 2050s, and 2080s (Spittlehouse 2006). The average for the normal dataset was compared to the greatest change predicted from the three models for annual precipitation and temperature for the 2020 period (2010 – 2039; Table 5; see Appendix 3 for details).

Table 5. Summary of greatest changes predicted from the three climate models for annual precipitation and temperature for the 2020 period (2010 – 2039; see Appendix 3 for details).

Climate variable	Predicted change
PRECIPITATION:	
Mean annual precipitation (mm)	+169
Precipitation as snow (mm water equivalent)	-74.5
Winter precipitation (Dec.-Feb.; mm)	+93
Spring precipitation (March-May; mm)	-14
Summer precipitation (June-Aug.; mm)	-12
AIR TEMPERATURE:	
Mean annual temperature (°C)	+0.8
Autumn mean temperature (Sept.-Nov.; °C)	+1.9
Summer mean temperature (June-Aug.; °C)	+1.1
Summer (May to Sept.) heat: Moisture index	3.9

For 2020, the models predict an increase in the amount of annual precipitation but a decrease in the amount of precipitation that will fall as snow. As well, the models predict an increase in amount of precipitation that will fall during the winter months, and a decrease in summer and fall. The mean annual temperature is expected to increase by 0.8°C, with the highest seasonal temperature increases expected in fall (by almost 2°C). These predicted climate changes are within the range that Coastal Giant Salamander experience at the southern end of the species' range, where it is hotter and drier; for example, populations in Weaverville, California, experience on average 4°C higher temperatures and 632 mm less precipitation each year than populations in Chilliwack. Although the species may have a tolerance for greater climate extremes, it remains unclear whether local populations would need to, or could, adapt within the time frame projected by the models. As well, we know little of which occupied streams in the Chilliwack Valley have flows that are closely linked to the amount of snow pack and rate of snow melt. In summary, although much uncertainty exists, more droughts and flooding events associated with climate change are expected to shrink the availability of habitats, curtail dispersal, and further fragment populations. These responses are likely exacerbated by logging, road building, and other human activities that continue to modify habitats through cumulative effects.

Limiting Factors

The Coastal Giant Salamander reaches the northern extent of its range 19.5 km north of the Canada – U.S. border. The Fraser River and climatic factors, including stream temperatures, probably act as barriers to northern range expansion in BC. Populations found in the Chilliwack region, therefore, may be particularly vulnerable to additional stresses caused by human activities. Populations on the periphery often have lower population densities, survival, and fecundity than those in the centre of a species' range (Hengeveld 1990; Lawton 1993). This lower viability is presumably due to climatic factors or competitive or predation gradients, which increase towards range margins and ultimately limit range expansion. Lower reproductive potential of Canadian populations, as reflected in longer time required for maturation (larval period is 2 – 3 times longer than in Oregon; Ferguson 1998), reduces the ability of populations to recover from perturbations.

Number of Locations

Previously the number of locations was reported as six, reflecting the number of known occupied streams with the majority of observations (Ferguson and Johnson 2000). Based on data compiled in 2010, Coastal Giant Salamanders occupy approximately 75 individual streams and tributaries within about 15 stream systems or 4th order watersheds. Additional sites (streams) where the species was present were identified during 2011 and 2012 surveys (nine new streams / tributaries). Given that forestry is deemed the greatest threat to the species and that information on the number and locality of cutblocks to be harvested in the next 10 years is not available, it is impossible to estimate the number of threat-based locations with accuracy. However, if each cutblock is considered a separate threatening event, then the number of locations is almost certainly >10, even if upstream effects of siltation of breeding streams are taken into account.

If the newly described chytrid fungus, *B. salamandrivorans*, becomes a threat in BC, then the number of locations could be reduced to only one. However, speculation on the rate of spread of this pathogen, which is yet to be documented from North America, is futile at present.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Federally, the Coastal Giant Salamander is listed under the *Species at Risk Act* as a Schedule 1 species (Threatened; 2003). Critical habitat for the species was drafted in 2013 but has not yet been formally proposed.

Under the recent changes to the *Canadian Fisheries Act* (1985), it is illegal to carry on work or engage in activities that result in serious harm to fish that are part of a commercial, recreational, or Aboriginal fishery, or to fish that support such a fishery, or that result in permanent alteration of or destruction of the aforementioned fish species habitat. These changes do not provide habitat protection for Coastal Giant Salamanders, which occur mainly in fishless streams; in cases where they co-occur with fish, the *Act* does not address situations that result in habitat degradation.

Some Coastal Giant Salamander habitat on provincial Crown land is protected under the provincial *Forest and Range Practices Act* (FRPA 2004). Under the Act, all streams containing fish or within a community watershed are classed as S1 – S4 (depending on their width). S1 – S3 streams receive a riparian reserve zone of 20 – 50 m, where no forest harvesting or road building is permitted (although stream crossings are allowed). S4 streams receive a 30 m wide riparian management zone only, where ≥ 10% of the tree basal area must be retained. S5 and S6 streams that do not contain fish or occur within a community watershed receive a 20 m wide riparian management zone. FRPA also applies to private land covered by a licence under the *Forest Act* (Tree Farm Licence, Woodlot Licence or Community Forest Licence). Other private forest land falls under the *Private Managed Forest Land Act* (2003), which only protects streams and riparian habitat that are fish-bearing. These regulations provide limited protection to the Coastal Giant Salamander, as they focus on larger fish-bearing streams.

The main means of protecting Coastal Giant Salamander habitat on provincial forestry lands is through Wildlife Habitat Areas (WHAs), established under the Identified Wildlife Strategy associated with the *Forest and Range Practices Act*. The *Accounts and Measures for Managing Identified Wildlife* guidebook outlines the identification of and layout for WHAs and general measures for managing these areas for the Coastal Giant Salamander (Johnston 2004). As of 2010, 20 WHAs encompassing a total of 771 ha and approximately 38 km of linear length of streams (25% of the total known occupied stream length) have been approved for the Coastal Giant Salamander (Pacific Giant Salamander Recovery Team 2010). As of 2013, 16 new proposed WHAs are at the development stage (George pers. comm. 2013). WHAs for Coastal Giant Salamanders consist of a 30 m wide protected core and 20 m wide management zone on each side of an occupied stream reach; most include some upland forest to aid in dispersal. The effectiveness of WHAs in protecting salamander habitat is yet to be confirmed. Preliminary evidence from surveys by BCIT students suggest that siltation from logging upstream or from the surrounding area is degrading stream habitat within WHAs; protection of the entire watercourse, including the source water (1^{st} order streams) may be needed to maintain both water quality and quantity (Welstead pers. comm. 2013).

WHAs established for other species at risk may also benefit Coastal Giant Salamander, such as those created for the Northern Spotted Owl (*Strix occidentalis*) in the Chilliwack Forest District, which occur in Liumchen Creek (2 long-term WHAs, and 1 managed forest habitat area), Chilliwack Lake - Depot Creek (2 WHAs), and Elk Creek, although logging has since been approved in some of these areas.

Non-Legal Status and Ranks

The Coastal Giant Salamander is ranked as a species at risk both nationally and provincially (Table 3). The species is listed as "secure or least concern" on a global scale, as well as within the majority of the species' range that occurs south of the border in the United States. In BC, the species is ranked as imperilled (S2), and it is on the provincial red list of species at risk.

Habitat Protection and Ownership

Nearly all of the Canadian distribution of the Coastal Giant Salamander is within provincial Crown land managed for forestry. A small portion is on privately owned land (~ 9%; Pacific Giant Salamander Recovery Team 2010), and an even smaller portion falls within protected areas. To date, Cultus Lake and Chilliwack Provincial Parks are the only protected areas in which Coastal Giant Salamanders have been found. Cultus Lake Provincial Park covers 65 ha, protecting the shoreline on the east and west sides of the lake itself, as well as the lowest reaches of some streams flowing into the lake. The upper reaches of streams where the Coastal Giant Salamander have been detected, however, are outside of the park, and receive no protection. Chilliwack Lake Provincial Park is 9,258 ha and includes the majority of the forested slopes on the west and east sides of the lake, the latter of which contains numerous Coastal Giant Salamander streams, as well as the Post Creek watershed. There are a few small parks and forest recreation areas scattered along the Chilliwack River, as well as an ecological reserve along the upper Chilliwack River, south of Chilliwack Lake. Coastal Giant Salamanders have not been found in these areas. Coastal Giant Salamanders also occur in a number of federal lands within the Chilliwack Valley managed by the Department of National Defence.

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED

Previous versions of this report were written by:

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The following people generously provided data, information, reports, and/or advice useful for this report:

Eric Anderson. BCIT - Fish, Wildlife & Recreation, Vancouver, BC.

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Purnima Govindarajulu. BC Ministry of Environment, Victoria, BC.

Jared Hobbs. Ministry of Forest, Lands and Natural Resource Operations, Victoria, BC.

Barb Johnston. Waterton Lakes National Park of Canada, Waterton, AB.

Denis Knopp. BC's Wild Heritage Environmental. Chilliwack, BC.

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Matt Wealick. Ch-ihl-kway-uhk Forestry Limited Partnership. Chilliwack, BC.

Kym Welstead. Ministry of Forests, Lands, and Natural Resource Operations. Surrey, BC.

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Elke Wind obtained her M.Sc. in Conservation Biology at the University of British Columbia in 1996 and her status as a Registered Professional Biologist in 2003. She has been self-employed as a contract biologist since 2002 and has more than 17 years experience studying amphibian populations. She specializes in the habitat associations and requirements of local aquatic-breeding amphibians in relation to impacts of timber harvesting, non-native species, development, and associated infrastructure (e.g., roads). Starting in 2008 she expanded into the field of wetland construction and restoration and has built or restored 20 wetlands.

Appendix 1. Summary of reports that include Coastal Giant Salamander observations from the Canadian range.

Source / Study	Year	Survey Method*	Total Search / Catch effort	General versus Targeted	Proportion of Potential Habitat Searched	Total # of Sites Searched
References / Studies obtainable for update						
Lynch and Hobbs 2012	summer 2012	VES (light touch)	37 person-hours in 4 sub-basins, including 2 main stems and 20 tributaries; 50 larvae found (0.03 larvae/ m) in 9 "new" streams; 34 larvae and 1 adult found in a creek on Elk Mountain.	Targeted	Unclear ; 19 km of track lengths recorded in GPS	
BCIT 2011	summer 2011	VES (light touch)	9 streams /sites; species found in 7 sites; 0–0.127 larvae/m of stream searched (0–19 individuals/stream); 38 larvae and neotenes found in total	Targeted	Sample sites in three areas	Nine streams on Vedder Mtn (3), Elk Mtn (4), and on Foley Creek (2); 150 m /stream = 1350 m in total; 5 within existing WHA's and 4 that were subject to some level of deforestation within 30 m of the stream.
Dudaniec and Richardson 2012 (Dudaniec *et al.* 2010 and 2012)	July and Aug. in 2008 and 2009	VES (poking into crevices, using flashlight, turning small cobbles); marked individuals with elastomer dye implants to prevent duplicate capture records between days and years	100 m reach/ stream, except one which had two 100 m reaches (Fin Creek); searched sites for 1–4 days consecutively or over a 1-week period; 'absent' = no individuals found after 3 h of searching; conducted searches for terrestrial adults along stream reaches for 10 sites, up to 10 m to either side of the stream reach (2–8 search-hours). A total of 856 salamanders (1–63 per stream) were found. The relative abundance of salamanders (excluding terrestrial adults) ranged from 0.09–4.20 individuals captured per hour (mean = 1.63 ± 0.20 SE); only 12 larvae from 7 sites in 2009 were recaptured in 2008.	Targeted (distribution and abundance); tail tissue samples collected from individuals from 12 sites	Sample sites were from across the majority of the species' BC range (from approx. 70 km^2).	48 streams searched (detections in 34)
Curtis and Taylor (2003)	May to July 1998	Stream surveys (majority of samples collected were from larvae); details (e.g., area covered or time spent searching) not included	31–65 tail tissue samples collected per site (stream)	Targeted (tissue samples)	Each of 8 sites was in a different stream and forest patch located at least 2 km apart; sites ranged from immediately west of Cultus Lake (Vedder Mtn) east to the upper end of Foley Creek, and from the upper ends of Tamihi Creek and	Searched 25 suitable headwater streams: two old-growth (>250 years), three second growth (30–60 years since clearcut harvest), and three recently clearcut (3–9 years since clearcut harvest) sites

Source / Study	Year	Survey Method*	Total Search / Catch effort	General versus Targeted	Proportion of Potential Habitat Searched	Total # of Sites Searched
					Nesakwatch Creek; total within stream survey area not indicated	yielded sufficient samples (i.e., 8 sites with > 30 larvae)
R. Ptolemy, unpubl. data (MFLNRO)	1985–2001	Electrofishing	16 sites along Chilliwack River; 2 passes with electrofisher (66 observations from 266 m of shoreline surveyed)	Incidental captures	266 m of shoreline surveyed	Multiple sites on Chilliwack River (16)
Ferguson 1998	Active season in 1996 & 1997	VES (turning all large rocks and debris); marked individuals with toe clips or PIT tags	120 m stream reaches; sampled weekly; mark recapture study; partial removal experiment in 4 streams; total of 734 captures and 293 recaptures; mean larval abundance 69–174 larvae/120 m^2	Targeted (larval survival, growth, density, and abundance)	Site locations not specified, but proportion was likely relatively small (intensive study at a few streams and sites)	5 headwater streams; 4 in 1997 only
Johnston 1998	Summer and fall 1996 & 1997	VES (night search with flashlight of stream bed and 5–10 m into riparian area)	Nightly searches from mid-May to mid-July in 1996 and 1997; 7.4 salamanders found in clearcuts and 13 in old growth per 100-search hours; radio telemetry on 20 individuals (> 25 g)	Targeted (terrestrial adults)	Not recorded (opportunistic)	Old-growth, second-growth, clearcuts, and riparian buffers (in BC and Washington)

*VES – Visual encounter survey

Appendix 2. Location of licensees with water power generation within the Chilliwack watershed summarized from the provincial iMAPBC online mapping tool (http://www.data.gov.bc.ca/dbc/geographic/view_and_analyze/imapbc/index.page)

File No.	Licensee	Licence status	Lic. status date	Prior. date	New since 2000	Power Purpose	Stream Name	Quant. (in m^3/sec.)	Penstock length (m)
2003034	TRIGEN RENEWABLE ENERGY	ACTIVE	20080218	20080205	X	GENERAL	Borden Creek	1.250	2652
2001928	KMC ENERGY CORP	ACTIVE	19911203	19920507		GENERAL	Tamihi Creek	15.000	1138
2003549	FROSST CREEK HYDRO INC.	ACTIVE	20120711	20120502	X	GENERAL	Frosst Creek	1.400	2483
2001929	KMC ENERGY CORP	REFUSED	19920930	19911122		GENERAL	Depot Creek	0.028	3481
2002286	ECKERT THERESA WANDA	ACTIVE	19980618	19980511		GENERAL	Paleface Creek	0.283	N/A
2002734	LINK POWER MANAGEMENT	ACTIVE	20040322	20040311	X	GENERAL	Nesakwatch Creek	2.000	N/A
2002550	HYDROMAX ENERGY LTD	ABAN.	20120912	20011003	X	GENERAL	Centre Creek	2.299	2447
2001982	LINK POWER MANAGEMENT	ACTIVE	19950512	19950512		GENERAL	Centre Creek	1.730	3702
2001994	RTD MANAGEMENT INC	REFUSED	20030918	19951129	X	GENERAL	Nesakwatch Creek	1.897	3706
2002572	LARSON FARMS INC	ACTIVE	20020123	20020121	X	GENERAL	Pierce Creek	0.110	N/A
2001964	0917630 BC LTD.	ACTIVE	19931112	19931112		GENERAL	Chipmunk Creek	2.973	4391
2001966	PAMAWED RESOURCES LTD	ABAN.	19981025	19940117		GENERAL	Foley Creek		842
2002795	INTERPAC POWER CORP.	ACTIVE	20050715	20050704	X	GENERAL	Chipmunk Creek	1.812	N/A
2002908	PATHEIGER PARIS L	ACTIVE	20070410	20070327	X	GENERAL	ZZ Creek (80653)	0.107	1764
2001969	0917630 BC LTD.	ACTIVE	19940126	19940126		GENERAL	Airplane Creek	1.200	3639
2002793	INTERPAC POWER CORP.	ACTIVE	20050715	20050520	X	GENERAL	Tamihi Creek	5.975	N/A
2002566	HYDROMAX ENERGY LTD	ABAN.	20120912	20011220	X	GENERAL	Post Creek	1.099	1140
0215438	RENWICK KATHLEEN J	CURRENT	19990930	19570327		RESID.	Marblehill Creek	0.028	

Appendix 3. Annual and seasonal weather variables predicted under three climate change scenarios for Coastal Giant Salamander populations in BC as compared to climate conditions currently experienced by populations at a similar elevation in a southern part of the species' range (Weaverville, California). Projected results are for a random location within the centre of the Coastal Giant Salamander Canadian range.[a]

(Source: BC data comes from the ClimateBC website - http://www.genetics.forestry.ubc.ca/cfcg/ClimateBC40/Default.aspx; Weaverville, CA data comes from the U.S. National Climatic Data Center - http://www.ncdc.noaa.gov/)

Annual Variables

	1961-1990	**1971-2000** (1981-2010 for CA)	**Aver.**	**2020s**	**2050s**	**2080s**
Mean Annual Temperature (°C)						
Climate Normals for BC	7.1	8.0	7.6			
Weaverville, CA		12.7				
Projected results:						
CGCM_A2x				8.0	9.1	10.4
CGCM_B2x				8.0	8.8	9.4
HADCM3_A2x				8.3	9.3	11.3
			Greatest Change[b]	**0.8**	1.8	3.8
Mean Annual Precipitation (mm)						
Climate Normals for BC	1625	1619	1622			
Weaverville, CA		987				
Projected results:						
CGCM_A2x				1671	1688	1726
CGCM_B2x				1689	1689	1688
HADCM3_A2x				1791	1577	1615
			Greatest Change	**169**	67	104
Precipitation as Snow (mm water equivalent)						
Climate Normals for BC	239	218	228.5			
Weaverville, CA		193 (mm)				
Projected results:						
CGCM_A2x				173	126	88
CGCM_B2x				175	140	115
HADCM3_A2x				154	148	93
			Greatest Change	**-74.5**	-102.5	-140.5
Summer (May to Sept.) Heat:Moisture Index[c]						
Climate Normals for BC	38.4	38.4	38.4			
Projected results:						
CGCM_A2x				42.3	47.4	51.5
CGCM_B2x				42.0	46.8	48.8
HADCM3_A2x				39.5	69.4	88.0
			Greatest Change	**3.9**	31	49.6

Seasonal Variables

	1961-1990	**1971-2000** (1981-2010 for CA)	**Aver.**	**2020s**	**2050s**	**2080s**
Summer Mean Temperature (June-Aug.; °C)						
Climate Normals for BC	14.3	14.4	14.35			
Weaverville, CA		21.44				
Projected results:						
CGCM_A2x				15.4	16.4	17.7
CGCM_B2x				15.4	16.1	16.7
HADCM3_A2x				15.4	17.9	20.7
			Greatest Change	**1.05**	3.55	6.35
Autumn Mean Temperature (Sept.-Nov.;°C)						
Climate Normals for BC	7.5	7.5	7.5			
Weaverville, CA		13.0				
Projected results:						
CGCM_A2x				8.4	9.3	10.4
CGCM_B2x				8.3	9	9.4
HADCM3_A2x				9.4	10.2	12.1
			Greatest Change	**1.9**	2.7	4.6
Winter Precipitation (Dec.-Feb.; mm)						
Climate Normals for BC	602	574	588			
Weaverville, CA		512.6				
Projected results:						
CGCM_A2x				627	656	693
CGCM_B2x				660	667	673
HADCM3_A2x				681	625	675
			Greatest Change	**93**	79	105
Spring Precipitation (March-May; mm)						
Climate Normals for BC	349	367	358			
Weaverville, CA		232.9				
Projected results for a random location within the centre of the Coastal Giant Salamander *Canadian range*						
CGCM_A2x				357	325	320
CGCM_B2x				344	339	321
HADCM3_A2x				355	367	372
			Greatest Change	**-14**	-33	-38
Summer Precipitation (June-Aug.; mm)						
Climate Normals for BC	202	218	210			
Weaverville, CA		31.2				
Projected results:						
CGCM_A2x				210	191	186
CGCM_B2x				198	190	188
HADCM3_A2x				219	117	101
			Greatest Change	**-12**	-93	-109

[a] "Two global circulation models — Canadian Centre for Climate Modelling and Analysis (CGCM2) and the Hadley Centre for Climate Prediction and Research (HADCM3) — generate predictions of changes to the monthly temperature and precipitation variables for three emissions scenarios." (Spittlehouse 2006).

[b] Highest predicted model value versus average from Climate Normals.

[c] [(mean warmest month temperature) / (mean summer precipitation (mm)] / 100