Recovery Strategy for the Pacific Giant Salamander (*Dicamptodon tenebrosus*) in British Columbia

Prepared by the Pacific Giant Salamander Recovery Team

British Columbia
The Best Place on Earth
Ministry of Environment

April 2010

About the British Columbia Recovery Strategy Series

This series presents the recovery strategies that are prepared as advice to the Province of British Columbia on the general strategic approach required to recover species at risk. The Province prepares recovery strategies to meet its commitments to recover species at risk under the *Accord for the Protection of Species at Risk in Canada*, and the *Canada – British Columbia Agreement on Species at Risk*.

What is recovery?

Species at risk recovery is the process by which the decline of an endangered, threatened, or extirpated species is arrested or reversed, and threats are removed or reduced to improve the likelihood of a species' persistence in the wild.

What is a recovery strategy?

A recovery strategy represents the best available scientific knowledge on what is required to achieve recovery of a species or ecosystem. A recovery strategy outlines what is and what is not known about a species or ecosystem; it also identifies threats to the species or ecosystem, and what should be done to mitigate those threats. Recovery strategies set recovery goals and objectives, and recommend approaches to recover the species or ecosystem.

Recovery strategies are usually prepared by a recovery team with members from agencies responsible for the management of the species or ecosystem, experts from other agencies, universities, conservation groups, aboriginal groups, and stakeholder groups as appropriate.

What's next?

In most cases, one or more action plan(s) will be developed to define and guide implementation of the recovery strategy. Action plans include more detailed information about what needs to be done to meet the objectives of the recovery strategy. However, the recovery strategy provides valuable information on threats to the species and their recovery needs that may be used by individuals, communities, land users, and conservationists interested in species at risk recovery.

For more information

To learn more about species at risk recovery in British Columbia, please visit the Ministry of Environment Recovery Planning webpage at:

<http://www.env.gov.bc.ca/wld/recoveryplans/rcvry1.htm>

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Disclaimer

This recovery strategy has been prepared by the Pacific Giant Salamander (*Dicamptodon tenebrosus*) Recovery Team, as advice to the responsible jurisdictions and organizations that may be involved in recovering the species. The British Columbia Ministry of Environment has received this advice as part of fulfilling its commitments under the *Accord for the Protection of Species at Risk in Canada*, and the *Canada – British Columbia Agreement on Species at Risk*.

This document identifies the recovery strategies that are deemed necessary, based on the best available scientific and traditional information, to recover Pacific Giant Salamander (*Dicamptodon tenebrosus*) populations in British Columbia. Recovery actions, which have been derived to achieve the goals and objectives identified herein, are subject to the priorities and budgetary constraints of participatory agencies and organizations. These goals, objectives, and recovery approaches may be modified in the future to accommodate new objectives and findings.

The responsible jurisdictions and all members of the recovery team have had an opportunity to review this document. However, this document does not necessarily represent the official positions of the agencies or the personal views of all individuals on the recovery team.

Success in the recovery of this species depends on the commitment and cooperation of many different constituencies that may be involved in implementing the directions set out in this strategy. The Ministry of Environment encourages all British Columbians to participate in the recovery of the Pacific Giant Salamander (*Dicamptodon tenebrosus*).

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RESPONSIBLE JURISDICTIONS

The recovery strategy for Pacific Giant Salamander (*Dicamptodon tenebrosus*) was developed by the Pacific Giant Salamander Recovery Team as advice to the Province of British Columbia.

Pacific Giant Salamander populations occur in the Chilliwack Forest District of British Columbia. The British Columbia Ministry of Environment is responsible for producing a recovery strategy for this species under the *Accord for the Protection of Species at Risk in Canada*.

Environment Canada's Canadian Wildlife Service also participated in the development of this document, as it is responsible under the federal *Species at Risk Act* (SARA) for this species (which is referred to as Coastal Giant Salamander under SARA), and is on the recovery team.

ACKNOWLEDGEMENTS

The original (2004) version of this report was prepared by Kristina Ovaska, Lennart Sopuck, Ross Vennesland, and Christian Engelstoft with input from Dennis Knopp and members of the Pacific Giant Salamander Recovery Team. The B.C. Ministry of the Environment has since developed a new set of recovery strategy format guidelines, and the Recovery Team is therefore submitting an updated version of the recovery strategy. Revisions and updates were made by Kym Welstead with assistance from Lennart Sopuck and Kristiina Ovaska. Jeff Brown, David Toews, Stephen Hureau, Marie-José Ribeyron, and Todd Manning provided useful comments on an earlier version of the revised strategy.

Many people have generously contributed information for this report. Sylvia Letay, Barbara Johnston, Marta Donavan, Erin Prescott, John Richardson, Jim Vickerson, Christine Chapman, Marie Goulden, Arthur Robinson, Gene MacInnes, and Todd Ewing contributed data and/or information on land use within the range of the Pacific Giant Salamander. Laura Friis, Mark Stone, Laura Matthias, and Kevin Chernoff helped with spatial data, literature search, and review and compilation of the report. Kelly McAllister and Bill Leonard kindly provided information on the distribution of the species in Washington State. Hartwell Welsh generously allowed us to use his unpublished map of the global distribution of this species prepared for *A Field Guide to the Amphibians of Northwestern North America* (Jones and Leonard [eds.] 2005).

EXECUTIVE SUMMARY

The Pacific Giant Salamander is a large charismatic salamander that can grow up to 30 cm in length. This marbled golden brown salamander is the only member of the family Dicamptodontidae that occurs in Canada. The species' range extends from extreme southwestern British Columbia through western Washington and Oregon to northwestern California. In Canada, the species is largely restricted to the Chilliwack River drainage in British Columbia. It is currently known from about 75 streams and tributaries within 15 stream systems. Because of the species' restricted Canadian distribution and threats to its habitat from forestry, urban developments, road building, and other human activities, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) reassessed the national status of the Pacific Giant Salamander changing it from "Special Concern" to "Threatened" in 2000. The species is on the provincial Red list in British Columbia and is listed as Threatened under Schedule 1 of the federal *Species at Risk Act* (SARA). As well, the Conservation Framework has assigned Pacific Giant Salamanders a conservation priority 1, the highest priority rank under Goal 3: Maintain the diversity of native species and ecosystems (Ministry of Environment 2010a).

Characteristics of the species' life history and ecology that contribute to the vulnerability of populations and influence their recovery potential include limited dispersal ability both in aquatic and terrestrial habitats; complex life history; low reproductive potential; and close association with cool, clear headwater streams and creeks.

The Pacific Giant Salamander has a complex life history, which includes an aquatic and a terrestrial phase. The habitat needs of all life stages must be met for populations to persist. The salamanders typically inhabit small, cascading streams and adjacent moist, shaded forest. Aquatic larvae spend several years in the streams, where they shelter under rocks in small pocket pools of calmer water and feed on aquatic invertebrates. Adults live in moist, shaded forest, close to streams and require either abundant coarse woody debris, or other shelter on the forest floor. Under some circumstances larvae attain maturity without transforming and remain permanently aquatic; this process is termed neoteny.

The recovery goal is to ensure a well-connected, viable, and self-sustaining population of the Pacific (= Coastal) Giant Salamander (*Dicamptodon tenebrosus*) within secure habitat[1] throughout its known range[2] in Canada where habitat still exists or can be restored (achieve within 10 years). The short-term (5-year) objectives focus on securing known populations, preventing fragmentation, inventorying for unidentified populations, and restoring historical populations through management and protection of survival, recovery, and dispersal habitats in the aquatic and terrestrial environments.

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[1] "Secure habitat" is suitable habitat that is managed to maintain the species for a minimum of 100 years and includes suitably connected breeding, foraging, overwintering, and dispersal habitat.

[2] "Known range" areas will include both occupied habitat and historically occupied habitat including streams and drainages where the species occurs naturally and was confirmed to occur in the past. It includes both streams where records of the species exist and streams in the same drainages that contain high-quality, unsurveyed habitat. This area may expand as new localities are discovered.

The broad strategies or approaches for recovery consist of habitat protection, management and stewardship, habitat mapping, population inventories, habitat restoration, population and habitat monitoring, threat clarification, research, outreach, and stewardship. Although no critical habitat as defined under SARA is proposed for identification at this time, continued habitat protection is urgent for occupied sites as only 40% of the occupied sites are conserved in parks, protected areas, community watersheds, and Wildlife Habitat Areas. Currently 20 Wildlife Habitat Areas have been approved encompassing approximately 38 km (linear) of known occupied streamside habitat in the Chilliwack Forest District (Ministry of Environment 2010b; see Appendix 2). Increasing survey coverage is also urgent, as less than 20% of potential stream habitat has been surveyed to date. Habitat on private lands can be conserved through stewardship, including working with municipal and regional governments to achieve habitat objectives at landscape and broader levels. A draft action plan has been developed and will be updated after the posting of the recovery strategy.

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BACKGROUND

Species Assessment Information from COSEWIC

Date of Assessment: November 2000
Common Name: Coastal Giant Salamander
Scientific Name: *Dicamptodon tenebrosus*
COSEWIC Status: Threatened
Reason for designation: "This salamander occurs only in 6 streams and their tributaries within a single watershed in Canada and has an area of occupancy under 100 km². This species is subject to habitat loss and degradation due to encroaching urban development, logging and road building."
Canadian Occurrence: Southwestern British Columbia
COSEWIC Status History: Designated Special Concern in April 1989. Status re-examined and up listed to Threatened in November 2000. Last assessment based on an updated status report.

* The common name of Pacific Giant Salamander reported in this recovery strategy follows the current naming convention of the Province of British Columbia.

Description of the Species

The Pacific Giant Salamander is the largest salamander in British Columbia with length of adults about 15–30 cm, including the tail. The salamanders are robust with a large head, blunt snout, and stout legs. The colour pattern of adults is often reticulated or marbled with lighter tan or gold interspersed with dark brown or grey. Completely aquatic forms (neotenic form) are drab grey or brown and often lack the marbled pattern. Absence of parotoid or "poison" glands (a pair of prominent protuberances behind the head capable of exuding toxins) and larger size distinguish this species from the Northwestern Salamander (*Ambystoma gracile*), with which it might be confused. Aquatic larvae are dark brown or black without distinct markings. They have short, fuzzy external gills and a short tail fin and grow to about 9–17 cm in length. See field guides (e.g., Matsuda et al. 2006; Jones et al. [eds.] 2006) for photographs and detailed descriptions.

Populations and Distribution

The distribution of the Pacific Giant Salamander extends from extreme southwestern British Columbia south through western Washington and Oregon to northwestern California (Figure 1). From east to west, the range extends from the eastern Cascade Mountain Range to the Pacific Coast. About 1% of the species' geographic range is in Canada.

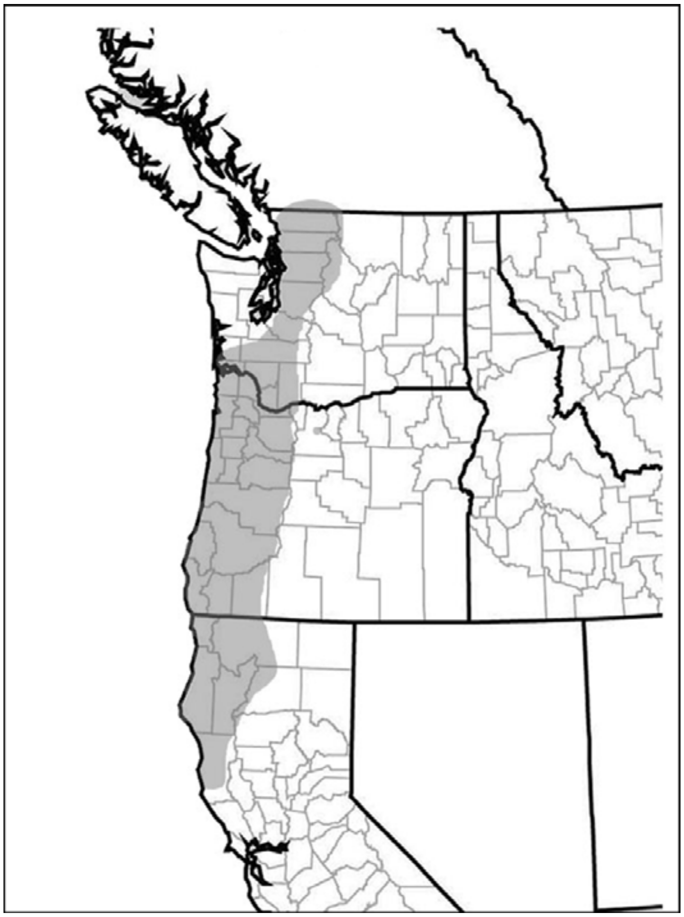

Figure 1. Global distribution of the Pacific Giant Salamander, *Dicamptodon tenebrosus*. Prepared by H. Welsh for *Field Guide to the Amphibians of Northwestern North America* (Jones and Leonard [eds.] 2005). Printed with permission of the author and editors.

The known Canadian range of the Pacific Giant Salamander is restricted to the Chilliwack River drainage and nearby smaller watersheds in southwestern British Columbia (COSEWIC 2000; MoE data files; Figure 2). Distribution records exist from the eastern slopes of Chilliwack Lake to the west side of Vedder Mountain, covering an area of about 850 km^2 (COSEWIC 2000). The salamanders are known from 15 stream systems or fourth-order watersheds (see Appendix 1 for a definition). Records exist from about 75 individual streams and tributaries based on data up to 2003 (estimated at 152 km [linear] of stream habitat; MoE, unpublished data files).[3] The area of occurrence is uncertain because less than 20% of the streams with potential habitat have been surveyed. There are no confirmed records of the species north of the Fraser River. Historically, the salamanders probably occurred in additional stream systems within the Chilliwack Watershed and in the Sumas Prairie/Chilliwack area. Detection probability of larvae also differs with stream conditions and timing of surveys.[4] Furthermore, many streams have been surveyed

[3] The number is approximate because the data were compiled from different sources where the locations of a few records were inexact and close to more than one tributary stream.

[4] W.E. Neill. 2000. Recovery of Pacific Giant Salamander populations threatened by clear-cut logging. Report for World Wildlife Fund – Endangered Species Recovery Fund, Canada. Final report, January 2000. Unpubl.

only once and have not been sampled along their entire length. Therefore, some of the streams deemed unoccupied may in reality support salamanders.

Dispersal of salamanders across the international border with the United States is possible but unlikely. In northwestern Washington State, the Pacific 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. Occupied streams that extend from Canada into Washington approach within 1–2 km of headwater streams of the Nooksack and Skagit drainages, but high elevation alpine passes between them probably pose a barrier to movements. The 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.

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 very isolated and the extent of surveys, if any, is unknown. A possible dispersal route into Canada may be along the upper Skagit Valley of Washington. The upper valley was flooded for hydro-electric development forming the Ross Lake Reservoir, which extends into Canada. The closest known locality record along the Skagit Valley in Washington is from about 45 km south of the Canadian border. Presently, the Ross Dam on the Skagit may limit dispersal potential of these populations, which lie downstream of the dam. However, it is possible that salamanders dispersed into Canada along the Skagit Valley in the past. Additional surveys for salamanders may be worthwhile within the Skagit and Silverhope drainages, especially adjacent to the U.S. border.

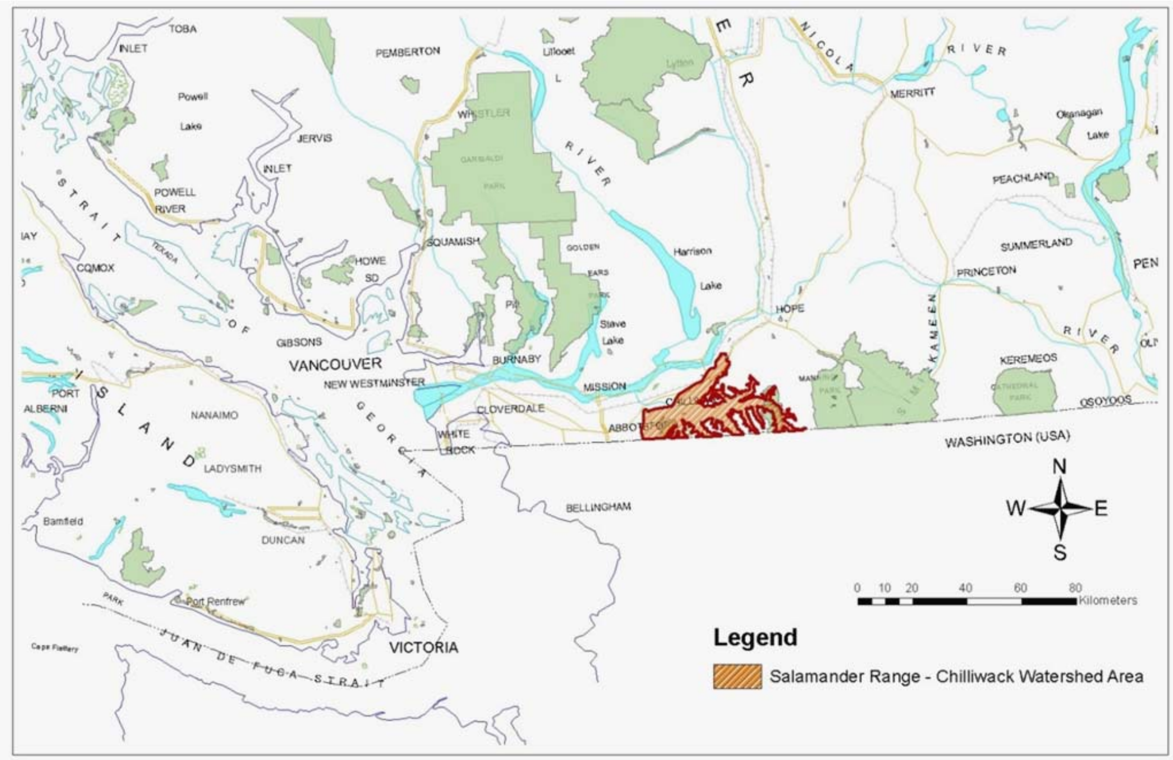

Figure 2. Distribution of the Pacific Giant Salamander, *Dicamptodon tenebrosus*, in British Columbia. Map prepared by K. Welstead based on data compiled by COSEWIC (2000) and L. Sopuck, and additional data from the B.C. Ministry of Environment data files.

No information is available on population trends. A rough estimate of the population size in the Chilliwack drainage was given in COSEWIC (2000): about 13,400 terrestrial adults and 4500–9000 aquatic, neotenic adults, but a large error may be associated with this estimate.[5] The overall distribution boundaries of the species in Canada are believed to have changed little in recent history, although presently unoccupied streams with suitable habitat may have been occupied in the past (Haycock 1991; COSEWIC 2000). An exception is a possible loss of a local population from the Sumas Prairie area due to extensive habitat modification in the early 1900s, when Sumas Lake was drained.

Within the past century, human activities and wildfires have extensively altered forest habitats over much of the species' Canadian range. Forest cover maps indicate that as of the year 2000, about 75% of the forest within Giant Salamander range (< 1200 m above sea level [asl]) was less than 120 years old. Most remaining old-growth forests are found at high elevations (> 1000 m asl) and, as a result, may be of less value to salamanders because of the harsh conditions at these elevations. Forestry and urban developments continue to modify habitats in the area today.

The Pacific Giant Salamander is ranked as nationally imperiled in Canada, but is considered to be secure globally and in the United States (see Table 1 for subnational ranks). It is on Schedule 1

[5] Estimate for terrestrial adults was calculated from a total of 131 adults reported from B.C. in 1996–1998 and multiplying this value by 99%, as telemetry studies suggest that the salamanders are above ground only 1% of the time (Neill 1998). The estimate for neotenes was based on the assumption that 0.5–1% of aquatic salamanders are neotenes multiplied by a further assumption of the total number of aquatic salamanders in B.C.

under the Canada *Species at Risk Act*. It is also a Priority 1 species under Goal 3: maintain the diversity of native species and ecosystems of the B.C. Conservation Framework (see <http://www.env.gov.bc.ca/conservationframework/> for details, Ministry of Environment 2010a).

Table 1. Conservation status of the Pacific Giant Salamander (B.C. Conservation Data Centre 2009; NatureServe 2009).

B.C.	Canada	USA	Global
S2 (imperiled); Red list	N2 (imperiled)	N5 (secure) California: SNR (unranked) Oregon: S4 (apparently secure) Washington: S5 (secure)	G5 (secure)

Needs of the Pacific Giant Salamander

Habitat and biological needs

The Pacific Giant Salamander has a complex life history, which includes an aquatic and a terrestrial phase. Under some circumstances, aquatic larvae attain sexual maturity and do not metamorphose (facultative neoteny). The habitat needs of all life stages must be met for populations to persist.

General habitat associates
In Canada, the Pacific Giant Salamander occurs within the Coastal Western Hemlock biogeoclimatic zone. Although the species has occasionally been found in larger water bodies (Chilliwack Lake and Chilliwack River), most sightings have been near headwater streams and the adjacent terrestrial habitats (COSEWIC 2000). Suitable streams are small, typically cascading with pools, and may run through a variety of moist forest types and plant communities (Farr 1989; Haycock 1991). Most of these streams are classified as permanent, although locality records from the west slope of Vedder Mountain are from streams too small to appear on maps. Some of these streams may be partially subterranean or seasonally intermittent.

In British Columbia, the species is typically associated with moist forest stands and has been recorded from stands with Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), and western redcedar (*Thuja plicata*) (Haycock 1991). These salamanders appear to prefer moist habitats, as indicated by the frequent presence of devil’s club (*Oplopanax horridus*) and salmonberry (*Rubus spectabilis*) in the shrub layer of their habitats. In Washington, the species has been found in western hemlock, western redcedar, and grand fir (*Abies grandis*) dominated forests and is absent from drier forests, such as ponderosa pine (*Pinus ponderosa*) (Haycock 1991). However, in Oregon the Pacific Giant Salamander has been known to occur in drier forest types where it has been associated with springs and seepages (Farr 1989).

In British Columbia, these salamanders appear to be restricted to elevations below 1200 m. The B.C. Conservation Data Centre database contains one record from an elevation of 1700 m, but the accuracy of that record cannot be confirmed. In the Chilliwack Valley, the average elevation of 22 occupied sites in headwater streams was 600 m (range: 140–1150 m).[6]

At the landscape level (such as a tributary watershed), the species appears to have rather general habitat requirements, and studies both in the United States (Corn and Bury 1991; Welsh and Lind 2002) and British Columbia[7] have found few correlations with habitat attributes, apart from decreased larval abundance with elevation. A study in California and Oregon (Welsh and Lind 2002) found no significant habitat correlations at the landscape level. At the macro-environmental (reach) level, habitat attributes had slightly more predictive power: salamander abundance varied negatively with an understory consisting of deciduous trees and grass, suggesting possible avoidance of ground disturbance and natural openings that often support these vegetation types. At the micro-environmental level (i.e., water and substrate features within a small portion of a reach), the habitat requirements of the salamanders were more specific, suggesting an overriding influence of microhabitat and microclimatic features on their distribution. In California, salamander abundance was correlated with increased pool density and pebble and bedrock substrates (Welsh and Lind 2002). These results are in accordance with those of previous studies (reviewed in COSEWIC 2000), and underline the importance of narrow, shaded streams with coarse, rocky substrates and abundant pocket pools and riffles. Notably, however, that the above studies mostly deal with requirements of the aquatic, rather than the terrestrial phases of the species.

Terrestrial adults occupy forested riparian habitats close to streams and require abundant shelter (Johnston 1998; Johnston and Frid 2002). Neotenic adults require permanent, relatively deep water and often occur at high elevations or, at lower elevations, and in large permanent water bodies (such as Chilliwack Lake and Chilliwack River).

Habitat requirements at different life stages

The following habitat features have been identified as important for the different life history phases of the Pacific Giant Salamander in the Chilliwack area (Farr 1989; Haycock 1991; COSEWIC 2000).

Reproductive stage

In British Columbia, development from egg to metamorphosis may take 4–6 years, compared to 2–3 years in Oregon (reviewed in COSEWIC 2000). The salamanders are long lived (20 years or more), and their reproductive potential is low. Pacific Giant Salamanders will create a “nest” where courtship, mating, and egg-laying occur in water-filled chambers under rocks, logs, or other cover-objects either within the stream or along its immediate shoreline (COSEWIC 2000; MoE 2004). Eggs have been found from the spring to autumn (Matsuda et al. 2006). The clutch size ranges from 85 to 200 eggs, which are colourless, very large (about 6.5 mm in diameter), and individually attached to the roof of the nest chamber by a short, gelatinous stalk (COSEWIC 2000). Females are thought to guard the developing eggs and young and may remain with them at the nest site for up to 200 days (Nussbaum et al. 1983).

[6] J.S. Richardson and W.E. Neill. 1995a. Distribution patterns of two montane stream amphibians and the effects of forest harvest: the Pacific Giant Salamander and Tailed Frog in southwestern British Columbia. Report prepared for the B.C. Ministry of Environment, Lands and Parks. Unpubl.
[7] Richardson and Neill, 1995a; Neill, 2000.

Aquatic larvae

The following habitat features are deemed important:

- small, cool, clear, well-oxygenated, moderate- to fast-flowing streams;
- permanent streams with a stable channel (not subject to scouring in spring or to drying up in summer);
- presence of small "pocket" pools in streams; and
- gravel and pebble substrate with refuges large enough to cover the animal.

Larval abundance tended to increase with decreasing wetted width.[8] The average wetted width where salamanders were found was 2.25 m (range: 0.7–10 m). Further habitat features examined at different spatial scales (stream, reach, and microhabitat) showed few correlations with larval abundance, with most correlations being at the microhabitat level.[9] The above study found a positive correlation of larval abundance with pocket pool density, decreased water velocity, and increased rock coverage. Pools with sand and large (> 2 m diameter) angular rocks provided habitat complexity and seemed to be preferred (Haycock 1991). Farr (1989) also stressed the importance of refuges for larval and other phases of this species in British Columbia. Several studies in the United States have shown similar correlations, and one study demonstrated experimentally that larval abundance increased with the availability of refuges, consisting of rocks of various sizes (Parker 1991).

Terrestrial phase

The following habitat features are deemed important:

- moist shady forest habitat adjacent to streams, such as in old-growth and mature second-growth forests;
- availability of refuges, such as decaying logs or other cover; and
- NESTING sites in or immediately adjacent to stream.

Few studies have addressed the habitat requirements of terrestrial phases of the salamanders. In old growth Douglas-fir dominated stands in Washington and Oregon, Corn and Bury (1991) found that terrestrial giant salamanders were most common in moderately moist and wet areas. In the Chilliwack Valley and adjacent areas in northwestern Washington, Johnston (1998) found that terrestrial adults typically occupied riparian areas.

In British Columbia, Johnston (1998) also found the species using both clearcuts (< 10 years old) and older forests, but in the clearcuts individuals altered their behaviour in ways consistent with moisture stress. Although terrestrial phases may not require old growth, they require old-growth attributes, such as large, well-decayed downed logs and other coarse woody debris, and moist forest floor conditions.

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[8] Richardson and Neill, 1995a.

[9] Hatziantoniou, Y. 1999. Habitat assessments for the Pacific Giant Salamander (*Dicamptodon tenebrosus*) in the Chilliwack River Valley at three spatial scales of investigation. Unpublished directed studies report. Univ. British Columbia, Vancouver, BC. 45 pp. Cited in COSEWIC (2000).

Both Farr (1989) and COSEWIC (2000) suggested that nesting sites (i.e., residences) form an essential habitat attribute for this species. Females are thought to guard the developing eggs and young and may remain with them at the nest site for up to 200 days (Nussbaum et al. 1983). Very few nests have ever been found anywhere within the range of the species. In British Columbia, Farr (1989) reported very small larvae from small spring-fed creeks on Vedder Mountain, and suggested that small stable creeks with abundant cover provide important nesting habitat.

Terrestrial adults appear to use similar refuges during winter as during other seasons, and the availability of overwintering habitat is not considered to be a limiting factor (COSEWIC 2000). However, little information is available on overwintering habitats.

Neotenic phase

In the Chilliwack area, neotenic adults are found at higher elevations (600–1100 m) and in large permanent water bodies at low elevations (Chilliwack Lake and River) (Haycock 1991). Neoteny is probably facultative in this species, although the two phases (terrestrial and aquatic adults) seem to be spatially segregated to some degree. Like aquatic larvae, neotenic adults require abundant shelter provided by rocks, boulders, or other coarse bottom substrates. They also require permanent, relatively deep water. Nothing specific is known about nesting habitats of neotenes.

Movement and dispersal

Movement within the riparian area was studied in the Chilliwack Valley and adjacent areas in northwestern Washington. Johnston (1998) and Johnston and Frid (2002) found that the majority (average of 67%) of locations of 18 radio-tracked adults in old-growth and mature second-growth forest were within 5 m of the stream bank. Of all locations, 80% were within 20 m and 88% were within 40 m of the stream bank (Johnston 1998; Johnston and Frid 2002). The longest distance of an adult from the stream bank was 66 m. Therefore, a minimum habitat width of 50 m each side of the watercourse would encompass most regular movements of adults along the riparian habitat. The extent of terrestrial habitat that the salamanders require is likely to vary both with the configuration and quality of habitat. Furthermore, terrestrial movements of different sex and age classes are unknown for this species.

Although terrestrial adults typically restrict their movements to small areas, they are capable of moving longer distances if environmental conditions are suitable (e.g., during periods of increased rainfall or when the ground is moist and temperatures are mild) (Johnston 1998, 1999). Availability of dispersal habitat is needed to enable these longer movements to allow dispersal of salamanders between streams and drainages. Dispersal of individuals among streams is important for maintaining genetic heterogeneity and population viability (COSEWIC 2000). Several studies in Oregon have reported the Pacific Giant Salamander up to 400 m from stream edges (reviewed in Olson et al. 2007). Sub-adult movements have not been studied and this stage may be responsible for most of the dispersal, as is the case in many other species (Horn 1983; Duellman and Trueb 1986, cited in MoE 2004; Trenham and Shaffer 2005).

The salamanders appear to occasionally use subterranean watercourses as travel corridors (D. Knopp, pers. comm. 2003). Subterranean streams could aid in dispersal, but only circumstantial evidence is available. Terrestrial adults are primarily active at night. During dry periods, their movements were restricted to times of low temperatures (Johnston 1998).

Larval salamanders are very sedentary and tend to remain in the same stretches of the stream even from year to year (Ferguson 2000),[10] where they shelter under rocks and other cover. Transplant experiments have established that larval salamanders can successfully inhabit an unoccupied nearby streams.[11] Larval mark-recapture studies found 73% of larvae stayed within 10 m of their initial location of capture over 3 years, and that only 10% of larvae ventured farther than 20 m over 2 years (Ferguson 1998). This finding supports the notion that the majority of dispersal occurs overland in adult and sub-adults and reinforces the importance of suitable terrestrial dispersal habitat to ensure gene flow.
Important terrestrial dispersal habitat probably has all of the following characteristics:

- elevation < 1200 m;
- a network of stream riparian zones;
- good canopy cover, such as in moist, old-growth or mature second-growth forest; and
- abundant cover on the forest floor, such as coarse woody debris including large pieces in advanced stages of decay.

Ecological role

The Pacific Giant Salamander plays an important role in the ecosystem as a top predator through predator–prey interactions. The species reaches the northern limits of its distribution in southern British Columbia. Populations at the periphery of a species' distribution might possess unique adaptations and contribute significantly to genetic diversity (Scudder 1989), and the general patterns of range collapse of many vertebrates have been towards the periphery of their ranges (Lomolino and Channell 1995, 1998). Peripheral populations may enhance a species' ability to respond to broad-scale environmental perturbations, including climate change. The British Columbia population may become increasingly important for the survival of the species in the future, if global climate change alters the cool, stream habitats occupied by the salamanders farther south.

Limiting factors

Limited dispersal ability

Larvae are relatively sedentary and typically confine their movements to small sections of streams (Ferguson 1998, 2000).[12] The colonizing ability of larvae is poor (Ferguson 2000). Terrestrial adults are also relatively sedentary and appear to seldom move between streams (Johnston 1998; Johnston and Frid 2002). However, they are capable of moving longer distances overland and possibly colonizing vacant habitat under favourable, moist conditions. Limited

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[10] Neill, 2000.
[11] Neill, W.E. 1998. Recovery of Pacific Giant Salamander populations threatened by logging. Report to World Wildlife Fund – Endangered Species Recovery Fund, Canada. Cited in COSEWIC (2000). Unpubl.
[12] Neill, 2000.

dispersal ability poses constraints to recovery in disturbed habitats and makes the population more susceptible to habitat fragmentation, which can isolate subpopulations.

Complex life history and restricted habitat requirements
A suitable juxtaposition of aquatic and terrestrial habitats is required for the salamanders to complete their life cycle. Although a complex life history and options such as whether to metamorphose into a terrestrial form or to remain in the aquatic habitat increase the resiliency of the species, impacts of human activities on different life history stages can be cumulative and interact in complex ways. The species is dependent on a specific set of habitat features both in streams and in adjacent forest habitats. The species is closely associated with cool, clear headwater streams and creeks, and availability of dispersal habitat remains a key issue.

Low reproductive potential
The Pacific Giant Salamander matures slowly, and females reproduce infrequently and are thought to breed only once every 2 years (Nussbaum 1976). In the Chilliwack Valley, development from egg to metamorphosis may take as long as 4–6 years, compared to 2–3 years in the centre of the species' range in Oregon (COSEWIC 2000). Low reproductive potential, together with limited dispersal ability, may contribute to low recovery rates after a disturbance.

Vulnerability of peripheral populations
The species exists at the northern extremity of its distribution in southern British Columbia. The persistence of peripheral populations is inherently precarious due to harsher climate, lower survival rates and abundance, and stochastic fluctuations in population size (Lawton 1993).

Threats

Threat classification

Table 2. Threat classification table for the Pacific Giant Salamander.

1	**Forestry activities affecting aquatic habitat**	**Threat attributes**		
Threat category	Habitat loss, degradation, and fragmentation (aquatic habitat)	**Extent**	Widespread	Range-wide
General threat	Forest harvesting, road construction, some silvicultural practices	**Occurrence**	Historical & current	
		Frequency	Recurrent	
Specific threat	Siltation/erosion, removal of riparian vegetation, increased water temperature, barriers to movement, reduced prey abundance, degradation of pool habitats, erratic stream flows	**Causal certainty**	High	
		Severity	High	
Stress	Increased mortality of larvae and neotenes; poor reproductive success	**Level of concern**	High	
2	**Forestry activities affecting terrestrial habitat**	**Threat attributes**		
Threat category	Habitat loss, degradation, and fragmentation (terrestrial habitat)	**Extent**	Widespread	Range-wide

General threat	Forest harvesting, road construction, and some silvicultural practices	**Occurrence**	Historical & current	
		Frequency	Recurrent	
Specific threat	Disturbance of terrestrial foraging, overwintering, and dispersal habitat; herbicide application; loss of overstory and ground cover (shrubs, coarse woody debris); decreased shelter and nesting habitat	**Causal certainty**	Moderate	
		Severity	High	
Stress	Changes in behaviour and movements; reduced survival and dispersal; moisture stress; reduced gene flow	**Level of concern**	High	
3	**Urban and rural development**	**Threat attributes**		
Threat category	Habitat loss, degradation, and fragmentation	**Extent**	Local	Localized
General threat	Land conversion, vegetation removal, alteration of streams, pollution	**Occurrence**	Historical & current	
		Frequency	Continuous	
Specific threat	Removal of riparian vegetation, alteration of stream channel, barriers to movement, reduced prey abundance, decreased water quality	**Causal certainty**	High	
		Severity	High	
Stress	Reduced population size and local extirpations (same stresses as forestry; see above)	**Level of concern**	High	
4	**Micro-hydro developments**	**Threat attributes**		
Threat category	Habitat loss, degradation and fragmentation	**Extent**	Local	Localized
General threat	Micro-hydro developments	**Occurrence**	Imminent	
		Frequency	Moderate	
Specific threat	Altered water flows, increased water temperature, removal of riparian vegetation, above-ground obstacles to salamander movements	**Causal certainty**	potentially high	
		Severity	Unknown, potentially high	
Stress	Reduced productivity, reduced movements, reduced population size	**Level of concern**	High	
5	**Pollution**	**Threat attributes**		
Threat category	Pollution	**Extent**	Local	Localized
General threat	Toxicity, changes in communities and species interactions, endocrine disruption	**Occurrence**	Historical & current	
		Frequency	Unknown	
Specific threat	Herbicide or pesticide application, accidental spills into creeks, contaminants in residential and industrial run-off	**Causal certainty**	Moderate	
		Severity	Unknown	

Stress	Reduced productivity and survival	**Level of concern**	Moderate	
6	**Climate change**	**Threat attributes**		
Threat category	Climate or natural disasters	**Extent**	Widespread	Range-wide
General threat	Increased summer drought; increased frequency of severe weather events	**Occurrence**	Imminent	
		Frequency	Continuous	
Specific threat	Decreased water flow in summer; increased water temperature, dry forest floor; periodic flooding and damage to streams; spread and emergence of diseases	**Causal certainty**	Low	
		Severity	Moderate	
Stress	Lower survival and productivity	**Level of concern**	Moderate	
7	**Disease**	**Threat attributes**		
Threat category	Disease	**Extent**	Widespread	Range-wide
General threat	Spread or introduction of epidemic diseases, such as chytridiomycosis; diseases or parasites spread by introduced fish or by humans	**Occurrence**	Unknown	
		Frequency	Unknown	
Specific threat	Increased mortality	**Causal certainty**	Moderate	
		Severity	Unknown; potentially high	
Stress	Reduced population size, local extirpations	**Level of concern**	Moderate	
8	**Introduced fish**	**Threat attributes**		
Threat category	Exotic or invasive species	**Extent**	Local	Localized
General threat	Intentional stocking of streams and other water bodies with fish; accidental releases	**Occurrence**	Historical & current	
		Frequency	Recurrent	
Specific threat	Predation, increased competition for shelter or food	**Causal certainty**	Moderate	
		Severity	Moderate	
Stress	Reduced population size	**Level of concern**	Moderate	
9	**Recreational activities**	**Threat attributes**		
Threat category	Habitat loss, degradation, and fragmentation	**Extent**	Local	Localized
General threat	Intensive recreational activities, such as use of ATVs or mountain bikes in riparian zones	**Occurrence**	Current	
		Frequency	Unknown	
Specific threat	Erosion, siltation, damage to riparian vegetation	**Causal certainty**	Unknown	
		Severity	Unknown	
Stress	Behavioural changes, reduced survival	**Level of concern**	Low	

Description of the threats

Forestry activities

Historical and recent forestry practices have modified forest habitats within much of the Canadian range of the Pacific Giant Salamander. Forestry activities continue to be widespread, and little older forest remains, particularly at lower elevations. Forestry activities include logging, associated road building, construction of landings and helipads, and various silvicultural activities/prescriptions that have the potential to remove ground vegetation or disturb the forest floor (i.e., soil layer, coarse woody debris, herbaceous/shrub cover) and change the forest composition and strata. In aquatic habitat, canopy removal increases water temperatures, and logging and road building have the potential to cause siltation, which fills in cracks and crevices and reduces shelter required by giant salamander larvae (Bury and Corn 1988). Logging practices may also reduce the persistence of small streams, particularly in dry years, resulting in loss of habitat, isolation of subpopulations, and possibly direct mortality (Cannings et al. 1999; COSEWIC 2000). In terrestrial habitat, canopy removal results in changes to the microclimate at ground level, including temperature and moisture regimes. Logging also alters the structure of the forest floor (i.e., changes in ground cover and amount and distribution of coarse woody debris) potentially limiting the availability and type of shelters for terrestrial salamanders. Clearcut logging constrains movements and dispersal of terrestrial phases of this salamander (Johnston 1999; Johnston and Frid 2002). These constraints can potentially isolate populations leading to lower survivorship and reduction in genetic variability

With the adoption of the *Forest Practices Code of British Columbia Act* in 1995 and the *Forest and Range Practices Act* (FRPA) in 2003, common standards have been applied to forestry practices throughout the province. Regulations pertaining to the construction of roads, in particular, have benefited habitats of the Pacific Giant Salamander by reducing siltation of streams due to erosion. However, stream buffering of small, fishless headwater streams is not required under FRPA unless constrained by some other mechanism such as a Wildlife Habitat Area. Watershed restoration plans within some areas of the Chilliwack Valley have addressed and attempted to restore habitats degraded by earlier logging practices.

Studies in the Chilliwack drainage system since 1994 have revealed that the effects of logging on the Pacific Giant Salamander are complex and often subtle (Richardson and Neill 1998; Johnston 1999; Johnston and Frid 2002).[13] For example, larval densities and body size differed between stream stretches adjacent to clearcuts and old-growth stands, possibly as a result of changes in growth rates, immigration rates, and/or survival (Richardson and Neill 1998).[14] In terrestrial habitat, adults in clearcuts altered their movement patterns consistent with moisture and temperature stress when compared to their behaviour in the adjacent forest (Johnston 1999; Johnston and Frid 2002). Effects of such changes on population sizes and dynamics are unknown and not easily studied.

Urban and rural development

Urban, industrial, and agricultural developments in the Chilliwack and adjacent watersheds continue to diminish aquatic and terrestrial habitats. Removal of forest cover and/or changes in

[13] Richardson and Neill, 1995a.
[14] Ibid.

drainage patterns in and around developments can lead to loss, fragmentation, and severe degradation of habitats. Currently, the effects of new developments are local and restricted to areas zoned for residential, commercial, or agricultural developments, which comprise about 9% of the species' range. However, developments occur in productive, lower elevation areas, leading to the loss and degradation of high-quality habitat for the salamanders.

Micro-hydro developments
Micro-hydro developments along a stream usually consist of a water intake structure (small dams, intake structures, or "run-of-river" systems), penstock/water conduit structures, small power plant with turbines, access road, and a power transmission line corridor. Such developments could lower or alter water flows, increase water temperature, result in removal of riparian vegetation, and create above-ground obstacles to movements of salamanders. As of 2009 there are 17 documented micro-hydro power water licence applications within the known range of the Pacific Giant Salamander (British Columbia Ministry of Environment 2009), although some of these may no longer be active.

Pollution
The main sources of pollution are contaminants in the run-off from residential and industrial developments and pesticide application on forestry lands. Accidental spills of hazardous materials such as fuels or lubricants can also contaminate streams. According to permit regulations for the Chilliwack Valley, herbicides cannot be applied within 10 m of large streams, and small headwater streams can only be sprayed when they are dry, thus reducing potential impacts on salamanders and other species using aquatic habitats. Herbicides such as the glyphosate formulation Roundup have been shown to reduce survival of amphibian larvae if the herbicide enters the water column (Relyea 2005). Synergistic interactions between pesticides and stress magnify the effects in some species of amphibians (Relyea 2005).

Climate change
Global climate change is predicted to result in increased incidence of summer droughts and extreme weather events such as flooding in winter (Gates 1993; IPCC 2001; MoE 2007). Increased aridity can affect persistence of streams and the availability of moist refuges in terrestrial habitats. Increased flooding due to severe storms can alter the habitat structure of streams. Impacts of climate change may be exacerbated in landscapes fragmented by logging and other human activities. For example, effects of prolonged summer droughts may be especially severe in logged landscapes, further reducing suitable moist refuges available for salamanders on the forest floor. Small streams may similarly be prone to increased drying in areas with reduced canopy cover, reducing quality and quantity of aquatic habitat.

Disease
Increased access through forestry roads and recreational trails may result in the spread of infectious diseases by humans to the salamander population. For example, sport fishers could spread disease organisms among different streams in their gear. Of particular concern is a pathogenic chytrid fungus *(Batrachochytrium dendrobatidis)*, which has been implicated in amphibian declines in the western United States and globally (Daszak et al. 1999). Other pathogens that are associated with epidemic disease in amphibians are the water mold *Saprolegnia ferax,* which can be transmitted from fish to amphibians, and various iridoviruses

(Daszak et al. 1999). Mortality associated with chytrid fungal infection has been reported from the Idaho Giant Salamander, *Dicamptodon aterrimus* (USGS 2001). At present there is no evidence that outbreaks of disease are a problem for Pacific Giant Salamander populations, but in light of the role of chytridiomycosis in precipitous declines of amphibian populations worldwide, the threat must be taken seriously.

Introduced fish
Pacific Giant Salamanders, especially young of the year, are vulnerable to predation by salmonid fish (Rundio and Olson 2003). The use of small headwater streams by Pacific Giant Salamanders for breeding and nurseries is considered to be at least partially an adaptation to avoid predation (COSEWIC 2000). The presence of fish may also increase competition for food resources in streams. Stocking of sport fish within the Chilliwack River Watershed may pose an important threat to this species (Orchard 1984). The extent of fish introductions and spread to headwater streams and water bodies within the Chilliwack drainage is unknown.

Recreational activities
Riparian and stream habitats can be adversely affected by the use of all terrain vehicles, mountain bikes, or other intensive recreational activities that result in erosion, siltation, and damage to riparian vegetation. Such intensive activities are localized and impacts on salamanders are minor at present. Spread of disease is potentially a greater threat (see section Disease, above).

Actions Already Completed or Underway

- Research: larval ecology and forestry interactions (Ferguson 1998, 2000; Richardson and Neill 1998).[15, 16]
- Research: movements of terrestrial adults and forestry interactions (Johnston 1998, 1999; Johnston and Frid 2002).
- Inventories:
    - University of British Columbia (1994–2000)
    - Department of National Defence lands (Knopp and Larkin 1995)
    - B.C. Conservation Corps (2006, private lands west side of Vedder Mountain and eastern hillsides)
- Habitat modeling: analyses done for an earlier of version of this document in 2004.[17]
- 20 Wildlife Habitat Areas were approved in 2007 encompassing approximately 38 km (linear) of known occupied streamside habitat in the Chilliwack Forest District (Ministry of Environment 2010b; see Appendix 2 for details).

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[15] Richardson and Neil, 1995a; Neil 1998, 2000.
[16] J.S. Richardson and W.E. Neill. 1995b. Biodiversity of stream invertebrates in streams used by Pacific Giant Salamanders. FRBC Project OPS.EN-128. Unpubl. report.
[17] J.P. Lemieux. 2005. A habitat model for the Pacific Giant Salamander (*Dicamptodon tenebrosus*) in British Columbia. Report prepared for the B.C. Ministry of Water, Land and Air Protection, Surrey, BC. Unpubl.

Knowledge Gaps

- Distribution within known range, including unsurveyed streams, those visited only once, and persistence in streams with only historical records; possible presence within other, adjacent drainages containing suitable habitat.
- Population dynamics, especially at landscape level.
- Reproduction and life history, including larval growth rates, period of larval phase, and age-specific survival rates in both aquatic and terrestrial habitats.
- Characteristics and availability of nesting sites.
- Characteristics of dispersal habitat and salamander movements.
- Effectiveness of linear riparian buffers prescribed for Wildlife Habitat Areas in protecting salamander populations.
- Further clarification of threats from all sources.

RECOVERY

Recovery Feasibility

Based on the answers to criteria outlined in Environment Canada's draft policy on the feasibility of recovery (Environment Canada 2005), the recovery team determined that recovery of Pacific Giant Salamander (*Dicamptodon tenebrosus*) is biologically and technically feasible in B.C.

1. Are individuals capable of reproduction currently available to improve the population growth rate or population abundance? Yes.

- An estimated population size in the Chilliwack drainage was about 13,400 terrestrial adults and 4500–9000 aquatic, neotenic adults (COSEWIC 2000).
- There is evidence of successful breeding within its range.

2. **Is sufficient habitat available to support the species or could it be made available through habitat management or restoration? Yes.**

- Pacific Giant Salamander is known in about 75 streams and tributaries within 15 stream systems and within an area of about 850 km^2.
- It is possible to recruit habitat after harvest.

3. Can significant threats to the species or its habitat be avoided or mitigated through recovery actions? Yes.

- Habitat protection on provincial Crown lands can in part be enabled using Wildlife Habitat Areas under the *Forests and Range Practices Act* and the *Wildlife Act*.
- Habitat loss, degradation, and fragmentation can be partially mitigated through various mechanisms ranging from landscape-level planning, reduced forest harvest levels, lengthened rotation periods, and reforestation.
- Appropriate habitat management on private lands can be facilitated through stewardship, good communications, and careful planning.

4. Do the necessary recovery techniques exist and are they demonstrated to be effective? Yes.

- Current availability of habitat continues to support populations within several core areas in the Chilliwack drainage.
- Pacific Giant Salamander is known to occupy 75 streams (previously estimated at 152 km [linear] of stream habitat in the Chilliwack Forest District). To date approximately 38 km or 25% (based on 152 km) of known occupied streams are managed in 20 approved Wildlife Habitat Areas, and approximately 15% are under parks and protected areas and community watersheds.

The Recovery Team believes that the recovery can be completed within a relatively short time-frame through habitat protection and restoration. The species can tolerate some degree of human disturbance, although it is unknown how much further habitat alteration the population can withstand. If reintroduction is deemed necessary in the future, translocation of individuals to currently unoccupied streams that contain suitable habitat is feasible.[18]

Recovery Goal

The overall long-term goal (***achieve within 10 years***) for recovery of the Pacific Giant Salamander in B.C. is:

To ensure a well-connected, viable, and self-sustaining population of the Pacific Giant Salamander (*Dicamptodon tenebrosus*) within secure habitat[19] throughout its known range[20] in Canada where habitat still exists or can be restored.

This long-term goal can be achieved by ensuring effective protection of known populations, conserving and restoring habitat connectivity, and increasing knowledge of habitat requirements and occurrences.

Thus, the short-term goals are:

- to ensure that the current B.C. population of Pacific Giant Salamander is maintained with no further loss of local populations[21] (achieve within 5 years); and
- to ensure that patterns of natural population dynamics and dispersal can be maintained or restored within the species' known range (achieve within 5 years).

A change in COSEWIC listing from Threatened to Special Concern might be possible if threats to habitat can be reduced.

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[18] Neill, 1998.
[19] "Secure habitat" is suitable habitat that is managed to maintain the species for a minimum of 100 years and includes suitably connected breeding, foraging, overwintering, and dispersal habitat.
[20] "Known range" areas will include both occupied habitat and historically occupied habitat including streams and drainages where the species occurs naturally and was confirmed to occur in the past. It includes both streams where records of the species exist and streams in the same drainages that contain high-quality, unsurveyed habitat. This area may expand as new localities are discovered.
[21] Local populations include all occupied reaches (segments of river with contiguous suitable habitat) to ensure meta-population dynamics and genetic diversity are retained.

Rationale for the Recovery Goal

The recovery goal assumes that sufficient habitat to maintain a viable population exists within the current geographic range of the species in B.C. Two sources of information support this assumption: the overall distribution of the species is believed to have changed little in recent history; and apparently viable local populations continue to persist in different parts of the range. Quantitative targets are not possible because of uncertainties in estimating the number of connected sub-populations and size of each sub-population needed for establishing a long-term viable population for species persistence.

The COSEWIC status criteria for listing the Pacific Giant Salamander as Threatened included (1) small geographic range (extent of occurrence); (2) small area of occupancy together with continuing decline in extent and/or quality of habitat; and (3) very restricted area of occupancy or number of locations, increasing vulnerability of the population to human activities or stochastic events. Recovery efforts will not improve the small geographic range, but mitigation of threats at occupied sites can alleviate the decline in extent and quality of habitat and decrease vulnerability of populations, possibly leading to down-listing of the species. Also, inventory of unsurveyed areas within the species' range (only about 20% of potentially suitable habitat has been surveyed) may result in increases to the known area of occupancy.

Recovery Objectives (2009–2013)

The recovery objectives focus on the short-term recovery goals but ultimately contribute to achieving the longer-term goal.

The recovery objectives are:

Objective 1: Protect all known local populations including their terrestrial and aquatic habitats within 2 years.

Objective 2: Create or maintain networks of upland and riparian dispersal habitat among and between occupied drainages throughout the species range to reduce fragmentation within 10 years.

Objective 3: Prevent the inadvertent loss of not-yet discovered populations by clarifying distribution of the species and ensuring the occurrence and habitat data are readily accessible within 5 years.

Objective 4: Increase understanding of the habitat needs, life history, population dynamics, and habitat use of the species and to clarify threats facing these populations, so that appropriate conservation measures can be taken and population and habitat targets can be quantified within 5 years.

Objective 5: Actively engage landowners, managers, and users in stewardship activities within 2 years.

Approaches Recommended to Meet Recovery Objectives

Recovery planning table

The broad approaches for recovery of this species consist of the following: habitat protection, management, and stewardship; habitat mapping; population inventories; habitat restoration; population and habitat monitoring; threat clarification; research on life history, population dynamics, and habitat use; and outreach and communication (Table 3). Protecting occupied terrestrial and aquatic habitat and maintaining or enhancing habitat connectivity among streams and stream systems are of highest priority. Other strategies in Table 3 are intended to support habitat protection by filling in data gaps, providing necessary information for management, communicating this information to stakeholders, and collaborating and coordinating with conservation initiatives for other species.

Table 3. Recovery strategies for the Pacific Giant Salamander.

Priority	Obj. #	Threats addressed	Broad strategy to address threat	Recommended approaches to meet recovery objectives
Urgent	1, 2, 5	Habitat loss, degradation & fragmentation; forestry activities; road construction; pollution	Habitat protection, management and stewardship	(i) Establish additional Wildlife Habitat Areas (WHAs) on provincial Crown lands with known occurrences; start with best quality habitats (moist, mature forest) and/or areas supporting high density populations; ensure that WHAs are spread throughout the species' range and include suitable areas of upland dispersal habitat; use WHAs to enhance habitat networks by connecting gaps between existing protected areas wherever possible; adjust buffer widths of WHAs, if required, based on effectiveness monitoring (see monitoring section in this table) (ii) Ensure that recommended measures in Identified Wildlife Management Strategy guidelines are implemented (e.g., riparian management guidelines, General Wildlife Measures) (iii) Evaluate the effectiveness of implemented protection measures such as WHAs (which use a core buffer of 30 m as recommended in the IWMS account rather than recommended 50 m core recommended by the recovery team) in achieving recovery objectives and refine as needed (iv) Integrate salamander protection with other management initiatives to create large reserves; other initiatives include Special Resource Management Zones, Old Growth Management Areas, Ungulate Winter Ranges, large (> 50 m wide) Wildlife Tree Patches, Ecological reserves, Community Watersheds, fisheries and watershed restoration activities, and WHAs for other species; priority is to create networks of contiguous riparian and terrestrial habitats throughout the species range (v) Work with timber licensees to protect and manage important habitats and essential habitat features. (vi) Leave forested riparian buffers around all streams

Priority	Obj. #	Threats addressed	Broad strategy to address threat	Recommended approaches to meet recovery objectives
				within the range of the species, as only a small proportion of streams with suitable habitat have been surveyed for salamanders, and minimize siltation and other downstream effects (vii) Minimize sedimentation and barriers to movements resulting from road construction (viii) Ensure that herbicides and pesticides are not applied over or adjacent to salamander habitat, including small or intermittent headwater streams
Urgent	1, 2, 5	Habitat loss, degradation and fragmentation; urban & rural development; micro-hydro development; recreation; pollution	Habitat protection, management and stewardship	(i) Work with land use planners in provincial, regional, and municipal governments to protect and manage important habitats in urban and rural areas; include needs of the species into land use plans (ii) Work with land developers to ensure that salamander habitat is not degraded by developments near occupied habitat (iii) Ensure that salamander habitat is not impacted by urban or industrial run-off, sedimentation, or pesticide or herbicide applications (iv) Work with micro-hydro developers (a.k.a. independent power producers) and other resource users to protect and manage occupied salamander habitats (v) In parks and recreational areas, minimize damage to salamander habitat caused by erosion and destruction of riparian vegetation; restrict intensive recreational activities and ATV use along occupied streams
Urgent	1, 2, 3	Habitat loss, degradation & fragmentation	Habitat mapping	(i) Refine existing habitat model[22] based on new survey information and ground-truthing; include information on habitat quality and relative abundance where possible (ii) Complete actions needed to delineate critical habitat (see Table 4) (iii) Identify degree of forest fragmentation and potential areas to be managed to facilitate dispersal of salamanders; identify opportunities to create networks of connected habitat throughout the species' range (iii) Map special management zones and occurrences of other species at risk to ensure coordination with other conservation initiatives
Urgent	3	Habitat loss, degradation & fragmentation	Inventory	(i) Survey unsearched habitat within the Chilliwack drainage and adjacent watersheds to better delineate distribution; use the habitat model to focus survey effort (ii) Resurvey streams in potential habitat with no records of salamanders and streams with only historical records
Urgent (i) High (ii- iv)	1, 2	Habitat loss, degradation & fragmentation	Habitat restoration	(i) Restore connectivity of habitat among streams in logged areas: maintain maturing forest in upland areas between streams in core areas; replace or adjust culverts so that they are passable to salamanders; rehabilitate streams clogged with debris and impassable rock embankments along roads at stream crossings

[22] Lemieux, 2005.

Priority	Obj. #	Threats addressed	Broad strategy to address threat	Recommended approaches to meet recovery objectives
				(ii) Restore forest cover and stabilize erosion in headwater gullies, slides, and road cuts to reduce siltation downstream (iii) Maintain or restore microhabitat features, such as large coarse woody debris, along stream banks to provide cover for terrestrial phases; deepen or enhance stream pools where degraded (iv) Incorporate the needs of salamanders in watershed restoration projects for salmonid fish habitat, such as gully management in upper watershed areas
Urgent	4	Habitat loss, degradation & fragmentation; forestry; urban & rural development; Introduced fish; pollution; recreational activities; disease; climate change	Population & habitat monitoring	(i) Develop and implement a monitoring plan, using population and habitat indicators (ii) Monitor windthrow, fire, and climate change effects on buffers and reserves within WHAs and other protected areas over the long term (iii) According to the monitoring plan, resurvey previously inspected streams at periodic intervals to determine persistence of local populations throughout the species range; examine persistence in relation to habitat connectivity; establish intensive monitoring sites in core habitats (e.g., within WHAs) using non-destructive sampling methods (iv) Conduct genetic studies to examine metapopulation dynamics to assess adequacy of habitat connectivity relative to large uncut reference areas (continue approach by Curtis and Taylor 2004) (v) Monitor and test effectiveness of specific mitigation measures (restoration of habitats; culvert designs; pattern of forest retention along potential dispersal routes)
High	4	Habitat loss, degradation & fragmentation; all threats	Threat clarification	(i) Record threats, such as forest harvesting, barriers to movement, erosion, presence of introduced fish, evidence of recreational or industrial use, and other factors, at each site visited as part of inventories or monitoring activities (ii) Monitor selected habitat indicators at protected sites and in relation to resource use (forestry, urban, mining, hydro-electric development); potential indicators include seasonal persistence of streams, pocket pool persistence, water temperatures, level of siltation, and temperature and humidity in riparian forest (iii) Review resource use plans (such as forest, mining, gravel extraction, and hydro-electric development plans) to identify possible new threats or threats to new areas within the species' range (iv) Communicate with responsible fisheries agencies to evaluate threat from sport fish introduction practices (past, presence, future)
High	4	Habitat loss & degradation	Research (habitat use)	(i) Identify features of nesting habitat, study habitat usages and movement patterns of sub-adults/juveniles (ii) Assess habitat features that facilitate movements and dispersal by salamanders (iii) Assess recovery and persistence of populations in

Priority	Obj. #	Threats addressed	Broad strategy to address threat	Recommended approaches to meet recovery objectives
				logged and unlogged areas at a board landscape scale. (iv) Test effectiveness of specific mitigation measures (restoration of habitat, retention of forested buffer zones along streams; patterns of forest harvest along potential dispersal routes) (v) Investigate the distribution and habitat correlates of neotenic salamanders
Medium	4	NA	Research (population biology)	(i) Clarify basic biology of the salamanders (reproductive biology; age structure and age-specific survival rates; larval growth rates and period of larval phase) (ii) Develop a population model to examine viability and extinction risk under different population sizes and percentage of habitat protection scenarios
Urgent	1, 2, 5	Habitat loss, degradation & fragmentation; introduced fish; pollution; recreational activities; disease	Outreach and stewardship	(i) Work with municipal and regional governments to include the species in land use, community, and development planning (ii) Facilitate the establishment of conservation covenants and other stewardship agreements through education, promotion, tax cuts, or other incentives (iii) Prepare detailed best management practices guidelines for mitigating adverse effects of developments on salamander populations for land users on private and municipal lands and on Crown lands, including independent hydro-electric producers, mine/quarry operators, private land developers, and the public, and complementing Identified Wildlife Management Strategy guidelines available for forestry licensees (v) Work with recreational fisheries to ensure that sports fish are kept out of prime salamander habitat (vi) Increase awareness of the seriousness of disease transmission to amphibians and promote adoption of safe practices by forest workers, researchers, and the public who enter salamander habitat (vii) Communicate protection initiatives and management guidelines to stakeholders and the public through workshops, presentations, and websites (viii) Communicate occurrence data and essential habitat areas to prevent inadvertent loss of habitat
Medium	4	Climate change	Monitoring	As part of a long-term monitoring program, assess changes in habitat use and distribution due to the effects of more frequent drought, weather events such as flooding, rising water temperatures, and changes in forest composition

Description of the recovery planning table

Habitat protection, management, and stewardship

Strategies for protecting occupied aquatic and terrestrial habitats are considered urgent. Habitat protection is to focus first on streams and associated terrestrial habitat within productive older forest (>100 years old), as remaining mature and old-growth forest continues to be lost. However, because much of high capability habitat for the species is in lower elevation forest that has been logged or otherwise modified in the past, the focus is also on protecting high-quality occupied habitat in younger, maturing forest in strategic areas, especially in areas with clusters of records of the species. The establishment of forested buffers of sufficient width and large reserve areas is a very important tool in the maintenance of Pacific Giant Salamander populations in managed forests (see review in Appendix 3). Properly designed buffers help maintain the quality of both terrestrial and in-stream habitats and minimize negative edge effects. The main purpose of large reserve areas is to increase habitat connectivity and provide overland dispersal habitat for salamanders within and between drainage systems.

Securing overland dispersal routes merits special consideration when protecting and managing salamander habitat. Where clusters of streams with distribution records and other suitable high-quality habitats occur, protecting or managing the entire subsystem of streams and associated forest is desirable, particularly where older forest remains. Securing overland dispersal routes within at least 50% of occupied sub-drainages (i.e., fourth-order watersheds as per Appendix 1) is recommended through managing forest harvesting and other human activities. However, where opportunities exist, options for similar connectivity at a broader scale among watersheds should also be explored, incorporating existing protected areas into the network whenever possible. Olson et al. (2007) provided a comprehensive review of various spatial patterns of reserves for amphibians in managed headwater forests of the Pacific Northwest of the United States. These options also apply for managing dispersal habitat for the Pacific Giant Salamander habitat in British Columbia.

Habitat mapping

An initial habitat model for the species has been prepared.[23] This recovery strategy calls for the refinement and extension of the model, including collecting additional field data on habitat attributes and relative abundance of salamanders at occupied sites. The model is useful for prioritizing survey efforts and contributes towards the delineation of critical habitat.

To help coordination with other conservation initiatives, the creation of a GIS map is needed, showing occurrences of protected areas, special management zones, fisheries restoration projects, and occurrences of other species at risk with overlapping distributions. This map will help in identifying opportunities for connecting habitats, coalescing smaller protected areas into larger units, and ensuring that habitat suitability for the Pacific Giant Salamander is maintained within areas managed for other species.

Population inventories

Less than 20% of potentially suitable streams within the species' Canadian range have been surveyed, and inventories are considered urgent. More accurate information on the species' distribution is needed to protect occupied habitat, refine the existing habitat model,[24] and describe critical habitat. It is expected that much of the survey effort can be conducted as part of ground-truthing surveys for the habitat model.

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[23] Lemieux, 2005.
[24] Ibid.

Habitat restoration

Degraded terrestrial and aquatic habitats can often be restored to increase their suitability for salamanders. It is important to identify and take advantage of restoration opportunities as they arise. While results of some habitat restoration measures, such as improving habitat connectivity among streams within logged landscapes, may take years to be realized, other measures can be completed quickly and with relatively little effort once the problem has been identified. Examples of the latter involve replacing or adjusting culverts so that they are accessible to salamanders or removing steep rock embankments along roads at stream crossings to facilitate salamander movements.

Population and habitat monitoring

Very little quantitative information is available on responses of the Pacific Giant Salamander to specific buffer widths extending from each side of a stream and the size and configuration of reserve areas (see Appendix 3). According to the Identified Wildlife Management Strategy guidelines, the linear Wildlife Habitat Area (WHA) for this species consist of a 30 m wide protected core area buffer and an additional 20 m wide management zone buffer, on both sides of the stream reach. Effectiveness monitoring is essential to validate these buffer widths and to adjust them if needed. Before and after studies of buffers of different widths and comparisons of existing buffers with uncut reference sites are recommended.

Habitat needed for dispersal and maintaining metapopulation structure of the salamanders at landscape scales is difficult to study directly but can be investigated indirectly using a genetic approach. Therefore, it is important to expand genetic studies initiated by Curtis and Taylor (2004) for the Pacific Giant Salamander to examine metapopulation dynamics in landscapes with different levels of connectivity. Such analyses can be used to assess the adequacy of different patterns of dispersal habitat within the landscape.

Long-term monitoring sites need to be established in the core and the periphery of the range of this species to assess the impact of climate change. Some climate change induced impacts include changes to stream flow, either increased frequency of droughts or flooding, changes in temperature and over the time scale of decades there could be changes in forest composition which could indirectly affect salamander habitat quality.

Threat clarification

Threat clarification strategies include assessing threats at each site during surveys and monitoring selected habitat indicators at protected sites, such as Wildlife Habitat Areas, and in areas subjected to forestry, micro-hydro developments, or other resource uses. Monitoring habitat indicators is intended to show trends in the quality of salamander habitat over time in areas subjected to different types and intensities of resource use. Introduced sports fish are considered a threat to salamanders, but their distribution within the upper Chilliwack Watershed is largely unknown. It is important to document their distribution patterns and to assess whether they are released in salamander habitat or in adjacent watercourses from where they can access salamander habitat. Fisheries habitat restoration is prevalent within the Chilliwack drainage and potentially affects salamander habitat. Coordination with responsible agencies is needed to evaluate whether these activities are compatible with salamander habitat protection.

Research on life history, population dynamics, and habitat use
Recommended research focuses on filling data gaps in knowledge on the ecology of the species. Suitable nesting sites are potentially a limiting resource for the salamanders and need further investigation. Life history and population dynamics also require further study. This information is needed for population viability modeling and for adequately managing habitat for all life history stages of the salamanders.

Outreach and communication
Effective communication with stakeholders and the public is vital for successful management and stewardship of salamander populations. Recommended strategies include workshops with stakeholders, increasing awareness of the species, its habitat requirements and protection needs among land use planners and managers, and promoting the adoption of best management practices through stewardship. Collaboration and coordination with recovery efforts for other species at risk with overlapping distributions is also essential (see “Recommended Approach for Recovery Implementation”).

Performance Measures

Performance measures below consist of a combination of procedural measures and assessment of biological outcomes. Performance measures are intended to show whether particular activities were carried out as intended, whereas biological measures address whether desired outcomes for the salamander population have been achieved.

- Percentage of the linear length of occupied streams and associated terrestrial habitat secured through Wildlife Habitat Areas, new protected areas, management plans on existing protected areas, stewardship agreements, or other (specify) means (Objective 1).
- Secure suitable overland dispersal routes among streams and stream systems by managing forest harvesting and other human activities within at least 50% of occupied sub-drainages (i.e., fourth-order watersheds as per Appendix 1) and explore options for connectivity among sub-drainages scored by forest age class (Objective 2).
- Percentage of new streams surveyed for salamanders in comparison with total number of streams with suitable habitat. Clarify occupancy within the known Canadian range of the species by increasing survey coverage to at least 50% of streams containing potential habitat for the salamanders and apply protective measures to streams where the species is found (Objectives 3, 4).
- Persistence of populations at secured sites (Objectives 1, 2).
- Persistence of suitable habitat conditions at secured sites (Objectives 1, 2).
- Increase knowledge of the habitat requirements, population processes, terrestrial movements, threats, and refined habitat model based on above and survey data, so that critical habitats can be accurately described, population and habitat targets can be determined, and ultimately the recovery goal can be met (Objectives 1, 2, 3, 4).
- Number of conservation covenants, stewardship agreements, or written habitat protection contracts, or management plans initiated and completed; number of hectares of salamander habitat protected by above means (Objective 5).

- Information flow and data management to support habitat protection and management so that Objectives 1 and 2 can be achieved.

Critical Habitat

Identification of the species' critical habitat

Critical habitat under the federal *Species at Risk Act* is not proposed for legal identification in this document. For Pacific Giant Salamander, critical habitat[25] may include both survival habitat (based on known occurrences) as well as recovery habitat. Additional detailed mapping and consultation work will be required before critical habitat can be proposed. Recovery habitat will be identified through the list of studies to identify critical habitat (below).

Biophysical attributes of critical habitat

The habitat needs of all life stages of the Pacific Giant Salamander must be met for populations to persist. Thus it is recommended that critical habitat will consist of both headwater streams and adjacent terrestrial forest. Occupied streams are typically small and cascading, and may flow through a variety of moist forest types (Farr 1989; Haycock 1991; COSEWIC 2000). Narrow, shaded, mid-gradient streams with coarse rocky substrates and abundant pocket pools form the best aquatic habitat. Neotenic adults require permanent, relatively deep water and often occur at high elevations, or at lower elevations, in large permanent water bodies. Terrestrial adults occupy forested riparian habitats close to streams and require abundant shelter. Based on the biological and habitat needs of the species, the area required for survival is recommended as 50 m core and an additional 30 m management zone area around each side of the stream associated with the capture location (where available) and additional upland habitat to maintain connectivity, dispersal habitat, and meta-population dynamics.

Based on the data available, the best quality habitat and important habitat features for the species are currently defined as (based on Farr 1989; Haycock 1991; COSEWIC 2000; Ovaska et al. 2004 and references therein):

<u>Aquatic habitat</u>: Small, cool, clear, well-oxygenated, moderate- to fast-flowing streams; average wetted width of occupied streams 2.25 m (range: 0.7–10 m);[26] streams permanent and with a stable channel (not subject to scouring in spring or drying up in summer); presence of small "pocket" pools in streams; gravel and pebble substrate with refuges large enough to cover the animal.

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[25] *Recovery habitat* is "The habitat needed by a species in order to maintain a self-sustaining and viable population level." In most cases this is more than *survival habitat*, which is "The habitat currently occupied by a species." This is usually the habitat occupied by the species at the time it was assessed by COSEWIC. Recovery habitat usually also includes potential habitat, defined as, "historically occupied habitat that is still available for use or which could be restored to its historical state, or habitat not known to be historically occupied that would be or could be rendered suitable for the species."

[26] Richardson and Neill, 1995a.

<u>Terrestrial habitat</u>: Moist, shady forest with western hemlock, western redcedar, and/or Douglas-fir adjacent to streams, such as in older forest; abundant coarse woody debris or other cover on the forest floor, including large logs in advanced stages of decay; suitable nesting sites in or immediately adjacent to stream.

<u>Dispersal habitat</u>: A network of forested stream riparian zones and moist upland forest between streams; shaded conditions, such as in old-growth or mature second-growth forest; abundant coarse woody debris or other cover on the forest floor.

Recommended Schedule of Studies to Identify Critical Habitat

Table 4. Schedule of studies for identifying critical habitat.

Description of activity	Outcome/rationale	Timeline
Inventory of streams in all watersheds that have not been surveyed; increase survey coverage from 16% to 50% of potentially suitable streams	Fill in gaps in knowledge of the species' distribution	2011–2015
Complete connectivity analysis using existing and new distribution data and biophysical maps; explore options for overland dispersal routes among streams both within and among fourth-order watersheds including restoring or maintaining connectivity with populations south of the boarder	Allows identification of gaps in habitat connectivity – prevents the population from becoming disjunct and improve "rescue effect"[27] potential	2012–2015
Consultation with landowners and stakeholders regarding optimal locations for overland dispersal habitat	Delineation of critical dispersal habitat, which allows for some degree of flexibility	2011–2015
Develop a population model to examine viability and extinction risk under different population sizes, and % habitat protection scenarios	Allows determination of the amount of recovery habitat needed to support a minimal viable population	2011–2015
Collect detailed information on habitat features and relative abundance from a sample of occupied and unoccupied streams in each watershed	Allows revision of habitat model[28]	2011–2015
Update and refine habitat model and apply it to the remaining unsurveyed streams	Allows recommendations for the remaining potential critical habitat in unsurveyed areas	2011–2015

Existing and Recommended Approaches to Habitat Protection

Most of the land base within the Canadian range of the Pacific Giant Salamander is on provincial Crown lands under timber licences. The Identified Wildlife Management Strategy under the B.C. *Forest and Range Practices Act* provides the main means for protecting and managing salamander habitat on these lands. As of January 2010, 20 Wildlife Habitat Areas (WHAs) have been approved with a minimum of 30 m core and 20 m management zone on either side of the stream reach.

The establishment of forested buffers of sufficient width and large upland reserve areas is a very important tool in the maintenance of Pacific Giant Salamander populations in managed forests

[27] Ability of individuals to emigrate to a small population and *rescue* that population from extinction.
[28] Lemieux, 2005.

(see review in Appendix 3 for details). Properly designed forested buffers along streams help maintain the quality of both terrestrial and in-stream habitats for Pacific Giant Salamanders and minimize negative edge effects. The Recovery Team recommends the protection of at least a 50 m core habitat on each side of an occupied stream with an additional 30 m management zone on each side to reduce edge effects. This buffer width is larger than currently prescribed for WHAs (30 m core with 20 m buffer zone on each side of stream). The effectiveness of these narrower buffers for this species is untested, and data for this and other salamanders indicate that wider buffers are needed both to provide adequate habitat for all segments of the population (adults, sub-adults, and transformed juveniles), and to reduce blowdown and changes in microclimate within the core area.

One study has specifically addressed terrestrial habitat use by this species through following movements of radio-tagged salamanders in British Columbia and Washington State (Johnston 1998; Johnston and Frid 2002). The authors found that although most movements were very close to the stream, the farthest distance that an individual tagged Pacific Giant Salamander moved from the stream edge during the study was 66 m in continuous forest (18 individuals were tagged). Hence the narrower buffers would not accommodate these potentially important long-distance movements. In the United States, movements of the Pacific Giant Salamander up to 400 m from streams have been documented (reviewed in Olson et al. 2007). Furthermore, the British Columbia study followed individual animals for only 3–4 months and involved a relatively few salamanders, most of which were adults; movements of sub-adults have not been studied. In other species of aquatic-breeding salamanders, sub-adults inhabit upland areas farther from aquatic habitats than do adults (Trenham and Shaffer 2005). Sub-adults are extremely important for maintaining population size, demographic structure, and genetic variability, and they represent recruits to the breeding population. Another important consideration is wind-firmness and changes in microclimate (temperature, humidity, wind velocity) on the forest floor within buffer zones. Studies indicate that edge effects on microclimate can extend far into the forest interior, depending on site-specific conditions (Chen et al. 1995; Anderson et al. 2007).

In light of current data on movements of adults, gaps in our knowledge about movements of sub-adults, and pervasiveness of potentially deleterious edge effects, the recovery team recommends a conservative approach and the retention of wider buffers. At the same time, monitoring the effectiveness buffers of different width, including existing narrower buffer zones, is recommended.

With the approved WHAs, the total within the core areas is 38 km (linear; 320 ha), which is approximately 25% of the estimated total known occupied stream lengths (Figure 3; Appendix 2). Existing additional mechanisms of protection include parks and ecological reserves (12.6% of linear stream habitat), and community watersheds (2.3%). Opportunities for protection of salamander habitat also exist within existing special management areas (Special Resource Management Zones, Old Growth Management Areas, and WHAs for other species).
This species also occurs on lands under federal jurisdiction (First Nation Reserves: 1 stream; Department of National Defence properties: 3 sites).

It is important to evaluate the effectiveness of approved Wildlife Habitat Areas (WHAs) on provincial Crown lands and apply for additional WHAs at occupied sites. Habitats at existing protected areas, such as parks, ecological reserves, community watersheds, and special management areas, such as Special Resource Management Zones and Old-growth Management Areas, need to be managed to meet needs of the salamanders before they can be considered secure. Habitat on private lands can be secured through stewardship, including working with municipal and regional governments to achieve habitat protection at landscape and broader levels. Stewardship activities include identification of salamander habitat, adoption of Best Management Practices, designation of Environmentally Sensitive Development Permit Areas, and provision of tax incentives that encourage the establishment of conservation covenants and stewardship agreements.

Private lands comprise only about 9% of the species' Canadian range and are zoned for residential, commercial, and agricultural land uses. However, these areas contain productive low-elevation habitats and hence are very important for the salamanders. Habitat on private lands can be secured through stewardship. Recommended stewardship activities for private lands include communications with municipal and regional governments to include provisions for salamander habitat in land use, community, and development planning and the adoption of Best Management Practices. Options for the province to directly purchase land at key sites should also be explored, especially within the western and northwestern portions of the species' range at low to moderate elevations where development is proceeding at rapid pace.

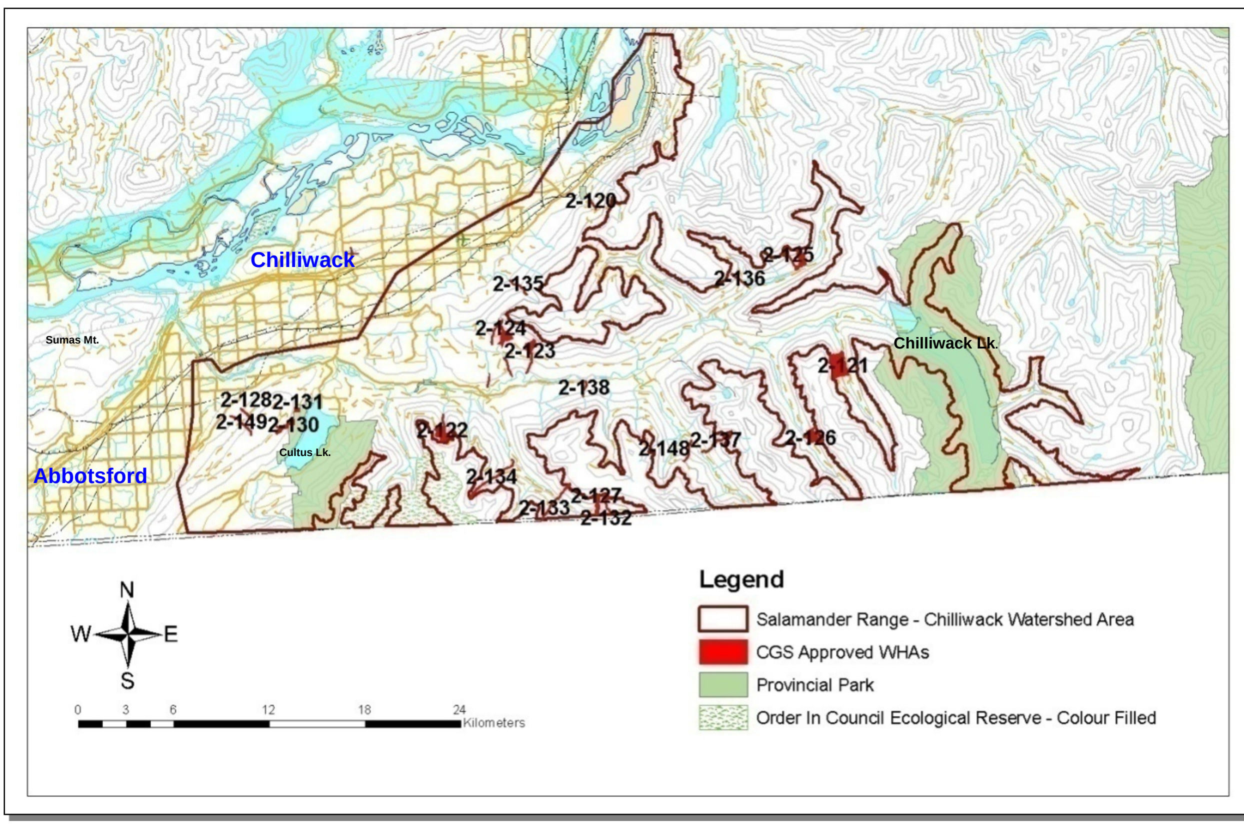

Figure 3. Map of existing habitat protection for Pacific Giant Salamanders in B.C. Map prepared by K. Welstead.

Effects on Other Species

Several species at risk occur within the range of the Pacific Giant Salamander and use similar habitats. The following species listed by COSEWIC are expected to accrue the greatest benefits:

- Spotted Owl (*Strix occidentalis;* Endangered, Red-listed), which will benefit from the protection of older forest stands in riparian areas.
- Coastal Tailed Frog (*Ascaphus truei*; Special Concern, Blue-listed), which has very similar habitat requirements to those of the Pacific Giant Salamander and will benefit from habitat protection and management measures.
- tall bugbane (*Actaea elata)*; Endangered, Red-listed), a plant that overlaps extensively with the Pacific Giant Salamander in distribution and habitat requirements. Many locality records for this species are from forested riparian zones, including several small headwater streams where the Pacific Giant Salamander occurs.
- Mountain Beaver, *rufa* subspecies (*Aplodontia rufa rufa*; Special Concern, Blue-listed), overlaps broadly in distribution with the Pacific Giant Salamander. The burrow systems of this species probably provide terrestrial salamanders with underground refuges, foraging sites, and travel corridors.

The following species listed by COSEWIC may also accrue benefits, but their distribution is limited to lower elevation zones:

- Pacific Water Shrew (*Sorex bendirii*; Endangered, Red-listed), which occupies riparian habitats along ponds and slow-moving creeks and streams.
- Oregon Forestsnail (*Allogona townsendiana*; Endangered, Red-listed), which occupies lower elevation mixedwood forests. Two locality records for this species are in the vicinity of Pacific Giant Salamander records.

Other species likely to benefit from the retention of older forest and its attributes and/or forested stream buffers include the Red-legged Frog (*Rana aurora*; Special Concern, Blue-listed), Marbled Murrelet (*Brachyrampus marmoratus*; Threatened, Red-listed), and Trowbridge's Shrew (*Sorex trowbridgii*; not assessed by COSEWIC, Blue-listed). Negative effects on prey species, such as Tailed Frog tadpoles and aquatic invertebrates, are possible in localized areas. However, giant salamanders have a long evolutionary history of coexistence with these organisms, and any negative effects will probably be greatly offset by benefits accrued from habitat management and protection.

Riparian ecosystems along headwater forest streams will benefit from habitat protection and restoration under the Pacific Giant Salamander recovery strategy. Species other than those already mentioned, such as semi-aquatic mammals (otters, mink, weasels, shrews), birds (American Dipper (*Cinclus mexicanus*), Harlequin Duck (*Histrionicus histrionicus*), songbirds, raptors), and aquatic invertebrates, are all likely to benefit. Moist, western redcedar dominated ecosystems with skunk cabbage and other moisture-loving plants are unique components of the Pacific rainforest and can be severely affected by canopy removal and associated drying of the forest floor. These ecosystems and their associated faunas are likely to benefit from the management and protection of riparian habitats for the Pacific Giant Salamander.

Socioeconomic Considerations

The following is a brief outline of potential and known socioeconomic cost and benefits.

The recovery team identifies several positive socio-economic benefits of Pacific Giant Salamander recovery related to (1) biodiversity and sustainable resource management, (2) species at risk legal obligations and jurisdictional independence, (3) international trade and cooperation, (4) forest certification, (5) scientific interest, (6) First Nations interests, and (7) eco-tourism.

Potential costs identified include (1) potential future reductions in timber harvest, (2) costs of increased private land protection and management, (3) costs of increased government management, and (4) increased resources for ecological research. Forestry is the main industry adversely affected by recovery measures for the Pacific Giant Salamander. Additional impacts to the forestry sector are anticipated because it is unlikely that all essential habitat can be protected under existing 1% policy limits set for timber supply impacts as the budget is also used to manage other species.

Social benefits resulting from improving stream quality and maintaining streamside forest habitats for the Pacific Giant Salamander include the following:

- improvement of downstream habitat for commercial and sports fish within the Chilliwack and Lower Fraser Watersheds;
- improvement in water quality for consumption by humans and livestock;
- reduction in erosion hazards in residential areas;
- increased opportunities for low impact recreational activities such as hiking; and
- improvement in ecosystem services, including maintenance of biodiversity, forest productivity, hydrological patterns, and clean water

Recommended Approach for Recovery Implementation

Many opportunities exist for integrating the implementation of the Pacific Giant Salamander recovery into other recovery or conservation efforts and the sharing of information and resources to benefit multiple species and ecosystems of conservation interest. This can be in part implemented through the South Coast Conservation Program (<http://www.sccp.ca/ >). The recovery team for the Pacific Giant Salamander should co-operate with recovery teams for other species at risk including tall bugbane, Spotted Owl, Coastal Tailed Frog, Mountain Beaver, *rufa* subspecies, Pacific Water Shrew, and Oregon Forestsnail. Recovery initiatives such as habitat protection, management, and restoration can be potentially improved for all species by pooling resources whenever possible. For example, by enlarging the size of a protected area to include multiple species at risk, the area would be more secure and less susceptible to fragmentation and edge effects. Co-operation would be enhanced by creating a centralized database for species of risk. Coordination of Species at Risk activities is also important to ensure that no harm is done inadvertently to other species.

Effective co-ordination of the many government agencies, programs, and conservation groups involved in the Chilliwack Watershed will benefit the recovery of this and other species and ecosystems at risk. This co-ordination can also be achieved through organizations such as the South Coast Conservation Program. It is important that landscape level planning and activities incorporate multi-species recovery objectives. Landscape level mechanisms that can help achieve multi-species recovery objectives include the *Forest and Range Practices Act* (FRPA), Community Watershed protection, Chilliwack River Watershed Strategy, and Land Use Planning initiatives of the Fraser Valley Regional District. FRPA is an important program available to protect and manage multiple species at risk in the Chilliwack Watershed. However, allowable timber harvesting land base impacts of conservation action (e.g., 1% Identified Wildlife budget) will likely need to be increased to accommodate conservation of listed identified wildlife. Government agencies at the federal, provincial, and local level all play a role in the recovery of the Pacific Giant Salamander. Some federal lands managed by the Department of National Defence and First Nations contain this and other species at risk, and the Department of Fisheries and Oceans undertakes numerous watershed restoration projects that can affect species at risk. At the provincial level, the MoE, MoFR, and B.C. Parks all have different roles to play in achieving recovery goals, and influence the majority of habitat occupied by the Pacific Giant Salamander and other species at risk in the Chilliwack Watershed. Local and regional governments, including the Fraser Valley Regional District, can help recovery efforts where the Pacific Giant Salamander occurs on private lands and lands under their jurisdiction in the western portion of the Chilliwack Watershed.

Statement on Action Plans

An action plan is being drafted and is expected to be completed within 2 years from the posting of the recovery strategy.

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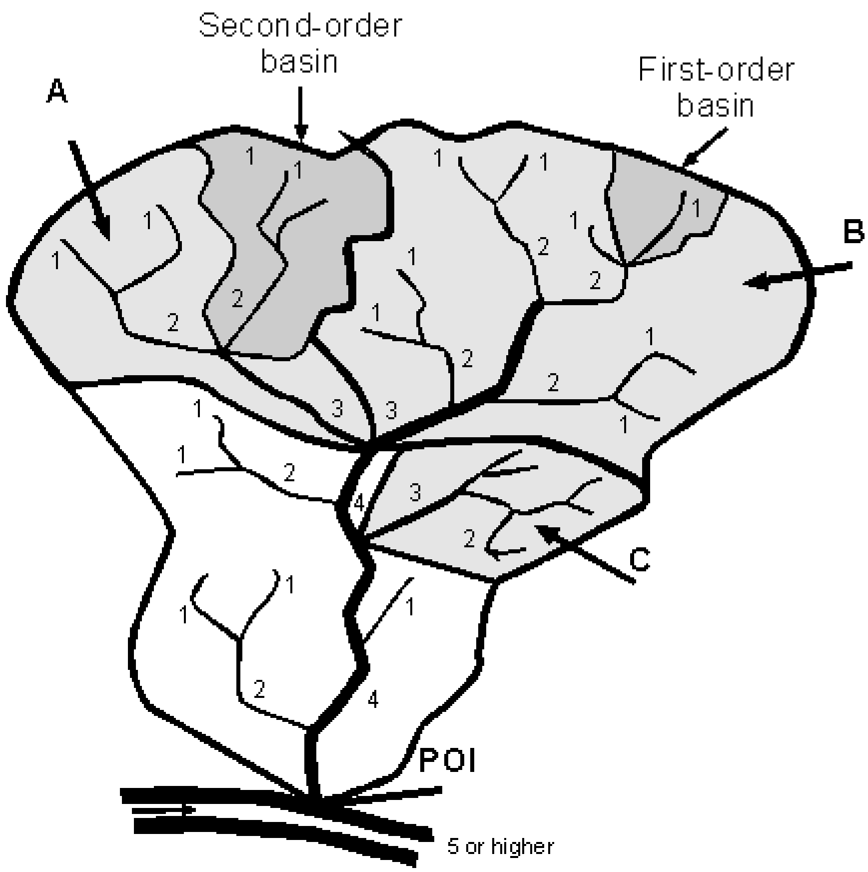
Appendix 1. Acronyms and definitions of terms

Elevation asl	Elevation above sea level
B.C.	British Columbia
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CWS	Canadian Wildlife Service
EC	Environment Canada
FRPA	*Forest and Range Practices Act*
GIS	Geographic Information System
IWMS	Identified Wildlife Management Strategy
MoE	Ministry of Environment
MoFR	Ministry of Forests and Range
SARA	*Species at Risk Act*
Special Concern	a species of special concern because of characteristics that make it particularly sensitive to human activities or natural events
Species	after COSEWIC, any indigenous species, subspecies, variety, or geographically defined population of wild fauna and flora
Threatened	a species that is likely to become endangered if limiting factors are not reversed
WHA	Wildlife Habitat Area

Appendix 2. Stream ordering system

The entire watershed is a fourth-order watershed. Sub-basins A, B, and C are third-order watersheds.
From: <http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/iwap/FIG3-1.HTM>



Appendix 3. Approved Wildlife Habitat Areas (as of January 2010)

There are 20 approved Wildlife Habitat Areas for Pacific Giant Salamander (as of January 2010). These are based on a 30 m core and 20 m management zone on either side of the stream reach. Connectivity implemented through upland zones.

Area of each WHA for Pacific Giant Salamander

Tag	WHA Feature	Area (ha)
2-120	WHA Core Area	6.6
	WHA Riparian Zone	4.4
	Total Area	11.0
2-121	WHA Core Area	31.8
	WHA Riparian Zone	18.6
	WHA Upland Zone	78.3
	Total Area	128.7
2-122	WHA Core Area	13.4
	WHA Riparian Zone	8.6
	WHA Upland Zone	39.3
	Total Area	61.3
2-123	WHA Core Area	22.8
	WHA Riparian Zone	14.3
	WHA Upland Zone	15.5
	Total Area	52.5
2-124	WHA Core Area	35.7
	WHA Riparian Zone	24.7
	WHA Upland Zone	30.0
	Total Area	90.3
2-125	WHA Core Area	30.3
	WHA Riparian Zone	18.7
	WHA Upland Zone	31.9
	Total Area	80.9
2-126	WHA Core Area	28.2
	WHA Riparian Zone	16.7
	WHA Upland Zone	19.8
	Total Area	64.6
2-126	WHA Core Area	28.2
	WHA Riparian Zone	16.7
	WHA Upland Zone	19.8
	Total Area	64.6
2-127	WHA Core Area	18.4
	WHA Riparian Zone	10.5
	WHA Upland Zone	3.9
	Total Area	32.8
2-128	WHA Core Area	5.8
	WHA Riparian Zone	4.2
	Total Area	10
2-130	WHA Core Area	10.7
	WHA Riparian Zone	6.8
	WHA Upland Zone	14.4
	Total Area	31.9

Tag	WHA Feature	Area (ha)
2-131	WHA Core Area	2.2
	WHA Riparian Zone	1.5
	WHA Upland Zone	5.0
	Total Area	8.7
2-132	WHA Core Area	11.4
	WHA Riparian Zone	7.0
	WHA Upland Zone	2.3
	Total Area	20.7
2-133	WHA Core Area	18.1
	WHA Riparian Zone	15.4
	Total Area	33.5
2-134	WHA Core Area	24.1
	WHA Riparian Zone	19.0
	Total Area	43.1
2-135	WHA Core Area	9.5
	WHA Riparian Zone	6.3
	Total Area	15.8
2-136	WHA Core Area	8.3
	WHA Riparian Zone	5.8
	Total Area	14.2
2-137	WHA Core Area	14.9
	WHA Riparian Zone	9.9
	Total Area	24.8
2-138	WHA Core Area	6.8
	WHA Riparian Zone	4.6
	Total Area	11.4
2-148	WHA Core Area	9.3
	WHA Riparian Zone	6.2
	Total Area	15.4
2-149	WHA Core Area	11.7
	WHA Riparian Zone	7.9
	Total Area	19.6

Total area (ha) of WHAs

WHA feature	**Total**
WHA Core Area	319.9
WHA Riparian Zone	211.0
WHA Upland Zone	240.5
Grand total	771.4

Length of WHAs for Pacific Giant Salamander

TAG	**Length (km)**
2-120	1.14
2-121	1.0
2-122	1.49
2-123	2.64
2-124	1.68
2-124	0.69
2-124	1.61
2-124	1.21
2-125	1.26
2-125	1.7
2-126	1.27
2-127	1.31
2-128	0.97
2-130	1.42
2-131	0.37
2-132	1.34
2-133	1.67
2-133	1.27
2-134	3.95
2-135	1.59
2-136	1.45
2-137	2.49
2-138	1.12
2-148	1.52
2-149	1.96
Grand total	38.13

Appendix 4. Design and effectiveness of forested buffers and reserves

The establishment of forested riparian buffers and large reserve areas is a very important tool in the maintenance of Pacific Giant Salamander populations in managed forests, including the Chilliwack Watershed. However, there is very little quantitative information on the response of the Pacific Giant Salamander to specific buffer widths extending from each side of a stream and the size and configuration of reserve areas. The type of forested buffers and reserves required will vary according to site characteristics such as terrain, elevation, hydrology, forest type, and susceptibility to windthrow. Properly designed buffers help to maintain the quality of both terrestrial and in-stream habitats and minimize negative edge effects. Buffers usually consist of a core area of undisturbed vegetation and an outer management zone designed to maintain the microclimatic conditions of the core area. If buffers are too narrow, the forest floor habitat used by salamanders will be subjected to temperature increases and desiccation as a result of increased solar radiation, wind penetration, and windthrow. In-stream habitats may also deteriorate as a result of temperature increases, shade reduction, and increased levels of siltation or pollution. This is especially important for cold water dependent species such as giant salamanders (Bury 2008). Buffers should also be continuous above and below occupied stream stretches to minimize downstream siltation and flooding, maximize connectivity of habitats, and provide travel routes to re-occupy new stretches of stream.

The main purpose of large reserve areas is to increase habitat connectivity and provide overland dispersal habitat for salamanders within and between drainage systems. Reserves should be configured so as to facilitate the re-colonization of previously occupied areas, colonization of new areas, and genetic interchange between local populations. They should also serve to buffer large areas of stream and riparian habitat from the potentially catastrophic effects of wildfire, flooding, windthrow, and climate change. Reserve areas also provide reference sites for research and effectiveness monitoring studies. Reserve areas should be large enough to cover the entire length of several tributary streams within a drainage. They should be continuous with existing protected areas whenever possible and be distributed widely over the species range. Olson et al. (2007) provide a comprehensive analysis of various spatial patterns of reserves for amphibians in managed headwater forests of the Pacific Northwest (see Figure 3c-g in Olson et al. 2007 for examples of reserve designs). One important feature for maintaining connectivity between local populations is to ensure that reserves from adjacent drainages extend all the way to the ridgeline and meet each other.

Forested buffers around streams provide essential foraging, refuge, and overwintering habitat for terrestrial adult Pacific Giant Salamanders and help maintain suitable in-stream conditions for larvae and neotenes. They also facilitate dispersal movements along streams. Increasing the width of forest buffers helps maintain the microclimate of terrestrial and in-stream habitats similar to undisturbed reference sites (Chen et al. 1995; Brosofske et al. 1997; Johnston and Frid 2002; Anderson et al. 2007). The cool moist conditions created by a stream and associated riparian vegetation are known to permeate upslope into upland habitat and create a microclimate suitable for terrestrial adults (Olson et al. 2007). In Oregon, Veseley and McComb (2002) reported that uncut riparian forest contained more canopy, fern, moss, and large-diameter log cover than did buffer strips (medium width of 21 m) along streams. Chen et al. (1995) found that forest strips had higher wind velocities, and greater variations in temperature and humidity than did forest interiors and that this influence of adjacent clearcuts extended 240 m or more into uncut forest. Anderson et al. (2007) recommend that the entire riparian vegetation zone be protected and that buffers extend to topographic breaks to be effective in buffering the effects of adjacent clearcuts or thinned forests.

The width of forest buffers should encompass the seasonal habitat requirements and movements of Pacific Giant Salamanders and protect these core areas of activity from adverse edge effects. Several studies in Oregon have found the Pacific Giant Salamander up to 400 m from stream edges (reviewed in Olson et al. 2007). During a radio-telemetry study in the Chilliwack and Nooksack Watersheds, Johnston and Frid (2002) found that the maximum distance of a Pacific Giant Salamander from the stream edge was 66 m in forest, 22 m in buffered areas, and 19 m in clearcuts, based on radio-telemetry techniques. Ninety-four percent of salamanders (16/17) in forested areas stayed within 25 m of the stream edge, during a 3- to 4-month period. The behaviour of salamanders along streams with 20–30m buffers was similar to forested habitats; however, only a small sample of salamanders (n = 7) were radio-tagged in areas with buffers. This study suggests that a core area of about 25–30 m would be required to account for most movements. However, to minimize adverse edge effects, an additional management zone is required to maintain the integrity of the core area over the long term and to account for occasional longer distance movements.

The width of the core area and management zone required is dependent on the characteristics of the site such as forest type, terrain, and susceptibility to windthrow. In Oregon, Stoddard and Hayes (2005) found that the presence of headwater stream populations of Pacific Giant Salamanders were positively associated with sections of streams that had at least a 46 m band of forested habitat on each side of the stream. Also in Oregon, Vesely and McComb (2002) reported that 80% of observations of three aquatic breeding salamanders, including the Pacific Giant Salamander, occurred within 20 m of the stream edge in areas with buffer zones ranging from 0 to 64 m. They estimated that that a buffer of 43 m would support salamander abundance (10 species in total) similar to that observed in uncut forest. They also recommend that a management zone of restricted harvesting may be required to protect against edge effects. In the eastern United States, Crawford and Semlitsch (2007) found that 95% of observations of four stream-breeding salamanders occurred within 27 m of the stream edge. They recommend an additional 50 m forested zone to reduce edge effects, resulting in a total buffer of 77 m on each side of the stream. Harper et al. (2008) conducted computer simulations on populations of pond-breeding spotted salamanders occupying forest buffers of different widths in the eastern United States. For buffer widths of 30 m or less, they predicted that survival rates would decline by 5% annually, leading to a 94% population decline and a 29% probability of extinction in 20 years. A buffer with of 100–165 m around breeding ponds was recommended to achieve a 95% probability of persistence of the population.

There is an urgent need to monitor the effectiveness of different buffer widths along and sizes of reserve areas in the Chilliwack drainage so that future protective measures can be adjusted if required. Before and after studies and comparisons of existing buffers with uncut reference sites are recommended.