Species at Risk Act
Management Plan Series
Adopted under Section 69 of SARA

Management Plan for the Wandering Salamander (*Aneides vagrans*) in Canada

Wandering Salamander

2021

Government of Canada
Gouvernement du Canada

Canada

Recommended citation:

Environment and Climate Change Canada. 2021. Management Plan for the Wandering Salamander (*Aneides vagrans*) in Canada. *Species at Risk Act* Management Plan Series. Environment and Climate Change Canada, Ottawa. 2 parts, 4 pp. + 49 pp.

Official version
The official version of the recovery documents is the one published in PDF. All hyperlinks were valid as of date of publication.

Non-official version
The non-official version of the recovery documents is published in HTML format and all hyperlinks were valid as of date of publication.

For copies of the management plan, or for additional information on species at risk, including the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) Status Reports, residence descriptions, action plans, and other related recovery documents, please visit the Species at Risk (SAR) Public Registry[1].

Cover illustration: © Scott Gillingwater

Également disponible en français sous le titre
« Plan de gestion de la salamandre errante (*Aneides vagrans*), au Canada »

ISBN 978-0-660-40324-3
Catalogue no. En3-5/116-2021E-PDF

[1] www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html

MANAGEMENT PLAN FOR THE WANDERING SALAMANDER (*Aneides vagrans*) IN CANADA

2021

Under the Accord for the Protection of Species at Risk (1996), the federal, provincial, and territorial governments agreed to work together on legislation, programs, and policies to protect wildlife species at risk throughout Canada.

In the spirit of cooperation of the Accord, the Government of British Columbia has given permission to the Government of Canada to adopt the *Management Plan for the Wandering Salamander (*Aneides vagrans*) in British Columbia* (Part 2) under Section 69 of the *Species at Risk Act* (SARA). Environment and Climate Change Canada has included a federal addition (Part 1) which completes the SARA requirements for this management plan.

The federal management plan for the Wandering Salamander in Canada consists of two parts:

Part 1 – Federal Addition to the *Management Plan for the Wandering Salamander (*Aneides vagrans*) in British Columbia*, prepared by Environment and Climate Change Canada.

Part 2 – *Management Plan for the Wandering Salamander (*Aneides vagrans*) in British Columbia*, prepared by the British Columbia Ministry of Environment.

Table of Contents

Part 1 – Federal Addition to the *Management Plan for the Wandering Salamander (*Aneides vagrans*) in British Columbia*, prepared by Environment and Climate Change Canada

Preface

The federal, provincial, and territorial government signatories under the Accord for the Protection of Species at Risk (1996)[2] agreed to establish complementary legislation and programs that provide for effective protection of species at risk throughout Canada. Under the *Species at Risk Act* (S.C. 2002, c. 29) (SARA), the federal competent ministers are responsible for the preparation of management plans for listed species of special concern and are required to report on progress within five years after the publication of the final document on the SAR Public Registry.

The Minister of Environment and Climate Change and Minister responsible for the Parks Canada Agency is the competent minister under SARA for the Wandering Salamander and has prepared the federal component of this management plan (Part 1), as per section 65 of SARA. To the extent possible, it has been prepared in cooperation with British Columbia (B.C.) Ministry of Environment as per section 66(1) of SARA. SARA section 69 allows the Minister to adopt all or part of an existing plan for the species if the Minister is of the opinion that an existing plan relating to wildlife species includes adequate measures for the conservation of the species. The Province of B.C. provided the attached management plan for the Wandering Salamander (Part 2) as science advice to the jurisdictions responsible for managing the species in British Columbia. It was prepared in cooperation with Environment and Climate Change Canada.

Success in the conservation of this species depends on the commitment and cooperation of many different constituencies that will be involved in implementing the directions set out in this plan and will not be achieved by Environment and Climate Change Canada and/or the Parks Canada Agency, or any other jurisdiction alone. All Canadians are invited to join in supporting and implementing this plan for the benefit of the Wandering Salamander and Canadian society as a whole.

Implementation of this management plan is subject to appropriations, priorities, and budgetary constraints of the participating jurisdictions and organizations.

[2] www.canada.ca/en/environment-climate-change/services/species-risk-act-accord-funding.html#2

Additions and Modifications to the Adopted Document

The following sections have been included to address specific requirements of the federal *Species at Risk Act* (SARA) that are not addressed in the *Management Plan for the Wandering Salamander (*Aneides vagrans*) in British Columbia* (Part 2 of this document, referred to henceforth as "the provincial management plan") and/or to provide updated or additional information.

Under SARA, prohibitions regarding the protection of species and their habitat do not apply to species of special concern. Conservation measures in the provincial management plan dealing with the protection of individuals and their habitat are still adopted to guide conservation efforts but would not result in federal legal protection.

1. Species Status Information

This section replaces information on the SARA legal designation for Wandering Salamander in Canada in Section 2 of the provincial management plan.

The legal designation of Wandering Salamander on SARA Schedule 1 is Special Concern (2018).

2. Effects on the Environment and Other Species

A strategic environmental assessment (SEA) is conducted on all SARA recovery planning documents, in accordance with the *Cabinet Directive on the Environmental Assessment of Policy, Plan and Program Proposals*[3]. The purpose of a SEA is to incorporate environmental considerations into the development of public policies, plans, and program proposals to support environmentally sound decision-making and to evaluate whether the outcomes of a recovery planning document could affect any component of the environment or any of the Federal Sustainable Development Strategy's (FSDS)[4] goals and targets.

Conservation planning is intended to benefit species at risk and biodiversity in general. However, it is recognized that implementation of management plans may also inadvertently lead to environmental effects beyond the intended benefits. The planning process based on national guidelines directly incorporates consideration of all environmental effects, with a particular focus on possible impacts upon non-target species or habitats. The results of the SEA are incorporated directly into the management plan itself, but are also summarized below in this statement.

[3] www.canada.ca/en/environmental-assessment-agency/programs/strategic-environmental-assessment/cabinet-directive-environmental-assessment-policy-plan-program-proposals.html
[4] www.fsds-sfdd.ca/index.html#/en/goals/

The provincial management plan for Wandering Salamander contains a section describing the effects of management activities on other species (i.e., Section 8). Environment and Climate Change Canada adopts this section of the provincial management plan as the statement on effects of management activities on the environment and other species. Conservation planning activities for Wandering Salamander will be implemented with consideration for all co-occurring species at risk, such that there are no negative impacts to these species or their habitats. Some management actions for Wandering Salamander (e.g., inventory and monitoring, threat mitigation, habitat conservation, education, and research) may promote the conservation of other species at risk that overlap in distribution and rely on similar habitat attributes.

Part 2 – *Management Plan for the Wandering Salamander (*Aneides vagrans*) in British Columbia*, prepared by the British Columbia Ministry of Environment

Management Plan for the Wandering Salamander (*Aneides vagrans*) in British Columbia

Prepared by B.C. Ministry of Environment

BRITISH COLUMBIA

March 2017

About the British Columbia Management Plan Series

This series presents the management plans that are prepared as advice to the Province of British Columbia. The Province prepares management plans for species that may be at risk of becoming endangered or threatened due to sensitivity to human activities or natural events.

What is a management plan?

A management plan identifies a set of coordinated conservation activities and land use measures needed to ensure, at a minimum, that the target species does not become threatened or endangered. A management plan summarizes the best available science-based information on biology and threats to inform the development of a management framework. Management plans set goals and objectives, and recommend approaches appropriate for species or ecosystem conservation.

What's next?

Direction set in the management plan provides valuable information on threats and direction on conservation measures that may be used by individuals, communities, land users, conservationists, academics, and governments interested in species and ecosystem conservation.

For more information

To learn more about species at risk recovery planning in British Columbia, please visit the B.C. Recovery Planning webpage at:
<http://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/species-ecosystems-at-risk/recovery-planning>

Management Plan for the Wandering Salamander (*Aneides vagrans*) in British Columbia

Prepared by the B.C. Ministry of Environment

March 2017

Recommended citation

B.C. Ministry of Environment. 2017. Management plan for the Wandering Salamander (*Aneides vagrans*) in British Columbia. B.C. Ministry of Environment, Victoria, BC. 49 pp.

Cover illustration/photograph

Barbara Beasley

Additional copies

Additional copies can be downloaded from the B.C. Recovery Planning webpage at: <http://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/species-ecosystems-at-risk/recovery-planning/recovery-planning-documents>

Disclaimer

The B.C. Ministry of Environment has prepared this management plan, as advice to the responsible jurisdictions and organizations that may be involved in managing the species.

This document identifies the management actions that are deemed necessary, based on the best available scientific and traditional information, to prevent Wandering Salamander populations in British Columbia from becoming endangered or threatened. Management actions 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 management approaches may be modified in the future to accommodate new objectives and findings.

The responsible jurisdictions 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 individuals.

Success in the conservation 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 management plan. The B.C. Ministry of Environment encourages all British Columbians to participate in the conservation of the Wandering Salamander.

ACKNOWLEDGEMENTS

The B.C. Ministry of Environment (ENV) funded preparation and reviews of the draft management plan. Barbara Beasley (Consultant) prepared the draft plan. Barbara Beasley, Purnima Govindarajulu (ENV), and Kristiina Ovaska (Biolinx Environmental Research) participated in the threats assessment. Purnima Govindarajulu, Kristiina Ovaska, and Louise Blight (ENV) provided review comments. Alain Filion (COSEWIC Secretariat) created the British Columbia distribution map and calculated the extent of occurrence and the index of area of occupancy. Special thanks to the COSEWIC Secretariat, Environment and Climate Change Canada, for allowing the use of data compiled for the status report in 2012. Unpublished data were provided directly by Barbara Beasley (Association of Wetland Stewards for Clayoquot and Barkley Sounds), Francis Cook (Canadian Museum of Nature), John Deal (Western Forest Products), Ramona DeGraaf (Bamfield resident), Linda Dupuis (Consultant), Christian Engelstoft (Biolinx Environmental Research), Dave Fraser (ENV), Leah Gelling (B.C. Conservation Data Centre), Tim Goater (Vancouver Island University), Purnima Govindarajulu (Haliburton Community Organic Farm and ENV), Kevin Head (Kyuquot resident), Jeff Hoy (BC Parks), Todd Jackman (Villanova University), Hitomi Kimura (Vancouver Island University), Moira Lemon (Canadian Wildlife Service), Joe Materi (Ursus Environmental), Erica McClaren (BC Parks), Liam McNeill (Kayak guide), Ryan Murphy (Tree climber), Dean Nernberg (National Defence), Kristiina Ovaska (Biolinx Environmental Research), Beth Rogers (Victoria resident), Jim Schieck (Researcher), Stanley Sessions (Researcher), Wendy Simms (Vancouver Island University), Mandala Smulders (Central Westcoast Forest Society), Michele Steigerwald (Canadian Museum of Nature), Chris Stinson (Beaty Biodiversity Museum), Warren Warttig (Interfor), Neville Winchester (University of Victoria), and Elke Wind (E. Wind Consulting). Data for the global range map were developed as part of the Global Amphibian Assessment and provided by IUCN–World Conservation Union, Conservation International, and NatureServe.

EXECUTIVE SUMMARY

The Wandering Salamander (*Aneides vagrans*) is a lungless terrestrial salamander of the family Plethodontidae. It requires moist microhabitats primarily in forested environments, and uses large-diameter logs for refuges and breeding sites. The Canadian distribution of this terrestrial salamander is restricted mainly to low-elevation forests on Vancouver Island and adjacent small offshore islands in southwestern British Columbia. In 2014, the Committee on the Status of Endangered Wildlife in Canada designated the Wandering Salamander as of Special Concern because of declining habitat availability and its restricted range. The overall threat impact for this species is high. Threats include logging, residential development, roads, severe droughts predicted under climate change, and tsunami events. Emerging diseases and herbicides used in forestry have no known effects on the species but impacts cannot be completely ruled out without further study. Low reproductive rate, poor dispersal ability, and specific habitat requirements contribute to the vulnerability of the species. In British Columbia, the Wandering Salamander is ranked S3S4 (Special Concern to apparently secure) by the B.C. Conservation Data Centre (2016) and it is on the provincial Blue list. The B.C. Conservation Framework ranks the Wandering Salamander as a priority 2 under goal 2 (prevent species and ecosystems from becoming at risk). It is protected from capture, killing, and harassment under the B.C. *Wildlife Act*.

The management goal for the Wandering Salamander is to maintain a stable or increasing population across the species' distribution in British Columbia.

The following are the management objectives:
1. to ensure habitat is protected[1] within Crown lands and private lands;
2. to assess and quantify threats for this species, develop mitigation measures, and assess the effectiveness of this mitigation;
3. to clarify patterns of abundance, connectivity, and population and distribution trends across the species' British Columbia range; and
4. to clarify the species' distribution, particularly the knowledge gaps about how patchy their distribution is, and the extent to which the species uses upper canopy habitats in British Columbia.

[1] Protection can be achieved through various mechanisms including voluntary stewardship agreements, conservation covenants, sale of private lands by willing vendors, land use designations, and protected areas.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 COSEWIC* SPECIES ASSESSMENT INFORMATION

Assessment Summary: May 2014
Common Name: Wandering Salamander
Scientific Name: *Aneides vagrans*
Status: Special Concern
Reason for Designation: The Canadian distribution of this terrestrial salamander is restricted mainly to low elevation forests on Vancouver Island and adjacent small offshore islands in southwestern British Columbia. These salamanders depend on the availability of moist refuges and large diameter logs on the forest floor, as found in intact forests. The salamanders are threatened by logging, residential development, and severe droughts, and storm events predicted under climate change. Low reproductive rate, poor dispersal ability, and specific habitat requirements contribute to the vulnerability of the species.
Occurrence: British Columbia
Status History: Special Concern in May 2014

* Committee on the Status of Endangered Wildlife in Canada.

2 SPECIES STATUS INFORMATION

Wandering Salamander[a]		
Legal Designation		
FRPA:[b] No	B.C. *Wildlife Act:*[c] Schedule A	SARA:[d] No
OGAA:[b] No		
Conservation Status[e]		
B.C. List: Blue	B.C. Rank: S3S4 (2010)	Canada Rank: N3N4 (2015) National Rank: N4 (2000) Global Rank: G4 (2005)
Subnational Ranks:[f] California: SNR		
B.C. Conservation Framework (CF)[g]		
Goal 1: Contribute to global efforts for species and ecosystem conservation.		Priority:[h] 3 (2010)
Goal 2: Prevent species and ecosystems from becoming at risk.		Priority: 2 (2010)
Goal 3: Maintain the diversity of native species and ecosystems.		Priority: 4 (2010)
CF Action Groups[g]	Monitor Trends; Compile Status Report; Planning	

[a] Data source: B.C. Conservation Data Centre (2016) unless otherwise noted.
[b] No = not listed in one of the categories of wildlife that requires special management attention to address the impacts of forestry and range activities on Crown land under the *Forest and Range Practices Act* (FRPA; Province of British Columbia 2002) and/or the impacts of oil and gas activities on Crown land under the *Oil and Gas Activities Act* (OGAA; Province of British Columbia 2008).
[c] Schedule A = designated as wildlife under the British Columbia *Wildlife Act*, which offers it protection from direct persecution and mortality (Province of British Columbia 1982).
[d] No = not on any schedules under the *Species at Risk Act* (SARA; Government of Canada 2002). The COSEWIC assessment will be reviewed by the Governor in Council who may, on the recommendation of the Minister, amend the List to include this species on Schedule 1 of SARA.
[e] S = subnational; N = national; G = global; X = presumed extirpated; H = possibly extirpated; 1 = critically imperiled; 2 = imperiled; 3 = special concern, vulnerable to extirpation or extinction; 4 = apparently secure; 5 = demonstrably widespread, abundant, and secure.
[f] Data source: NatureServe (2015).
[g] Data source: B.C. Ministry of Environment (2009).
[h] Six-level scale: Priority 1 (highest priority) through to Priority 6 (lowest priority).

3 SPECIES INFORMATION

3.1 Species Description

The Wandering Salamander is a slender salamander with light grey or bronze mottling covering a brown to greyish black head, back, and tail (Figure 1A). Adults weigh 1.5–5.6 g, and measure 50–76 mm from snout to vent and 75–130 mm in total length (Davis 1991). A vertical slit between each nostril and upper lip (nasolabial groove) identifies it as a member of the family Plethodontidae or "lungless salamanders." It respires through its skin and membranes in its mouth (Duellman and Trueb 1986). Squared-off toes and no constriction at the base of the tail distinguish the Wandering Salamander from other plethodontid salamanders found in British Columbia.

Clusters of 3–28 eggs, 5–6 mm in diameter, are laid within a gelatinous envelope attached to the roof of a cavity inside a log or under bark (Davis 2003) (Figure 1B). Juvenile salamanders, not free-living larvae, hatch directly from the eggs. Hatchlings weigh less than 1 g, and measure 13–16 mm from snout to vent. Juveniles have a bronze dorsal stripe and bronze patch on the head and snout that disappear with age (Figure 1C). Adult colouration is reached at a size of approximately 45 mm snout to vent (Davis 1991).

The Wandering Salamander is unique in at least two ways. First, it has a disjunct distribution (Figure 2) that provides a rare opportunity to investigate rates of dispersal and evolution. Approximately 40% of its global range is in northern California, and 60% is on Vancouver Island and its close surroundings in British Columbia. It does not occur in Oregon or Washington. One explanation for its disjunct distribution is that the species dispersed to Vancouver Island from California on natural log rafts carried in north-flowing ocean currents, such as the Davidson Current (COSEWIC 2014). Two other hypotheses have been proposed: survival of the Vancouver Island population in glacial refugia during the Pleistocene (Beatty 1979; Davis and Gregory 1993), and introduction to Vancouver Island from California in shipments of Tanoak (*Lithocarpus densiflorus*) bark from California in the late 1800s (Jackman 1998). Although the two disjunct populations are genetically very similar, the latter hypothesis is poorly supported by the wide distribution of the species throughout Vancouver Island, including remote areas on small offshore islands and Brooks Peninsula.

The other unique quality of the species is its ability to survive in two unusual and distinctly different environments: the upper canopy of old-growth trees (Spickler *et al.* 2006; Murphy, pers. comm., 2014), and on treeless, seabird-nesting islands within large drift logs and moist nesting seabird burrows (Campbell and Stirling 1968; Jaremovic 1978; Beasley, unpubl. data). No other amphibians are known to live in these habitats in British Columbia.

A

B C

Figure 1. Illustration of Wandering Salamander adult (A), egg mass (B), and hatchling (C) (Kristiina Ovaska).

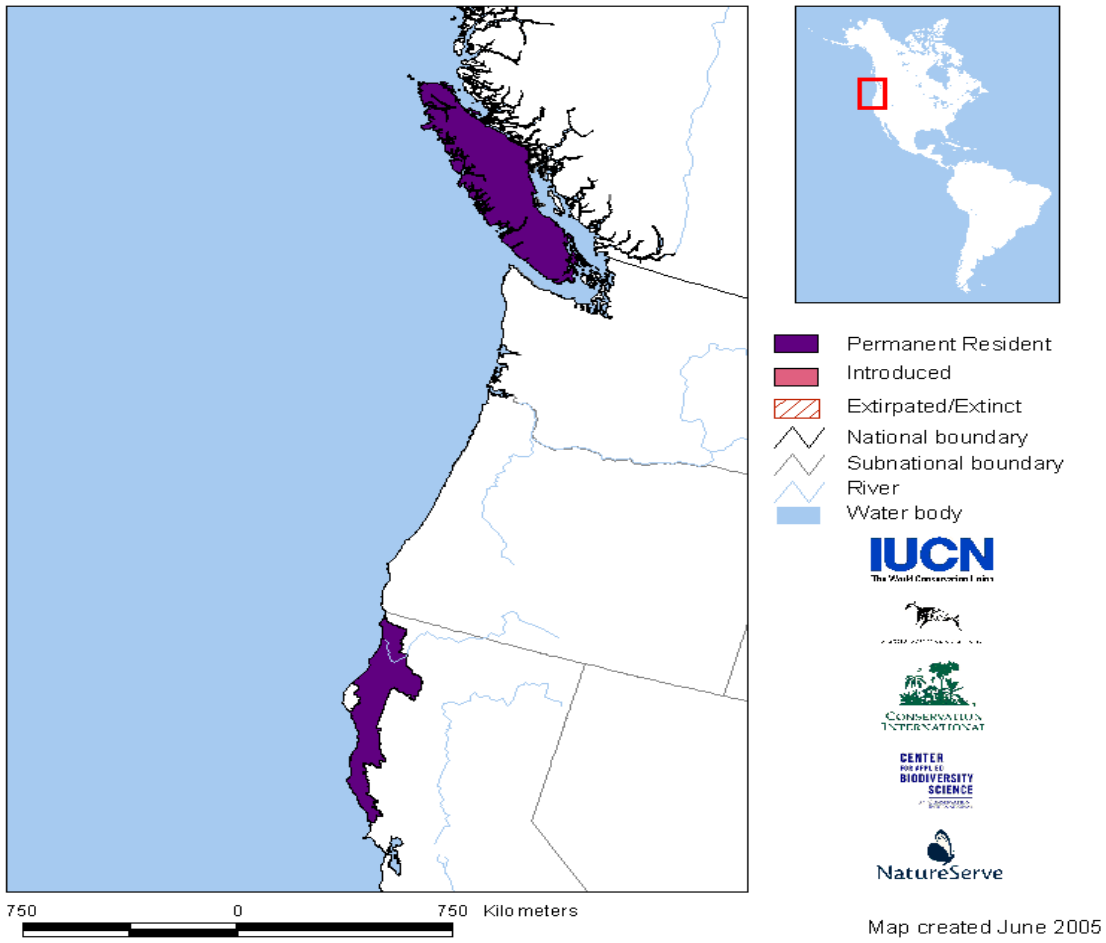

Figure 2. Wandering Salamander distribution in Canada/North America (IUCN *et al*. 2004).

3.2 Populations and Distribution

3.2.1 Distribution in British Columbia

British Columbia provides approximately 60% of the global range of the Wandering Salamander. It is widespread on and around Vancouver Island at elevations lower than 600 m. It has been documented at over 175 occurrences (≥ 1 km apart) across Vancouver Island, on 18 surrounding offshore islands, and in the vicinity of Trout Lake, near Halfmoon Bay on the Sunshine Coast (Ryder and Campbell 2004; Figure 3; Table 1; Appendix 1). Many records are from museum collections and incidental observations made more than 20 years ago. Population persistence is difficult to assess because historical sites have not been systematically revisited; however, 50% of the occurrences are extant (< 20 years old) and within the same general areas and/or interspersed among historical (pre-1981) and more recent occurrences (1981[2]–1995). Therefore,

[2] We used 1981 to mark the start of the time frame that would encompass the last three generations for Wandering Salamanders. A generation time of 8–11 years for this species is based on demographic data obtained for its congener, *Aneides lugubris* (Lee *et al.* 2012).

it is reasonable to conclude that the species has maintained the extent of its historical range (Figure 3).

3.2.2 Relative Abundance

The distribution and relative abundance of the species appears to be patchy across its range. Wandering Salamanders were detected at only 37% of the sites where surveyors have specifically searched for it (N = 183) from 1981 to 2013 (Appendix 2). Surveyors found very low numbers of Wandering Salamanders per unit effort, typically less than 10 individuals per hectare, with exceptions at: Woss (Stelmock and Harestad 1979); Rosewall Creek and Cook Creek (Davis 1991, 1996); and the Tofino watershed (Beasley *et al.* 2000). Maximum numbers were extrapolated to be about 100 individuals per hectare. This patchiness is likely related to site-specific habitat availability, but challenges also exist in reliably detecting the species related to their small size and cryptic colouration, habitat use (inside decaying logs), seasonal activity patterns, site tenacity, sampling methods, and weather conditions before and during sampling (Davis 1998). Numbers increased when decaying logs were cracked open and thoroughly searched (Dupuis 1993, 1996), but this type of destructive sampling was used at only 44% of the sites surveyed and is generally not recommended. More amphibians are found during mild rainy weather than cooler, hotter, or drier periods. No models exist to explore the relationships between relative abundance and habitat while accounting for detectability.

3.2.3 Population Trends

A patchy distribution, detectability issues, and inconsistent sampling efforts make it impossible to accurately assess population trends from the data sources available. Quantitative surveys repeated over a long time frame at two areas indicate a decline in relative abundance; however, survey methods, seasonal timing, weather conditions, and exact localities were not all consistent between time periods. Within Tree Farm Licence 37 around Woss, surveyors conducted active searching with destructive habitat sampling (peeling bark and cracking logs) in summer 2001 (AXYS Environmental Consulting 2002). This sampling detected fewer salamanders per unit effort than that reported from similar methods in summer 1976 (Stelmock and Harestad 1979), although the set of survey sites and plot sizes were not the same. Further efforts around Woss that used artificial cover boards in 2004 and 2005 (Beauchesne and Cooper 2006) had higher capture rates than those that looked under large pieces of bark in 1991 (Schieck, pers. comm., 2013). Thus, the microhabitats and specific sites searched differed over time. Along Highway 4 between Tofino and Ucluelet, pitfall trapping and road surveys between 2005 and 2012 (Beasley, unpubl. data) found fewer salamanders per unit effort than 2 days of destructive habitat sampling in 1977 (Sessions, pers. comm., 2012). Again, sites and sampling techniques differed, making the results inconclusive.

3.2.4 Population Size

Inconsistent sampling methods, variable sites, coarse sampling across the species' range, and no models exploring the relationships between abundance, habitat, and detectability make it difficult to estimate the total Canadian population size; however, based on the high number of occurrences across its range and its abundance at a few sites, it is likely more than 10 000 adults

exist (COSEWIC 2014). Further work to monitor and model population persistence and abundance over time is needed.

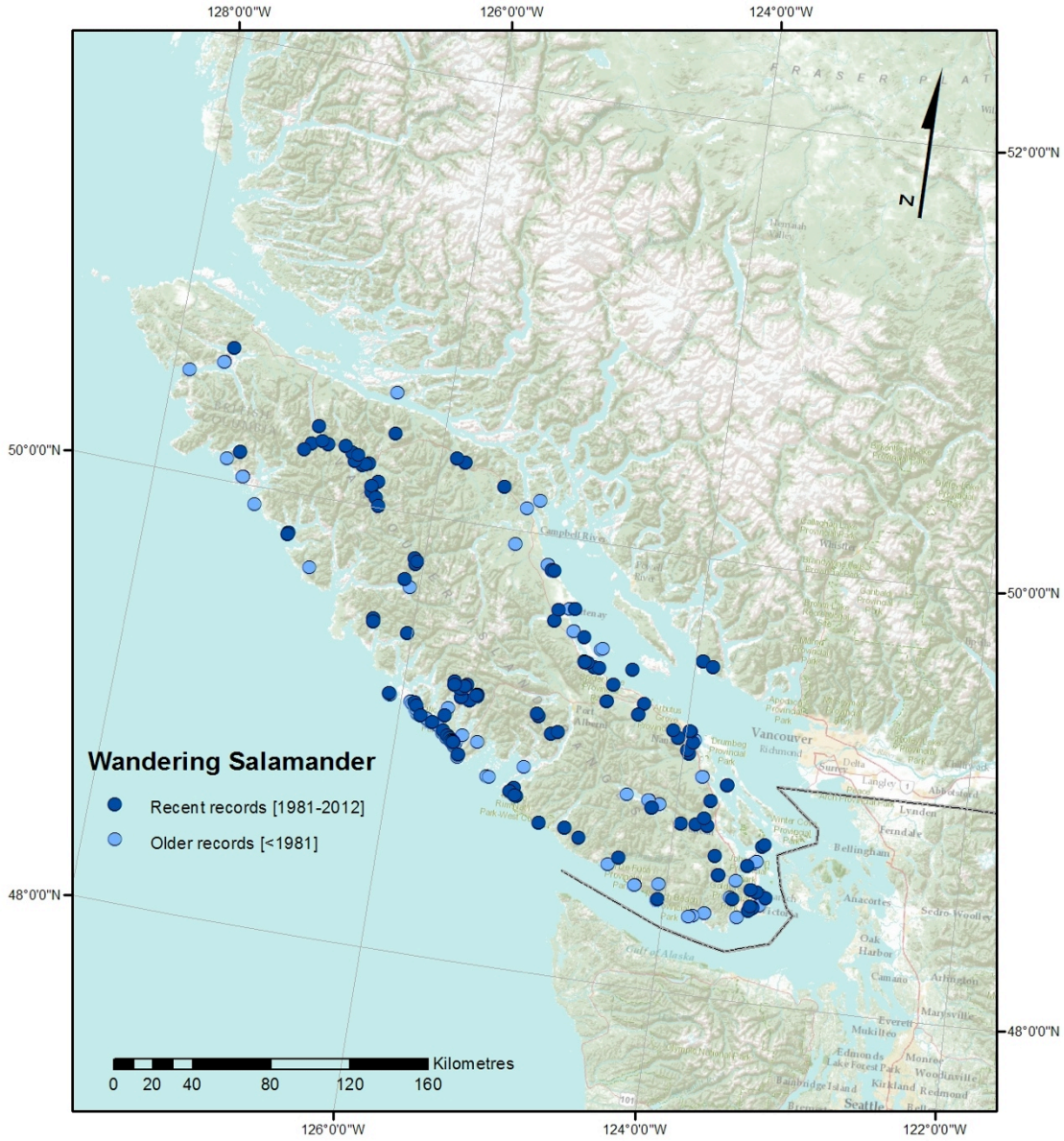

Figure 3. Wandering Salamander distribution in British Columbia (COSEWIC 2014).

Table 1. Summary of the number of Wandering Salamander occurrences[a] known in British Columbia based on opportunistic efforts and some systematic surveys.

Region	Area	Historical[b] pre-1981	More recent[c] 1981–1995	Extant[d] 1996–2016
Near Victoria	North Saanich	3		1
	Saanich		1	4
	Esquimalt and Victoria West		1	2
	Metchosin	1		2
	Greater Victoria Watershed		4	
	Goldstream Park			1
Southeast Vancouver Island	Shawnigan Lake			1
	Portland Island			1
	Chemainus River		1	1
	Saltspring Island		1	
	Ladysmith	1		
	Thetis Island			1
Southwest Vancouver Island	Sooke	3		
	Jordan River	3	1	
	Port Renfrew	1		1
South-central Vancouver Island	Lake Cowichan	1	2	2
	Youbou	2		
East Vancouver Island	Nanaimo	1		5
	Lantzville			2
	Errington		1	2
	Qualicum		1	
	Bowser		3	2
	Union Bay	1		
	Hornby Island	1		
	Denman Island		1	
	Courtenay			1
	Comox	1		1
	Cumberland			1
	Black Creek	1	1	
	Campbell River	1		

Region	Area	Historical[b] pre-1981	More recent[c] 1981–1995	Extant[d] 1996–2016
	Quadra Island	1		
	North of Campbell River	1	1	
	Sayward		1	1
	Cracroft Island	1		
Central and North Vancouver Island	Port Alberni		4	
	Woss	4	9	15
	Carmanah–Walbran		1	3
West Vancouver Island	Bamfield	1	1	3
	Tzartus Island	1		
	Effingham Island	1		
	Gilbert Island	1		
	Toquaht to Ucluelet Junction	2		3
	Ucluelet			1
	Ucluelet Junction to Tofino	6	1	9
	Clayoquot Watershed			3
	Tofino Watershed and Inlet	1		4
	Tranquil Watershed			4
	Stubbs Island	1		
	Cleland Island			1
	Shelter Inlet			1
	Sydney Inlet			2
	Gold River			4
	Nootka Island			2
	Grassy Island		1	
	Thornton Island		1	
	Walters Island			1
	Spring Island		1	
	Little Bunsby Island	1		
	Kyuquot		1	
	Brooks Peninsula		1	

Region	Area	Historical[b] pre-1981	More recent[c] 1981–1995	Extant[d] 1996–2016
Northwest Vancouver Island	Quatsino	2		
	Coal Harbour			1
Sunshine Coast	Sechelt			2
Total		**45**	**41**	**91**

[a] Distinct occurrences were defined as records separated by ≥ 1 km based on the species small home range (Davis 1991). Details for the number of individuals recorded and land status are provided in Appendix 1.
[b] Historical: records of museum specimens collected at sites before 1981 for which there is a lack of recent field information verifying the continued existence of the occurrence.
[c] More Recent: records from intensive field studies and incidental sightings between 1981 and 1995 for which there is a lack of field information since 1995 verifying the continued existence of the occurrence.
[d] Extant: occurrence has been verified in the last 20 years as still existing.

3.3 Habitat and Biological Needs of the Wandering Salamander

3.3.1 Habitat Requirements

The habitat of the Wandering Salamander must provide for its basic physiological needs of moisture and moderate temperature to avoid desiccation and freezing, as well as access to resources throughout its life (Table 2). Eggs are laid in moist terrestrial sites and have no protective shell to prevent water loss. Egg capsules and mucous membranes need to stay moist for respiratory gas exchange. Once hatched and through to adulthood, the Wandering Salamander has no protective barrier to prevent water loss across its skin. Further, it has no lungs. Instead, it respires through its skin and the highly vascularized surface of its mouth cavity. These surfaces must stay moist for respiratory function. Like all amphibians, the body temperature of the Wandering Salamander varies with ambient temperature. It requires insulated habitats to prevent overheating and freezing during particularly hot and cold times of the year. Other habitat requirements include refuge and security cover for protection from predators such as small mammals, birds, and snakes (Davis and Gregory 1993), adequate food, and areas for courtship, mating, and dispersal.

The nest site serves as an enclosed shelter where females lay and guard their eggs over a minimum of 3 months throughout the summer. The site needs to maintain the appropriate range of temperature and humidity conditions for embryonic development and the survival of the attending non-feeding mother, as well as the survival of the hatchlings immediately after hatching. It also must provide physical protection from predators and disturbance. Nests are typically in moist cavities created by wood decay processes inside logs or under bark (and rarely in rock crevices or among the stems and leaves of ground vegetation). Of the six egg clutches described from Vancouver Island, five were in Douglas-fir (*Pseudotsuga menziesii*) logs 0.7–1.5 m in diameter (Davis 2003) and one was in a large western redcedar (*Thuja plicata*) log (Dupuis 1993). Cavities varied in size from 120 to 140 mm wide, 31 to 70 mm high, and 24 to 35 mm deep (Davis 1991).

Diurnal refuges provide protection from dehydration, extreme temperatures, and predation. More than 95% of observed Wandering Salamanders are individuals inside moist cavities, cracks and burrows, and under loose bark of large decaying logs and stumps. Most often they occur in wood

at the mid-stages of decay (Douglas-fir decay class 3: loose bark, heartwood intact; Welsh and Lind 1991; Davis 2002). When sampling cover objects, the Wandering Salamander is almost always seen under bark or between layers of wood and rarely in contact with the ground (98% of observations, $N = 62$; Davis 1996).

The diet of the Wandering Salamander consists mainly of invertebrates found in soil, litter, and decaying wood. Sampled stomach contents contained primarily ants (Hymenoptera), spiders (Acarina and Araneae), springtails (Collembola), and beetles (Coleoptera) (Bury and Martin 1973; Stelmock and Harestad 1979). Aphids (Aphididae) and mealy bugs (Pseudococcidae), typically found above ground, were also eaten (Stelmock and Harestad 1979). Foraging activity occurs at night on the surface of the forest floor, on logs and stumps, within cracks and cavities of decaying wood, and on woody stems and vegetation above ground. Moist, temperate microhabitats with abundant food are needed. The abundance of some soil invertebrates (e.g., Collembola) was found to be highest in unlogged stands (Addison *et al.* 2003).

Courtship and mating occur at night in spring or fall (Davis and Gregory 1993), although little is known about specific habitat requirements for these activities. The same is true for dispersal movements. It seems that movements away from the forest floor (i.e., across open habitats or roads) only occur during mild, rainy weather (Beasley, pers. comm., 2015).

In the winter, during cold periods (< 3–5ºC), the Wandering Salamander disappears from diurnal refuge sites (Davis 1991) and may move to subterranean retreats or deep within larger logs, but there are no data available to describe their overwintering residence.

In addition to occupying the forest floor, the Wandering Salamander is known to live and lay eggs within tree cavities and the rhizomes of fern mats up to 85 m above ground in the canopies of large redwoods (*Sequoia sempervirens*), Sitka spruce (*Picea sitchensis*), and Douglas-fir (*Pseudotsuga menziesii*) in northern California (Welsh and Wilson 1995; Spickler *et al.* 2006; Welsh, pers. comm., 2013). The water storage capacity of the large fern mats affects the humidity in tree crowns and is a significant predictor of salamander abundance among trees (Spickler *et al.* 2006). A single canopy record exists of the species in British Columbia, 57 m above ground in a Sitka spruce in Walbran Provincial Park (Murphy, pers. comm., 2014).

In British Columbia, most occurrences of Wandering Salamanders have been reported in low-elevation (< 600 m, maximum at 540 m) forest stands within parts of the Coastal Western Hemlock biogeoclimatic zone and the Coastal Douglas-fir biogeoclimatic zone (Meidinger and Pojar 1991). These stands are dominated by western hemlock, Douglas-fir, western redcedar, and Sitka spruce. Researchers have found the species in both young and old forests, sometimes with higher abundances in older stands but not always. Around Woss, Stelmock and Harestad (1979) found similar densities in 8- and 28-year-old and old-growth forest stands, but Beauchesne and Cooper (2006) found Wandering Salamanders less often in young forest (clearcuts < 25 years old and 5-year-old partial retention sites) than older stands. In California, Bury (1983) found more Wandering Salamanders in young (< 15 years) stands than unlogged ones; however, Welsh and Lind (1991) and Welsh *et al.* (2007) found more individuals in late seral (> 200 years old) than mature (100–199 years old) sites in inland areas but no difference among stand ages on the Coast. They suggested that logged coastal forests experienced less drying than those in the Interior. Ashton *et al.* (2006) encountered five times as many Wandering Salamanders along

streams in older, unharvested seral stages than in 37–60-year-old post-harvest redwood stands. Therefore, the abundance of downed wood and moist habitats may influence salamander density in recently logged forests. Recently logged sites may contain an abundance of large, decaying old-growth legacy logs for many years after canopy removal. A detection bias may also occur, as these semi-arboreal salamanders may be easier to find after logging.

Wandering Salamanders can live close to marine shorelines, within metres of the upper tideline, among rotting logs, driftwood, and plastic floats (Peacock 2008; McNeil, pers. comm., 2012; Winchester, pers. comm., 2012; Wind, pers. comm., 2016). The most unusual occurrences are on two treeless islands used by nesting seabirds, Cleland Island in Clayoquot Sound (Campbell and Stirling 1968; Jaremovic 1978; Beasley, pers. comm., 2015) and Grassy Island in Kyuquot Sound (Lemon, pers. comm., 2013). These islands contain nesting seabird burrows that may provide moist microhabitat for the species.

The Wandering Salamander can sometimes persist at disturbed sites where it can continue to find moist refuge inside or under wood (Bury and Martin 1973; Bury 1983), and occasionally talus, rubble, or artificial cover objects. It is often found along the edges of forests and within clearings, burned-over areas, and transmission corridors (Ryder and Campbell 2004). Individuals found in residential yards, porches, and gardens may be a part of viable remnant populations or brought in inadvertently with firewood. Several records exist of individuals associated with moist anthropogenic structures, including one in an eaves trough (Rogers, pers. comm., 2012) and one in a downspout (Engelstoft, pers. comm., 2012), both in residential areas in Victoria, BC.

Table 2. Summary of essential functions, features, and attributes of Wandering Salamander habitat in British Columbia.

Life stage	Function[a]	Feature(s)[b]	Attributes[c]
Mother, eggs, and early hatchlings	Nests for egg-laying, embryonic development, hatching, and refuge for early hatchlings	• Enclosed moist shelter • Insulation for protection from desiccation, and hot/cold temperatures for at least 3 months • Cryptic and snug refuges for protection from predators • At a suitable elevation to avoid flooding • Sufficient space for female to deposit eggs from ceiling, and curl around them • Safe from physical disturbance between May and October • Persisting for potential reuse over multiple years	• Large log or stump of decay class 3[d] and > 0.7 m diameter • Thick fern mat, such as leathery polypody (*Polypodium scouleri*) high up on large branches in old tree canopy • Crack or cavity inside wood, under thick exfoliating bark, or within a fern mat small enough to keep predators away, typically 120–140 mm wide, 31–70 mm high, and 24–35 mm deep • Suitable species of wood include western redcedar, western hemlock, Sitka spruce, Douglas-fir, amabalis fir, red alder • Downed wood that is not physically disturbed

Life stage	Function[a]	Feature(s)[b]	Attributes[c]
Hatchlings, Immature individuals, Adults	Refuge habitat during active season	• Enclosed moist shelter • Insulation for protection from desiccation, and hot/cold conditions during spring, winter and fall • Cryptic and snug for protection from predators • At a suitable elevation to avoid flooding • Available for reuse over multiple years	• Logs, stumps, and snags of various diameters and decay classes (typically > 0.5 m diameter with moderate decay) • In the canopies of large old trees that have thick fern mats and decaying branches • Ideal refuges have similar attributes as those described for nests above
Hatchlings, Immature individuals, Adults	Feeding/foraging	• Invertebrate prey • Moisture • Cover objects to provide protection from predators	• Vegetated forest floor under overstory canopy with downed wood of variable decay classes, litter, and soil • Thick moss and fern mats in tree canopy • Inhabited by ants, termites, springtails, beetles, and other invertebrates
Hatchlings, Immature individuals, Adults	Dispersal	• Moisture • Cover objects to provide protection from predators • No impediments to movement.	• Moist soil with leaf litter, logs, ferns, other plants; overstory canopy cover important for moisture retention except when raining • No barriers, such as rivers, water-filled ditches, roads, or fences with overhanging lips, or vertical structures more than a few centimetres high that individuals could not climb, nor dry open habitats, such as parking lots prone to predation and desiccation risk
Adults	Mating: courtship and spermatophore transfer	• Moisture • Cover objects to provide protection from predators	• Moist soil with cover by logs, litter, ferns, and other plants; (habitat data on mating sites is very limited; attributes are based on what is known for similar plethodontid salamanders)
Immature individuals, Adults	Overwintering	• Thermal cover from cold • Moisture	• Subterranean burrows or deep cavities within large logs and snags where temperatures stay above 3–5ºC; (habitat data on overwintering sites is very limited; attributes are based on what is known for other amphibians)

[a] Function: a life-cycle process of the species (e.g., breeding, denning, nursery, rearing, feeding/foraging, and migration).

[b] Feature: the essential structural components of the habitat required by the species.

[c] Attribute: the building blocks or *measurable* characteristics of a feature.

[d] Decay classification following the standards of the B.C. Ministry of Forests, Lands and Natural Resource Operations (2016).

3.4 Ecological Role

Plethodontid salamanders may comprise a major portion of vertebrate biomass in temperate forests, similar to mice and shrews, and greater than the combined biomass of all birds at the peak of the avian breeding season (Burton and Likens 1975a, b). They play significant roles in the food web dynamics of forest ecosystems. Quantitative studies have shown that plethodons reduce invertebrate numbers and indirectly reduce the rate of decomposition of forest litter by as much as 11–17% (in the case of *Plethodon cinereus* and *Ensatina eschscholtzii*), arguably altering forest carbon dynamics (Wyman 1998; Best and Welsh 2014). They convert small invertebrate prey into biomass available to larger predators, such as birds and small mammals (Davic and Welsh 2004).

3.5 Limiting Factors

Limiting factors are generally not human-induced and include characteristics that make the species less likely to respond to management/conservation efforts (e.g., long-lived species with low rate of reproduction, poor dispersal ability that can lead to genetic isolation, and specific habitat and microclimatic requirements that can limit the potential for range expansion).

The Wandering Salamander is long-lived with a low rate of reproduction. The generation time is assumed to be 8–11 years, based on the average age of *Aneides lugubris* parents in a California population (Lee *et al.* 2012). These salamanders may live at least 10 years and possibly as long as 20 years, like many other species of plethodontid salamanders (Tilley 1977; Duellman and Trueb 1986). Females breed biennially or less frequently and clutches are small (average 12 eggs) (Davis and Gregory 1993). The low reproductive rate reduces the species' capacity for quick response to stochastic events and means that recovery from declines would be slow.

Wandering Salamanders have high site fidelity, small home ranges, and low rates of active dispersal and movement. At Rosewall Creek, the average distance between first and second capture of a marked individual was 2.8 m (N = 176); 75% of these capture–recaptures were less than 2 m apart, 94% were less than 10 m, and the greatest distance was 38 m (Davis 2002). The interval between the first and second captures ranged from 17 days to 497 days (74.4 ± 86.2 SD, N = 176), but no significant relationship was evident between the number of days and the distance moved between captures (Davis 2002). Wandering Salamanders have been occasionally found on roads (Beasley, unpubl. data; Ovaska, unpubl. data; Wind 2012); however, if these occurrences represent dispersal movements, they are very rare compared to other amphibian species. Their high site fidelity and limited dispersal ability make them vulnerable to genetic isolation, inbreeding depression, and local extinction.

Range expansion northward and to higher elevations in British Columbia is probably currently limited by climatic conditions that affect the duration of the species' active season. Active periods in British Columbia occur during the rainy seasons of autumn and spring. Activity in winter occurs during mild periods, and activity in summer depends on the availability of moist microhabitats associated with large logs and stumps under forest canopy. Drought, cold, and snow cover restricts foraging at the surface of the forest floor, which directly influences rates of growth and reproduction of plethodontids (Welsh and Droege 2001). Further, the species'

distribution is limited to areas that have downed wood in the appropriate stage of decomposition; that is where sufficient numbers of trees grow large enough to continually provide for the recruitment of large decaying logs and stumps (including recruitment of large driftwood on shorelines).

4 THREATS

Threats are defined as the proximate activities or processes that have caused, are causing, or may cause in the future the destruction, degradation, and/or impairment of the entity being assessed (population, species, community, or ecosystem) in the area of interest (global, national, or subnational) (adapted from Salafsky *et al.* 2008). For purposes of threat assessment, only present and future threats are considered.[3] Threats described here do not include limiting factors,[4] which are presented in Section 3.5.

For the most part, threats are related to human activities, but they can also be natural. The impact of human activity may be direct (e.g., destruction of habitat) or indirect (e.g., introduction of invasive species). Effects of natural phenomena (e.g., fire, flooding) may be especially important when the species is concentrated in one location or has few occurrences, which may be a result of human activity (Master *et al.* 2012). As such, natural phenomena are included in the definition of a threat although they should be considered cautiously. These stochastic events should only be considered a threat if a species or habitat is damaged from other threats and has lost its ability to recover. In such cases, the effect on the population would be disproportionately large compared to the effect experienced historically (Salafsky *et al.* 2008).

[3] Past threats may be recorded but are not used in the calculation of threat impact. Effects of past threats (if not continuing) are taken into consideration when determining long-term and/or short-term trend factors (Master *et al.* 2012).

[4] It is important to distinguish between limiting factors and threats. Limiting factors are generally not human-induced and include characteristics that make the species or ecosystem less likely to respond to management/conservation efforts (e.g., inbreeding depression, small population size, and genetic isolation).

4.1 Threat Assessment

The threat classification below is based on the IUCN–CMP (World Conservation Union–Conservation Measures Partnership) unified threats classification system and is consistent with methods used by the B.C. Conservation Data Centre. For a detailed description of the threat classification system, see the Open Standards website (Open Standards 2014). Threats may be observed, inferred, or projected to occur in the near term. Threats are characterized here in terms of scope, severity, and timing. Threat "impact" is calculated from scope and severity. For information on how the values are assigned, see Master *et al.* (2012) and table footnotes for details.

Threats for the Wandering Salamander were assessed for the entire province (Table 3). The scope of each threat was calculated in two different ways to determine the appropriate score. In most cases, the two approaches resulted in the same score. Using the first method, we examined the proportion of total occurrences (N = 177, Table 1) that likely will be affected by each threat within the next 10 years (see timing criteria for Scope in footnotes of Table 3). As uncertainty surrounded the assignment of some occurrences to different threats, we also used a second method that calculated the proportion of the species' range on Vancouver Island under threat by different land uses within the next 10 years. The species' range was restricted to elevations less than 600 m and did not include the Sunshine Coast, with only two known occurrences. Unless otherwise indicated, the information source for area of land use was baseline thematic mapping available from Hectares BC (2012). For threats with an unknown number of occurrences, or for which the score differed between the two approaches (Threats 4.1, 11.1), we chose the score resulting from the second method. See Section 4.2 for more detailed information on the scope assessment for each threat.

Table 3. Threat classification table for Wandering Salamander in British Columbia.

Threat #[a]	Threat description	Impact[b]	Scope[c]	Severity[d]	Timing[e]	Occurrences
1	Residential & commercial development	Low	Small	Extreme	High	
1.1	Housing & urban areas	Low	Small	Extreme-Serious	High	~16 (9%); e.g., Saanich, Sooke, Nanaimo, Courtenay, Comox
1.2	Commercial & industrial areas	Negligible	Negligible	Extreme	High	
1.3	Tourism & recreation areas	Negligible	Negligible	Serious	High	
2	Agriculture & aquaculture	Negligible	Negligible	Extreme	High	
2.1	Annual & perennial non-timber crops	Negligible	Negligible	Extreme	High	~2 (1%); e.g., Sooke, Denman Island
2.3	Livestock farming & ranching	Negligible	Negligible	Serious	High	

Threat #[a]	Threat description	Impact[b]	Scope[c]	Severity[d]	Timing[e]	Occurrences
3	Energy production & mining	Negligible	Negligible	Extreme	High	
3.2	Mining & quarrying	Negligible	Negligible	Extreme	High	1 known (0.6%) at Ucluelet Junction; ~12 others within 5 km e.g., Lantzville Foothills, Little Mountain Rd, Rosewall Creek, Oyster River at Black Creek, Cowichan Lake, Riverbottom Road, Shawnigan Lake
3.3	Renewable energy	Negligible	Negligible	Serious–Moderate	High	
4	Transportation & service corridors	Low	Restricted	Slight	High	
4.1	Roads & railroads	Low	Restricted	Slight	High	~13 (7%); e.g., Nanaimo Lakes Road, Lazo Road, Highway 4, Pacific Rim National Park Reserve trail
4.2	Utility & service lines	Negligible	Negligible	Slight	High	
5	Biological resource use	Medium	Large	Moderate	High	
5.1	Hunting & collecting terrestrial animals	Negligible	Negligible	Slight	High	
5.3	Logging & wood harvesting	Medium	Large	Moderate	High	~55 (31%); e.g., private forest on southeast Vancouver Island, Crown forest near Campbell River, Woss, Quatsino, Kyuquot, Port Alberni, etc.
6	Human intrusions & disturbance	Negligible	Negligible	Slight	High	
6.1	Recreational activities	Negligible	Negligible	Negligible	High	
6.3	Work & other activities	Negligible	Negligible	Sight	High	
7	Natural system modifications	Negligible	Restricted	Extreme	High	
7.1	Fire & fire suppression	Negligible	Negligible	Extreme	High	Number unknown; potentially at forest sites within Coastal Douglas-fir biogeoclimatic zone on southeast Vancouver Island
7.3	Other ecosystem modifications (see 8.1)					
8	Invasive & other problematic species, genes & diseases	Unknown	Restricted–Small	Unknown	High	
8.1	Invasive non-native/alien species/diseases	Unknown	Restricted–	Unknown	High	Potentially all occurrences

Threat #[a]	Threat description	Impact[b]	Scope[c]	Severity[d]	Timing[e]	Occurrences
			Small			
9	Pollution	Negligible	Negligible	Unknown	High	
9.3	Agricultural & forestry effluents	Negligible	Negligible	Unknown	High	Number unknown; less than 1% of the species' range overlaps with young forests that are treated with herbicides; most involve spot treatment, although some roadside spraying occurs for access management
9.5	Air-borne pollutants	Unknown	Negligible	Unknown	High	Very little aerial spraying is conducted within the species' range
10	Geological events	Low	Small	Extreme–Serious	High	
10.2	Earthquakes/tsunamis	Low	Small	Extreme–Serious	High–Low	~4 (2.3%); e.g., low-lying islands and shorelines: Cleland Island, Grassy Island, Sydney Estuary, Nuchatlitz
10.3	Avalanches/landslides	Negligible	Negligible	Slight	High	
11	Climate change & severe weather	High–Low	Large–Restricted	Serious–Slight	Moderate	
11.1	Habitat shifting & alteration	Unknown	Small	Unknown	High	~22 (12%); all sites within the Coastal Douglas-fir biogeoclimatic zone
11.2	Droughts	High–Low	Large-Restricted	Serious–Slight	High	All occurrences possible; greatest impact at ~22 sites within Coastal Douglas-fir biogeoclimatic zone

[a] Threat numbers are provided for Level 1 threats (i.e., whole numbers) and Level 2 threats (i.e., numbers with decimals).

[b] **Impact** – The degree to which a species is observed, inferred, or suspected to be directly or indirectly threatened in the area of interest. The impact of each threat is based on severity and scope rating and considers only present and future threats. Threat impact reflects a reduction of a species population. The median rate of population reduction for each combination of scope and severity corresponds to the following classes of threat impact: Very High (75%), High (40%), Medium (15%), and Low (3%). Unknown: used when impact cannot be determined (e.g., if values for either scope or severity are unknown); Not Calculated: impact not calculated as threat is outside the assessment time (e.g., timing is insignificant/negligible [past threat] or low [possible threat in long term]); Negligible: when scope or severity is negligible; Not a Threat: when severity is scored as neutral or potential benefit.

[c] **Scope** – Proportion of the species that can reasonably be expected to be affected by the threat within 10 years. Usually measured as a proportion of the species' population in the area of interest. (Pervasive = 71–100%; Large = 31–70%; Restricted = 11–30%; Small = 1–10%; Negligible < 1%).

[d] **Severity** – Within the scope, the level of damage to the species from the threat that can reasonably be expected to be affected by the threat within a 10-year or three-generation time frame. For this species, a generation time of 8–11 years, based on work on a similar species *Aneides lugubris* (Lee *et al.* 2012) was used, resulting in severity being scored over a 30-year time frame. Usually measured as the degree of reduction of the species' population. (Extreme = 71–100%; Serious = 31–70%; Moderate = 11–30%; Slight = 1–10%; Negligible < 1%; Neutral or Potential Benefit ≥ 0%).

[e] **Timing** – High = continuing; Moderate = only in the future (could happen in the short term [< 10 years or three generations]) or now suspended (could come back in the short term); Low = only in the future (could happen in the long term) or now suspended (could come back in the long term); Insignificant/Negligible = only in the past and unlikely to return, or no direct effect but limiting.

4.2 Description of Threats

The overall province-wide threat impact for this species is High.[5] This overall score considers the cumulative impacts of multiple threats. The threat with the highest potential impact is prolonged droughts caused by climate change and severe weather (Table 3). Biological resource use in the form of logging is the second highest and widespread threat, with medium impact. Threats deemed to have low impacts are residential and commercial development, transportation and service corridors, and earthquakes and tsunamis under the category of geological events. Disease and pollution, which are often ranked as high threats to amphibians, are scored as "unknown" as there is no information currently available on potential for these threats to impact Wandering Salamanders. Details are discussed below under the Threat Level 1 headings.

Threat 1. Residential & commercial development (Low impact)
Clearing forest to build houses and commercial properties kills salamanders and permanently destroys most of the species' habitat. Wandering Salamanders have been documented from residential neighbourhoods in Victoria and Nanaimo (Engelstoft, pers. comm., 2012; Rogers, pers. comm., 2012; Simms, pers. comm., 2012) indicating that, occasionally, sufficient moist habitat (wood and talus) is associated with house structures and gardens to support a few individuals at least over the short term; however, these salamanders are likely to experience mortality from domestic cats, raccoons, crows, lawnmowers, and recreational use, such as mountain bike parks. Higher risks are also associated with traffic on roads, exposure to pollution, and introduced species, but these threats are considered separately in categories below.

Residential and commercial development will expand within Vancouver Island's municipalities over the next 10 years,[6] and housing developments on private lands formerly managed for forestry is an increasing trend. If existing residential and commercial development (currently 3% of the species' range and 9% of occurrences) doubled in the next 10 years, the scope of the threat would remain small (under 10%).

Threat 2. Agriculture & aquaculture (Negligible impact)
Conversion of forest to agricultural fields kills salamanders and destroys habitat. Remnant populations could persist in forest along the edges of fields, if sufficient downed wood was available. Livestock could trample salamanders and degrade habitat. Only two known occurrences (1% of the total) are adjacent to farms. The small proportion of the species' range is more likely to become housing and urban development than farms over the next 10 years, thus, the scope of this threat is negligible.

Threat 3. Energy production & mining (Negligible impact)
Mining operations destroy habitat and animals, but the overall scope is scored as negligible because mining and quarries currently comprise 0.08% of the species' range and their expansion over the next 10 years is expected to be less than 4000 ha (0.1% of the species' range) (Northcote, pers. comm., 2016); however, numerous smaller quarrying operations (240+ permits)

[5] The overall threat impact was calculated following Master *et al.* (2012) using the number of Level 1 Threats assigned to this species where timing = High or Moderate, which included 0 Very High, 1 High, 1 Medium, and 3 Low (Table 4). The overall threat impact considers the cumulative impacts of multiple threats.
[6] Sprawling development is underway around Victoria, Nanaimo, Courtenay, Campbell River and most other municipalities on Vancouver Island.

are scattered across the island, which expand slowly over time to support local road building and housing construction. The B.C. Ministry of Energy and Mines typically receives 10–20 "Notices of Work" annually relating to new operations, changes to existing operations, bulk samples, and other mechanized work (Northcote, pers. comm., 2016). Thus, over the next 10 years, it would be possible to see 200 Notices of Work related to the expansion of small quarries by up to 2 ha (many are < 1 ha). The only known imminent quarry expansion that will affect an area occupied by the Wandering Salamander is at the Ucluelet–Tofino Junction along the border of Pacific Rim National Park Reserve. This comprises less than 1% of all occurrences; however, at least 10 other existing quarries and one large mine are currently permitted for development near Port Alberni, within 5 km of known Wandering Salamander occurrences.

The construction footprint of renewable energy, such as wind energy development, is expected to be much less than 1% of the species' range.

Threat 4. Transportation & service corridors (Low impact)
Transportation and service corridors affect the species in various ways: through conversion of forest habitat to newly built roads; through the production of edge effects that increase the risk of desiccation related to increased temperatures and wind adjacent to openings; through the disruption of habitat connectivity; as well as through direct road mortality. Roads and pathways are continuously being built around and between communities; for example, plans are under way to build a 3-m wide paved bicycle path through 22 km of forest habitat to connect Ucluelet and Tofino, which will destroy habitat and potentially dry out adjacent habitat in an area known to have relatively high numbers of Wandering Salamanders (Appendices 1 and 2). The Digital Atlas in Hectares BC (2012) indicates that 17% of the species' entire range on Vancouver Island is less than 30 m from existing roads and 34% is less than 100 m away; 13 occurrences (7% of the total) were recorded on or immediately adjacent to roads. Marsh *et al*. (2008) showed that plethodontid populations bisected by large highways are likely to diverge genetically from each other. Direct road mortality seems the least important effect of roads. Very few Wandering Salamanders are found dead on roads relative to suspected population sizes at roadkill-monitoring sites (Beasley, unpubl. data, 2005–2012; Materi and Forrest 2007; Materi 2008; Wind 2012; Ovaska, pers. comm., 2016). Low road mortality probably results from the species' non-migratory habits, very small home ranges, and site tenacity (see Section 3.5).

Clearing tree canopy to create new transmission lines would create drier conditions for the species. Persistent downed wood, shrub cover, and adjacent forest cover would allow Wandering Salamanders to persist in moist forest types. Two occurrences (1%) were noted where the species has been found within a hydro transmission corridor on the Sunshine Coast (Ryder and Campbell 2004).

Threat 5. Biological resource use (Medium impact)
Forests greater than 140 years of age (36% of the species' range) and younger (35%) will probably be logged at a similar rate as in the recent past. For example, 18% of the entire species' range on Vancouver Island was logged in the last 20 years (Hectares BC 2012), and much of it was coastal old growth (Long *et al*. 2011). Within managed forest, 55 occurrences (31% of the total) were recorded. Logging has many negative impacts on the Wandering Salamander. Canopy removal, by itself, causes the forest floor to become drier and temperatures to fluctuate more extremely (Chen *et al*. 1993). Heavy machinery compacts underground refuges (such as the

burrows of small mammals and root channels) and log-skidding can displace or fragment cover objects. Log removal and site preparation for planting, even with retention, reduces the amount and distribution of downed wood in the short term, from 31 to 76% of pre-logging values (B.C. Ministry of Forests, Lands and Natural Resources Operations 2011). Several studies have shown that the relative abundance of Wandering Salamanders is highest in unlogged late seral and mature forests (Welsh and Lind 1991; Davis 1996; Ashton *et al*. 2006; Beauchesne and Cooper 2006); however, when large amounts of downed wood remain, Wandering Salamanders persist in recent clearcuts (Stelmock and Harestad 1979; Welsh and Droege 2001). Impacts are expected to increase over time as more forests are converted to even-aged stands. As forests are logged on 60–80-year rotations, progressively fewer large downed logs at appropriate stages of decay will be available for breeding habitat and refuges, and trees will no longer grow to a large size; thus, the size and amount of downed logs and snags will decline, and legacy logs from previous downed old growth will decompose (Aubry *et al*. 1988; Spies *et al*. 1988; Welsh and Droege 2001; Bunnell and Houde 2010).

Logging large, old trees also reduces the amount of arboreal habitat. The large limbs, complex branching trunks, and large fern mats, shown to support arboreal salamanders in California (Spickler *et al*. 2006), develop very slowly. On Vancouver Island, where less than 30% of the original old-growth forests remain, less than 8% of productive old-growth Douglas-fir and Sitka spruce stands, where salamanders would find suitable arboreal habitat, are protected (Sierra Club BC 2009). Although the rate of old-growth logging has slowed, many old-growth stands are still slated for harvest within the species' range.

Threat 6. Human intrusions & disturbance (Negligible impact)
Along the west coast of Vancouver Island, Wandering Salamanders have been found on the beach in driftwood, and have been reported to crawl out when driftwood was used for recreational beach fires. Very high densities of Wandering Salamanders are aggregated under large plastic and polystyrene foam floats, as well as drift beach logs on Cleland Island (Beasley, pers. comm., 2015). Beach log salvage and collection of plastics and polystyrene foam objects during beach cleanups could affect these small, local beach populations, but it is expected to have a negligible effect on the provincial population.

Pitfall traps to collect invertebrates have been known to kill Wandering Salamanders, but pitfall traps typically capture very low numbers (i.e., less than one per 2000 trap nights) (Welsh and Lind 1988; Beasley, unpubl. data, 2012), and hence have a negligible effect. This threat would be of local greater concern if pitfall trapping occurred in highly productive salamander habitat, such as Cleland Island.

Threat 7. Natural system modifications (Negligible impact)
Natural system modifications are considered negligible threats to the Wandering Salamander throughout its range in British Columbia. Wildfires within the Coastal Western Hemlock biogeoclimatic zone are of extremely low incidence and severity (Gavin *et al.* 2003). Fire within this biogeoclimatic zone is now controlled such that it would not have much effect on the species. In addition, no known large dams are planned for Vancouver Island. Changes that result from invasive species are described under Threat 8.

Threat 8. Invasive & other problematic species, genes & diseases (Unknown impact)
The impacts of invasive species and diseases on the Wandering Salamander are unknown. A recently emerged infectious disease caused by the chytrid fungus *Batrachochytrium salamandrivorans* has not yet been detected in North America, and the vulnerability of the Wandering Salamander to this disease is unknown (Stephen *et al.* 2015). A similar infectious disease caused by *Batrachochytrium dendrobatidis* has caused declines in amphibian populations in North America, as well as worldwide. Although this disease has aquatic zoospores, and is mainly detected in aquatic species, researchers have found a small number of wild-caught terrestrial plethodontid salamanders with signs of it (Pasmans *et al.* 2004; Cummer *et al.* 2005; Weinstein 2009), and one species suffered high mortality after being experimentally infected (Vazquez *et al*. 2009). It is possible that aquatic-breeding amphibians could spread *B. dendrobatidis* to moist terrestrial habitats.

Scotch broom (*Cytisus scoparius*), Japanese knotweed (*Fallopia japonica*), English ivy (*Hedera helix*), and Himalayan blackberry (*Rubus armeniacus*) are invasive plant species that are continuously spreading across Vancouver Island in areas disturbed by logging, agriculture, urban development, and road building. These species likely have negative effects on Wandering Salamanders by decreasing the survival of regenerating conifers (Harrington and Schoenholtz 2010), reducing plant biodiversity and the quality of litter and soil, and altering the integrity of invertebrate community structure and food web dynamics (Maerz *et al*. 2009). The severity of these effects on salamanders is unknown. The herbicide treatments required to control these invasive species may also lead to negative effects (See Threat 9).

Threat 9. Pollution (Negligible impact)
Amphibians, in general, are sensitive to the effects of glyphosate herbicides that are used in the province for controlling invasive species, alder suppression, and conifer release in logged areas (Govindarajulu 2008). The lethal concentration value for many aquatic-breeding species is lower than the expected environmental concentration, but actual environmental concentrations and the direct effects on terrestrial salamanders are unknown. Application is almost entirely through small-scale spot treatments (i.e., hack and squirt or paint of individual plant stems) rather than aerial spraying, and is expected to affect less than 1% of the species' range over the next 10 years (Deal, pers. comm., 2016; Grutzmacher, pers. comm., 2016; Warttig, pers. comm., 2016). Wandering Salamanders may be protected from direct contact because they are typically active at night, whereas herbicide applications would occur during the day. Eastern Red-backed Salamanders could detect and avoid glyphosate at 10% of the recommended concentration but not at lower concentrations (Gertzog *et al*. 2011). Avoidance could have negative effects if it requires the species to disperse from an area or reduces surface activity.

Threat 10. Geological events (Low impact)
Tsunamis are a threat to populations in low-lying areas, especially those using drift logs on beaches, which is recorded at four occurrences (2.3% of the total). Tsunami waves are predicted to reach as high as 20 m above sea level on the west coast of Vancouver Island. Inundation by salt water will likely kill all individuals within the zone. Timing is impossible to predict.

Threat 11. Climate change & severe weather (High–Low impact)
Habitat shifting and droughts associated with climate change are potentially high threats to the Wandering Salamander. The Coastal Douglas-fir ecosystem on southeastern Vancouver Island is expected to shrink 19% from its current extent and expand 16% into other areas by 2050 (Wang

et al. 2012). Although the predicted net loss is low (–3%), the species' limited dispersal behaviour and extensive habitat fragmentation will restrict its ability to move into new areas over the next three generations. Limited dispersal ability has increased the vulnerability of amphibians to changing climatic conditions in Europe (Araújo *et al*. 2006). The 19% loss of Coastal Douglas-fir forest to drier open habitats is expected to cause large population declines of the Wandering Salamander, affecting approximately 6% of the species' total range on Vancouver Island. Twenty-two recorded occurrences would be affected (12% of the total).

Temperatures within the cooler maritime-moderated Coastal Western Hemlock forests on Vancouver Island are expected to increase by 2–4ºC by 2080 (Lerner [ed.] 2011). Wandering Salamanders will likely withstand higher temperatures and longer summer droughts based on the survival of the species through similarly warm, dry summers that are currently the norm in northern California (National Oceanic and Atmospheric Administration 2014); however, longer and more frequent and intense summer droughts, particularly in open habitats such as young logged stands, treeless islands, and shorelines, could severely reduce foraging opportunities for salamanders.

5 MANAGEMENT GOAL AND OBJECTIVES

5.1 Management Goal

The management goal is:

- Maintain a stable or increasing population across the distribution of the Wandering Salamander in British Columbia.

5.2 Rationale for the Management Goal

The species is widespread but patchily distributed across Vancouver Island and faces several known threats. Taking management actions to reduce the negative impacts of threats across its range will help the population persist and recover from previous declines. The current total Canadian population size of Wandering Salamanders is difficult to estimate because sampling has been inconsistent and at a coarse scale; however, based on its abundance at a few sites and its wide distribution, it is reasonable assume a baseline population of at least 10 000 adults.

5.3 Management Objectives

The management objectives for Wandering Salamander are:

1. To ensure habitat is protected[7] within Crown lands and private lands;
2. To assess and quantify threats for this species, develop mitigation measures, and assess the effectiveness of this mitigation;
3. To clarify patterns of abundance, connectivity, and population and distribution trends across the species' British Columbia range; and

[7] Protection can be achieved through various mechanisms including voluntary stewardship agreements, conservation covenants, sale of private lands by willing vendors, land use designations, and protected areas.

4. To clarify the species' distribution, particularly the knowledge gaps about how patchy their distribution is, and the extent to which the species uses upper canopy habitats in British Columbia.

6 APPROACHES TO MEET OBJECTIVES

6.1 Actions Already Completed or Underway

The following actions have been categorized by the action groups of the B.C. Conservation Framework (B.C. Ministry of Environment 2009). We include actions in addition to those assigned to the species because the Conservation Framework has not been updated for a few years. Status of the action group for this species is given in parentheses.

Compile Status Report (complete)

- COSEWIC report completed (COSEWIC 2014).

Send to COSEWIC (complete)

- Wandering Salamander assessed as Special Concern (COSEWIC 2014). Reassessment will occur in 2024.

Planning (in progress)

- British Columbia Management Plan completed (this document, 2017).

Inventories (incomplete)

- Past inventories in forest stands of different age and under variable management have occurred at: Tree Farm Licence No. 37 near Woss (Stelmock and Harestad 1979; AXYS Environmental Consulting 2002; Beauchesne and Cooper 2006; Schieck, pers. comm., 2012); 20 sites along southeastern Vancouver Island (Davis 1996); 11 sites near Port Alberni (Dupuis 1993); and 25 sites in Clayoquot Sound (Beasley *et al.* 2000; for others, see Appendix 2).

Monitor Trends (incomplete / in progress)

- Long-term monitoring plots, using artificial cover objects, to monitor other vertebrates and invertebrates, were established at various sites, including Goldstream Provincial Park, Observatory Hill, and the Urban Biodiversity Enhancement and Restoration Project at Haliburton Community Organic Farm. These have yielded too few Wandering Salamanders to be useful for detecting population trends but do provide information about the persistence of the species.
- Davis (1996, 1998) set up cover-board monitoring plots at nine sites on eastern Vancouver Island and did time-constrained searches at an additional 16 sites between 1992 and 1994. These, and other short-term monitoring programs, could be revived (see Table 4).
- Long-term monitoring routes for amphibian road mortality are regularly resurveyed at Nanaimo Lakes Road and Highway 4 near Ucluelet (Wind 2012; Beasley, unpubl. data). Given the low numbers of Wandering Salamanders detected, this type of monitoring is only useful for detecting continued presence at these sites over time.

Habitat Protection (in progress)

- Ten occurrences (including historical) are in provincial parks, ecological reserves, and wildlife management areas.
- Ten occurrences (including historical) are in national park reserves.
- Although the *Forest and Range Practices Act* (Province of British Columbia 2002) does not specifically address the Wandering Salamander, the species may benefit from requirements for wildlife tree retention, riparian reserves, old/mature forest retention, and retention of downed wood under the Act.

Private Land Stewardship (in progress)

- Addressed through the *Guidelines for Amphibian and Reptile Conservation during Urban and Rural Land Development in British Columbia* (B.C. Ministry of Environment 2014)

Species and Population Management (in progress)

- Addressed through the *Best Management Practices for Amphibian and Reptile Salvages in British Columbia* (B.C. Ministry of Environment 2016) and the *Interim Hygiene Protocols for Amphibian Field Staff and Researchers* (B.C. Ministry of Environment 2008)

6.2 Recommended Management Actions

Table 4. Recommended management actions for Wandering Salamander.

Objective	Conservation Framework action group	Actions to meet objectives	Threat[a] or concern addressed	Priority[b]
1	Habitat Protection	Ensure sufficient habitat is protected[c] within private and Crown forestry lands. An effective way to accomplish this is to list the Wandering Salamander as a species at risk that requires special management attention to address the impacts of forest and range activities under the *Forest and Range Practices Act*.	4.1, 5.3, 11.1, 11.2	Essential
1	Habitat Protection	Work in collaboration with resource ministries and land managers to review existing forestry retention practices and strategies to determine whether retention is sufficient to ensure long-term availability of large logs in appropriate decay classes for breeding. This will involve predictive modeling. It may also involve better guidance or enforcement of existing regulations.	5.3	Essential
1	Habitat Protection	Decrease threats to the species by reducing the rate of forest clearing and conversion, and road and trail construction. Tsunamis cannot be mitigated, but habitat protection measures will help to secure the species if such stochastic events destroy nearshore populations.	1.1, 4.1, 5.3, 11.1, 11.2	Essential

Objective	Conservation Framework action group	Actions to meet objectives	Threat[a] or concern addressed	Priority[b]
1	Private Land Stewardship	Raise awareness about the importance of retaining large downed wood in appropriate decay classes to provide habitat on private lands. Encourage relocation of large downed wood and stumps before any construction or habitat conversion occurs. This will involve developing and delivering educational materials to the public and to consultants who conduct environmental impact assessments.	1.1, 4.1, 5.3, 11.1, 11.2	Essential
2	Species and Population Management	Learn more about the actual impacts of threats that are currently poorly understood for this species, especially introduced disease, invasive species, pollution, and climate change. Develop and test mitigation for these, as well as the threat of logging. This will involve research.	Knowledge gap; Unknown threats 8.1 and 9.3; Primary threats 5.3, 11.1, 11.2	Essential
3	Monitor Trends	Both extensive and intensive monitoring activities are needed. Revisit historical sites and their surroundings to determine persistence and overall trends in the species' distribution. Monitor persistence, relative abundance, and age structure at selected occurrences across the species' range by conducting standardized surveys (e.g., artificial cover-board plots). Use occupancy modeling to account for detectability.	Knowledge gap	Necessary
3	Species and Population Management	Use genetic tools to understand connectivity among the patchily distributed subpopulations. This will result in either managing subpopulations separately or aiming to re-establish connectivity among historically interbreeding populations.	Knowledge gap	Beneficial
4	Inventory	Clarify the species' distribution on the Sunshine Coast and elsewhere throughout its range by conducting standardized surveys that account for detectability (e.g., occupancy modeling). Develop a habitat suitability model to guide search efforts and identify knowledge gaps.	Knowledge gap	Necessary
4	Inventory	Clarify the extent of canopy habitat use by surveying the canopies of large trees, especially in very moist forests, such as on the west coast of Vancouver Island.	Knowledge gap	Beneficial

[a] Threat numbers according to the IUCN–CMP classification (see Table 3 for details).

[b] Essential (urgent and important, needs to start immediately); Necessary (important but not urgent, action can start in 2–5 years); or Beneficial (action is beneficial and could start at any time that was feasible).

[c] Protection can be achieved through various mechanisms, including voluntary stewardship agreements, conservation covenants, sale of private lands by willing vendors, land use designations, and protected areas.

6.3 Narrative to Support Management Actions Table

Recommended actions have been categorized by the action groups of the B.C. Conservation Framework (B.C. Ministry of Environment 2009).

6.3.1 Habitat Protection

Given that logging is the most widespread threat to the Wandering Salamander across its range in British Columbia, the species should be considered for listing as a species at risk that requires special management attention to address the impacts of forest activities under the *Forest and Range Practices Act*. This would allow for the establishment of wildlife habitat areas and the development of general wildlife management measures for this species on forestry lands.

Inventory data will be necessary to build a habitat suitability model that will help prioritize areas of Crown land for conservation of the species.

Habitat degradation for the Wandering Salamander is expected in logged stands over the long term as the number of large pieces of downed wood declines. Field data and computer projections indicate that logging over several rotations results in smaller volumes of downed wood, smaller pieces, and fewer pieces in advanced stages of decay over time (Bunnell and Houde 2010). Although a delay exists between habitat change and a species decline, local extirpations have been documented for fungi, lichen, bryophytes, and invertebrates after multiple rotations in Sweden (Berg *et al*. 1994). Reviewing current requirements and actual retention practices under the *Forest and Range Practices Act* would help determine whether sufficient future recruitment of large logs and stumps will occur at the appropriate stages of decay into perpetuity. These results could help assess whether current prescriptions for retaining downed wood are adequate to protect habitat and, if not, then how much more is required.

6.3.2 Private Land Stewardship

Private forest managers should be encouraged to manage for the retention of large logs and stumps required by the species. Evaluation of existing educational materials would be worthwhile along with the development of new products, if necessary, to deliver a coordinated, multi-species public awareness campaign on amphibian conservation and threat mitigation. Stewardship groups could receive support to implement outreach programs that would increase awareness of stewardship options and best management practices on private forest lands, residential areas, and agricultural lands.

Environmental impact assessments for land development should consider the species and its habitat needs and reduce project impacts where possible.

6.3.3 Species and Population Management

Research is needed to better understand and find ways to lessen the impacts of threats that are currently poorly understood for this species, especially climate change, pollution, invasive species, and introduced disease.
Research collaborations should be developed to model climate change effects and predict future distribution patterns, particularly those related to open habitats, such as young logged stands and treeless islands and shorelines. Ameliorating the impacts of longer summer droughts may be feasible, but any mitigation actions will require design and testing (Shoo *et al.* 2011). Possibilities include supplementing artificial shelter (e.g., pipes, cover boards) in open habitats to reduce desiccation and thermal stress, and thinning treatments in second-growth forests to

accelerate the growth of large trees and late-successional forest conditions, which may be better at buffering climate extremes (Shoo *et al.* 2011).

Research is needed to confirm whether Wandering Salamanders are unharmed by the methods used to apply herbicides used to control invasive plant species and promote regeneration of logged stands. Identification of the specific localities of herbicide treatment that overlap with occurrences of the Wandering Salamander would help determine whether the scope of the threat is negligible.

Experimental enclosures could be used to assess the effects of invasive plant species on litter and soil quality, invertebrate community structure, food web dynamics, and Wandering Salamanders. Such studies could be modeled after research done by Wyman (1998) and Best and Welsh (2014).

Baseline disease and parasite monitoring in collaboration with provincial and federal wildlife disease agencies and academia would improve our understanding of potential emerging disease threats. Laboratory tests would be useful in determining whether infectious chytridiomycosis could be transmitted from other amphibian species to the Wandering Salamander. Looking at the synergistic effects of emerging diseases, pollution, climate change, and human modification of habitats will be important.

Use of genetic tools will help to better understand connectivity and fragmentation among the patchily distributed subpopulations of Wandering Salamanders. Understanding the extent of genetic differentiation across the range of a species can have implications to population management.

6.3.4 Monitor Trends

Monitoring is needed to meet the management goal of maintaining the species' population across its range. Surveys should be numerous enough, of sufficient duration, and of sufficient geographical scope to establish a measure of the variability within and among various regions on Vancouver Island, including sites in protected areas and areas subject to logging and other threats. Surveys need to be planned and conducted in ways that will obtain estimates of relative abundance and population and distribution trends over time, while considering the high variability in detection probability of salamanders between visits and among sites. Occupancy modeling would be a useful approach to assess population persistence (presence/no detection) relative to detectability at a selection of sites throughout the species' range. More intensive measures of population viability could be assessed at a few sites by looking for evidence of reproduction (presence of gravid females and juveniles) and evidence of a stable age structure and sex ratio (presence of a range of sizes and both sexes).

Inventories and short-term monitoring have been done at several sites (Appendix 2), which could be revisited. Ideally, a standardized survey procedure, which measures abundance relative to survey effort, will be applied at all sites throughout the range.

Because of the species' sensitivity and relatively stable populations, monitoring plethodontid salamanders is recommended as an effective way to assess long-term forest health in the face of

climate change (Welsh and Droege 2001). The Wandering Salamander is a particularly good indicator of the persistence of moist forest microhabitats (Davis 1991); it has a relatively low coefficient of variation in counts of individuals over time (28%) compared to Lepidoptera (93%), passerine birds (57%), small mammals (69%), and other amphibians (37–46%) (Welsh and Droege 2001). This low coefficient provides an important statistical advantage over other species in the monitoring of long-term forest health because changes will be easier to detect.

6.3.5 Inventory

More information about the distribution of the Wandering Salamander on Vancouver Island will clarify the species' vulnerability to threats and help with directing management actions. If occurrences are confirmed to be very patchy when mapped at a finer scale, then the scope of each threat could be re-examined at a finer scale to achieve a more accurate assessment of the impacts.

The 2014 COSEWIC status report includes two records of Wandering Salamander near Trout Lake on the Sunshine Coast; therefore, the species may be more widespread on the mainland of British Columbia than previously known.

Inventories of habitat attributes and salamander abundance may help us better understand the reasons for their patchy distribution, as well as their spatial and habitat requirements. The most poorly known habitat for the Wandering Salamander in British Columbia is the canopy of large trees. Because canopy inventories require expensive and specialized sampling techniques, they may only be feasible at a very small scale. Past monitoring of canopy arthropods in moss mats within 1500 trees failed to detect the Wandering Salamander (Winchester, pers. comm., 2012), but a sighting in 2012 at approximately 50 m in a large Sitka spruce tree confirms that they can occur there (Murphy, pers. comm., 2013). Future inventories should target salamanders based on recommended approaches used by researchers who have sampled the Wandering Salamander in the redwood canopies of California.

7 MEASURING PROGRESS

The following performance measures provide a way to define and measure progress toward achieving the management goal and objectives. Performance measures are listed below for each objective.

Successful achievement of the management goal will be indicated by:

- No reduction in the species' range;
- No reduction in the index of area of occupancy;
- Stable populations with representation of all size, age, and sex classes; and
- Reduction of current threat impacts.

Measurables for Objective 1

- Inclusion of the Wandering Salamander on the *Forest and Range Practices Act* list of species at risk considered by 2018.

- Protected areas such as wildlife habitat areas, and practices such as Identified Wildlife Measures, in place to protect at least 10 vulnerable populations by 2025.
- Educational products emphasize the importance of retaining downed wood habitat for this species on private land by 2018.

Measurables for Objective 2

- Baseline information on the occurrence of *Batrachochytrium salamandrivorans* and *B. dendrobatidis* in terrestrial salamanders (in British Columbia) collected by 2020: through networking with researchers across North America; by soliciting reports of dead or diseased salamanders in British Columbia; and by monitoring occurrence of diseased salamanders as part of ongoing population monitoring studies.
- Prevalence and effects of the herbicides used to control invasive species and manage regenerating forests on Vancouver Island on terrestrial salamanders reviewed by 2020.
- Research on ways to mitigate climate change and drought in the most vulnerable areas initiated by 2020.
- The effectiveness of current best management practices and regulations to maintain Wandering Salamander habitat in logged and otherwise developed land (e.g., in housing developments, agricultural and range land) assessed by 2020.
- Development of effective mitigation measures as needed and testing of these methods.

Measurables for Objective 3

- A monitoring plan for population and distribution trends in place by 2018, with such monitoring occurring by 2020.
- An understanding attained of the genetic relatedness and distance across the range of the Wandering Salamander in British Columbia.
- The monitoring plan to include ways of detecting emerging and current threats at an appropriate scale.
- Mitigation plans developed to reduce threat impacts detected or suspected during ongoing monitoring by 2025.

Measurables for Objective 4

- Adequate surveys conducted to provide maps of searched areas and the distribution of the Wandering Salamander occurrences on the Sunshine Coast by 2020.
- Adequate surveys conducted to fill gaps in our knowledge of the species' distribution across its range on Vancouver Island by 2020.
- Fifty percent of historical sites revisited across the species' range by 2020.
- Adequate surveys conducted to determine the extent of canopy occupations by the Wandering Salamander in at least one patch of old forest by 2020.

8 EFFECTS ON OTHER SPECIES

The benefits of good forest management for Wandering Salamanders will be advantageous for many other species of terrestrial invertebrates, amphibians, mammals, and birds that depend on downed woody material and moist forest floor habitats. These include: the Northern Red-legged Frog (*Rana aurora*) and Western Toad (*Anaxyrus boreas*), both of which are designated as of Special Concern under the federal *Species at Risk Act* (SARA) and are on the provincial Blue

list; the Dromedary Jumping Slug (*Hemphillia dromedarius*), designated as Threatened under SARA and on the provincial Red list; and the Blue-grey Taildropper (*Prophysaon coeruleum*), designated as Threatened under SARA, and on the provincial Blue list. Wandering Salamander management activities will be implemented with consideration for all co-occurring species at risk, such that these species or their habitats are not negatively affected.

Habitat protection for the Wandering Salamander will also benefit several at-risk ecosystems that it occupies, including sand dune habitats (S1), Sitka spruce floodplain forests (S1), as well as Douglas-fir–Arbutus (S2) and Garry Oak (S1) ecosystems (B.C. Conservation Data Centre 2016).

9 REFERENCES

Addison, J.A., J.A. Trofymow, and V.G. Marshall. 2003. Abundance, species diversity and community structure of Collembola in successional coastal temperate forests on Vancouver Island, Canada. Appl. Soil Ecol. 24:233–246.

Araújo, M.B., W. Thuiller, and R.G. Pearson. 2006. Climate warming and the decline of amphibians and reptiles in Europe. J. Biogeog. 33:1712–1728.

Ashton, D.T., S.B. Marks, and H.H. Welsh. 2006. Evidence of continued effects from timber harvesting on lotic amphibians in redwood forests of northwestern California. For. Ecol. Manage. 221:183–193.

Aubry, K.B., L.L.C. Jones, and P.A. Hall. 1988. Use of woody debris by plethodontid salamanders in Douglas-fir in Washington. *In* Management of amphibians, reptiles and small mammals in North America. R.C. Szara, K.E. Severson, and D.R. Patton (eds.). U.S. Dep. Agric. For. Serv., Rocky Mtn. Res. Stn., Fort Collins, CO. Gen. Tech. Rep. RM-166:32–37.

AXYS Environmental Consulting Ltd. 2002. Wildlife monitoring program on TFL 37: pilot year – terrestrial salamander inventory, 2001. Canadian Forest Products Ltd., Woss, BC.

Beasley, B., C. Addison, and K. Lucas. 2000. Clayoquot Sound amphibian inventory 1998–1999. B.C. Min. Environ., Lands Parks, Nanaimo, BC, and Long Beach Model For. Soc., Ucluelet, BC.

Beatty, J.J. 1979. Morphological variation in the clouded salamander, *Aneides ferreus* (Cope) (Amphibia: Caudata: Plethodontidae). PhD dissert., Oregon State Univ., Corvallis, OR.

Beauchesne, S.M. and J.M. Cooper. 2006. Ecosystem-based harvesting effectiveness monitoring terrestrial salamander project (2005) CANFOR TFL 37, Woss, BC. Canadian Forest Products Ltd., Woss, BC. <http://www.for.gov.bc.ca/hfd/library/FIA/2006/LBIPI_6451006a.pdf> [Accessed December 2012]

Berg, Ä., B. Ehnström, L. Gustafsson, T. Hallingbäck, M. Jonsell, and J. Weslien. 1994. Threatened plant, animal, and fungus species in Swedish forests: distributions and habitat associations. Conserv. Biol. 8:718–731.

Best, M.L. and H.H. Welsh, Jr. 2014. The trophic role of a forest salamander: impacts on invertebrates, leaf litter retention, and the humification process. Ecosphere 5(2):1–19. <http://dx.doi.org/10.1890/ES13-00302.1> [Accessed September 21, 2016]

B.C. Conservation Data Centre. 2016. BC species and ecosystems explorer: Wandering Salamander (*Aneides vagrans*). B.C. Min. Environ., Victoria, BC. <http://a100.gov.bc.ca/pub/eswp/reports.do?elcode=AAAAD01060> [Accessed March 22, 2017]

B.C. Ministry of Environment. 2008. Interim hygiene protocols for amphibian field staff and researchers.< http://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/wildlife-wildlife-habitat/wildlife-health/wildlife-health-documents/bc_protocol-amphibian_field_researchers.pdf> [Accessed July 20, 2016]

B.C. Ministry of Environment. 2009. Conservation framework—Conservation priorities for species and ecosystems: primer. Ecosystems Br., Environ. Stewardship Div., Victoria, BC. <http://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/species-ecosystems-at-risk/species-at-risk-documents/cf_primer.pdf> [Accessed August 20, 2016]

B.C. Ministry of Environment. 2014. Guidelines for amphibian and reptile conservation during urban and rural development in British Columbia. B.C. Min. Environ., Victoria, BC. <http://www.env.gov.bc.ca/wld/documents/bmp/HerptileBMP_complete.pdf> [Accessed July 20, 2016]

B.C. Ministry of Environment. 2016. Best management practices for amphibian and reptile salvages in British Columbia. Ver. 1.0. <http://a100.gov.bc.ca/pub/eirs/viewDocumentDetail.do?fromStatic=true&repository=BDP&documentId=12490> [Accessed July 20, 2016]

B.C. Ministry of Forests, Lands and Natural Resource Operations. 2016. Vegetation resources inventory – British Columbia ground sampling procedures. Ver. 5.3. For. Anal. Invent. Br., Victoria, BC. <https://www.for.gov.bc.ca/hts/vri/standards/RISC/2016/VRI_Ground_Sampling_Procedures_2016.pdf> [Accessed February 2017]

Bunnell, F.L. and I. Houde. 2010. Down wood and biodiversity: implications to forest practices. Environ. Rev. 18:397–421.

Burton, T.M. and G.E. Likens. 1975a. Energy flow and nutrient cycling in salamander populations in the Hubbard Brook Experimental Forest, New Hampshire. Ecology 56:1068–1080.

Burton, T.M. and G.E. Likens. 1975b. Salamander populations and biomass in the Hubbard Brook Experimental Forest, New Hampshire. Copeia 1975:541–546.

Bury, R.B. 1983. Differences in amphibian populations in logged and old growth redwood forest. Northwest Sci. 57:167–178.

Bury, R.B. and M. Martin. 1973. Comparative studies on the distribution and foods of plethodontid salamanders in the redwood region of Northern California. J. Herpetol. 7:331–335.

Campbell, R.W. and D. Stirling. 1968. Notes on the natural history of Cleland Island, British Columbia, with emphasis on the breeding bird fauna. *In* Provincial Museum of Natural History and Anthropology, Report for 1967. Victoria, BC. pp. 25–43.

Chen, J., J.F. Franklin, and T.A. Spies. 1993. Contrasting microclimates among clearcut, edge, and interior of old-growth Douglas-fir forest. Agr. For. Meteorol. 63:219–237.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2014. COSEWIC assessment and status report on the Wandering Salamander *Aneides vagrans* in Canada. Ottawa, ON. <https://www.registrelep-sararegistry.gc.ca/virtual_sara/files/cosewic/sr_Wandering Salamander_2014_e.pdf> [Accessed July 12, 2016]

Cummer, M., D.E. Green, and E.M. O'Neill. 2005. Aquatic chytrid pathogen detected in a terrestrial plethodontid salamander. Herpetol. Rev. 36:248–249.

Davic, R.D. and H.H. Welsh, Jr. 2004. On the ecological roles of salamanders. Annu. Rev. Ecol. Evol. S. 35:405–434.

Davis, T.M. 1991. Natural history and behavior of the clouded salamander, *Aneides ferreus* Cope. MSc thesis. Univ. Victoria, Victoria, BC.

Davis, T.M. 1996. Distribution, abundance, microhabitat use and interspecific relationships among terrestrial salamanders on Vancouver Island, British Columbia. PhD thesis. Univ. Victoria, Victoria, BC. <http://hdl.handle.net/1828/6209> [Accessed March 22, 2017)

Davis, T.M. 1998. Terrestrial salamander abundance in successional forests of coastal British Columbia. Northwest Sci. 72:89–90.

Davis, T.M. 2002. Microhabitat use and movements of the Wandering Salamander, *Aneides vagrans*, on Vancouver Island, British Columbia, Canada. J. Herpetol. 36:699–703.

Davis, T.M. 2003. *Aneides vagrans* (Wandering Salamander): reproduction. Herpetol. Rev. 34:133.

Davis, T.M. and P.T. Gregory. 1993. Status of the clouded salamander in British Columbia. B.C. Min. Environ. Lands Parks, Victoria, BC. Wildl. Work. Rep. No. WR-53.

Densmore, N. 2011. Coastal Forest Region: analysis of stand-level biodiversity sampling results in six predominant biogeoclimatic subzones. B.C. Min. For. Lands Nat. Resour. Oper., For. Prac. Invest. Br., Victoria, BC. FREP Exten. Note No. 21. <http://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/frep/frep-docs/frep-extension-note-21.pdf?fileName=frep-extension-note-21.pdf> [Accessed October 2012]

Duellman, W.E. and L. Trueb. 1986. Biology of amphibians. McGraw-Hill, New York, NY.

Dupuis, L.A. 1993. The status and distribution of terrestrial amphibians in old-growth forests and managed stands. MSc thesis. Univ. British Columbia, Vancouver, BC.

Dupuis, L.A., J.N.M. Smith, and F. Bunnell. 1995. Relation of terrestrial-breeding amphibian abundance to tree-stand age. Conserv. Biol. 9(3):645–653.

Gavin, D.G., L.B. Brubaker, and K.P. Lertzman. 2003. Holocene fire history of a coastal temperate rain forest based on soil charcoal radiocarbon dates. Ecology 84:186–201.

Gertzog, B.J., L.J. Kaplan, D. Nichols, G.R. Smith, and J.E. Rettig. 2011. Avoidance of three herbicide formulations by Eastern Red-backed Salamanders (*Plethodon cinereus*). Herpetol. Conserv. Biol. 6:237–241.

Government of Canada. 2002. *Species at Risk Act* [S.C. 2002] c. 29. Justice Laws website <http://laws-lois.justice.gc.ca/eng/acts/S-15.3/page-1.html> [Accessed August 23, 2016]

Govindarajulu, P. 2008. Literature review of impacts of glyphosate herbicide on amphibians: what risks can the silvicultural use of this herbicide pose for amphibians in B.C. B.C. Min. Environ., Victoria, BC. Wildl. Rep. No. R-28.

Harrington T.B. and S.H. Schoenholtz. 2010. Effects of logging debris treatments on five-year development of competing vegetation and planted Douglas-fir. Can. J. For. Res. 40:500–510.

Hectares BC. 2012. Vancouver Island, land use/cover, baseline thematic mapping. <http://www.hectaresbc.org/app/habc/HaBC.html> [Accessed July 16, 2012]

IUCN, Conservation International, and NatureServe. 2004. Global amphibian assessment. Washington, DC and Arlington, Virginia, VA.

Jackman, T.R. 1998. Molecular and historical evidence for the introduction of clouded salamanders (genus *Aneides*) to Vancouver Island, British Columbia Canada, from California. Can. J. Zool. 76:1570–1580.

Jaremovic, R.V. 1978. Distribution and movements of the salamander *Aneides ferreus* (Cope, 1869) on Cleland Island, B.C. BSc Thesis. Univ. British Columbia, Vancouver, BC.

Lee, D.E., J.B. Bettaso, M.L. Bond, R.W. Bradley, J.R. Tietz, and P.M. Warzybok. 2012. Growth, age at maturity and age-specific survival of the Arboreal Salamander (*Aneides lugubris*) on southeast Farallon Island, California. J. Herpetol. 46(1):64–71.

Lerner, J. (editor). 2011. Climate change adaptation in Clayoquot Sound: Ahousaht, Hesquiaht, and Tla-o-qui-aht community-based climate change adaptation plan, phase II report. Prepared by Equilibrio and Ecotrust Canada for the Hesquiaht First Nation, Tofino, BC.

Long, J.A., S.L. Hazlitt, T.A. Nelson, and K. Laberee. 2011. Estimating 30-year change in coastal old-growth habitat for a forest-nesting seabird in British Columbia, Canada. Endanger. Species Res. 14:49–59.

Maerz, J.C., V.A. Nuzzo, and B. Blossey. 2009. Declines in woodland salamander abundance associated with non-native earthworm and plant invasions. Conserv. Biol. 23(4):975–981.

Marsh, D.M., R.B. Page, T.J. Hanlon, R. Corritone, E.C. Little, D.E. Seifert, and P.R. Cabe. 2008. Effects of roads on patterns of genetic differentiation in red-backed salamanders, *Plethodon cinereus*. Conserv. Genet. 9:603–613.

Master, L.L., D. Faber-Langendoen, R. Bittman, G.A. Hammerson, B. Heidel, L. Ramsay, K. Snow, A. Teucher, and A. Tomaino. 2012. NatureServe conservation status assessments: factors for evaluating species and ecosystems at risk. NatureServe, Arlington, VA. <http://www.natureserve.org/sites/default/files/publications/files/natureserveconservationstatusfactors_apr12_1.pdf> [Accessed August 23, 2016]

Materi, J. 2008. Rupert Road post-construction wetland and amphibian monitoring in 2008. Town of Qualicum Beach, Qualicum Beach, BC. Progr. Rep.

Materi, J. and C.A. Forrest. 2007. Post-construction wetland and amphibian monitoring for the Rupert/Laburnum Ring Road Completion Project. 2006 Annual Report. Town of Qualicum Beach, Qualicum Beach, BC.

Meidinger, D. and J. Pojar. 1991. Ecosystems of British Columbia. B.C. Min. For., Victoria, BC. Spec. Rep. Ser. No. 6. <https://www.for.gov.bc.ca/hfd/pubs/docs/Srs/SRseries.htm> [Accessed March 19, 2016]

National Oceanic and Atmospheric Administration. 2014. Daily station normals (1971–2000) for Klamath, California. Natl. Climatic Data Cent., Asheville, NC. <hurricane.ncdc.noaa.gov/cgi- bin/climatenormals/climatenormals.pl> [Accessed February 2014]

NatureServe. 2015. NatureServe explorer: an online encyclopedia of life [web application]. Ver. 7.1. NatureServe, Arlington, VA. <http://www.natureserve.org/explorer> [Accessed August 10, 2016]

Open Standards. 2014. Threats taxonomy. <http://cmp-openstandards.org/using-os/tools/threats-taxonomy/> [Accessed August 26, 2016]

Ovaska, K. and L. Sopuck. 2001. Potential of terrestrial gastropods and salamanders as indicators for monitoring ecological effects of variable-retention logging practices: a pilot study in the North Island Timberlands, May–November 2000. Weyerhaeuser Company Ltd., Nanaimo, BC.

Ovaska, K., C. Engelstoft, and L. Sopuck. 2003. A pilot monitoring program for plethodontid salamanders on Vancouver Island, British Columbia. B.C. Min. Water, Land Air Protect., Biodiver. Monitor. Rep. Sect., Victoria, BC.

Pasmans, F., P. Zwart, and A. Hyatt. 2004. Chytridiomycosis in the Central American bolitoglossine salamander (*Bolitoglossa dofleini*). Vet. Rec. 154:53.

Peacock, S. 2008. Atypical habitat use by the Wandering Salamander (*Aneides vagrans*). Biol. Co-Op Progr., Dep. Biol., Univ. Victoria, Victoria, BC. Work Term Rep.

Province of British Columbia. 1982. *Wildlife Act* [RSBC 1996] c. 488. Queen's Printer, Victoria, BC. <http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/00_96488_01> [Accessed August 26, 2016]

Province of British Columbia. 2002. *Forest and Range Practices Act* [RSBC 2002] c. 69. Queen's Printer, Victoria, BC. <http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/00_02069_01> [Accessed August 26, 2016]

Province of British Columbia. 2008. *Oil and Gas Activities Act* [SBC 2008] c. 36. Queen's Printer, Victoria, BC. <http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/00_08036_01> [Accessed August 26, 2016]

Ryder, G.R. and R.W. Campbell. 2004. First occurrence of Wandering Salamander on the Sunshine Coast of British Columbia. Wildl. Afield 1:5–6.

Salafsky, N., D. Salzer, A.J. Stattersfield, C. Hilton-Taylor, R. Neugarten, S.H.M. Butchart, B. Collen, N. Cox, L.L. Master, S. O'Connor, and D. Wilkie. 2008. A standard lexicon for biodiversity conservation: unified classifications of threats and actions. Conserv. Biol. 22:897–911.

Shoo, L.P., D.H. Olson, S.K. McMenamin, K.A. Murray, M. Van Sluys, M.A. Donnelly, D. Stratford, J. Terhivuo, A. Merino-Viteri, S.M. Herbert, P.J. Bishop, P.S. Corn, L. Dovey, R.A. Griffiths, K. Lowe, M. Mahony, H. McCallum, J.D. Shuker, C. Simpkins, L.F. Skerratt, S.E. Williams, and J. Hero. 2011. Engineering a future for amphibians under climate change. J. Appl. Ecol. 48:487–492.

Sierra Club BC. 2009. State of British Columbia's coastal rainforest: mapping the gaps for ecological health and climate protection. Victoria, BC. <http://sierraclub.bc.ca/wp-content/uploads/2015/08/CoastForestReport2009_email_corrected.pdf> [Accessed March 22, 2017]

Spickler, J.C., S.C. Sillett, S.B. Marks, and H.H. Welsh. 2006. Evidence of a new niche for a North American salamander: *Aneides vagrans* residing in the canopy of old-growth redwood forest. Herpetol. Conserv. Biol. 1:16–26.

Spies, T.A., J.F. Franklin, and T.B. Thomas. 1988. Coarse woody debris in Douglas-fir forests of western Oregon and Washington. Ecology 69:1689–1702.

Stelmock, J.J. and A.S. Harestad. 1979. Food habits and life history of the clouded salamander (*Aneides ferreus*) on northern Vancouver Island, British Columbia. Syesis 12:71–75.

Stephen, C., M.J. Forzan, T. Redford, and M. Zimmer. 2015. *Batrachochytrium salamandrivorans*: threat assessment of salamander chytrid disease. Can. Wildl. Health Coop., Saskatoon, SK. <http://www.cwhc-rcsf.ca/docs/technical_reports/Salamander_Chytrid_Threat_Assessment.pdf> [Accessed August 2016]

Tilley, S.G. 1977. Studies of the life histories and reproduction in North American plethodontid salamanders. *In* The reproductive biology of amphibians. D.H. Taylor and S.I. Guttman (eds.). Plenum Press, New York, NY. pp. 1–41.

Vazquez, V.M., B.B. Rothermel, and A.P. Pessier. 2009. Experimental infection of North American plethodontid salamanders with the fungus *Batrachochytrium dendrobatidis*. Dis. Aquat. Org. 84:1–7.

Wang, T., E.M. Campbell, G.A. O'Neill, and S.N. Aitken. 2012. Projecting future distributions of ecosystem climate niches: uncertainties and management applications. For. Ecol. Manage. 279:128–140.

Weinstein, S.B. 2009. An aquatic disease on a terrestrial salamander: individual and population level effects of the amphibian chytrid fungus, *Batrachochytrium dendrobatidis*, on *Batrachoseps attenuatus* (Plethodontidae). Copeia 2009:653–660.

Welsh, H.H. Jr., and S. Droege. 2001. A case for using plethodontid salamanders for monitoring biodiversity and ecosystem integrity of North American forests. Conserv. Biol. 15:558–569.

Welsh, H.H. Jr., G.M. Fellers, and A.J. Lind. 2007. Amphibian populations in terrestrial environments: is there evidence of decline of terrestrial forest amphibians in northwestern California? J. Herpetol. 41:469–482.

Welsh, H.H. Jr., and A.J. Lind. 1988. Old growth forests and the distribution of the terrestrial herpetofauna. *In* Management of amphibians, reptiles and small mammals in North America. R.C. Szara, K.E. Severson, and D.R. Patton (eds.). U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO. Gen. Tech. Rep. RM-166. pp. 439–455.

Welsh, H.H. Jr., and A.J. Lind. 1991. The structure of the herpetofaunal assemblage in the Douglas-fir/hardwood forests of northwestern California and southwestern Oregon. *In* Wildlife and vegetation of unmanaged Douglas-fir forests. L. F. Ruggiero, K. B. Aubry, A. B. Carey, and M. H. Huff (tech. coord.). U.S. Dep. Agric. For. Serv., Pac. NW Res. Stn., Portland, OR. Gen. Tech. Rep. PNW-GTR-285. pp. 395–414.

Welsh, H.H. Jr., and R.A. Wilson. 1995. *Aneides ferreus* (Clouded Salamander) reproduction. Herpetol. Rev. 26:196–197.

Wind, E. 2012. Amphibian road surveys and mitigation assessments at three sites on Vancouver Island. B.C. Min. Trans. Infrastr., Environ. Manage. Sect., Victoria, BC. Victoria, BC.

Wyman, R.L. 1998. Experimental assessment of salamanders as predators of detrital food webs: effects on invertebrates, decomposition and the carbon cycle. Biodiv. Conserv. 7:641–650.

Personal Communications

Beasley, B., Biologist, Association of Wetland Stewards for Clayoquot and Barkley Sounds, Ucluelet, BC.

Deal, J., Senior Biologist, Western Forest Products Inc., Campbell River, BC.

Engelstoft, C., Biologist, Biolinx Environmental Research Ltd., Victoria, BC.

Grutzmacher, B., North Island Operations Forester, TimberWest, Nanaimo, BC.

Lemon, M., Biologist, Canadian Wildlife Service, Delta, BC.

McNeil, L., Kayak Guide, Tofino, BC.

Murphy, R., Former student, Camosun College Environmental Technical Program, Victoria, BC.

Northcote, B., Regional Geologist, Mineral Development Office, Geological Survey Branch, B.C. Ministry of Energy and Mines, Vancouver, BC.

Ovaska, K., Biolinx Environmental Research, Ltd. North Saanich, BC.

Rogers, B., University Programs Coordinator, Bamfield Marine Sciences Centre, Bamfield, BC.

Schieck, J., Co-director–Science, Alberta Biodiversity Monitoring Institute, Vegreville, AB.

Sessions, S.K., Professor Biology, Hartwick College, Oneonta, New York, NY.

Simms, W., Biology Lab Technician, Vancouver Island University, Nanaimo, BC.

Warttig, W., Former Senior Planning Biologist, International Forest Products, Campbell River, BC.

Welsh, H., Research Wildlife Biologist, U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Arcata, CA.

Winchester, N., Adjunct Professor, Geography Department, University of Victoria, Victoria, BC.
Wind, E., E. Wind Consulting, Nanaimo, BC.

APPENDIX 1. Reported Wandering Salamander Occurrences by Period in British Columbia

Region	Area	Historical[a] pre-1981	More recent[a] 1981–1995	Extant[a] 1996–2016	Land tenure
Southern Vancouver Island	North Saanich	Brentwood 1941[f,1]; Sidney 1926–27[f,2], 1963–65[f,5], 1968[f,1]		Ardmore Rd 2006[b,1]	Private rural & urban land, provincial park
	Saanich		Mount Douglas 1930[f,1], 1983[b,1]	Gordon Head 1997–2012[c,18]; Haliburton Farm 2008–12[d,6*]; Observatory Hill 2012[d,1,*]; Ross Durrance Rd 2016[e,1]	Private residential land; municipal park; municipal road
	Esquimalt and Victoria West		Powderly Ave 1992[c,e,4]	CFB Dockyard 2009[1]; Saxe Point 2001[b,1]	Federal Crown defence land; private residential land; municipal park
	Metchosin	9.7 mi E of Milnes Landing 1948[f,2]		Rocky Point 1997–98[d,2]; Matheson Lake 2015[h,1]	Municipal rural land; regional park
	Greater Victoria Watershed		4 sites at 4 different seral stages 1992–93[b,d,16*]		Municipal land protected for drinking water
	Goldstream Park			Riparian area 1977[b,1], 1992–93[b,d,1*], 2000–2003[d,3*], 2013[d,2*], 2014[d,1*], 2015[d,3*], 2016[d,1*]	Provincial park
Southeast Vancouver Island and Gulf Islands	Shawnigan Lake			Renfrew Rd "R953" 2001[d,1,*]	Private forest land
	Portland Island			Portland Island 1996[b,3]	Federal park
	Chemainus River		S side of Chemainus River Rd 1993[b,1,*]	Hillcrest Rd 1993[b,2,*], 2000[f,2]	Private forest land

Region	Area	Historical[a] pre-1981	More recent[a] 1981–1995	Extant[a] 1996–2016	Land tenure
	Saltspring Island		Saltspring Island 1985[b,1]		Private land
	Ladysmith	Near Ivy Green Provincial Park 1959[f,5]			Private forest land
	Thetis Island			Thetis Island 1989[b,d,] "large population"[*], 1992[f,3], 2005[f]	Private rural land
Southwest Vancouver Island	Sooke	Sooke 1925[f,4]; 2.1 mi Wt 1948[f,1]; 3.4 mi W 1948[f,2]			Private urban land; rural residential and farm land
	Jordan River	3 mi N 1941[f,1]; 3.7 mi NW 1977[f,6]; 9 mi W 1977[f,21]; 5 mi N 1968[f,2]	Jordan River 1942[f,2], 1977[f,4], 1989[b,] "relatively dense"		Provincial Crown forest land
	Port Renfrew	Port Renfrew 1925[f,1]		Port Renfrew 2008[b,1]	Provincial Crown forest land
South-central Vancouver Island	Lake Cowichan	Cowichan Lake 1943[f,1]	Mayo Rd 1993[b,2]; Riverbottom Rd 1993[b,d,4,*]	Marble Bay 1992–93[b,d,10,*], 2000[f,3]; Skutz Falls 2000[b,1]	Private forest land
	Youbou	4.3 mi SE 1948[f,2]; Youbou 1948[f,14]			Private forest land
East Vancouver Island North of Ladysmith and offshore islands	Nanaimo	"5 Acres" 1942[f,1]		Departure Bay 1932[f,4], 2004[2], 2012[c,1]; 114 Fifth St 2012[c,1]; Nanaimo Lakes Rd 2011[e,1]; Morrell Nature Sanctuary 2013[1]; Mt Benson 2011[b,10]	Municipal urban residential; private recreational; regional park; private forest land
	Lantzville			Lantzville Foothills forest 2012[b,4]; Lantzville Woodlot 2015[b,2]	Private forest land

Region	Area	Historical[a] pre-1981	More recent[a] 1981–1995	Extant[a] 1996–2016	Land tenure
	Errington		Little Mountain Rd 1993[b,7,*]	Chalet Rd and Little Qualicum Falls 2000[f,7]; Englishman River Falls 2000[f,3]	Private forest land; provincial Crown land
	Qualicum		Railroad 0.4 km S of Baylis Rd 1993[b,1]		Private forest land
	Bowser		Crosley Rd 1993[b,8,*]; McNaughton Ck 1993[b,7,*]; Thames Ck 1993[b,1,*]	Cook Ck 1993[b,d,45,*], 2000[b,f,2]; Rosewall Ck 1988–89[b,459,*], 1992–93[b,d,75,*], 2005[b,2]	Regional rural agricultural land; private forest land; provincial park
	Union Bay	Union Bay 1904[f,3]; 1968[f,4]			Private land
	Hornby Island	Hornby Island 1929[f,6]; 1930[f,11]; 1947[f,2]			Regional park; private agricultural land
	Denman Island		Denman Isle 1989[f,] "common"		Private land
	Courtenay			Cumberland and Arden Rds 2012[b,1]	Municipal park
	Comox	Comox 1926[f,3], 1929[f,1], 1958[f,2]		Lazo Rd 2011[e,3]	Municipal residential; Provincial protected area
	Cumberland			Cumberland 2000[f,2], 2005[b,1]	Municipal residential
	Black Creek	Black Ck 1977[f,1]	Miracle Beach 1964[f,2], 1989[b,] "common"		Regional rural residential; provincial park

Region	Area	Historical[a] pre-1981	More recent[a] 1981–1995	Extant[a] 1996–2016	Land tenure
	Campbell River	Lower Quinsam 1959[f,1], 1960[f,1]			Provincial Crown forest
	Quadra Island	6.5 km N-NW Heriot Bay 1977[f,2]			Provincial Crown forest
	North of Campbell River	11 km NW 1980[f,1]	22.5 km N 1988[f,1]		Provincial Crown forest
	Sayward		11 km SE 1987[f,1]	Dalrymple Ck 2000[f,11], 2001[b,2]	Provincial Crown forest
	Cracroft Island	Cracroft Isle 1944[f,3]			Provincial Crown forest
Central and North Vancouver Island	Alberni Valley		Anderson Ck 1991–92[b,1,*]; Kanyon Ck 1991–92[b,1,*]; Mactush Ck 1991–92[b,1,*]; Nahmint R 1991–92[b,1,*]		Provincial Crown forest
	Woss	4 sites near Woss Airport 1975–75[b,99,*]	8 sites in the Nimpkish 1991[b,131,*]; Rooney Lk 1988[f,2];	9 sites in TFL 37 2001[b,14,*]; 6 sites in TFL 37 2005[d,14,*]	Provincial Crown forest
	Carmanah–Walbran		Carmanah Provincial Park 1989[b,] "common at low elevation"	Cheewhat Lk 2006[b,1]; Tsusiat 2006[b,1]; Walbran 2013 "canopy"[1]	Federal and provincial park

Region	Area	Historical[a] pre-1981	More recent[a] 1981–1995	Extant[a] 1996–2016	Land tenure
West Vancouver Island and offshore islands	Bamfield	Roadside swamp 1923[f,1]	Pachena River trail 1995[b,1]	Pachena Bay 2001[b,1]; Bamfield Marine Sciences Centre property 2002[b,1]; 22 S Bamfield Rd 2011[b,2]	Provincial Crown forest; private land
	Tzartus Island	Holford Ck 1969[f,1]			Private forest land
	Effingham Island	Between west end of lake and ocean 1973[f,1]			National park
	Gilbert Island	Gilbert Isle 1970[f,1]			National park
	Toquaht to Ucluelet Junction	Maggie Lake 1941[f,1]; 3.7 mi NE of junction 1971[f,1];		Conference Creeks 2015[b,3]; 0.8 mi NE of junction 1971[f,4], 2012–14[e,6*]; 0.4 mi NE of junction 1971[f,1], 2013[e,4]	Provincial Crown forest
	Ucluelet			Bay St. Ucluelet 2001[c,1], 2012[c,1]	Private rural residential land
	Ucluelet Junction to Tofino	Pacific Rim National Park Reserve 1909[f,8]; 13.4, 14.1, 14.3, and 15.5 mi NW of Ucluelet 1971[f,4]; Wickaninnish Beach dunes 1971[f,1]; Tofino 1977[f,37]; Logging road 10 mi S of Tofino 1977[f,3]; Little Sandhill Ck trib 1970[f,1]	Kootowis Ck 1993[h,1], 2015[b,3]	0.4 mi NW of junction near Swan Lake 1977[f,4], 1993[g,1], 2005–2012[e,39,*]; 2.4 mi NW of junction 1976–77[f,34], 2002[e,1]; 14.5 mi NW of Ucluelet 1971[f,1], 2001[e,1]; Cox Bay 1976–77[f,2], 2011[b,1]; 0.8, 7.3, 23.8, 27, and 29 km SE of Tofino 2001–02[e,6,*]	Federal park and provincial Crown forest and quarries
	Clayoquot Watershed			4 sites 1997–98[g,14,*]	Provincial Crown forest
	Tofino Watershed and Inlet	NE shore Kennedy Cove 1977[f,8]		6 sites 1997–98[g,37,*]	Provincial Crown forest

Region	Area	Historical[a] pre-1981	More recent[a] 1981–1995	Extant[a] 1996–2016	Land tenure
	Tranquil Watershed			4 sites 1998[g,4,*]	Provincial Crown forest
	Stubbs Island	Stubbs Island 1960–61[f,6]			Private forest in land trust
	Cleland Island			Cleland Island 1967[a,2], 2010[b,3], 2015[b,23]	Provincial ecological reserve
	Shelter Inlet			Watta Estuary 2008[b,1]	Provincial park
	Sydney Inlet			2 sites 2007–08[b,3]	Provincial park
	Gold River			4 sites 2001[b,8]	Provincial Crown forest
	Nootka Island			Nootka Isle 1930[f,1]; 2000[b,2]; Nuchatlitz 2004[b,1]	Provincial park
	Grassy Island		Grassy Island 1958[f,1], 1982[3]		Provincial Crown land
	Thornton Island		Thornton Island 1982[4]		Unknown
	Walters Island			Walters Island 1957–58[f,14], 2013[c,1]	Unknown, private land
	Spring Island		Spring Island 1994[1]		Kyuquot First Nation land
	Little Bunsby Island	Little Bunsby Isle 1955[1]			Provincial park
	Kyuquot		North side Malksope River 1993[g,1]		Kyuquot First Nation land and provincial Crown forest
	Brooks Peninsula		Brooks Peninsula 1981[1]		Provincial park

Region	Area	Historical[a] pre-1981	More recent[a] 1981–1995	Extant[a] 1996–2016	Land tenure
Northwest Vancouver Island	Quatsino	Quatsino 1936–38[f,33]; Koskimo Bay 1980[f,1]			Provincial Crown forest
	Coal Harbour			Coal Harbour 2000[f,1]	Provincial Crown forest
Sunshine Coast	Sechelt			Homestead Ck 2001[b,2]; Trout Lake 2001[b,1]	Provincial Crown hydro transmission corridor

[a] Historical: records of museum specimens collected at sites before 1981 for which there is a lack of recent field information verifying the continued existence of the occurrence. More Recent: records from intensive field studies and incidental sightings between 1981 and 1995 for which there is a lack of field information since 1995 verifying the continued existence of the occurrence. Extant: occurrence has been verified in the last 20 years as still existing.
[b] Found under/within logs, stumps, or pieces of bark at site.
[c] Found in yard at urban residence.
[d] Found between or under artificial cover objects set out to sample invertebrates and/or vertebrates.
[e] Found on road or sidewalk, or at barricade fence alongside road.
[f] Collected for museum specimen or lab study.
[g] Found on forest floor.
[h] Found on live tree.
[x] Number of individuals recorded at the site.
[*] Repeated surveys done at the site targeting plethodontid salamanders.

APPENDIX 2. Quantitative Surveys and Relative Abundance of Wandering Salamanders in British Columbia

Project or source	Site	Season/year	Method[a]	Description of effort	Total effort	Total caught	Average caught per unit effort (range)	No. of sites where found
Stelmock and Harestad 1979	Woss, 4 sites: old growth, mature, clearcut, and clearcut with retention	Summer 1976	ACS–COS Destructive	4 sites × 5 plots × 10 × 10 m	0.2 ha	21	105/ha (80–160)	4 of 4 (100%)
	Woss, 2 sites: old growth and immature	Summer 1976	TCS–COS	2 sites × 1 person × 3 h	6 person-h	15	2.5/person-h (2.3–2.7)	2 of 2 (100%)
Schieck, pers. comm., 2012	Nimpkish, 10 sites: old-growth stands of variable size	Spring and Fall 1991	Natural COS	10 sites × 17 dates × 100 natural cover objects	17 000 flips	131	0.008/flip (0–0.019)	8 of 10 (80%)
AXYS 2002	Woss, 41 sites in TFL 37	Summer 2001	ACS–COS Destructive	41 sites × 100 × 6 m; 41 sites × 2 people × ~2.5 h	2.46 ha; 205 person-h	14	5.7/ha (0–66.7); ~ 0.068/person-h (~ 0–4)	9 of 41 (22%)
Beauchesne and Cooper 2006	Woss, 14 sites in TFL 37	Spring 2004-05	ACO (2 layers of 0.9 × 0.3m boards)	3 dates × 221 ACO (variable per site)	663 flips	14	0.021/flip (0–0.044)	6 of 14 (42%)
Davis 1991	Rosewall Ck, 1 site	All year 1988–89	TCS–COS Destructive	13 plots × 3 h	39 person-h	228	5.8/person-h (0–10)	15 of 25 (60%)
	Rosewall Ck, 1 site	All year 1989–90	Natural COS	20 dates × 202 natural COS stations	4040 cover flips	439	0.11/flip ([b])	

Project or source	Site	Season/year	Method[a]	Description of effort	Total effort	Total caught	Average caught per unit effort (range)	No. of sites where found
Davis 1996	Greater Victoria Watershed, 4 sites; Rosewall Ck, 3 sites; Goldstream Pk, Lake Cowichan	Spring and Summer 1993	ACO (2 layers of 1.8 × 0.3 m boards)	8 dates × 228 ACO (variable number per site)	1536 flips	32	0.021/flip (0–0.146)	
	Same as per ACO, except none at Rosewall Ck	Spring 1992–93	ACS	10-m diam. plots and 12 × 12 m plots	1.45 ha	10	6.9/ha (0–14.2)	
	20 sites between Rosewall Ck and Sooke Lake; all within 20 min driving time of Hwy 19	Spring 1993	TCS: min. 2 people searching ~2500 m^2 plot	3 plots × 2 person-h × 12 sites; 1 × 2 person-hour × 8 sites	88 person-h; approx. 11 ha	57	0.65/person-h (0–2.2); ~5.2/ha (~0–20)	
Ovaska, pers. comm., 2013 (in conjunction with Sharp-tailed Snake surveys by Engelstoft and Ovaska for B.C. Ministry of Environment, Lands, and Parks, Nanaimo office)	Rocky Point, Metchosin (2 EMAN monitoring plots in Garry oak and Douglas-fir/grand fir habitats)	Established in fall 1996; checked in 1997 and 1998	ACO (2 layers of 1.8 × 0.3 m boards)	24 ACO/site × 2 sites; 4 plots of 6 ACO at each plot	48 ACO checked annually = 96 flips	2 (on Garry oak plot only)	0.021/flip ([b])	50%
Ovaska, pers. comm., 2012	Goldstream Provincial Park, 1 site	Spring 2000–12, annually	ACO (2 layers of 1.8 × 0.3 m boards)	37 dates × 12 ACO and 38 dates × 15 ACO	954 flips	3	0.003/flip (0–0.037)	1 of 1 (100%)

Project or source	Site	Season/year	Method[a]	Description of effort	Total effort	Total caught	Average caught per unit effort (range)	No. of sites where found
Dupuis 1993; Dupuis *et al.* 1995	Alberni Valley and surrounding area: mixed Douglas-fir/western hemlock, 11 sites	Spring 1991–92	ACS–COS	290 × 3 × 3 m plus 1305 × 1 × 2 m; approx. 5 h per 90 m^2 plot	0.522 ha; ~290 person-h	2	3.8/ha (0–12.4); 0.007/person-h (0–0.022)	4 of 11 (36%)
	Alberni Valley Area mixed Douglas-fir/western hemlock, 6 of same sites as above	Spring 1991–92	Log Search	900 logs, max 20 min per log	900 logs, approx. 300 person-h	7	0.008/log; ~0.023/person-h ([b])	
Beasley *et al.* 2000	Clayoquot Sound, 25 sites in 4 watersheds, all within riparian zones	Fall 1998	ACS/TCS–VES	368 transects × 30 × 2m; 368 person-h	2.208 ha	40	17.2/ha (0–93.8); 0.10/person-h (0–0.56)	11 of 25 (44%)
Peacock 2008	Clayoquot Sound, 5 sites in 3 inlets: Sydney, Watta, Moyeha; beach edges	Summer 2008	ACS–COS destructive	5 sites × 1.5 person-h per site	7.5 person-h	2	0.27/person-h (0–0.67)	2 of 5 (40%)
Beasley, unpubl. data	Ucluelet–Tofino, 1 site on verge of Hwy 4	Spring and Fall 2005–10	Pitfalls	155 dates × ~23 traps along 3 × 90 m × 2 sides of highway	21 357 trap-nights; ~41.9 km	10	0.468/1000 trap-nights; 0.24/km ([b])	3 of 5 (60%)
	Ucluelet–Tofino, 1 site in forest beside Hwy 4	Spring and Fall 2010–12	Pitfalls	76 dates × a variable number of traps/date	1825 trap-nights	8	4.38/1000 trap-nights ([b])	
	Ucluelet–Tofino, 1 site Hwy 4	Spring and Fall 2006–12	Road Survey	200 dates × ~0.5–1.44 km of road	284 km	21	0.074/km ([b])	
Materi and Forrest 2007; Materi 2008	Qualicum–Rupert Road	Fall 2006, 2008, Spring 2007	Road Survey	24 dates × 2.2 km of road	52.8 km	0	0/km ([b])	

Project or source	Site	Season/year	Method[a]	Description of effort	Total effort	Total caught	Average caught per unit effort (range)	No. of sites where found
Wind 2012	Nanaimo Lakes Road, 1 site	Mainly Fall 2007–2011	Road Survey	34 dates × ~9 km of road	298.5 km	1	0.003/km ([b])	
	Lazo Road, Comox, 1 site	Spring and Fall 2011	Road Survey	14 dates × 1 km of road	14 km	3	0.214/km ([b])	
	Barnjum and Riverbottom Roads, 1 site	Spring and Fall 2011	Road Survey	23 dates × 1.3 km of road	29.9 km	0	0.000/km ([b])	
Ovaska and Sopuck 2001	19 sites from Black Creek to Tsitika River north of Sayward	Spring and Fall 2000	ACO; variable size and materials; 2-layered salamander boards (0.9 × 0.3 m boards) at 4 sites	2 to 4 dates per site × 8–40 ACO per site	1510 flips	0	0/flip ([b])	1 of 35 (2.9%)
	5 sites at Keating Lake and Renfrew Road; 8 sites at Ripple Rock and Tsitika; 5 sites near Stillwater, Sunshine Coast	Spring and Fall 2001	ACO variable size, about 70 were 2-layered salamander boards (0.9 × 0.3 m)	2–3 dates per site × 80–120 ACO per site	5700 flips	1	0.00017/ flip (0–0.0042)	
Ovaska *et al.* 2003	2 sites in Metchosin (Rocky Point, Royal Roads Univ. campus)	Spring 2003, 2004	2-layered salamander boards (0.9 × 0.3 m)	3–4 dates in May–June; 45 boards/site set at 3 plots at each site	~360 flips	0	0/flip ([b])	0 of 2 (0%)
Govindarajulu, unpubl. data	Haliburton Farm, Saanich, small patch of mature second-growth Douglas-fir	Spring and Fall 2008–12	ACO; 2-layered salamander boards (0.9 × 0.3 m)	11 dates × 17 boards	187 flips	6	0.032/flip ([b])	1 of 1 (100%)
Total						**1067**		**68 of 183 (37%)**

[a] TCS = Time Constrained Search, ACS = Area Constrained Search, COS = Cover Object Search, VES = Visual Encounter Survey, ACO = Artificial Cover Object (checked repeatedly, usually over several years).
[b] Not reported. Source: COSEWIC 2014.