PROPOSED

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

Management Plan for the Coastal Tailed Frog (*Ascaphus truei*) in Canada

Coastal Tailed Frog

2016

Government of Canada
Gouvernement du Canada
Canada

Recommended citation:

Environment and Climate Change Canada. 2016. Management Plan for the Coastal Tailed Frog (*Ascaphus truei*) in Canada [Proposed]. *Species at Risk Act* Management Plan Series. Environment and Climate Change Canada, Ottawa. 2 parts, 3 pp. + 49 pp.

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: © Linda Dupuis

Également disponible en français sous le titre
« Plan de gestion de la grenouille-à-queue côtière (*Ascaphus truei*) au Canada [Proposition] »

ISBN
Catalogue no.

[1] http://www.registrelep-sararegistry.gc.ca

MANAGEMENT PLAN FOR THE COASTAL TAILED FROG (*Ascaphus truei*) IN CANADA

2016

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 Coastal Tailed Frog (*Ascaphus truei*) 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 Coastal Tailed Frog in Canada consists of two parts:

Part 1 – Federal Addition to the *Management Plan for the Coastal Tailed Frog (*Ascaphus truei*) in British Columbia*, prepared by Environment and Climate Change Canada.

Part 2 – *Management Plan for the Coastal Tailed Frog (*Ascaphus truei*) in British Columbia*, prepared by British Columbia Ministry of Environment.

Table of Contents

Part 1 – Federal Addition to the *Management Plan for the Coastal Tailed Frog (*Ascaphus truei*) 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 is the competent minister under SARA for the Coastal Tailed Frog 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 the 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 British Columbia provided the attached management plan for the Coastal Tailed Frog (Part 2) as science advice to the jurisdictions responsible for managing the species in B.C. 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 management plan and will not be achieved by Environment and Climate Change Canada or any other jurisdiction alone. All Canadians are invited to join in supporting and implementing this plan for the benefit of the Coastal Tailed Frog 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] http://registrelep-sararegistry.gc.ca/default.asp?lang=en&n=6B319869-1#2

Additions and Modifications to the Adopted Document

The following section has been included to address specific requirements of SARA that are not addressed in the *Management Plan for the Coastal Tailed Frog (*Ascaphus truei*) in British Columbia* (Part 2) and/or to provide updated or additional information.

Under SARA, there are specific requirements and processes set out regarding the protection of species and their habitats. Recovery measures in the provincial management plan dealing with protection of habitat are adopted, but these may not directly correspond to federal requirements.

1 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[4] (FSDS) 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 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.

The provincial management plan for the Coastal Tailed Frog contains a short section describing the effects of management activities on other species (i.e., Section 9). 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. The distribution of Costal Tailed Frog may overlap with that of other federally-listed species at risk occurring in freshwater streams and coastal forests (e.g., Western Toad, Northern Red-legged Frog, Western Screech-Owl *kennicottii* subspecies) that could be affected by management actions at the watershed level. Conservation planning activities for Coastal Tailed Frog 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 Coastal Tailed Frog (e.g., research and monitoring, habitat conservation, public education and mitigation about general threats to amphibians) may promote the conservation of other species at risk that overlap in distribution and rely on similar habitat attributes.

[3] www.ceaa.gc.ca/default.asp?lang=En&n=B3186435-1
[4] www.ec.gc.ca/dd-sd/default.asp?lang=En&n=F93CD795-1

Part 2 – *Management Plan for the Coastal Tailed Frog (*Ascaphus truei*) in British Columbia*, prepared by British Columbia Ministry of Environment

Management Plan for the Coastal Tailed Frog (*Ascaphus truei*) in British Columbia

Prepared by B.C. Ministry of Environment

December 2015

About the British Columbia Management Plan Series

This series presents the management plans that are prepared as advice to the Province of British Columbia. Management plans are prepared in accordance with the priorities and management actions assigned under the British Columbia Conservation Framework. 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 Ministry of Environment Recovery Planning webpage at:

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

Management Plan for the Coastal Tailed Frog (*Ascaphus truei*) in British Columbia

Prepared by the B.C. Ministry of Environment

December 2015

Recommended citation

B.C. Ministry of Environment. 2015. Management plan for the Coastal Tailed Frog (*Ascaphus truei*) in British Columbia. B.C. Ministry of Environment, Victoria, BC. 49 pp.

Cover illustration/photograph

Linda Dupuis

Additional copies

Additional copies can be downloaded from the B.C. Ministry of Environment Recovery Planning webpage at:

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

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 Coastal Tailed Frog 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 all 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 Coastal Tailed Frog.

ACKNOWLEDGEMENTS

This management plan was prepared by Linda Dupuis (Hatfield Consultants Partnership) with inputs from Pierre Friele, Purnima Govindarajulu, Alexis McEwan, Volker Michelfelder, Rylee Murray, Kathy Paige, Brad Pollard, Lars Reese-Hansen, Melissa Todd, and Len Vanderstar. Funding for consultant's fees was provided by the Land Based Investment Strategy Program. An earlier draft of this management plan was prepared by Brent Matsuda (Biodiversity West Environmental Consulting) and Purnima Govindarajulu (B.C. Ministry of Environment). The threat assessment was completed by Linda Dupuis in September 2014, and reviewed and finalized in November 2014 following expert discussion.

EXECUTIVE SUMMARY

Tailed frogs are the only frogs in Canada to breed in mountain streams. As a result, they possess a unique set of morphological characteristics, including a ventrally flattened body, a vertical pupil, hardened clawlike toes on their forefeet, and long hind legs with large, powerful hind feet. Males possess a tail-like cloaca used for internal fertilization. Tailed frogs belong to the family Ascaphidae of which there are two members: the Coastal Tailed Frog (*Ascaphus truei*) in the Coast and Cascade Mountains, and the Rocky Mountain Tailed Frog (*Ascaphus montanus*) in the east Kootenays.

The Coastal Tailed Frog is federally listed as Special Concern on Schedule 1 of the *Species at Risk Act* based on a recommendation by the Committee on the Status of Endangered Wildlife in Canada. It is listed because its extreme habitat specialization makes it potentially vulnerable to habitat changes arising from human activities and other threats such as climate change. In British Columbia, the Coastal Tailed Frog is Blue-listed and ranked as priority 1 by the B.C. Conservation Framework under goal 2 (preventing species and ecosystems from becoming at risk) and priority 2 under goal 3 (maintaining the diversity of native species and ecosystems). The Coastal Tailed Frog is provincially protected from capture and killing under the *Wildlife Act.* It has also been identified as a species requiring special habitat management attention to address the impacts of forest and range activities under the *Forest and Range Practices Act* and/or the impacts of oil and gas activities under the *Oil and Gas Activities Act* on Crown land (as described in the Identified Wildlife Management Strategy).

Much of the Coastal Tailed Frog's range lies within areas that are subject to forestry activities. As such, the primary threats to the species are a result of site- and watershed-level habitat changes related to logging and associated activities such as road building. Aquatic degradation is mainly linked with sediment delivery at road crossings, sedimentation from bank failures and landslides, and clogging by excesses of wood as a function of cross-stream yarding. Terrestrial degradation is a function of riparian forest loss, the conversion of old forests to younger seral stages, and isolation from landscape fragmentation, which can disrupt movement, dispersal, and population connectivity. Road networks and wide-scale loss of trees can also alter the hydrological regime of streams, accentuating peak and base flows, which are conditions likely to be exacerbated by climate change. High peak flows may increase the probability of tadpole mortality from channel bedload events. Lower base flows can lead to channel impermanence and the shrinking of habitats particularly in headwater areas.

The recent development of small run-of-river hydroelectric facilities presents a secondary, more localized threat. Effects are largely unknown but may include aquatic habitat loss in diversion reaches; detrimental temperatures; sedimentation in streams with a relatively low transport potential; riparian habitat loss; disruption of aquatic and terrestrial connectivity within a watershed (genetic isolation); and direct mortality from impingement, entrainment, stranding, flushing, and collision below weirs. Effects likely vary with watershed and stream characteristics, as well as with project construction and operation designs. Future research is needed to understand the interaction between these

factors, the magnitude of the threat, and the effectiveness of existing mitigation measures for Coastal Tailed Frogs.

The management goal of this plan is to maintain viable, self-sustaining populations of the Coastal Tailed Frog throughout its range. The following are the management objectives for the Coastal Tailed Frog:

1. to prevent extirpation of populations in occupied Coastal Tailed Frog watersheds through land use conservation practices that:
    a. maintain quality and quantity of stream, riparian, and upland habitats;
    b. protect and prevent degradation of specialized aquatic and terrestrial habitats; and
    c. ensure connectivity within and between populations;
2. to address knowledge gaps in Coastal Tailed Frog ecology that currently constrain the design of management actions; and
3. to address knowledge gaps in how Coastal Tailed Frog populations respond to threats and management actions (i.e., effectiveness evaluation of conservation management).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 COSEWIC* SPECIES ASSESSMENT INFORMATION

Assessment Summary – November 2011
Common name: Coastal Tailed** Frog
Scientific name:** *Ascaphus truei*
Status: Special Concern
Reason for designation: This unusual frog of an ancient lineage has a scattered distribution in western British Columbia, where it occupies cool, clear, fast-flowing mountain streams and adjacent older forest. Habitats continue to be lost and degraded as a result of forestry and other human activities that occur throughout much of its Canadian distribution. Siltation of breeding streams and loss of older forest cover associated with resource use are main threats. Threats identified in the previous assessment in 2000 continue to degrade and fragment habitats, and new threats, such as run-of-river independent hydropower projects, have the potential for rapid and widespread increase throughout the species' Canadian range. Specialized habitat requirements, life history characteristics that include low reproductive potential, and patchy distribution make the frogs particularly vulnerable to human activities and climate change.
Occurrence: B.C.
Status history: Designated Special Concern in May 2000. Status re-examined and confirmed in November 2011.

* Committee on the Status of Endangered Wildlife in Canada.
**Common and scientific names reported in this management plan follow the naming conventions of the B.C. Conservation Data Centre, which may be different from names reported by COSEWIC.

2 SPECIES STATUS INFORMATION

Coastal Tailed Frog[a]			
Legal Designation:			
FRPA:[b] Species at Risk OGAA:[b] Species at Risk	B.C. *Wildlife Act:*[c] Schedule A	SARA:[d] or Schedule 1 – Special Concern (2003)	
Conservation Status[e]			
B.C. List: Blue	B.C. Rank: S3S4 (2010R)	National Rank: N3N4 (2011)	Global Rank: G4 (2004)
Other Subnational Ranks:[f] CA: S2S3; OR: S3; WA: S4			
B.C. Conservation Framework (CF)[g]			
Goal 1: Contribute to global efforts for species and ecosystem conservation.			Priority:[h] 4 (2009)
Goal 2: Prevent species and ecosystems from becoming at risk.			Priority: 1 (2009)
Goal 3: Maintain the diversity of native species and ecosystems.			Priority: 2 (2009)
CF Action Groups:[f]	Compile Status Report; Monitor Trends; Planning; Send to COSEWIC; Habitat Protection; Private Land Stewardship		

[a] Data source: B.C. Conservation Data Centre (2014) unless otherwise noted.
[b] Species at Risk = a listed species that requires special management attention to address the impacts of forest 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) as described in the Identified Wildlife Management Strategy (Province of British Columbia 2004).
[c] Schedule A = designated as wildlife under the B.C. *Wildlife Act*, which offers it protection from direct persecution and mortality (Province of British Columbia 1982).
[d] Schedule 1 = found on the List of Wildlife Species at Risk under the *Species at Risk Act* (SARA; Government of Canada 2002).
[e] S = subnational; N = national; G = global; 1 = critically imperiled; 2 = imperiled; 3 = special concern, vulnerable to extirpation or extinction; 4 = apparently secure; 5 = demonstrably widespread, abundant, and secure; NA = not applicable; NR = unranked; U = unrankable.
[f] Data source: NatureServe (2014).
[g] Data source: B.C. Ministry of Environment (2010).
[h] Six-level scale: Priority 1 (highest priority) through to Priority 6 (lowest priority).

3 SPECIES INFORMATION

3.1 Species Description

The Coastal Tailed Frog is adapted to life in mountain streams, which can be fast flowing and steep. This is reflected in the distinct morphological traits of both adults and tadpoles. Adults possess vertical pupils, lack tympana, and are slightly ventrally compressed (Figure 1). Moreover, they typically possess a copper or gold bar between the eyes, have clawlike toes on their forefeet, and broad, webbed hind feet. Colour can vary from tan or brown to olive green or red, and individuals can be speckled with black. The skin has a distinct granular texture most easy to detect in terrestrial environments. Adults range in length from 2.2 cm to 5.1 cm (COSEWIC 2011). Adult females are larger than males (e.g., average weight of females at the northwest edge of the species' range is 9 g, compared to 6 g for males, McEwan 2014). Only males possess a conical tail, which is an extension of the cloaca and is used for internal fertilization.

Figure 1. Coastal Tailed Frog adult (Linda Dupuis).

Tadpoles are primarily distinguished by their mouth, which consists of a flattened disc that allows them to adhere to rocks in the channel and resist displacement by fast flows. This disc is bordered by several thin, black rows of vomarine (knoblike) teeth used to scrape algae from the surface of rocks, embedded wood, and other substrates in streams (Figure 2). Tadpoles also have a streamlined, ventrally flattened body (Figure 3) and laterally flattened tail bordered by a broad, thick dorsal fin for ease of movement through fast-flowing water. In their first year, tadpoles tend to be slate grey; in later years, they may become brown and grey, with or without fine black and white flecks. A white spot on the tip of the tail is presumably to confound predators. Tadpoles range from 1.8 to 6.5 cm in length (COSEWIC 2011).

Eggs are attached inconspicuously to the underside of large, anchored rocks in streams and are rarely observed. Large (4–5 mm in diameter), colourless, and enclosed by a thin, transparent jelly (Jones *et al.* 2005), these eggs are laid in pearl-like strings that may be compressed into

clusters. Clutch size ranges from 20 to 96 eggs (Karraker *et al.* 2006). Females lay eggs either individually or communally (Jones *et al.* 2005; Palmeri-Miles *et al.* 2010). Embryos hatch from mid-July to mid-September (Karraker *et al.* 2006). Hatchlings are approximately 11 mm in total length and carry a conspicuous ventral yolk sac.

Figure 2. Oral disc of a Coastal Tailed Frog tadpole (Wayne Lynch).

Figure 3. Coastal Tailed Frog tadpole (Linda Dupuis).

Courtship and mating take place in late summer and early fall. At the northern extent of its range (Skeena), amplexus is documented throughout September and October in streams and adjacent wet habitats (McEwan *et al.* 2012). Females lay eggs the following year from June to August (Karraker *et al.* 2006), but this varies depending on latitude, elevation, and stream temperature. In the Skeena, females move to streams in May and June, oviposit in July, and leave streams by early August (McEwan 2014; Todd *et al.* 2015). Females may reproduce only every second year (COSEWIC 2011).

The embryonic period lasts 4–6 weeks (Metter 1964; Brown 1975), depending on stream temperature. After emerging from eggs in late summer or early fall, Coastal Tailed Frog hatchlings remain at the hatching site until their oral disk is fully developed and yolk sac is depleted. Tadpoles may take an additional 1–4 years to metamorphose, depending on stream temperature and productivity. Metamorphs appear to comprise 1–3% of the population based on multiple years of Coastal Tailed Frog surveys across the province (L. Dupuis, unpubl. data, [1995 to 2002]).

Tailed frogs do not reach sexual maturity until 7–9 years from the time of hatching (Brown 1975; Daugherty and Sheldon 1982). Adults live 10–20 years (Brown 1975; Daugherty and Sheldon 1982).

3.2 Populations and Distribution

3.2.1 Populations

Genetically distinct populations of the Coastal Tailed Frog exist at the periphery of its range in the Pacific Northwest (i.e., Olympic Peninsula, northern California, Siskiyou Mountains, Oregon coast, and Oregon Cascades Mountains). Populations from the coast to the northern and central Cascade Mountains are relatively uniform, signifying a relatively recent range expansion or contemporary gene flow (Nielson *et al.* 2006). This suggests that the current known Coastal Tailed Frog population in British Columbia forms part of a single northern subpopulation and, as such, represents a single unit at which to address its status, conservation, and management needs.

Coastal Tailed Frog populations appear to be structured at a watershed level (e.g., Aguilar *et al.* 2013). In the Skeena, frogs inhabiting stream tributaries linked by a main stem with a catchment area of approximately 50 km^2 may be considered a population (Dupuis and Friele 2003). Approximately 770 such basins occur within the species' range in British Columbia (COSEWIC 2011), although a 40% occurrence rate was observed within the species' provincial range, suggesting that not all creeks are suitable. It is very difficult to estimate density of populations because frogs are not evenly distributed and seasonal variations in density occur related to patterns of life history movements.

3.2.2 Distribution

The Coastal Tailed Frog is endemic to the Pacific Northwest of North America, and occurs throughout the Coast and Cascade Mountains from British Columbia to northern California (Figure 4). It is absent from most offshore islands and generally does not range into lowlands

where streams tend to be sluggish and warm. Eggs do not tolerate stream temperatures in excess of 18°C and tadpoles tend to avoid temperatures greater than 22°C (Brown 1975). Juveniles and adults seek ambient terrestrial temperatures in the range of 10–11°C (McEwan 2014).

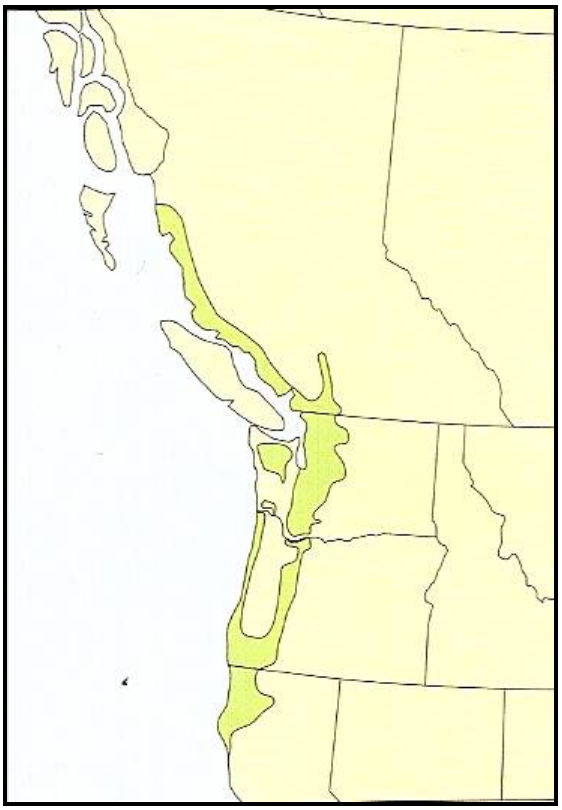

Figure 4. Coastal Tailed Frog distribution in North America (greenish yellow range; Jones *et al,* 2005).

Its distribution overlaps with the Coast and Mountains Ecoprovince along the British Columbia coast and the most western ecosections (Leeward Pacific Ranges, Hozameen Range) of the Southern Interior Ecoprovince (Figure 5). In the more continental (peripheral) parts of its range, populations appear to be scattered, low density, and limited by stream temperatures, requiring warm summer temperatures for larval development and snow buffers against winter freezing (Dupuis *et al.* 2000; Leupin 2000; Wind 2009). Transient satellite populations have also been suggested at the northern periphery of the Rocky Mountain Tailed Frog's range (Dupuis and Friele 2006), but this may be attributed to limited detection at low density.

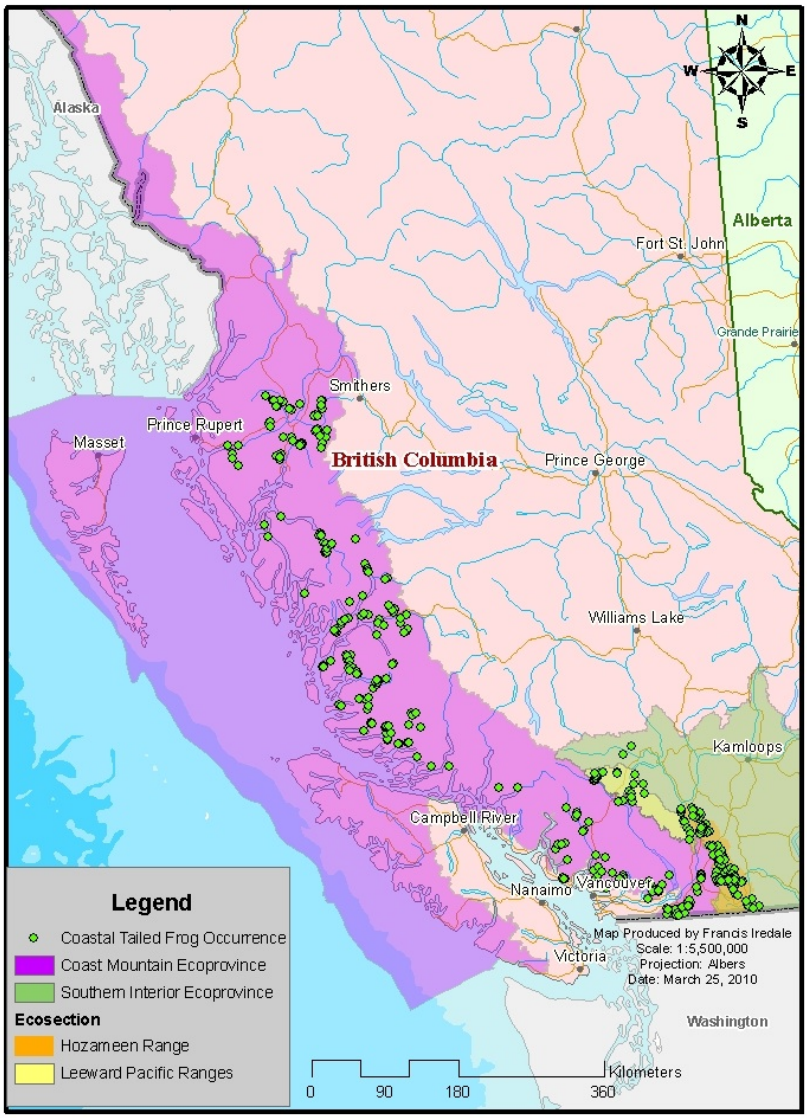

Figure 5. Distribution of the Coastal Tailed Frog relative to provincial biogeographic units (based on surveys undertaken from 1954 to 2010; COSEWIC 2011).

The Coastal Tailed Frog occurs from sea level to approximately 1800 m (Gyug 2000), although it is found at elevations in excess of 2000 m in the more southern parts of its North American range (Corkran and Thoms 2006). The Coastal Tailed Frog is most commonly found in the Coastal Western Hemlock and Mountain Hemlock biogeoclimatic zones; it occurs more sporadically at higher elevations within the Engelmann Spruce–Subalpine Fir, Interior Cedar–Hemlock, and Alpine Tundra biogeoclimatic zones (B.C. Ministry of Forests, Lands and Natural Resource Operations 2014b). Continental (dry, "interior") climate, with its very cold winters and very hot summers, limits distribution at the periphery of the frog's range to streams with moderately warm summer temperatures (Dupuis and Friele 2003) and areas with sufficient snow to buffer streams from winter freezing and summer drying (Dupuis *et al.* 2000).

The occurrence of Coastal Tailed Frogs appears to be influenced by basin size, relief, and ruggedness (Dupuis and Friele 2003). These frogs typically breed in contributing basins (catchments) of approximately 1–10 km^2, with moderate levels of relief and ruggedness. Stable bedrock geology is also important (Diller and Wallace 1999; Wilkins and Peterson 2000; Dupuis and Friele 2003). Basin steepness and rock type affect the frequency and severity of geological processes, which in turn govern habitat stability and thus survival rates for the species. Based on predictive modeling, an estimated 22% of streams at the centre of this species' range on the mid-coast of British Columbia represent optimal breeding habitat (J. Michelfelder, pers. comm., 2010). At the stream and sub-basin level, tadpole densities may range from 0.1 to 10.0 individuals per square metre within a single stream (Dupuis and Steventon 1999) and may be governed by adult distribution, stream channel characteristics, or whether females have laid their eggs communally

Based on pitfall trap surveys in the Skeena, McEwan (2014) reported that 60% of adults were captured within 30 m of streams and 82% of adults were captured in forest retention buffer sites located less than 30 m from the stream edge. Studies conducted in southern British Columbia showed that adults had a greater affinity for areas within 20 m of the stream in clearcuts and mature forests (Wahbe *et al.* 2004; Matsuda and Richardson 2005). Reproductive behaviour appears to drive a seasonality in distribution, with increased stream-side captures made during ovipositioning and, to a lesser degree, during fall breeding (McEwan 2014). Telemetry demonstrated that females traveled widely and were documented at distances of up to 174 m from stream edges; conversely, males were more sedentary. Females also had larger mean estimates of space use compared to males (730.50 m^2, SE = 317.33; 481.86 m^2, SE = 109.83) (McEwan 2014). In the moist forests of the Skeena, most movements by females were perpendicular to streams (McEwan 2014); in drier forest variants of the south coast, movement was parallel to streams (Matsuda and Richardson 2005). During the fall mating season, males and females may congregate in wet environments, such as ephemeral drainages and seepages with some flow, away from larval rearing streams (McEwan *et al*. 2012) or in larval streams (J. Malt, pers. comm., 2013). Aggregate ovipositioning has been observed in the Skeena (Todd *et al.* 2015). Communal ovipositioning has been reported for Coastal Tailed Frogs, with "nests" containing hundreds of eggs from multiple females (Palmeri-Miles *et al*. 2010).

3.3 Habitat and Biological Needs of the Coastal Tailed Frog

3.3.1 Aquatic habitat

Coastal Tailed Frogs specialize in cascade (cobbles, boulders, and pocket pools) and step-pool (cobble/boulder steps and underlying channel-spanning pools) habitats, which are characteristic of hillslope channels (typically streams with gradients of 2–93%). By tumbling into pools from steps made up of coarse substrates, stream flows are reduced, as is the pulling force on the channel. As such, these channel morphologies are relatively stable compared to riffle-pool sequences and plane beds (rapids) found in larger basins, where channel materials are more mobile because of the smaller rock sizes and flows are laminar and thus more powerful. Eggs, and hatchlings in particular, lack the ability to resist pulling forces. Cascades and step-pools are subject to collapse at 5–50-year recurrence intervals (Chin 1998, 2002), thereby accommodating the lengthy (multiple year) aquatic development period of most tadpoles. Cascades and step-

pools allow for one or more successful (catastrophe-free) egg-laying and post-metamorphic recruitment cycles during the lifespan of a breeding adult (COSEWIC 2011).

Tadpoles and frogs occupy steps and pools, and are found on or under boulders and cobbles, or in the interstitial (matrix) spaces between them. Tadpoles are also found on or among large pebbles in pools. Their distribution in streams is primarily influenced by the substrate. Large proportions of fine sediment (sand and small pebbles) in stream channels are detrimental to tadpoles (Ardea 1999; Diller and Wallace 1999; Dupuis and Steventon 1999; Wilkins and Peterson 2000; Adams and Bury 2002; Stoddard 2002; Dupuis and Friele 2003). Based on a laboratory study of substrate use, tadpoles seek rocks greater than 55 mm in diameter (Altig and Brodie 1972). In a field-based study, however, tadpoles selected rocks of 100 mm or greater in diameter (Hawkins *et al.* 1988). Fine sediments fill the interstitial matrix, reducing habitat suitability by eliminating refuge sites used by Coastal Tailed Frogs. Fine sediment also covers food sources, reduces adherence surface availability, and decreases the stream's traction surfaces (COSEWIC 2011).

Aquatic habitat is also affected by stream temperatures. Although Coastal Tailed Frog larval populations in the province are most frequently found in creeks with moderately low temperature regimes associated with deep snowpack and prolonged snow melt (P. Friele, pers. comm., 2015; Friele et al. in prep.), embryonic and tadpole development is not possible in streams below 7°C (Brown 1975). In continental areas at the northern extent of its range, the Coastal Tailed Frog appears to be uncommon in north-facing basins, presumably because these are too cold to support development (Dupuis and Friele 2003). A meta-analysis of data sets from British Columbia and Washington showed a higher rate of Coastal Tailed Frog tadpole occurrence in streams with southern and eastern aspects (Sutherland *et al.* 2001). Eggs require stream temperatures of 5–18.5°C for survival, whereas tadpoles tolerate temperatures of up to 22°C. Temperatures above 24°C are lethal to adults (COSEWIC 2011).

3.3.2 Terrestrial habitat

Outside of the mating and egg-laying seasons, Coastal Tailed Frogs are strongly tied to riparian forests (Bury *et al.* 1991; Hawkes and Gregory 2012; McEwan 2014) but are also found in upland forest habitats, which appear to contribute to population density. McEwan (2014) observed a higher abundance of tailed frogs in sites with intact upland and riparian forests (> 140 years) when compared with sites with 30–50 m wide riparian forest (>140 years) buffers but clear-cut uplands. Hawkes and Gregory (2012) found tailed frog relative abundance declined in upland habitats adjacent to riparian buffers 2 years after clear-cut logging, and dropped to zero by 10 years post-logging, while numbers within the riparian buffers and unlogged control sites (riparian and upland habitats) remained the same.

Densities also appear positively correlated with ground cover (Corn and Bury 1991; Welsh 1993), large downed wood, and moist microhabitat availability (Welsh 1990; Aubry and Hall 1991; Bury *et al.* 1991; McEwan 2014). A strong association with old-growth forest has been reported for British Columbia, Washington, and Oregon (COSEWIC 2011), although maturing forests may also be suitable (Matsuda and Richardson 2005).

Older forests are structurally complex and productive (Franklin 1988), and contain more stable and cool microhabitats (Chen *et al.* 1993; Brosofske *et al.* 1997). The higher leaf area index (leaf area per unit ground cover surface area) associated with old forests is effective at maintaining humid microclimates and moderately moist, organic soils (Sridhar *et al.* 2004). Claussen (1973) first suggested that cool, moist forests with abundant cover can facilitate the movement and dispersal of amphibians. In support of this idea, McEwan (2014) found a greater number of Coastal Tailed Frogs on cooler and moister days, observed more movement within 24 hours of rain events, documented an adult preference for temperatures in the range of 11–12°C, and observed a greater use of space in old-growth forests than in riparian buffers. Hailman (1982) also suggested that Coastal Tailed Frogs are not adapted to high ambient light levels of exposed habitats such as clearcuts.

An occupancy model assessing the effects of environmental variables and management on species detection probability also showed that forest age was positively correlated with tadpole abundance (Kroll *et al.* 2008). Both Stoddard (2002) and Welsh and Lind (2002) observed a positive correlation between the presence of old-forest patches in a watershed and larval abundances. Richardson and Neill (1995) reported reduced tadpole numbers and biomass in south coastal streams flowing through 25-year-old managed stands than in old-growth forests. In addition, the closed canopy characteristics of young stands prevent understory establishment (Alaback and Herman 1988; Franklin *et al.* 2002), which may be associated with reduced cover and insect food sources for Coastal Tailed Frog juveniles and adults.

3.4 Ecological Role

Tailed frogs are among the most primitive frogs in the world (Brown 1975); their closest relatives occur in New Zealand. This unique and ancient lineage is reflected in a distinctive morphology and life history (COSEWIC 2011). Tailed frogs are the only frogs in North America adapted to life in mountain streams (Cook 1984). As such, these frogs contribute to biodiversity levels and serve as indicators in the management of healthy headwater streams, much as salmon reflect the integrity of rivers. Protecting Coastal Tailed Frog tadpole habitat safeguards smaller (invertebrate) stream inhabitants, which can be a food source for fish in larger, downstream reaches. The large biomass of tadpoles may serve as a significant food source for small vertebrates, such as the gartersnake (*Thamnophis* sp.; Karraker 2001), water shrews (*Sorex* sp.; Lund *et al.* 2008), American Dipper (*Cinclus mexicanus*; Morrissey and Olenick 2004), and Coastal Giant Salamander (*Dicamptodon tenebrosus*; c.f. Johnston 2004), as well as trout species (*Oncorhynchus* sp.; Daugherty and Sheldon 1982) and large predaceous invertebrates (Jones and Raphael 1998).

3.5 Limiting Factors

Limiting factors are generally not human induced and include characteristics that make the species less likely to respond to recovery/conservation efforts (e.g., extreme habitat specialization, slow maturation, and aggregation during breeding).

Extreme habitat specialization (i.e., cascade and step-pool morphologies with low levels of fine sediment and slash, and temperatures warm enough to support development) limit the distribution and abundance of Coastal Tailed Frog populations. The dynamic nature of this

stream environment (e.g., susceptibility to floods and sediment associated with critical flows; debris flows and landslides) make these frogs susceptible to potential mortality and displacement. A strong association with moist and cool terrestrial habitats may constrain dispersal because of the frog's small size and vulnerability to desiccation (Claussen 1973).

Coastal Tailed Frogs lay a small number of eggs compared to other frog species. Larvae take up to 4 years to metamorphose, with the frogs reaching sexual maturity 3–5 years after metamorphosis (Matsuda *et al.* 2006). Aggregation during breeding and ovipositioning as well as in high-quality larval rearing habitats makes these frogs vulnerable to mass mortality through natural disturbances and anthropogenic threats. These life history attributes may limit certain aspects of recovery efforts (e.g., basin recolonization and maintenance of genetic health), particularly when combined with natural channel events such as landslides and debris flows.

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.[1] Threats presented here do not include limiting factors, which are presented in Section 3.5.[2]

In most cases, threats are related to human activities, but they can also be naturally occurring. The impact of human activity may be direct (e.g., destruction of habitat) or indirect (e.g., invasive species introduction). Effects of natural phenomena (e.g., fire, hurricane, flooding) may be especially important when the species or ecosystem is concentrated in one location or has few occurrences, which may be a result of human activity or the frequency or intensity of these natural phenomenon increase as a result of human activities (e.g., effects of climate change) (Master *et al.* 2009). 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 resilience, and is thus vulnerable to the disturbance. In such cases, the effect on the population/ecosystem would be disproportionately large compared to the effect experienced historically (Salafsky *et al.* 2008).

[1] 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).

[2] 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 recovery/conservation efforts (e.g., inbreeding depression, small population size, and genetic isolation; or likelihood of regeneration or recolonization for ecosystems).

4.1 Threat Assessment

The threat classification below is based on the World Conservation Union–Conservation Measures Partnership (IUCN–CMP) unified threats classification system and is consistent with methods used by the B.C. Conservation Data Centre and the B.C. Conservation Framework. For a detailed description of the threat classification system, see the Open Standards for the Practice of Conservation website (CMP 2015). 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 Coastal Tailed Frog were assessed for the entire provincial range of the species (**Table 1**).

Table 1. Threat classification table for Coastal Tailed Frog in British Columbia.

Threat #[a]	Threat description	Impact[b]	Scope[c]	Severity[d]	Timing[e]
1	Residential & commercial development	Low	Small	Moderate	High
1.1	Housing & urban areas	Low	Small	Moderate	High
1.2	Commercial & industrial areas	Negligible	Negligible	Serious	High
1.3	Tourism & recreation areas	Negligible	Negligible	Negligible	High
2	Agriculture & aquaculture	Low	Small	Slight	High
2.2	Wood and pulp plantations	Negligible	Negligible	Serious	High
2.3	Livestock farming & ranching	Low	Small	Slight	High
3	Energy production & mining	Low	Small	Moderate	High
3.2	Mining & quarrying	Negligible	Negligible	Serious	High
3.3	Renewable energy	Low	Small	Moderate	High
4	Transportation & service corridors	Low	Large	Slight	High
4.1	Roads & railroads	Low	Large	Slight	High
4.2	Utility & service lines	Low	Small	Slight	High
5	Biological resource use	Medium	Restricted	Serious	High
5.3	Logging & wood harvesting	Medium	Restricted	Serious	High
6	Human intrusions & disturbance	Negligible	small	Negligible	High
6.1	Recreational activities	Negligible	Negligible	Negligible	High
7	Natural system modifications	Low	Small	Moderate	High
7.1	Fire & fire suppression	Low	Small	Moderate	High
7.2	Dams and water management/use	Negligible	Negligible	Negligible	High
8	Invasive & other problematic species, genes &diseases	Low	Restricted	Slight	High

Threat #[a]	Threat description	Impact[b]	Scope[c]	Severity[d]	Timing[e]
8.1	Invasive non-native/alien species/diseases	Unknown	Pervasive	Unknown	High
8.2	Problematic native species/diseases	Low	Restricted	Slight	High
9	Pollution	Medium	Large	Moderate	High
9.2	Industrial & military effluents	Low	Small	Moderate	High
9.3	Agricultural & forestry effluents	Medium	Large	Moderate	High
10	Geological events	Low	Restricted	Moderate	High
10.3	Avalanches/landslides	low	Restricted	Moderate	High
11	Climate change & severe weather	Low	Small	Serious–Moderate	High
11.1	Habitat shifting & alteration	Low	Small	Serious–Moderate	High
11.2	Droughts	Low	Small	Serious–Moderate	High
11.3	Temperature extremes	Unknown	Unknown	Unknown	High
11.4	Storms & flooding	Low	Small	Serious–Moderate	High

[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 or decline/degradation of the area of an ecosystem. The median rate of population reduction or area decline for each combination of scope and severity corresponds to the following classes of threat impact: Very High (75% declines), 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 3-generation time frame. For this species, a generation time of 15 years (COSEWIC 2011) was used, resulting in severity being scored over a 45-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 3 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 (cumulative) Threat Impact for this species is High.[3] Two factors are deemed to be of medium magnitude: (1) pollution (largely in the form of sediment and wood slash), and (2) logging/wood harvesting (Table 1). Pollution is expected to affect a large proportion of the species' distribution (31–70%) and cause a moderate level of damage within that scope (an 11–30% reduction in population size). Additional logging/wood harvesting in the province is expected to affect a restricted proportion of the species' distribution (11–30%), but the magnitude of this threat is thought to be serious (potentially reducing the population by 31–70%). These threats are associated with: stream degradation (sedimentation) from chronic bank failure, poor surface water management, increased potential for landslides in areas of steep terrain, and changes in stream hydrology from cross-stream yarding (unmoderated flows) or from clogging by wood slash as a result of this yarding. Logging/wood harvesting causes the loss of high suitability (structurally complex) riparian habitat.

IUCN–CMP Threat 1. Residential & commercial development (impact low)

1.1 Housing & urban areas

Residential development can result in the loss of upland foraging habitats for post-metamorphic life stages, degradation of breeding stream conditions (flow regime, channel morphology, sedimentation levels) because of inadequate no-disturbance zones (buffer widths), and habitat fragmentation extensive enough to disrupt dispersal and metapopulation dynamics. Residential development is currently a threat primarily in the Lower Mainland–Southwest Region, which is the largest economic region of British Columbia and includes the Fraser Valley, Squamish-Lillooet, and Sunshine Coast Regional Districts. A large proportion of the habitat in the Metro Vancouver, Squamish, and Pemberton municipalities constitute floodplains where hillslope channels are absent. As such, threats to the Coastal Tailed Frog occur primarily in the outskirts of town centres, namely in the mountainous areas of the North Shore, Sea-to-Sky Highway communities, Pemberton, and the Sunshine Coast. These "fringe" developments overlap with less than 10% of the species range and are thus small in scope. In addition, only a proportion of streams encompass low to high suitability habitat (e.g., 36% of streams along the Sea-to-Sky Highway [Dupuis 2003]; 40% of stream in the province overall [COSEWIC 2011]). The effects of this threat will vary, depending on geographic location and development size and type, but on average, severity is expected to be moderate.

1.2 Commercial & industrial areas

Commercial and light industrial developments (e.g., public facilities, commercial lots, landfills, municipal well upgrades, saw mills, resource shipping terminals) can degrade and fragment Coastal Tailed Frog habitat in much the same way as residential developments. Commercial and light industrial developments are often within or close to existing municipalities and thus less likely to disrupt undisturbed lands than developments associated with resource extraction. In

[3] 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. This includes 0 Very High, 2 High, 1 Medium–High, 0 Medium, and 8 Low-level threats (Table 1). The overall threat considers the cumulative impacts of multiple threats.

2014, nine proposed commercial facilities were within the species' range (EAO 2014); these are local and expected to affect a negligible proportion (< 1%) of the Coastal Tailed Frog population.

More damaging, heavier industrial activities such as pulp and paper mills can disrupt and degrade habitats, extract large volumes of water, and generate significant effluent discharges to aquatic environments. No new pulp and paper mills have been certified or are proposed within the Coastal Tailed Frog's range (EAO 2014).

Four liquefied natural gas export terminals have been proposed: two near Prince Rupert (Grassy Point and Digby Island), one at Kitimat, and one at Woodfibre near Squamish. These facilities mainly involve the disturbance of shoreline and submerged lands. The primary threat to Coastal Tailed Frogs from the oil and gas industry is the construction and operation of associated pipelines (refer below to threat descriptions pertaining to "Utility & service lines" and "Industrial effluents").

1.3 Tourism & recreation areas

Resorts are not a fast-growing industry within the Coastal Tailed Frog's provincial range. Although resorts can cause habitat loss and degradation, only two are currently proposed (one at Garibaldi in Squamish, and one at Coquihalla Pass); only one resort has been certified since the late 1990s (the Melvin Lake/Cayoosh resort in 2008; EAO 2014). Therefore, the scope of impacts from tourism and recreation developments is negligible.

IUCN–CMP Threat 2. Agriculture & aquaculture (impact low)

2.2 Wood & pulp plantations

To keep up with the increasing demand for bioenergy and wood and fibre-based products, a provincial initiative is seeking to develop new wood product opportunities (Thomas *et al.* 2000; Browne *et al.* 2011). Such opportunities are limited to areas within a short (< 100 km) distance from pulp and wood facilities, where access structures are already in place and no environmental concerns exist, and where the potential for insect infestations and disease are minimal but the application of herbicides is an option (B.C. Ministry of Forests and Range 2010). Such pulp plantations will likely pose a negligible threat to Coastal Tailed Frogs as they target currently disturbed areas close to existing facilities for processing wood products. Although plantations are subject to riparian development constraints under the *Forest and Range Practices Act*, the severity of this threat is considered serious if they were to occur in Coastal Tailed Frog habitats; monocultures are environments incapable of sustaining terrestrial life stages in the long term. Research has shown reduced recruitment to adulthood in watersheds dominated by young seral stages.

Given the higher elevation range of this species, little conflict is expected with agricultural areas, which tend to occur primarily in valley bottoms. Future wood and pulp plantations have been discussed sporadically. No definite plans or proposals exist but may require consideration within the 3-generation time frame. At present, this threat impact is considered negligible.

2.3 Livestock farming & ranching

Rangelands occur primarily in low-elevation grasslands and open forests, which are widespread in the province's Bunchgrass, Ponderosa Pine, and Interior Douglas-fir biogeoclimatic zones. With the exception of the expansive livestock farms in the Fraser Valley, livestock farms and rangelands are small and scattered in low-lying areas within the Coastal Tailed Frog's range, and likely occupy a small to moderate portion of its range (< 10%). The severity of the threat within the affected proportion of the population is slight because rangelands generally only overlap with the lower reaches of mountain streams. Livestock impacts include riparian habitat degradation, localized streambank erosion, increased stream temperatures, and methane pollution.

IUCN–CMP Threat 3. Energy production & mining (impact low)

3.2 Mining & quarrying

Mining and quarrying operations can cause aquatic and riparian habitat loss and degradation. Two ore mines and one aggregate mine have been certified within, or at the periphery of, the Coastal Tailed Frog range since the mid-1990s (EAO 2014). Under review are two proposed aggregate quarries, and two proposed carbonate quarries with facilities for producing magnesium rock. Together, these mines account for less than 1% of the species' range and thus potential impacts are considered negligible. Threat severity is expected to be serious because mines and quarries generally involve extensive habitat loss and degradation.

3.3 Renewable energy

Renewable energy in coastal British Columbia is primarily hydroelectric (one geothermal plant is proposed within the frog's range near Pemberton; no wind farms are proposed). Most hydroelectric projects involve clusters of interconnected run-of-river facilities on several different streams. Seven are currently certified and another five proposals are under EAO review. Each of these projects will generate 44–180 MW. Most are found on the South Coast (Lower Mainland, Pitt Meadows, Upper Harrison Lake, Pemberton, Narrows Inlet, Jervis Inlet, and Toba Inlet); two are on the Central Coast (Bute Inlet - just north of Toba Inlet, Bella Coola), and one is on the North Coast (Kitimat). An estimated 40 basins likely containing Coastal Tailed Frogs will be affected by these developments. Smaller run-of-river facilities, which are not subject to a review under the *Environmental Assessment Act* (EAA), will also affect some streams.

Given that run-of-river facilities are localized and that some occur in streams of limited to moderate suitability to Coastal Tailed Frogs (i.e., too large to be optimal breeding sites), the threat from these projects is thought to be small in scope (though project footprints can be quite extensive in some parts of the species' range). Hydroelectric projects can cause aquatic and riparian habitat loss and degradation as a result of diversion reaches, intake structures, penstock/road stream crossings, and riparian encroachment by facilities and infrastructure. In areas of high drainage density, and where tributaries are incised (gullied), penstock crossings can cause substantial aquatic and terrestrial habitat loss, directly affecting adults and juveniles; these facilities can also disrupt aquatic and terrestrial movement and dispersal within a watershed. Salvage efforts to relocate terrestrial life forms to new habitats, from habitats slated for destruction, may not be completely effective if captured individuals return to the sites from which they were salvaged, or if carrying capacity at relocation sites is limited (Moss and Dupuis 2007).

Threat impacts arise when installing culverts in gullies containing tailed frogs or when filling gullies to accommodate the passage of the rigid penstock piping across the tops of banks (B. Pollard, pers. comm., 2015). Movement and connectivity can also be hindered by large intake structures, particularly where several interconnected facilities are established within multiple neighbouring catchments. In some large basins, the diversion of water through a penstock might reduce water power and associated channel instability, thereby increasing habitat suitability. The level of threat is influenced by the size of the power project, its juxtaposition within a basin, the physical attributes of the project area, Coastal Tailed Frog habitat suitability, and the effectiveness of mitigation measures employed to minimize mortality and loss of habitat. Based on several ramping commissioning studies conducted by Ecofish, tadpoles do not appear to be stranded as a result of rapid ramping rates at run-of-river operation start-up, during flows after start-up, or during emergency or maintenance shutdown periods (D. Lacroix, pers. comm., 2014). Generally, the severity of this threat is considered moderate (although severe in areas with high concentrations of drainage gullies) and the overall impact low; however, hydroelectric projects bring a concomitant threat of transmission lines (refer below to threat descriptions pertaining to "Utility & service lines").

IUCN–CMP Threat 4. Transportation & service corridors (impact low)

4.1 Roads & railroads

Roads include highways and other roads used primarily for public transportation, as well as resource roads used by the forestry, oil and gas, mining, and renewable energy sectors. Resource roads are prevalent in the landscape, and primarily associated with timber harvesting. In 2005, forestry road density in the coast and Mountain Ecoprovince was 0.5 km/km^2 (increasing by 0.06 km/km2 from 2000 to 2005), and road density in the Georgia Depression Ecoprovince, that includes the Lower Fraser Valley, was much higher at 2.7km/km2 (B.C. Ministry of Environment 2007). Conversely, highways and public roads are concentrated in three areas within the Coastal Tailed Frog's range, including the Terrace corridor (Highway 16 and associated road network), the Bella Coola corridor (Highway 20 and associated road network), and the South Coast (especially Highways 101, 99N, 1, and associated roads as these intersect hillslope channels). No highway or large public road developments are currently proposed in the South Coast, Terrace, or Bella Coola corridors. Road works are localized and population effects are expected to be negligible in scope.

Habitat degradation impacts are greatest during the construction of new roads or the widening of existing road alignments. Construction and upgrades involve vegetation clearing and soil disturbance (terrestrial habitat loss), and instream works for culvert and bridge replacements/installations (aquatic habitat loss). Roads can fragment forest habitats and interfere with movement and dispersal of metamorphs, juveniles, and adults. Culverts can potentially hinder tadpole movements by disrupting channel beds and local flow patterns, particularly if these culverts are suspended above the channel bed. Vehicles using roads can cause direct frog mortality (e.g., Vanlaar *et al.* 2012; Malt 2013). Threat severity is expected to be slight for several reasons: the majority of roads occur in upslope habitats less occupied by Coastal Tailed Frogs (i.e., not near and parallel to watercourses); some downstream drift by tadpoles does occur through culverts (L. Dupuis, pers. obs., 2006, 2007); there are no known road mortalities for this species; and the Coastal Tailed Frog does not migrate in mass during the spring or fall as do some other amphibian species.

Insufficient knowledge is available to assess railroad impacts to Coastal Tailed Frog populations, but these are expected to be negligible as railroads occupy less than 1% of the frog's range.

4.2 Utility & service lines

Utility and service lines include BC Hydro transmission lines, power lines associated with energy facilities, as well as oil and gas pipelines.

The southern portion of the 344-km Northern Transmission Line recently established between Terrace and Bob Quinn Lake likely intersected Coastal Tailed Frog streams. The doubling of the 255-km Interior–Lower Mainland transmission line between Merritt and Coquitlam intercepted Coastal Tailed Frog streams, although most of the route coincided with existing rights-of-way. No large BC Hydro transmission line projects are currently proposed (EAO 2014).

Power lines are required to tie in local electricity supplies from energy projects with the existing BC Hydro grid. These power lines can be lengthy and intercept numerous creeks. Only six large renewable energy projects are currently proposed for coastal British Columbia (EAO 2014) but transmission lines are also associated with smaller projects (< 50 mW) not being tracked through the Environmental Assessment Office.

The EAO is currently reviewing three LNG pipelines, including: (1) the Pacific Northwest pipeline from Summit Lake (north of Prince George) to Kitimat, 200 km of which would intercept the Coast Mountain Ranges in the mid-coast region; (2) the Prince Rupert Gas Transmission pipeline from Hudson Hope to Lelu Island near Prince Rupert, 200 km of which would intercept the Coast Mountain Ranges just south of the species' northern range limit; and (3) the West Coast Connector, which would involve a 851-km pipeline from the Cypress area of the south coast to Prince Rupert (EAO 2014). More than 90% of this latter pipeline will intercept the Coastal Tailed Frog's provincial range.

Enbridge's proposed Northern Gateway Pipeline to ship oil from Alberta's tar sands to Kitimat would cross dozens of Coastal Tailed Frog streams (Pembina Institute 2006). The Kinder Morgan oil pipeline already exists, but the planned tripling of this pipeline's capacity would cause new areas of disturbance across the species southern range, which would likely affect numerous creeks. Based on the width of the Coast Mountains near Kitimat and Vancouver, the Northern Gateway and Kinder Morgan pipelines would intercept approximately 500 km of mountainous terrain that overlaps Coastal Tailed Frog habitat.

Potential upcoming utility and service line corridors may intercept numerous Coastal Tailed Frog breeding streams (across an estimated 2,000–3,000 km distance of coastal forests), but these corridors have a narrow footprint and thus should not result in a substantial loss of Coastal Tailed Frog habitat. Although disturbance during construction might be significant, disturbance after construction is limited to maintenance works (i.e., continual tree and shrub removal).

IUCN–CMP Threat 5. Biological resource use (impact medium)

5.3 Logging & wood harvesting

Provincial Crown land, which makes up 93.4% of British Columbia (B.C. Ministry of Forests, Lands and Natural Resource Operations 2011), has been subject to widespread timber harvesting. Logging results in upstream and riparian habitat loss and degradation (conversion from old to young seral stages). The literature indicates that the loss of old (140+ years) riparian and adjacent upslope forest is harmful to juvenile and adult Coastal Tailed Frogs (Welsh 1990; Corn and Bury 1991; Richardson and Neill 1995; Bull and Carter 1996; Dupuis and Steventon 1999; Aubry 2000; Welsh and Lind 2002; Stoddard 2002; Kroll *et al.* 2008; Hawkes and Gregory 2012; McEwan 2014). Tailed frogs have a higher need for moisture and a lower ability to absorb water than do other forest frogs (Claussen 1973); riparian and old forests in coastal British Columbia are generally moist, cool, and microclimatically stable (Chen et al. 1993; Brosofske *et al.* 1997; Chen *et al.* 1999).

McEwan (2014) found that undisturbed sites with intact upland and riparian forest have more frogs than sites with a logged upland, even if the riparian forest is retained (varying buffer widths up to 50 m); however, frogs were not absent from logged habitats, and were found associated with structural complexity and moist microsites, such as ephemeral drainages and wet draws.

Hawkes and Gregory (2012) provided compelling evidence for reduced Coastal Tailed Frog abundance as a result of canopy removal in an experimental setting (buffers 10–30 m wide) in dry forests dominated by Douglas-fir. Before logging, the relative abundance of Coastal Tailed Frogs was positively associated with greater canopy cover. After logging, the canopy cover was effectively zero, as was the abundance of Coastal Tailed Frogs (Hawkes and Gregory 2012). The near absence of frogs in this logged drier forest type (Douglas-fir, cedar, hemlock), compared to the wetter Coastal Western Hemlock variants of the Skeena and mid-coast, implies a regionality in the response of Coastal Tailed Frogs to logging.

Although increased larval numbers were observed in streams running through new clearcuts (Richardson and Neill 1995; Matsuda 2001; Matsuda and Richardson 2005), these densities do not reflect population sustainability. Tadpoles readily move downstream from intact upstream habitats. The possibility of recolonization is reduced if the scope of logging is extensive enough to remove source habitats within a watershed. The persistence of Coastal Tailed Frogs for a few years after logging followed by precipitous declines (Hawkes and Gregory 2012) aligns with the concept of a temporal lag affecting populations suggested by Spear and Storfer (2008). Moreover, the number of individuals surviving to reproductive age dictates population viability in the long term (Winker *et al.* 1995).

At the landscape level, logging disrupts movement and dispersal through habitat fragmentation. Preliminary data show that loss of forest cover may lead to a genetic bottleneck (Wahbe *et al.* 2005). More specifically, tadpoles in clearcuts appear less genetically diverse than those in old growth and exhibit no relationship between physical distance and genetic relatedness; genetic similarity decreased with the physical distance of tadpoles from streams flowing through old growth. Spear and Storfer (2008) used landscape-level genetic analysis to assess the effect of habitat fragmentation caused by large-scale timber removals on tailed frog connectivity, finding that intact forest patches (forests with closed canopy cover and low solar radiation) were necessary for gene flow. In British Columbia, Dupuis *et al.* (2010) suggested that large

reductions in Coastal Tailed Frog populations are the predicted result of a more than 50% loss of their riparian forest habitat. Even at lower harvest levels, logging has the potential to cause substantial declines, given the tendency for frogs to seasonally concentrate at specific locations along streams and nearby wet features.

In coastal areas of the province, 41% of forests are old (140+ years) but most of this is at high elevation. Although Coastal Tailed Frogs do occupy high-elevation habitats, these can be limiting in areas of high relief, high ruggedness, and cold temperatures. As of 2002, much low-elevation forest had been eliminated (B.C. Ministry of Environment 2007); a total of 860,000 ha (26%) remains, of which 260,000 ha (8%) are protected in parks and old-growth management areas (B.C. Ministry of Forests and Range 2006; Ancient Forest Alliance 2013). As such, mid-elevation forests are an important stronghold for this species yet are at risk of increased fragmentation and degradation. Undeveloped watersheds, which covered 26% of the province's forested land base in 2006, are expected to cover 18% of the forested land base in the long term (B.C. Ministry of Forest and Ranges 2006). This level of old forest loss is expected to affect 11–30% of the Coastal Tailed Frog population. A serious cumulative effect is expected because of the decades it takes for a forest to recover its old-growth characteristics and because of the already substantial cumulative loss of habitat based on the proportion of young age classes in coastal areas (19% in the mid-1990s).

Cross-stream yarding can cause stream temperatures to rise (Brown and Krygier 1970; Holtby 1988) by removing shading vegetation and causing streams to widen through lateral (bank) instability (Pike et al. 2010). Logging can cause increases in maximum stream temperatures to persist for 15 years (Johnson and Jones 2000). Maximum temperature thresholds do not appear to reach lethal levels for Coastal Tailed Frogs (> 21°C) based on research on the effect of forest fires on stream temperatures (Hitt 2003; Mahlum *et al.* 2011).

In addition to terrestrial habitat loss and increased stream temperatures, large-scale forest removal and associated road construction can change a watershed's hydrological regime (Jones and Grant 1996). Roads intercept shallow groundwater and convert it to surface flows in ditch lines, with surface flow much more rapid than groundwater flow. Thus, road networks can increase the drainage efficacy in the landscape, causing a greater amount of scour and sediment transport and decreasing channel stability during peak flow events, with reduced base flows during the summer when the species is most active. The latter can lead to increased stream impermanence and reduced habitat for aquatic life stages (COSEWIC 2011).

In summary, timber harvesting represents a serious threat to Coastal Tailed Frogs. Although previously pervasive, a restriction in this threat's scope is expected in the next 10 years (even with continued high rates of harvest for log export in some areas such as the Skeena Region; L. Vanderstar, pers. comm., 2014). Additional habitat loss and fragmentation will arise as a result of future harvesting activities, but the effects from past timber harvesting persist because it takes decades for old riparian and upslope forests to become re-established. Threat severity remains serious, especially in watersheds that are extensively logged.

IUCN–CMP Threat 6. Human intrusions & disturbance (impact negligible)

6.1 Recreational activities

Throughout the populated portion of coastal British Columbia, networks of trails are particularly common on the outskirts of existing communities; however, much of this region is unpopulated and thus the scope of threat and the severity of any impacts from trail networks should be negligible.

IUCN–CMP Threat 7. Natural system modifications (impact low)

7.1 Fire & fire suppression

Fire can result in mortality of juvenile and adult Coastal Tailed Frog populations, and reduce riparian and upland habitat quality through combustion of understory vegetation and surface materials (Pilliod *et al.* 2003). It can take decades for terrestrial communities to regain original levels of productivity and structural diversity and as such fire may affect carrying capacity and long-distance movements. Nevertheless, Spear *et al.* (2012) demonstrated that tailed frogs and other amphibians have a high level of resilience to natural catastrophic disturbance in the long term, particularly if affected areas are left to regenerate naturally. More specifically, Spear *et al.* (2012) found that tailed frog recolonization of the 600 km^2 blast area 30 years after the Mount St. Helens eruption was widespread and from multiple sources. Gene flow in the unmanaged portion of the blast area was only influenced by distance between sites and the frost-free periods ($r^2 = 0.74$), whereas gene flow pathways in areas subject to salvage logging and replanting was strongly limited by the physiologically important variables of heat load and precipitation ($r^2 = 0.83$). This work suggests that lack of understory and coarse woody debris (i.e., downed logs and snag boles) refugia in salvaged areas may leave frogs susceptible to desiccation and mortality, and that naturally regenerating habitat may better maintain the genetic diversity of populations over the long term.

In the short term, a fire typically burns irregularly and leaves scattered vegetation patches in its wake. This is particularly true in areas of reduced solar radiation such as deep valleys, and in older forests with open crowns and large coarse woody debris capable of withstanding combustion—these features reduce fire intensity and slow rates of fire spread (Lindenmayer 2009). Islands of unaffected habitat serve as source pools for local recolonization of areas (Mazza 2010). In coastal, mountainous areas unaffected habitat may include gullies, riparian zones (especially along incised streams with northern aspects), deep valleys, and older forests. During hot summer conditions, when wild fires in North America are most likely to burn, amphibians tend to hide in moist underground refuges or near water (Pilliod *et al.* 2003), further increasing their chance of survival. Many Coastal Tailed Frogs likely seek underground refuge within the hyporheic zone underlying streams and riparian forests during the fire season.

Fire may cause stream temperatures to rise to lethal levels for larvae but many individuals appear to survive in pockets of low-intensity burns over creeks (Friele 2006). Hitt (2003) reported a rise (i.e., from 7.8 to 17.2°C) in water temperature 900 m downstream from a severe intensity wildfire in Montana, although maximum temperatures did not exceed the thermal threshold for fish and aquatic insects. Mahlum *et al.* (2011) examined effects of wild fires on maximum water temperature for a suite of second- to fourth-order streams with a range of burn severities and found no apparent increase in maximum water temperatures during the fires. One month later

and in the subsequent year, increases of 1.4–2.2°C were observed in burned sites over reference sites with the greatest differences in late summer. Maximum temperature changes at sites more than 1.7 km downstream from burns did not differ from those at reference sites. Seven years after the fires, maximum stream temperatures apparently did not return to pre-fire norms. Although temperatures do not typically reach lethal temperatures for tadpoles, changes in temperature arising from fire are likely long lasting and exacerbated by forestry and climate change.

Delayed effects of fire consist primarily of erosion and sedimentation, including slope wash of charcoal, ash, sand and fine gravel, and landslide or debris flow activity (Wondzell and King 2003). The degree of erosion and sedimentation depends on the severity of the burn, topography, and occurrence of intense rainfall before significant re-vegetation (Miller *et al.* 2003).

Storm-generated overland flow soon after a severe wildfire, which has consumed the duff layer and exposed bare mineral soil, can lead to stream sedimentation, particularly on steep slopes or where there is direct channel connectivity. Small headwater channels traversing a burnt area may act as sediment vectors to larger mainstems (Benda *et al.* 2003). Sedimentation can cause mid-term (< 10 year) declines in larval populations if levels of fines are high. Critical flows (discharge rates during peak events) eventually restore natural channel conditions over time, although this process may be slow in streams with low transport potential.

In summary, fire impacts should be low for this species because natural burns are small in scope, occurring only rarely in moist biogeoclimatic zones such as the Coastal Western Hemlock zone (Wong *et al.* 2004). Threat magnitude is moderate as many individuals are likely to survive in the areas of light-intensity burns; Coastal Tailed Frogs are capable of recolonizing areas subject to catastrophic natural disturbances in the long term (the effect of fire on tadpoles appears low). Fire is a greater threat in continental areas along the periphery of this species' range, where young forests are more widespread and precipitation levels are lower. The fire threat is expected to increase with climate change (refer below to threat descriptions pertaining to "Climate change & severe weather").

7.2 Dams & water management/use

Water-bottling plants could cause localized aquatic habitat loss from water diversions and riparian habitat loss as a result of facility establishments. One bottled water project was certified in 2011 and no new ones have been proposed to date (EAO 2014). The certified bottled water project involves the removal of 110 m^3 of water per day from 34 different streams located at Bute, Toba, Jervis, and Knight Inlets. The extraction takes place in a subset of streams from one inlet at a time, and involves the removal of a maximum of 10% of stream flow for a period of up to 1 hour. Water is passively removed using a funnel and pipe extended from a skiff equipped with a telescopic arm, which is placed into a waterfall or deep pool just above tide water. Tadpoles occurring in these areas may be subject to direct mortality from the telescopic arm. No shore facilities are involved, and no vegetation is removed from the extraction sites. The water is off-loaded to a barge and transported to a facility on Vancouver Island. This project has negligible effects on Coastal Tailed Frog populations.

Other water management projects include development of river crossings or marinas, de-watering projects, and the establishment and use of reservoirs and groundwater wells. Aside from two well projects occurring within the Coast Mountain Ranges, no water management

projects have been established in the province since the late 1990s (EAO 2014). Well developments involve the withdrawal of water from aquifers and do not affect habitat in hillslope channels.

IUCN–CMP Threat 8. Invasive & other problematic species & genes (impact low)

8.1 Invasive non-native/alien species

Amphibians are prone to chytridiomycosis, which is an infectious disease caused by the aquatic fungal pathogen *Batrachochytrium dendrobatidis* (Bd). Chytridiomycosis is linked to worldwide declines in amphibians but does not cause declines in all infected species (e.g., Pilliod *et al.* 2010). Based on several studies of Bd contamination in North American streams, which examined 1,322 individuals from 21 species, only 3% of sampled stream amphibians were Bd-positive. This represents a low infection rate compared to rates observed in no-flow or slow-flowing wetlands in the same regions, and in streams of Central America and Australia (Hossack *et al.* 2010). Differences in infection rates may be related to species-specific vulnerability to chytridiomycosis or to habitat and climate differences. In a study involving 226 Coastal Tailed Frogs from 14 first- to third-order streams in the United States Pacific Northwest, Hossack *et al.* (2010) found that three adult Coastal Tailed Frogs (1.3% of individuals) from one stream in Oregon were infected; these individuals had low estimated zoospore loads and did not exhibit signs of chytridiomycosis. Although Bd occurs throughout British Columbia, it has not yet been found in the province's populations of the Coastal Tailed Frog (M. Todd and P. Govindarajulu, unpublished data). The threat impact and severity of Bd is currently unknown, but the effect of this disease could be widespread.

Introduced trout can enter some lower-elevation stream reaches, becoming predators of Coastal Tailed Frog tadpoles. Such streams tend to be close to urban and recreation areas and are few in number, affecting less than 1% of the species' population.

8.2 Problematic native species

Filamentous algae may eliminate substrate surfaces on which tadpoles adhere to resist displacement from flows, and reduce the amount of exposed rock surface on which tadpoles graze for periphytons (Feminella and Hawkins 1994). These algae occur in slower, more exposed streams and can dominate when flows are very low, and in the absence of forest canopies.

IUCN–CMP Threat 9. Pollution (impact medium)

9.2 Industrial & military effluents

Aquatic habitat can be compromised by pollution from the breaching of tailings ponds, or from acid drainage into streams. Two ore mines and one aggregate mine have been certified within or at the periphery of the Coastal Tailed Frog range since the mid-1990s (EAO 2014). Under review are two proposed aggregate quarries, and two proposed carbonate quarries with facilities for producing magnesium rock. Together, these mines account for a very small portion (< 1%) of the species' range.

Oil spills from pipelines could contaminate local habitats. Spills at creek crossings would contaminate reaches downstream as well. Spills can potentially reduce species survivorship and ecosystem productivity (Service *et al.* 2012). A 10–1,000 m^3 spill has occurred on average every

16 years per 1,000 km section of pipeline (NEB 2010); this implies a local spill for every two generations of Coastal Tailed Frogs. Van Hinte *et al.* (2007) calculated that the average spill between 1992 and 2002 among eight major spill events in Canada was 9,814 barrels (the largest spill was 25,000 barrels). Despite the length of pipelines proposed in the province (~ 1,800 km), areas affected by a spill would be relatively local (affecting < 1% of the species' range). Nevertheless, effects are expected to be serious, resulting in habitat loss and/or degradation, as well as mortality from contamination.

9.3 Agricultural & forestry effluents

Sedimentation associated with logging roads can cause significant degradation of stream habitats. Even though inactive roads are often chronic sources of sedimentation, heavily used active roads can produce up to 130 times more sediment than abandoned ones (Reid and Dunne 1984). Logging road density in the Coastal Tailed Frog range ranged from 0.5-2.7 km/km^2 as of 2005 (B.C. Ministry of Environment 2007). In addition to sedimentation from roads, logging can also introduce sediments into streams when timber harvesting triggers landslides in unstable areas (Rollerson *et al.* 2001; Millard *et al*. 2002), and during cross-stream yarding practices when banks become more prone to failures as trees are removed, reducing the tensile strength of the soil mantle (Beschta 1978). Regulations under the provincial *Forest and Range Practices Act* are geared towards fish and fish habitat mitigation and protection, and do not generally protect smaller hillslope channels and banks, which are the typical habitats favoured by Coastal Tailed Frogs. Sedimentation can also arise from improper surface runoff management and from road failures. Declines in tadpole abundance following timber harvesting and road construction are well documented (Gaige 1920; Noble and Putnam 1931; Metter 1964; Murphy *et al.* 1981; Bury 1983; Corn and Bury 1989; Aubry and Hall 1991; Bull and Carter 1996; Welsh and Ollivier 1998; Ardea 1999; Dupuis and Steventon 1999; Biek *et al.* 2002; Welsh and Lind 2002). Sediments fill the interstitial spaces between larger rocks and can wash out stable step-pool bedforms in streams with relatively low critical flows and/or unstable rock types (Dupuis and Friele 2006). High-risk areas include channels incised in incompetent rock, erosion-prone rock types, or thick glacial sediments, with low water transport potential (COSEWIC 2011). Threat severity is variable and governed by watershed steepness, rock type, and discharge rates. Wood (logs and slash) is also a forestry effluent in streams that are subject to machines and cross-stream yarding. By clogging low-order (i.e., class S5 and S6) streams, large amounts of woody debris can degrade step-pool morphologies, impede tadpole movement, and eliminate foraging substrates (L. Dupuis, pers. obs., [1995-2005]; P. Friele, pers. obs., [1995-2005; 2007-2009]; L. Vanderstar, pers. comm., 2015).

Coastal Tailed Frogs are not found in areas of high agricultural use and are thus not typically exposed to agricultural pollutants.

IUCN–CMP Threat 10. Geological events (impact low)

10.3 Avalanches & landslides

Coastal Tailed Frogs are adapted to landscapes prone to natural landslides and debris flows. These events, although devastating where they occur, tend to be localized in nature and are unlikely to cause irreversible population declines. Landslides and avalanches are exacerbated by large-scale timber removal and by roads built in areas with unstable terrain.

IUCN–CMP Threat 11. Climate change & severe weather (impact low)

An average temperature increase of 1.4–5.8°C by 2100 is currently predicted for British Columbia, which could result in a decreased snowpack, increased winter rain (and flows), earlier spring freshet, increased flood risk, greater water turbulence and related scouring, and lower summer flows and drought-associated low flows (Hamlet and Lettenmaier 2000; Gayton 2008). Tadpoles thrive when channel conditions are stable but increased storm events and flood risks could lead to loss of channel stability and increased tadpole mortality from churning during bedload movement events.

Similarly, declining snowpack and summer low flows could lead to increased stream impermanence and the shrinking of aquatic habitats, particularly in the headwaters. Loss of headwater habitat can reduce connectivity between basins by increasing the overland distance between channels. Coastal Tailed Frogs are known to survive drought conditions by moving to subsurface flows (tadpoles; Zevit and Matsuda 2010) or terrestrial hollows (frogs); however, the extended periods of drought predicted by climate change models are likely to cause declines in fitness and survivorship, and to affect metapopulation dynamics (i.e., increase isolation by unsuitable habitat). The effects of habitat shifts, headwater shrinking, droughts, storms, and flooding are unknown but are likely to range from moderate to serious. The stream and ambient temperature thresholds reached as a result of climate change are unknown. Stream temperatures of 18.5°C are lethal to eggs, whereas temperatures of 21–24°C are lethal to frogs.

Road developments and run-of-river projects, increased fire events, and landslides are likely to exacerbate the threats of climate change. In analyzing the timing of amphibian species losses in relation to changes in sea surface and air temperatures, Pounds *et al.* (2006) concluded that many highland localities in the Americas are shifting towards the growth optimum of Bd (see Threat 8.1 above), which could encourage outbreaks of the disease. The scope and severity of climate change effects, and the cumulative effects of climate change in conjunction with other ongoing threats are currently unknown.

5 CURRENT MANAGEMENT FRAMEWORK

The Identified Wildlife Management Strategy (IWMS) guides the implementation of management actions for species at risk under the *Forest and Range Practices Act*, including the establishment of species-specific wildlife habitat areas (WHAs). Coastal Tailed Frog WHAs are meant to maintain important streams and suitable breeding areas. More specifically, a WHA should be approximately 20 ha in size, although size will vary with site-specific factors, and its boundaries should be designed to maintain stream conditions (substrate, temperature, macro-invertebrate, and algae communities).

Wahbe et al (2004) recommended preserving groups of interconnected streams, and this approach has been advocated in WHA design (Dupuis and Friele 2003; Michelfelder *et al.* 2008). As currently defined in the IWMS guide, a Coastal Tailed Frog WHA should include at least two streams or stream reaches (e.g., class S5 or S6) with evidence of tailed frog presence (B.C. Ministry of Water, Land and Air Protection 2004b). A 30-m core area and 20-m management zone should be established on both sides. On slopes that exceed 60%, the WHA should extend to

the top of the inner gorge. When several streams with these characteristics occur, priority is given to sites adjacent to mature or old forest, or with the potential to establish or maintain forest connectivity. Wildlife habitat areas vary by region however: in the Skeena Region where WHAs are basin-wide, 50-m reserve zones are established along tributaries, and the remainder of the WHA represents a special management zone within which general wildlife measures are applied (B.C. Ministry of Environment, 2014a). Logging is not permitted in three of twelve Skeena WHAs; these three represent benchmarks (L. Vanderstar, pers. comm., 2014). General wildlife measures for the remaining nine Skeena WHAs require 70% structural retention (B.C. Ministry of Environment 2014a).

General management measures for Coastal Tailed Frog WHAs (B.C. Ministry of Water, Land and Air Protection 2004b) include the following.

- Maintenance of clean and stable cobble/boulder gravel substrates, natural step-pool channel morphology, and stream temperatures within the tolerance limits of the species.
- Maintenance of microclimatic, hydrological, and sedimentation regimes to: (1) minimize the occurrence of extreme discharge events, (2) limit the mortality rate of tailed frogs during floods, and (3) meet foraging and dispersal requirements of post-metamorphic life stages.
- Maintenance of riparian forest.
- Maintenance of important structural elements (e.g., coarse woody debris).
- Maintenance of water quality and naturally dispersed water flows.
- Minimization of windthrow risk.
- Avoidance of cross-stream yarding.
- Prohibition of pesticide use or chemical applications.
- Provision of adequate stream crossing structures and suitable road designs to minimize impacts to tailed frog instream and riparian habitats.
- Use of wildlife tree retention areas, when possible, to augment the width of management zones.
- Management of stream reaches adjacent to WHAs according to riparian management recommendations.
- Prevention of fish introductions and re-channelization of areas with tailed frog populations.
- Maintenance of slash-free headwater creeks and forested riparian buffers, especially within fragmented areas.

Provincial best management practices for amphibians and reptiles (B.C. Ministry of Water, Land and Air Protection 2004a) outline general management guidelines for tailed frogs, such as:

- maintaining moist forested habitat with abundant coarse woody debris along streams (at least 30 m wide on both banks; the wider, the better);
- taking special care to avoid sedimentation of stream habitats;
- avoiding alteration of stream-flow patterns;
- maintaining pocket and step-pools within streams, and abundant in-stream cover;
- allowing streamside vegetation to recover; and
- using open-bottom culverts to facilitate movements of animals across roads.

6 MANAGEMENT GOAL AND OBJECTIVES

6.1 Management Goal

The management goal is to maintain viable self-sustaining populations of the Coastal Tailed Frog throughout its range.

6.2 Rationale for the Management Goal

The Coastal Tailed Frog is designated by COSEWIC as a species of Special Concern. This classification is assigned to wildlife species that are particularly sensitive to human activities or natural events. Species of Special Concern are not endangered or threatened with extirpation but may become so if adverse effects are neither reversed nor managed with demonstrable effectiveness (http://www.cosewic.gc.ca/eng/sct0/assessment_process_e.cfm). The species' sensitivity results from a biphasic life history, extreme habitat specialization in all phases, low reproductive rates, a narrow stream temperature tolerance, and a physiological intolerance to high temperatures and low humidity in terrestrial environments.

6.3 Management Objectives

The following are the management objectives for Coastal Tailed Frog:

1. to prevent extirpation of populations in occupied Coastal Tailed Frog watersheds through land use conservation practices that:
    a. maintain quality and quantity of stream, riparian, and upland habitats;
    b. protect and prevent degradation of specialized aquatic and terrestrial habitats; and
    c. ensure connectivity within and between populations;
2. to address the knowledge gaps in Coastal Tailed Frog ecology that currently constrain the design of management actions; and
3. to address the knowledge gaps in how Coastal Tailed Frog populations respond to threats and management actions (i.e., effectiveness evaluation of conservation management).

7 APPROACHES TO MEET OBJECTIVES

7.1 Actions Already Completed or Underway

The following actions have been categorized by management objective. The action under each objective is classified by the action groups of the B.C. Conservation Framework (B.C. Ministry of Environment 2010).

7.1.1 Actions completed or underway for Objective 1

Planning

- Coastal Tailed Frog are a focal species for ecosystem-based management, which is an initiative to ensure that landscape and forest management does not create a high level of risk

on the north and central coast (CIT 2004). High- and low-risk habitat thresholds for Coastal Tailed Frogs were developed based on expert opinion (Daust *et al.* 2010).

Habitat protection

- Wildlife habitat areas have been established within watersheds in the four B.C. Ministry of Forests, Lands and Natural Resource Operations regions that intersect the Coastal Tailed Frog's range (Figure 6). Currently, basin-level WHAs conserve and protect 3,876.5 ha in the Skeena Region (Coast Mountains Resource District). Riparian buffer WHAs conserve and protect 187 ha in the West Coast Region (North Island–Central Coast Resource District), 56 ha in the South Coast Region (Chilliwack Natural Resource District), and 384.8 ha in the Thompson–Okanagan Region (Cascades Natural Resource District) (B.C. Ministry of Environment 2014a). An additional 3,302.2 ha of WHA protection is proposed for the Central Coast Region based on a query of DataBC (2005).
- BC Hydro has prepared a protocol for work associated with their facilities and transmission line infrastructure in and around streams (BC Hydro 2014; Connie Miller-Retzer, pers. comm., 2015).
- Other best management practice guidance for Coastal Tailed Frog has been developed for various land uses in the province (B.C. Ministry of Environment 2014b; B.C. Ministry of Forests, Lands and Natural Resource Operations 2014a, 2014c).

7.1.2 Actions completed or underway for Objective 2

Species and population management (research and monitoring)

- A collaborative research program (B.C. Ministry of Forests, Lands and Natural Resource Operations; B.C. Ministry of Environment; University of Northern British Columbia) initiated in 2010 is examining the spatial ecology of the Coastal Tailed Frog at the northern extent of its range in the Skeena Region (Todd *et al*. 2014a). Projects continue to provide valuable information on: the terrestrial habitat requirements and riparian and upland forest use of juvenile and adult frogs (McEwan 2014); factors, including microclimate, that influence tailed frog abundance and distribution at multiple scales (Todd and Johnson 2014; Cadori 2015; Todd *et al.* 2015); reproductive ecology (McEwan *et al.* 2012; Todd *et al.* 2015); population genetics and landscape connectivity (Mosher 2014); and the detection and prevalence of chytridiomycosis in tailed frog populations. Methods for the effective detection and inventory of terrestrial (visual encounter surveys; Millard-Martin 2015) and aquatic life history phases (i.e., eDNA; Murray and Flores 2013; Grob 2014) are also under study. A comprehensive set of research and monitoring protocols are available to ensure comparability in future data collection (Todd *et al.* 2014b).

7.1.3 Actions completed or underway for Objective 3

Planning

- A Wildlife Species Framework has been developed as part of the Forest and Range Evaluation Program (FREP) strategy to evaluate wildlife habitat practices under the *Forest and Range Practices Act* (FRPA; Paige and Darling 2009). Indicators and protocols for determining the effectiveness of FRPA Wildlife Habitat Areas for Coastal Tailed Frog are in

development, or have been developed and are under field testing (e.g., Maxcy 2004; Gyug 2005a, 2005b; Sutherland 2008; Gyug 2012).

- A field pilot for regional effectiveness monitoring of tailed frog WHAs began in 2012 in the Cascades Forest District (Gyug 2012). Further inventories were recommended to help determine the strategic placement of any additional WHAs.
- An effectiveness evaluation of forest practices along smaller mid-coast watercourses (S4–S6 streams) is taking place using the FREP fish/riparian protocol (Tripp et al. 2009) augmented with site-level Coastal Tailed Frog aquatic habitat indicators.
- As part of a provincial initiative to produce an environmental values and components manual for cumulative effects assessment (Robertson *et al.* 2012), an expert elicitation process was undertaken in spring 2013 to address knowledge gaps for Tailed Frog. This process produced a draft knowledge report and tailed frog values summary to identify components, indicators, and benchmarks that can be used in assessing current and future habitat conditions (K. Paige, pers. comm., 2015). Tailed frogs shared many indicators with fish values and watershed process values (see first bullet above).
- One project in the Skeena Region collaborative research program (see Section 7.1.2) is evaluating the conservation effectiveness of WHAs at the basin level to support the development of FREP aquatic and terrestrial monitoring indicators and field protocols for Coastal Tailed Frogs (Todd *et al.* 2014b).
- As part of the Coast Experimental Watersheds Programme, a multi-scale spatial distribution model for Coastal Tailed Frog is currently under development to evaluate the Coast Information Team's physiographic model that was used to support the North and Central and South Central Coast Land Use Orders (Rumsey *et al.* 2004; Leversee 2009). Tailed frog survey and observation data from across the species' range has been compiled and will be available to improve the current distribution map of the species (http://www.mapservices.ca/EBM/). The improved model will be used to guide conservation planning at multiple scales, including future WHA establishment.
- Concern over clusters of south coast independent power projects has triggered government research to monitor the relative abundance of Coastal Tailed Frog in diversion reaches, below tail races, and upstream of the intake ponds. In 2013, the B.C. Ministry of Forests, Lands and Natural Resource Operations initiated a Before-After-Control-Impact (BACI) study to monitor the effects of these projects on Coastal Tailed Frogs. Simon Fraser University's Palen Lab assisted in designing the study and in setting up an appropriate statistical framework that uses multi-season abundance models (refer to Dail and Madsen 2011). Two years of "before" data have been gathered at all the sites. Preliminary analyses were performed to better understand the power of inferences possible with the types of data collected (Malt and Crockett 2013). Results should help understand the impacts of hydroelectric facilities, and may inform future project planning. The ministry recently released guidance for Coastal Tailed Frog monitoring of run-of-river power projects (Malt *et al*. 2014). These guidelines will ensure that data collection methods for other upcoming, large projects are consistent with those of the ongoing study.

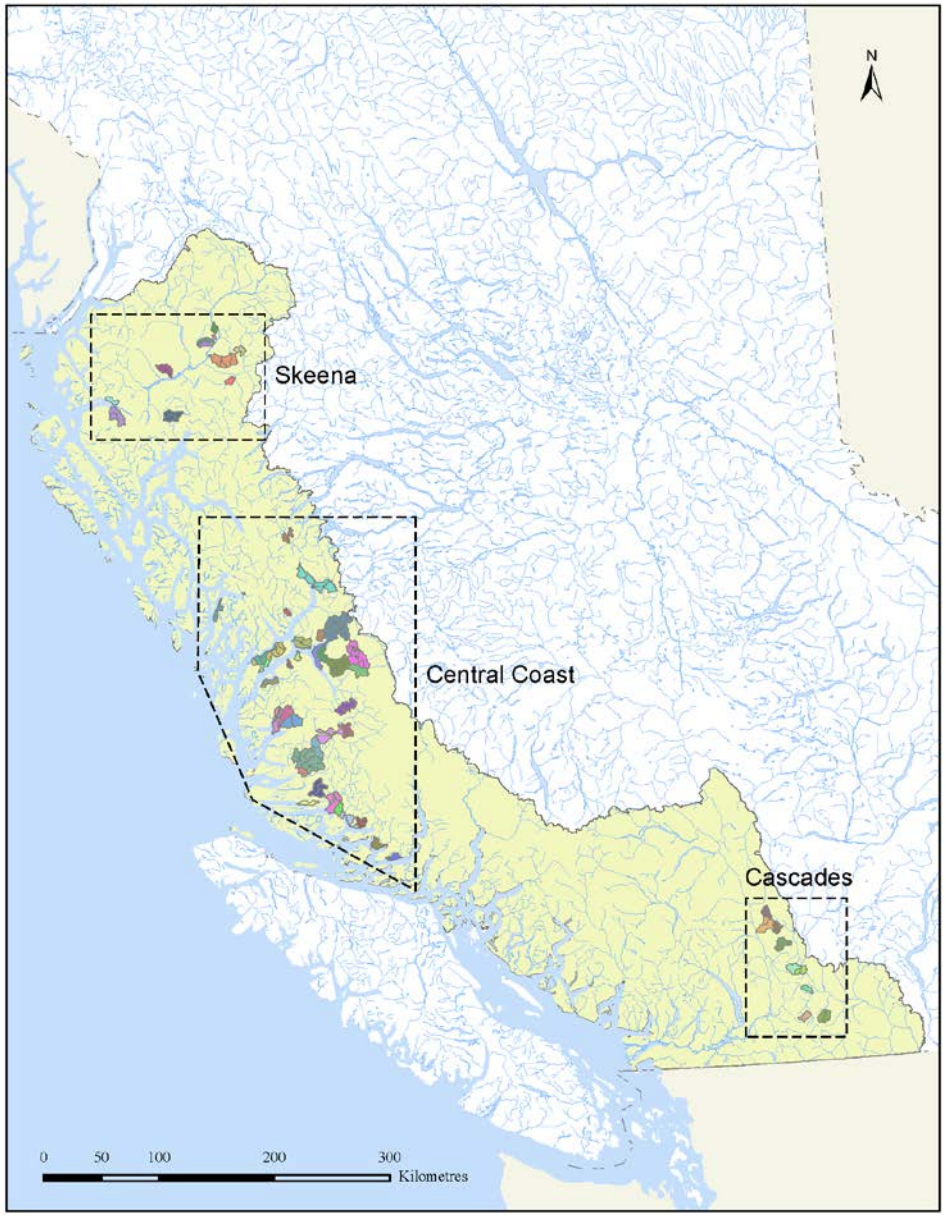

Figure 6. Coloured patches indicate watersheds containing proposed and existing Wildlife Habitat Areas for Coastal Tailed Frog within the known range of the Coastal Tailed Frog in British Columbia (2015 data supplied by Ministry of Environment and Ministry of Forests, Lands and Natural Resource Operations).

7.2 Recommended Management Actions

Table 2 lists recommended new actions by management objective (1–3) and Conservation Framework action groups. See Section 7.1 for the completion and potential extension of ongoing projects.

Table 2. Recommended management actions for the Coastal Tailed Frog.

Objective	Conservation Framework action group	Actions to meet objectives	Threat[a] or concern addressed	Priority[b]
1	Habitat protection	Continue to prioritize the entry of Coastal Tailed Frog records into the Conservation Data Centre database to effectively conserve and manage existing populations	Knowledge gap in distribution	Essential
1	Habitat protection	Conduct inventories in areas where data are scant or non-existent, and improve inventory techniques (e.g., eDNA)	Knowledge gap in distribution	Necessary
1	Habitat protection	Designate proposed WHAs as soon as possible	5	Essential
1	Planning	Use a strategic approach when determining the location of future WHAs to target optimal streams and conservation gaps; site placement should be assessed at a regional and district level; use predictive models as a tool for WHA site selection, followed by field verification	5	Necessary
1	Habitat protection	Improve and implement better WHA designs and measures to address watershed-level protection based on recent research	5	Necessary
1	Habitat protection	Design and implement retention buffers to protect in-stream and streamside riparian habitats for all occupied Coastal Tailed Frog basins	1, 3, 4, 5, 9	Essential
1	Habitat protection	Design and implement best management practices for the protection of structural habitat attributes critical to maintaining frog movement through terrestrial habitats (e.g., ephemeral streams, seeps, moist microsites, large downed wood)	1, 3, 4, 5, 9	Essential
1	Habitat protection	If identified, protect specialized habitats where Coastal Tail Frogs aggregate, such as fall mating locations, spring oviposition sites, and high-quality larval rearing habitats	1, 3, 4, 5, 9	Essential
1	Habitat protection	Design and implement best management practices for location, construction, and maintenance of roads and other linear developments (e.g., pipelines, hydro rights-of-way) and their associated stream crossings	4	Essential
1	Habitat protection	Establish and manage landscape connectivity between Coastal Tailed Frog watersheds through the strategic placement of stand- and landscape- level conservation areas and reserves (e.g., Old Growth Management Areas, Special Resource Management Zones, Wildlife Tree Retention Areas, Riparian Reserve Zones, Riparian Management Zones)	2, 3, 4, 5	Necessary
1,2	Species and population management	Design and conduct genetic research to determine whether the provincial population of Coastal Tailed Frog represents a single subpopulation, and to	Knowledge gap constraining	Beneficial

Objective	Conservation Framework action group	Actions to meet objectives	Threat[a] or concern addressed	Priority[b]
		ascertain the level of connectivity between watersheds	management	
2	Planning	Design and conduct research on the potential effects of climate change to habitat alterations and availability	11	Beneficial
2	Planning	Assess cumulative effects of multiple threats (e.g., timber harvest, roads, hydroelectric development, fire and fire management) to Coastal Tailed Frogs	1, 3, 4, 5, 8, 9	Necessary
2	Planning	Evaluate the effect of potential threats (e.g., run-of-river projects, pipeline developments, invasive species, and emerging disease) to Coastal Tailed Frog populations	1, 3, 4, 5, 8, 9	Necessary
1,2	Species and population management	Design and conduct research on the dispersal and distribution of Coastal Tailed Frogs within and between watersheds; replicate studies to capture potential regional variation	Knowledge gap constraining management	Beneficial
3	Planning	Assess effectiveness of land use conservation management practices implemented by forestry (i.e., FREP monitoring) and other development proponents	1, 3, 4, 5, 9	Necessary

[a] Threat numbers according to the IUCN–CMP classification (see Threat Assessment Table 1 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).

7.3 Narrative to Support Management Actions Table

Recommended actions within Conservation Framework action groups to support some or all management objectives.

7.3.1 Habitat protection

Recommended actions focus on land use practices at multiple scales to conserve and protect populations and habitats. Adequate habitat protection and management needs to occur along all Coastal Tailed Frog streams and address the survival requirements of terrestrial juveniles and adults and aquatic tadpoles. The historic focus of managing for stream integrity is, in part, the legacy of a fish-based approach to stream habitat management, as well as the very low detectability of frogs compared to tadpoles. Good stewardship will become increasingly important as climate change compounds the effects of land use.

Wildlife habitat areas

Wildlife habitat areas are strategic tools directed at the conservation of Coastal Tailed Frog populations and habitats; however, these areas cover a very small fraction 0.12%) of the species' extent of occurrence; L. Dupuis, pers. comm.), and large gaps exist in their distribution (Figure 6). Wildlife habitat areas function as source pools for this species, in the advent that areas subject to large scale and/or stochastic disturbances require recolonization. As such, these areas must provide a maximum of protection on high-suitability, productive streams distributed through the

species' range. Designating proposed WHAs is essential, and locating new areas to fill gaps within the species' range is a necessary priority for the conservation of this species.

The current goal of WHAs is to maintain important streams and suitable breeding habitats, and the focus of WHA design and general wildlife measures is to protect stream-associated habitat quality (B.C. Ministry of Water, Land and Air Protection 2004b). However, recent adult frog telemetry research in the Skeena Region shows that this species is reliant on good canopy cover and cool/moist conditions for movement throughout riparian and upland forests (McEwan 2014). Adults and juveniles are highly mobile and vulnerable to disturbance during seasonal movements through forests to and from specialized terrestrial and aquatic habitats (Todd and Johnson 2014; Todd *et al*. 2015). Spear and Storfer (2008) demonstrated that the loss of mature forest cover is associated with genetic bottlenecks for this species on Washington's Olympic Peninsula.

Existing WHAs are primarily stream buffer designs, ranging from 100 m to several kilometres in length along targeted Coastal Tailed Frog streams. Re-designing WHA dimensions and general wildlife measures is necessary to protect all Coastal Tailed Frog life history stages and to address the important conservation role of these areas as species source pools within landscapes. Watershed-level designs should be anchored on windfirm reserves 50 m or more wide to protect larval stream and riparian forest habitats. General wildlife measures outside of reserves should conserve canopy cover, protect moist upland habitats (e.g., seepages, wet draws, ephemeral streams), and retain and recruit important structural attributes, such as large downed woody debris and shrub understory, which facilitate frog movement through forests.

The effectiveness of Coastal Tailed Frog WHAs as source pools to recolonize disturbed landscapes will improve if forest linkages are established between their borders and neighbouring watersheds. Research shows high rates of gene flow between watersheds in the Olympic Peninsula; this gene flow occurred terrestrially as connectivity was high across unconnected river basins (Spear and Storfer 2008). Similarly, the strategic placement of WHAs with other types of landscape-level conservation areas and reserves (i.e., old growth management areas and WHAs for other identified wildlife species) will help keep watersheds within landscapes connected.

Best management practices

Stream retention buffers and best management practices are essential to maintain functional tailed frog habitats and populations across landscapes between WHAs. At lower latitudes, Coastal Tailed Frog populations are resilient to catastrophic disturbance and periodic intensive land use, as long as source populations remain available and opportunities are in place to facilitate recolonization (e.g., Spear *et al.* 2012; Aguilar *et al.* 2013).

Where present, tailed frogs are resident throughout streams, riparian areas, and upland forests, with high larval densities in optimal rearing stream reaches, and frogs moving seasonally through terrestrial environments to and from specialized habitats such as oviposition or mating sites. All occupied tailed frog tributaries should therefore have some stream-side retention to protect aquatic habitats and maintain functional terrestrial habitats adjacent to streams through which frogs may move. Variable stream retention buffer designs will reflect site characteristics (e.g., topography, slope, and gradient) and habitat quality (e.g., presence of specialized tailed frog habitats). The need for windfirmness will influence buffer design and may require management

actions adjacent to buffers. For example, a retention buffer should be 30 m wide to allow for an effective (wind-firm) 20-m wide protective streamside setback (Lars Reese-Hansen, pers. comm., 2015).

Research indicates seasonal concentrations of Coastal Tailed Frogs within 5–10 m of streams in tailed frog basins, and generally higher relative densities within 30 m of streams throughout the growing season (e.g., Matsuda and Richardson 2005; McEwan 2014). Nevertheless, frog distribution within watersheds is expected to exhibit regional and local variability. For example, higher use of riparian forests is anticipated in drier landscapes with fewer moist habitats in upland forests, whereas a broader distribution is expected in upland forests of the wetter biogeoclimatic variants. Latitude can produce regional differences in gene flow, population structure, behaviour, and habitat use patterns (Aguilar *et al.* 2013).

Best management practices aimed at structural retention are essential for any land use activity that partially or entirely removes the tree canopy in riparian and upland forests beyond stream-side retention buffers in occupied tailed frog basins. These practices should: protect wet and moist habitats from degradation in upland forest; retain attributes of structural complexity, such as large downed wood and shrub cover; and maintain fine-scale connectivity to facilitate seasonal and annual patterns of movement and dispersal to and from streams. Research has demonstrated the effects of tree canopy removal on Coastal Tailed Frog upland habitat use (e.g., Hawkes and Gregory 2012; McEwan 2014), as well as the positive association of tailed frogs with moist microsites and large downed wood, particularly in logged forests (Aguilar *et al.* 2013; McEwan 2014). Coastal tailed frogs are associated with low light and high moisture levels (McEwan 2014); preliminary research indicates that temperature and relative humidity in tailed frog habitats correlates with shrub cover (Cadori 2015). Spear and Storfer (2012) reported that a lack of understory and coarse wood refugia left frogs susceptible to desiccation and mortality in salvaged stands near Mount St. Helens. Aguilar *et al.* (2013) reported that wet and moist areas serve as significant corridors for gene flow in areas subject to intense timber harvesting at the southern-most latitude of the species' range in northern California.

Buffer designs and best management practices should make optimal use of existing land development and stand-level retention tools to meet Coastal Tailed Frog management objectives in occupied basins (e.g., *Forest and Range Practices Act* wildlife tree retention areas, riparian reserve zones on larger streams, and riparian management zones on smaller streams). Tools developed and utilized for the management of fish habitats and adjacent riparian areas (refer to Tripp et al. 2009; Tschaplinski 2010) could be modified for use with tailed frogs.

The acute and chronic sedimentation effects of road construction and maintenance within or adjacent to riparian areas, and linear development of stream crossings for roads, pipelines, and hydro rights-of-way, are well documented, as are the effects of fine sediment on Coastal Tailed Frog aquatic habitat quality (e.g., Dupuis and Steventon 1999; Stoddard and Hayes 2005). It is essential to design and implement best management practices that address the location, construction, and maintenance of linear features and their associated stream crossings in tailed frog streams. These practices will likely vary with development type, site characteristics, and habitat quality, and should preferentially locate roads outside of riparian zones and crossings away from identified specialized habitats. These practices should also enhance (where required)

existing best management practices for linear developments and stream crossings (e.g., *Fish-Stream Crossing Guidebook*, B.C. Forests, Lands and Natural Resource Operations *et al.* 2012) to meet Coastal Tailed Frog management objectives in occupied basins and watersheds. In addition, best management practices should include actions to address the impacts of clearing rights-of-way associated with stream crossings, including the use of structural retention. Seasonal timing windows may be necessary during critical periods when behavioural and physiological life history traits (e.g., adult aggregation for summer oviposition and fall mating, overwintering larvae in substrates) place populations at high risk of disturbance.

Inventory

Inventory and occurrence records are fundamental to mitigate the effects of land use on Coastal Tailed Frog populations and habitats. These records are crucial for the effective establishment of WHAs, the assessment of direct and cumulative threats and land use impacts to the species, and the effective implementation of conservation practices (i.e., stream buffers and best management practices). New tailed frog survey data has become available with the recent increase in proposed resource activities along the province's coast, including independent run-of-river power projects and liquefied natural gas pipeline developments. Prompt entry of existing records into the Conservation Data Centre's database will support analyses of inventory data gaps, helping to identify new locations where data are scant or non-existent.

Standard time-constrained larval surveys used to confirm tailed frog occupancy may locate and protect high-quality, high-density larval habitats; however, these surveys reduce the likelihood of detecting locations with low larval densities or stream reaches with only adults. Although area-constrained methods can improve rates of larval detection, the likelihood of locating specialized reproductive or overwintering habitats used by frogs during larval surveys remains low. Most larval surveys in the province are conducted at the lowest flow possible to maximize larval detection (August). This occurs after ovipositioning females have left the streams but before adults move to mating locations in the fall, resulting in low adult detection rates in some portions of the species' range (Todd and Johnson 2014). Larval surveys generally do not include searches of adjacent side channels, gullies, and other areas of minor flow outside of main-stem tributaries, where specialized habitats such as fall mating aggregations may exist. Overwintering distributions of frogs and tadpoles are unknown. Coastal Tailed Frog conservation management should recognize the presence, but low detectability, of these specialized habitats, and where successfully identified, these habitats should be protected. Improved inventory methods are needed to detect adults and to detect the species when it is present at low densities. Environmental DNA (eDNA) is more sensitive to tailed frog detection than conventional time-constrained surveys, although the influence of environmental factors on eDNA detection and its usefulness as a predictor of abundance are still under study (Grob 2014).

7.3.2 Planning

Up-to-date inventory data can be used to improve predictive models of tailed frog distribution and thus support the science-based location of new WHAs and cumulative effects assessments. It is also important to identify conservation gaps in the landscape, by measuring the level of protection afforded to species at risk in various jurisdictions, and the different forms in which this protection takes place. Reporting tailed frog protection levels by Resource District and

Region will, when used in conjunction with predictive models, facilitate the strategic placement of additional WHAs to meet species' management objectives.

Monitoring studies provide a means to evaluate the effectiveness of conservation management strategies and land stewardship actions; without monitoring, adaptive management is not possible. FREP is currently developing an effectiveness evaluation framework for Coastal Tailed Frog WHAs, and strategies to monitor the impacts of independent power projects in the South Coast Region are also being formulated. An integrated approach (i.e., across different types of land use activities) will require the monitoring and assessment of conservation outcomes of Coastal Tailed Frog strategic reserves, riparian buffers, and best management practices. Designating one or two WHAs in each tailed frog region (e.g., Skeena, Central Coast, South Coast, Cascades) as control benchmarks for research and monitoring will also be a necessary component of any conservation effectiveness evaluation.

Evaluating the effects of potential threats (e.g., pipeline developments, invasive species, and emerging diseases) to population persistence is necessary to identify land uses that require mitigative measures for Coastal Tailed Frog conservation. Research on habitat associations, constraints to health and survival, and responses to human activities advances our understanding of protection and management needs for species at risk. This information can help to improve planning, stewardship, and protection initiatives. In particular, research into the cumulative effects of multiple development threats on Coastal Tailed Frog populations is a necessary priority. The rate of proposed development on the coast is accelerating and our understanding of impacts to tailed frog habitats and population response lags behind. The effects of climate change and potential interactions with other environmental stressors is an unknown but looming cumulative threat to tailed frogs who rely on the wet, cool environments in mountain streams, which are at risk from shifting climate envelopes.

7.3.3 Species and population management

Current management objectives and strategies are constrained by the need to better understand the dispersal and distribution of Coastal Tailed Frogs within and between watersheds. Tailed frogs are spatially and temporally patchy in their fine-scale distribution within watersheds, placing segments of the population at differential risk in space and time (i.e., at particular locations at specific times). Frogs and tadpoles may use specialized habitats to meet key life history requirements. Although the frequency of occurrence and distribution of these sites is largely unknown, it is essential to protect them when located.

Female Coastal Tailed Frogs may aggregate in high-quality oviposition habitats and under individual features (e.g., large boulders) to lay eggs between June and August (Karraker *et al.* 2006; Palmeri-Miles 2010). Recent telemetry research in the Skeena Region shows that gravid females arrive at these communal sites weeks in advance of egg-laying, extending the period of vulnerability to disturbance (Todd *et al.* 2015). Breeding adults may aggregate to mate in the fall, although these aggregations are not necessarily confined to main-stem tributaries, occurring in small side channels and gullies where surface or subsurface flow occurs (McEwan *et al*. 2012). Non-breeding adults and juvenile frogs have also been found at these fall aggregations late in the year (e.g., November in the Skeena Region), suggesting the possibility of communal overwintering at or near these locations (McEwan *et al.* 2012).

High-quality larval rearing habitat (i.e., stable channels with moderate slope, coarse clean cobble substrates, and cool summer stream temperatures) will tend to support high tadpole densities, representing a range of development cohorts (young to old), and have been referred to as core breeding reaches (Dupuis and Friele 2005, Gyug 2005a, 2012). Tadpoles overwinter by moving down into these coarse, clean cobble streambeds for extended periods of reduced activity, making them subject to streambed disturbance and sedimentation.

Tailed frogs are thought to be highly philopatric, having a poor dispersal capability (e.g., Daugherty and Sheldon 1982). In general, long-distance dispersal events are rare for amphibians, with topography and geography mitigating gene flow (see discussion in Aguilar *et al.* 2013); however, recent research shows that terrestrial gene flow may occur between unconnected tailed frog watersheds on the Olympic Peninsula (Spear and Storfer 2008). Other research in the United States Coast Mountains suggests a reduced gene flow and higher genetic differentiation between populations at lower latitudes, and a lower level of genetic differentiation at higher latitudes (Nielsen *et al.* 2006; Aguilar *et al.* 2013). Climate-induced limitations on dispersal in the south that are not present in more northerly populations, which reside in wetter, cooler ecologies, may cause these varying levels of differentiation. Another explanation relates to post-glacial range expansion, with northern populations not yet having the time to diverge.

Research to determine the level of genetic differentiation across the provincial range of Coastal Tailed Frogs is necessary to inform the scales at which to apply conservation management actions. Understanding how habitat alteration, fragmentation, and potential genetic isolation may affect population structure and connectivity will help guide conservation management planning, and provide insights on the potential regional specificity of development impacts and conservation practices related to climate and latitude. Because of the patchy distribution and low detectability of the species, genetic research into patterns of gene flow is required to help explain dispersal capacity and predict recolonization. This will provide specific information related to the frequency, distribution, and placement of WHAs and other Coastal Tailed Frog conservation efforts in British Columbia.

8 MEASURING PROGRESS

Completing ongoing management actions and implementing recommendations in Table 2 based on priority will provide a measure of progress. Successful achievement of the management goal may be indicated when monitoring indicates stable distribution and populations with all size, age, and sex classes.

9 EFFECTS ON OTHER SPECIES

Negative impacts to other species are not anticipated. Watershed- and site-level land management measures specific to Coastal Tailed Frog WHAs will benefit other stream- and riparian-dependent species.

10 REFERENCES

Adams, M.J. and R.B. Bury. 2002. The endemic headwater stream amphibians of the American Northwest: association with environmental gradients in a large forest reserve. Global Ecol. Biogeogr. 11:169–178.

Aguilar, A., R.B. Douglas, E. Gordon, J. Baumsteiger, and M.O. Goldsworthy. 2013. Elevated genetic structure in the Coastal Tailed Frog (*Ascaphus truei*) in managed redwood forests. J. Hered. 104 (2):202–216 <http://jhered.oxfordjournals.org/content/104/2/202> [Accessed August 4, 2015]

Alaback, P.B. and F.R. Herman. 1988. Long-term response of understorey vegetation to stand density in *Picea–Tsuga* forests. Can. J. For. Res. 18:1522–1530. <http://www.nrcresearchpress.com/doi/pdf/10.1139/x88-233> [Accessed August 4, 2015]

Altig, R. and E.D. Brodie, Jr. 1972. Laboratory behavior of *Ascaphus truei* tadpoles. J. Herpetol. 6:21–24. <http://www.jstor.org/stable/1563089> [Accessed August 4, 2015]

Ancient Forest Alliance. 2013. New maps highlight BC's "Crisis in the Woods" due to old-growth logging. Victoria, BC. <http://www.ancientforestalliance.org/news-item.php?ID=657> [Accessed August 4, 2015]

Ardea Biological Consulting Ltd. (Ardea). 1999. Tailed frog (*Ascaphus truei*) habitat and population monitoring within Joe Bell and Apprentice Creeks from 1994 to 1998. B.C. Min. For., Kalum Distr., Terrace, BC.

Aubry, K.B. 2000. Amphibians in managed, second-growth Douglas-fir forests. J. Wildl. Manag. 64(4):1041–1052. <http://www.jstor.org/stable/3803215> [Accessed August 4, 2015]

Aubry, K.B. and P.A. Hall. 1991. Terrestrial amphibian communities in the southern Washington Cascade Range. Pages 327–337 *in* L.F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H. Huff, eds. Wildlife and vegetation of unmanaged Douglas-fir forests. U.S. Dep. Agric. For. Serv., Portland, OR. Gen. Tech. Rep. PNW-GTR-285. <http://www.fs.fed.us/pnw/pubs/gtr285/> [Accessed August 4, 2015]

BC Hydro. 2014. Approved work practices for water crossings installation, maintenance and deactivation. B.C. Hydro, Vancouver, BC.

Benda, L., D. Miller, P.E. Bigelow, and K. Andras. 2003. The effects of post-wildfire erosion on channel environments, Boise River, Idaho. For. Ecol. Manag. 178(1–2):105-–119. <http://www.sciencedirect.com/science/article/pii/S0378112703000562> [Accessed August 4, 2015]

Beschta, R.L. 1978. Long-term patterns of sediment production following road construction and logging in the Oregon Coast Range. Water Resour. Res. 14(6):1011–1016. <http://onlinelibrary.wiley.com/doi/10.1029/WR014i006p01011/pdf> [Accessed August 4, 2015]

Biek, R., L.S. Mills, and R.B. Bury. 2002. Terrestrial and stream amphibians across clearcut-forest interfaces in the Siskiyou Mountains, Oregon. Northwest Sci. 76(2):129–140.

B.C. Conservation Data Centre. 2014. BC Species and Ecosystems Explorer. B.C. Min. Environ., Victoria, BC. <http://a100.gov.bc.ca/pub/eswp/> [Accessed August 4, 2015]

B.C. Ministry of Environment. 2007. Ecosystems. Pages 217–284 *in* Environmental trends in British Columbia. Victoria, BC. <http://www.env.gov.bc.ca/soe/archive/reports/et07/chapters/ET2007_Ecosystems_Chapter.pdf> [Accessed August 4, 2015]

B.C. Ministry of Environment. 2010. Conservation framework. Victoria, BC. <http://www.env.gov.bc.ca/conservationframework/index.html> [Accessed August 4, 2015]

B.C. Ministry of Environment. 2014a. Approved wildlife habitat areas. Ecosystems Br., Victoria, BC. <http://www.env.gov.bc.ca/wld/frpa/iwms/wha.html> [Accessed August 4, 2015]

B.C. Ministry of Environment. 2014b. Develop with care 2014: environmental guidelines for urban and rural land development in British Columbia. Fact Sheet No. 17: Tailed frogs. Ecosystems Br., Victoria, BC. <http://www.env.gov.bc.ca/wld/documents/bmp/devwithcare/Fact-Sheet-17-tailed-frog.pdf> [Accessed August 4, 2015]

B.C. Ministry of Forests, Lands and Natural Resource Operations. 2011. Crown Land: indicators and statistics report 2010. Victoria, BC. <http://www2.gov.bc.ca/assets/gov/business/land-water-use/crown-land/crown_land_indicators__statistics_report.pdf> [Accessed August 4, 2015]

B.C. Ministry of Forests, Lands and Natural Resource Operations. 2014a. A compendium of wildlife guidelines for industrial development projects in the North Area, British Columbia: interim guidance. Victoria, BC. <http://a100.gov.bc.ca/pub/eirs/finishDownloadDocument.do;jsessionid=2pdmVjsTBvRp2CtnkWvcvyttPh7lSVQsXxdlBfCpD1DBpjjPc5zZ!415402940?subdocumentId=9921> [Accessed August 4, 2015].

B.C. Ministry of Forests, Lands and Natural Resource Operations. 2014b. Biogeoclimatic zones of British Columbia. <ftp://ftp.for.gov.bc.ca/HRE/external/!publish/becmaps/papermaps/BGCzones.8x11.pdf> [Accessed July 29, 2015]

B.C. Ministry of Forests, Lands and Natural Resource Operations. 2014c. Guidelines for amphibian and reptile conservation during urban and rural land development in British Columbia. Victoria, BC. <http://www.env.gov.bc.ca/wld/documents/bmp/HerptileBMP_complete.pdf> [Accessed August 4, 2015].

B.C. Ministry of Forests, Lands and Natural Resource Operations, B.C. Ministry of Environment, and Fisheries and Oceans Canada. 2012. Fish-stream crossing guidebook. Rev. ed. For. Pract. Invest. Br. Victoria, BC. <https://www.for.gov.bc.ca/hfp/fish/Fish-Stream Crossing Print.pdf> [Accessed August 4, 2015]

B.C. Ministry of Forests and Range. 2006. The state of British Columbia's forests 2006. For. Pract. Br., Victoria, BC. <https://www.for.gov.bc.ca/hfp/sof/2006/pdf/sof.pdf> [Accessed August 4, 2015]

B.C. Ministry of Forests and Range. 2010. Forests and Range 2010/11 to 2012/13 Land Based Investment Strategy. Victoria, BC. <https://www.for.gov.bc.ca/ftp/hcp/external/!publish/web/fia/land-based-investment-strategy_2010-11.pdf> [Accessed August 4, 2015]

B.C. Ministry of Water, Land and Air Protection. 2004a. Best management practices for amphibians and reptiles in rural and urban environments in British Columbia. Ecosystem Standards and Planning, Biodiversity Br., Nanaimo, BC. WLAP BMP Series. <http://www.env.gov.bc.ca/wld/BMP/herptile/HerptileBMP_final.pdf> [Accessed August 3, 2015].

B.C. Ministry of Water, Land and Air Protection. 2004b. Identified Wildlife Management Strategy: accounts and measures for managing identified wildlife, Version 2004, Amphibians, Coastal Tailed Frog. <http://www.env.gov.bc.ca/wld/frpa/iwms/documents/Amphibians/a_coastaltailedfrog.pdf> [Accessed August 4, 2015]

Brosofske, K.D., J. Chen, R.J. Naiman, and J.F. Franklin. 1997. Harvesting effects on microclimatic gradients from small streams to uplands in western Washington. Ecol. Appl. 7(4):1188–1200.

Brown, G.W. and J.T. Krygier. 1970. Effects of clear-cutting on stream temperature. Water Resour. Res. 6(4):1133–1139.

Brown, H.A. 1975. Temperature and development of the tailed frog, *Ascaphus truei*. Comp. Biochem. Phys. A 50(2):397–405.

Browne, T., R. Gilsenan, D. Singbeil, and M. Paleologou. 2011. Bio-energy and bio-chemicals synthesis report. FP Innovations. Vancouver, BC. <http://www.fpac.ca/publications/Bio%20Energy%20Final_En.pdf> [Accessed August 4, 2015]

Bull, E.L. and B.E. Carter. 1996. Winter observations of tailed frogs in Northeastern Oregon. Northwest. Nat. 77(2):45–47.

Bury, R.B. 1983. Differences in amphibian populations in logged and old growth redwood forest. Northwest Sci. 57(3):167–178.

Bury, R.B., P.S. Corn, K. Aubry, F.F. Gilbert, and L.L.C. Jones. 1991. Aquatic amphibian communities in Oregon and Washington. Pages 353–362 *in* L.F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H. Huff (eds.). U.S. Dep. Agric. For. Serv., Portland, OR. Gen. Tech. Rep. PNW-GTR-285. <http://www.fs.fed.us/pnw/pubs/gtr285/> [Accessed August 4, 2015]

Cadori, G.C. 2015. The effects of foresting harvesting intensities over riparian forest microclimate. Univ. B.C. Forest Resources Management Directed Studies 449C Research Report. Unpublished report.

Chen, J., S.C. Saunders, T.R. Crow, R.J. Naiman, K.D. Brosofske, G.D. Mroz, B.L. Brookshire, and J.F. Franklin. 1999. Microclimate in forest ecosystem and landscape ecology. Bioscience 49(4): 288-297.

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.

Chin, A. 1998. On the stability of step-pool mountain streams. J. Geol. 106(1):59–70.

Chin, A. 2002. The periodic nature of step-pool mountain streams. Am. J. Sci. 302:144–157.

Claussen, D.L. 1973. The thermal relations of the tailed frog, *Ascaphus truei*, and the Pacific tree frog, *Hyla regilla*. Comp. Biochem. Phys. A 44(1):137–153.

Coast Information Team (CIT). 2004. Ecosystem-based management planning handbook. Victoria, BC. <http://www.coastforestconservationinitiative.com/pdfNS/c-ebm-hdbk-fin-22mar04.pdf> [Accessed August 4, 2015]

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2011. COSEWIC assessment and status report on the Coastal Tailed Frog (*Ascaphus truei*) in Canada. Ottawa, ON. <http://publications.gc.ca/collections/collection_2012/ec/CW69-14-639-2012-eng.pdf> [Accessed July 29, 2015]

Conservation Measures Partnership (CMP). 2015. Open standards for the practice of conservation: threats taxonomy [website]. <http://cmp-openstandards.org/using-os/tools/threats-taxonomy/> [Accessed July 29, 2015]

Cook, F.R. 1984. Introduction to Canadian amphibians and reptiles. National Museum of Natural Sciences, Ottawa, ON.

Corkran, C. and C. Thoms. 2006. Amphibians of Oregon, Washington, and British Columbia: a field identification guide. Lone Pine Publishing, Vancouver, BC.

Corn, P.S. and R.B. Bury. 1989. Logging in western Oregon: responses of headwater habitats and stream amphibians. For. Ecol. Manag. 29(1–2):39–57.

Corn, P.S. and R.B. Bury. 1991. Terrestrial amphibian communities in the Oregon Coast Range. Pages 305–317 *in* L.F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H. Huff, eds. Wildlife and vegetation of unmanaged Douglas-fir forests. U.S. Dep. Agric. For. Serv., Portland, OR. Gen. Tech. Rep. PNW-GTR-285. <http://www.fs.fed.us/pnw/pubs/gtr285/> [Accessed August 4, 2015]

Dail, D. and L. Madsen. 2011. Models for estimating abundance from repeated counts of an open metapopulation. Biometrics 67(2):577–587.

Data BC. 2005. Publicly available wildlife habitat area dataset. Accessed August 2014. Available at: http://catalogue.data.gov.bc.ca/dataset/wildlife-habitat-areas

Daugherty, C.H. and A.L. Sheldon. 1982. Age-determination, growth, and life history of a Montana population of the tailed frog (*Ascaphus truei*). Herpetologica 38(4):461–468.

Daust, D., L. Kremsater, C. Apps, K. Brunt, A. Burger, F. Doyle, K. Dunsworth, L. Dupuis, P. Friele, G. MacHutchon, T. Mahon, E. McLaren, V. Michelfelder, B. Pollard, D. Seip, J.D. Stenventon, and L. Waterhouse. 2010. Focal species risk thresholds for BC's north and central coast: workshop proceedings. Joint Coastal Land and Resource Forum Technical Liaison Committee, Integrated Land Management Bureau, Nanaimo, BC.

Dupuis, L.A. 2003. The ranking of tailed frog habitat suitability in streams intercepting the Sea-to-Sky highway. B.C. Min. Transport. Hwy., Vancouver, BC. Contract #720-LM-6571. Unpublished letter to Angela Bunkingham.

Dupuis, L.A., F.L. Bunnell, and P.A. Friele. 2000. Determinants of the tailed frog's range in British Columbia, Canada. Northwest Sci. 74(2):109–115.

Dupuis, L.A. and P.A. Friele. 2003. Watershed-level protection and management measures for the maintenance of *Ascaphus truei* populations in the Skeena Region. B.C. Min. Water, Land Air Protect., Smithers, BC. <http://www.env.gov.bc.ca/wildlife/wsi/reports/4873_WSI_4873_RPT_2002.PDF> [Accessed August 4, 2015]

Dupuis, L.A. and P.A. Friele. 2006. The distribution of the Rocky Mountain Tailed Frog (*Ascaphus montanus*) in relation to the fluvial system: implications for management and conservation. Ecol. Res. 21:489–502.

Dupuis, L.A., P. Friele, and V. Michelfelder. 2010. Tailed Frog (*Ascaphus truei*). Pages 72–91 *in* D. Daust, et al. (eds.). Focal species risk thresholds for BC's north and central coast: workshop proceedings. Joint Coastal Land and Resource Forum Technical Liaison Committee, Integrated Land Management Bureau, Nanaimo, BC.

Dupuis, L.A. and D. Steventon. 1999. Riparian management and the tailed frog in northern coastal forests. For. Ecol. Manag. 124:35–43.

Diller, L.V. and R.L. Wallace. 1999. Distribution and habitat of *Ascaphus truei* in streams on managed, young growth forests in North Coastal California. J. Herpetol. 33(1):71–79.

Environmental Assessment Office (EAO). 2014. Project Information Centre (e-PIC) [website]. <http://a100.gov.bc.ca/pub/epic/projectStatusCategoryReport.do#cert> [Accessed August 4, 2015]

Feminella, J.W. and C.P. Hawkins. 1994. Tailed frog tadpoles differentially alter their feeding behavior in response to non-visual cues from four predators. J. N. Am. Benthol. Soc. 13(2):310–320.

Franklin, J. 1988. Structural and functional diversity in temperate forests. Pages 166–175 *in* E.O. Wilson and F.M. Peter, eds. Biodiversity. National Academy Press, Washington, DC.

Franklin, J., T. Spies, R. Van Pelt, A. Carey, D. Thornburgh, D. Berg, D. Lindenmayer, M. Harmon, W. Keeton, D. Shaw, K. Bible, and J. Chen. 2002. Disturbances and structural development of natural forest ecosystems with silvicultural implications, using Douglas-fir forests as an example. For. Ecol. Manag. 155(1–3):399–423.

Friele, P. 2006. Ram fire N10689, post-fire assessment. B.C. Min. For. Contract (CNL WL06043) report, Ascaphus Consulting, Squamish, BC. Unpublished report.

Friele, P., K. Paige, D. Moore. In prep. Stream temperature regimes and the distribution of the Rocky Mountain tailed frog at its northern range limit, southeastern British Columbia. Northwest Science.

Gaige, H.T. 1920. Observations upon the habits of *Ascaphus truei* Stejneger. Occasional Papers of the Museum of Zoology, University of. Michigan Mich., Ann Arbor, MI. Occas. Pap. Mus. Zool. No. 84. <http://deepblue.lib.umich.edu/bitstream/handle/2027.42/56523/OP084.pdf?sequence=1&isAllowed=y> [Accessed August 4, 2015]

Gayton, D.V. 2008. Impacts of climate change on British Columbia's biodiversity: a literature review. FORREX Forest Research Extension Partnership, Kamloops, BC. FORREX Series No. 23. <http://www.forrex.org/sites/default/files/forrex_series/FS23.pdf> [Accessed August 4, 2015]

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 September 7, 2015]

Grob, A. 2014. Investigating the use of environmental DNA as a quantitative predictor of Coastal Tailed Frog (*Ascaphus truei*) abundance in streams. B.Sc. thesis. Univ. North. B.C., Prince George, BC.

Gyug, L.W. 2000. Tailed frog inventory, year 2000, Merritt Forest District. B.C. Min. Water, Land Air Protect. South. Interior Reg., Kamloops, BC. (astr 2001 merritt final.pdf) <http://a100.gov.bc.ca/pub/siwe/details.do?id=2668)> [Accessed August 4, 2015]

Gyug, L. 2005a. Pilot evaluation of tailed frog Wildlife Habitat Area effectiveness monitoring protocols. Ecosystems Branch, BC Ministry of Environment, Victoria, BC.

Gyug, L. 2005b. Tailed frog tadpole population estimation methods, Wildlife Habitat Area monitoring pilot project, 2005, Ecosystems Branch, BC Ministry of Environment, Victoria, BC.

Gyug, L.W. 2012. Field pilot for regional effectiveness monitoring of tailed frog wildlife habitat areas in the Cascades. B.C. Ministry of Environment, Ecosystems, Protection and Sustainability Branch, Victoria, BC.

Hailman, J.P. 1982. Extremely low ambient light levels of *Ascaphus truei*. J. Herpetol. 16(1):83–84.

Hamlet, A.F. and D.P. Lettenmaier. 2000. Effects of climate change on hydrology and water resources in the Columbia River Basin. J. Am. Water Res. Assoc. 35(6):1597–1622.

Hawkes, V.C. and P.T. Gregory. 2012. Temporal changes in the relative abundance of amphibians relative to riparian buffer width in western Washington, USA. For. Ecol. Manag. 274:67–80.

Hawkins, C.P., L. Gottschalk, and S. Brown. 1988. Densities and habitat of tailed frog tadpoles in small streams near Mt. St. Helens following the 1980 eruption. J. N. Am. Benthol. Soc. 7(3):246–252.

Hitt, N.P. 2003. Immediate effects of wildfire on stream temperature. J. Freshwater Ecol. 18(1):171–173.

Holtby, L.B. 1988. Effects of logging on stream temperatures in Carnation Creek, British Columbia, and associated impacts on the coho salmon (*Oncorhynchus kisutch*). Can. J. Fish. Aquat. Sci. 45(3):502–515.

Hossack, B.R., M.J. Adams, E.H. Campbell Grant, C.A. Pearl, J.B. Bettaso, W.J. Barichivich, W.H. Lowe, K. True, J.L. Ware, and P.S. Corn. 2010. Low prevalence of chytrid fungus (*Batrachochytrium dendrobatidis*) in U.S. headwater amphibians. J. Herpetol. 44(2):253–260.

Johnson, S. and J.A. Jones. 2000. Stream temperature responses to forest harvest and debris flows in western Cascades, Oregon. Can. J. Fish. Aquat. Sci. 57(Suppl. 2):30–39.

Johnston, B.E. 2004. Coastal giant salamander Dicamptodon tenebrosus In: *Identified Wildlife Management Strategy* Accounts and Measures for Managing Identified Wildlife. Coast Forest Region. Version 2004. Ministry of Water, Land and Air Protection, Victoria, B.S.

Jones, J.A. and G.E. Grant. 1996. Peak flow responses to clear-cutting and roads in small and large basins, Western Cascades, Oregon. Water Resour. Res. 32(4):959–974.

Jones, L.C., W.P. Leonard, and D.H. Olson, eds. 2005. Amphibians of the Pacific Northwest. Seattle Audubon Society, WA.

Jones, L.C. and M. Raphael. 1998. *Ascaphus truei* (Tailed Frog): predation. Herpetol. Rev. 29:39.

Karraker, N. 2001. *Ascaphus truei* (Tailed Frog): predation. Herpetol. Rev. 32:100.

Karraker, N., D. Pilliod, M. Adams, E. Bull, P.S. Corn, L. Diller, L. Dupuis, and M. Hayes. 2006. Taxonomic variation in oviposition by tailed frogs (*Ascaphus* spp.). Northwest. Nat. 87:87–97.

Kroll, A., K. Risenhoover, T. McBride, E. Beach, B. Kernohan, J. Light, and J. Bach. 2008. Factors influencing stream occupancy and detection probability parameters of stream-associated amphibians in commercial forests of Oregon and Washington, USA. For. Ecol. Manag. 255(11):3726–3736.

Leupin, E. 2000. Distribution and habitat characterization of the tailed frog in the Lillooet Forest District. B.C. Min. Environ., Lands Parks and J.S. Jones Timber Ltd., Kamloops, BC.

Leversee, D. 2009. Ecosystem-based Management Working Group Tailed Frog Habitat Model Summary. B.C. Min. Agric. Lands, Land Info., Nanaimo, BC. Unpublished report.

Lindenmayer, D. 2009. Forest pattern and ecological process: a synthesis of 25 years of research. CSIRO Publishing, Collingwood, Australia.

Lund, E., M. Hayes, T. Curry, J. Marsten, and K. Young. 2008. Predation on the Coastal Tailed Frog (*Ascaphus truei*) in Washington State. Northwest. Nat. 89:200–202.

Mahlum, S.K., L.A. Eby, M.K. Young, C.G. Clancy, and M. Jakober. 2011. Effects of wildfire on stream temperatures in the Bitterroot River Basin, Montana. Int. J. Wildland Fire 20:240–247.

Malt, J. 2013. Assessing impacts of wetland fragmentation on the Sea to Sky Highway: cumulative population-level effects on red-legged frogs (*Rana aurora*). Proc. Soc. Northwest. Vertebr. Biol. Annu. Gen. Meet., 2013, Squamish, BC.

Malt, J., D. Courcelles, and S. Nathan. 2014. Study design and field methods: guidance on coastal tailed frog monitoring of run-of-river hydropower projects. Version 1.3. B.C. Min. For., Lands Nat. Resour. Ops., Victoria, BC. <http://sccp.ca/sites/default/files/species-habitat/documents/Pacific tailed frog study design %26 field methods monitoring ror hydropower projects-_Malt_2014_v1.3.pdf> [Accessed September 2, 2015]

Malt, J. and E. Crockett. 2013. Power analysis for coastal tailed frog monitoring of run-of-river hydropower projects. B.C. Min. For., Lands Nat. Resour. Ops., Victoria, BC. Draft. <http://sccp.ca/sites/default/files/species-habitat/documents/Pacific tailed frog draft power analysis _monitoring ROR Hydropower _Malt_2013_v1.0.pdf> [Accessed September 2, 2015]

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 September 2, 2015]

Matsuda, B.M. 2001. The effects of clear-cut timber harvest on the movement patterns of tailed frogs (*Ascaphus truei*) in southwestern British Columbia. M.Sc. thesis. Univ. B.C., Vancouver, BC.

Matsuda, B.M. and J.S. Richardson. 2005. Movement patterns and relative abundance of Coastal Tailed Frogs in clearcuts and mature forest stands. Can. J. For. Res. 35:1131–1138. <http://www.nrcresearchpress.com/doi/pdf/10.1139/x05-042> [Accessed August 4, 2015]

Matsuda, B.M., D.M. Green, and P.T. Gregory. 2006. Amphibians and reptiles of British Columbia. Royal B.C. Museum, Victoria, BC.

Maxcy, K. 2004. Indicators and methods for effectiveness monitoring of tailed frog Wildlife Habitat Areas. B.C. Ministry of Water, Land and Air Protection. Victoria, BC

Mazza, R. 2010. Mount St. Helens 30 years later: a landscape reconfigured. U.S. Dep. Agric. For. Serv., Pac. NW Res. Sta., Portland, OR. Pac. NW Sci. Update 19:1–3. <http://www.fs.fed.us/pnw/pubs/science-update-19.pdf> [Accessed August 4, 2015]

McEwan, A.L. 2014. The habitat ecology of the post-metamorphic Coastal Tailed Frog (*Ascaphus truei*). M.Sc. thesis, Univ. North. B.C., Prince George, BC.

McEwan, A., M.A. Todd, L. Rach, K. Golob, C. Johnson, and D. Steventon. 2012. Field observations of breeding aggregations of Coastal Tailed Frogs in north-western British Columbia [poster presentation abstract]. Page 43 *in* A river runs through it: riverine systems ecology and restoration. Proc. Soc. NW Vertebr. Biol. 2012 Annu. Meet., Mar. 20–23, 2012, Hood River, OR. <http://thesnvb.org/wp-content/uploads/2014/04/2012-program-hoodriver.pdf> [Accessed July 29, 2015]

Metter, D.E. 1964. A morphological and ecological comparison of two populations of the frog, *Ascaphus truei* Stejneger. Copeia 1964(1):181–195.

Michelfelder, V., R. van der Marel, and K. Dunsworth. 2008. Proposed wildlife habitat areas for the Coastal Tailed Frog (*Ascaphus truei*) on the central coast of British Columbia. B.C. Min. Environ., Environ. Steward. and Protect. Areas Div., Hagensborg, BC. <https://www.for.gov.bc.ca/tasb/slrp/lrmp/nanaimo/cencoast/ebmwg_docs/e102a_tailed_frog_report.pdf> [Accessed August 4, 2015]

Millard, T., T. Rollerson, and B. Thomson. 2002. Post-logging landslide rates in the Cascade Mountains, southwestern British Columbia. B.C. Min. For., Nanaimo, BC. Tech. Rep. TR-023. <https://www.for.gov.bc.ca/rco/research/georeports/tr023.pdf> [Accessed August 4, 2015]

Millard-Martin, B. 2015. The efficacy, applicability and limitations of visual encounter surveys in the detection of *Ascaphus true*i. B.Sc. thesis, Univ. North. B.C., Prince George, BC.

Miller, D., C. Luce, and L. Benda. 2003. Time, space, episodicity of physical disturbance in streams. For. Ecol. Manag. 178(1–2):121–140.

Morrissey, C. and R. Olenick. 2004. American Dipper, *Cinclus mexicanus*, preys upon larval tailed frogs, *Ascaphus truei*. Can. Field Nat. 118(3):446–448. http://canadianfieldnaturalist.ca/index.php/cfn/article/view/22/21 [Accessed August 4, 2015]

Mosher, C. 2014. Spatial structure for Coastal Tailed Frog (*Ascaphus truei*) populations in northwestern British Columbia. Ph.D. thesis proposal. Univ. North. B.C. Natural Resources and Environmental Studies, Prince George, BC. Unpublished.

Moss, K. and L. Dupuis. 2007. Pinecrest Amphibian Salvage 2007. Golder Associates report to Hatfield Consultants, North Vancouver, BC.

Murray, B. and A. Flores. 2013. Environmental DNA analysis for tailed frog distribution in northwestern BC: protocol development and initial results. Univ. North. B.C., Prince George, BC. Unpublished report.

Murphy, M.L., C.P. Hawkins, and N.H. Anderson. 1981. Effects of canopy modification and accumulated sediment on stream communities. Trans. Am. Fish. Soc. 110(4):469–478.

National Energy Board (NEB). 2010. Focus on safety and environment: a comparative analysis of pipeline performance 2000–2008. Calgary, AB. <https://www.neb-one.gc.ca/sftnvrnmnt/sft/archive/sftprfrmncndctr/fcssft/2010/2000-2008fcssftsmmr-eng.pdf> [Accessed August 4, 2015]

NatureServe. 2014. NatureServe explorer: an online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. <http://www.natureserve.org/explorer> [Accessed August 4, 2015]

Nielson, M., K. Lohman, C. Daugherty, F. Allendorf, K. Knusden, and J. Sullivan. 2006. Allozyme and mitochondrial DNA variation in the tailed frog (Anura: *Ascaphus*): the influence of geography and gene flow. Herpetologica 62(3):235–258.

Noble, G.K. and P.G. Putnam. 1931. Observations on the life history of *Ascaphus truei* Stejneger. Copeia 1931:97–101.

Paige, K. and L. Darling. 2009. A framework for monitoring and evaluating wildlife resource values. B.C. Min. Environ., Forest and Range Evaluation Program, Victoria, BC. <https://www.for.gov.bc.ca/ftp/hfp/external/!publish/frep/values/Wildlife_Framework_Paper.pdf> [Accessed September 2, 2015]

Palmeri-Miles, A.F., K.A. Douville, J.A. Tyson, K.D. Ramsdell, and M.P. Hayes. 2010. Field observations of oviposition and early development of the Coastal Tailed Frog (*Ascaphus truei*). [Poster presentation]. 6th Annu. Wash. For. Pract. Adapt. Manag. Sci. Conf., Apr. 13, 2010. Olympia, WA. <http://wdfw.wa.gov/publications/00555/wdfw00555.pdf> [Accessed August 4, 2015]

Pembina Institute. 2006. Major fossil fuel projects in northern British Columbia. Vancouver, BC. Resource Development in the North Fact Sheets. <http://www.pembina.org/reports/BC_oilgas04.pdf> [Accessed August 4, 2015]

Pike, R.G., M.C. Feller, J.D. Stednick, K.J. Rieberger, and M. Carver 2010. Water quality and forest management. Pages 401–440 *in* R.G. Pike, T.E. Redding, R.D. Moore, R.D. Winkler and K.D. Bladon, eds. Compendium of forest hydrology and geomorphology in British Columbia. B.C. Min. For. Range, For. Sci. Prog., Victoria, BC and FORREX Forum for Research and Extension in Natural Resources, Kamloops, BC. Land Manag. Handb. 66. <https://www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh66/Lmh66_ch12.pdf> [Accessed August 4, 2015]

Pilliod, D.S., R.B. Bury, E.J. Hyde, C.A. Pearl, and P.S. Corn. 2003. Fire and amphibians in North America. For. Ecol. Manag. 178(1–2):163–181.

Pilliod, D.S., E. Muths, R.D. Scherer, P.D. Bartlet, P.S. Corn, B.R. Hossack, B.A. Lambert, R. McCaffery, and C. Gaughan. 2010. Effects of amphibian chytrid fungus on individual survival probability in wild boreal toads. Conserv. Biol. 24(5):1259–1267.

Pounds, J.A., M.R. Bustamante, L.A. Coloma, J.A. Consuegra, M.P.L. Fogden, P.N. Foster, E. La Marca, K.L. Masters, A. Merino-Viteri, R. Puschendorf, S.R. Ron, G.A. Sánchez-Azofeifa, C.J. Still, and B.E. Young 2006. Widespread amphibian extinctions from epidemic disease driven by global warming. Nature 439:161–167.

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 4, 2015]

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 4, 2015]

Province of British Columbia. 2004. Identified wildlife management strategy. B.C. Min. Environ., Victoria, BC. <http://www.env.gov.bc.ca/wld/frpa/iwms/index.html> [Accessed August 4, 2015]

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 4, 2015].

Reid, L.M. and T. Dunne. 1984. Sediment production from forest road surfaces. Water Resour. Res. 20(11):1753–1761.

Richardson, J.S. and W.E. Neill. 1995. Distribution patterns of two montane stream amphibians and the effects of forest harvest: the Pacific Giant Salamander and Tailed Frog in southwestern British Columbia. B.C. Min. Environ., Lands Parks, Victoria, BC. Unpublished report.

Robertson, I., C. Murray, M. Miles, S. Allegretto, E. Goldsworthy, A. Hall, M. Nelitz, D. Pickard, M. Porter, R. Robitaille, N. Sands, S. Sloboda and J. Werner. 2012. Environmental Values and Components Manual, Phase I. Working Draft. Prepared for BC Ministry of Environment, Ecosystem Protection & Sustainability Branch, Victoria B.C. by Robertson Environmental Services Ltd., Langley, B.C., ESSA Technologies Ltd., Vancouver, B.C. and M. Miles & Associates Ltd., Victoria, B.C. 221pp.

Rollerson, T., T. Millard, C. Jones, K. Trainer, and B. Thomson. 2001. Predicting post-logging landslide activity using terrain attributes: Coast Mountains, British Columbia. B.C. Min. For., Nanaimo, BC. Tech. Rep. TR-011. <https://www.for.gov.bc.ca/rco/research/georeports/tr011.pdf> [Accessed August 4, 2015]

Rumsey, C., J. Ardron, K. Ciruna, T. Curtis, Z. Ferdaña, T. Hamilton, K. Heinemeyer, P. Iachetti, R. Jeo, G. Kaiser, D. Narver, R. Noss, D. Sizemore, A. Tautz, R. Tingey, and K. Vance-Borland. 2004. An ecosystem spatial analysis for Haida Gwaii, central coast, and north coast British Columbia. Coast Information Team, Victoria, BC. <https://www.for.gov.bc.ca/tasb/slrp/citbc/c-esa-fin-04may04.pdf> [Accessed August 4, 2015]

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.

Service, C.N., T.A. Nelson, P.C. Paquet, W.S.S. McInnes, and C.T. Darimont. 2012. Pipelines and parks: evaluating external risks to protected areas from the proposed northern gateway oil transport project. Nat. Area. J. 32(4):367–376.

Spear, S.F. and A. Storfer. 2008. Landscape genetic structure of coastal tailed frogs (*Ascaphus truei*) in protected vs. managed forests. Mol. Ecol. 17:4642–4656.

Spear, S.F., C.M. Crisafulli, and A. Storfer. 2012. Genetic structure among coastal tailed frog populations at Mount St. Helens is moderated by post-disturbance management. Ecol. Appl. 22(3):856–869.

Sridhar, V., A. Sansone, J. LaMarche, T. Dubin, and D. Lettenmaier. 2004. Prediction of stream temperature in forested watersheds. J. Am. Water Resour. Assoc. 40(1):197–213.

Stoddard, M.A. 2002. The influence of forest management on headwater stream amphibians at multiple spatial scales. M.Sc. thesis, Oreg. State Univ., Corvallis, OR.

Stoddard, M.A. and J.P. Hayes. 2005. The influence of forest management on headwater stream amphibians at multiple spatial scales. Ecological Applications 15(3): 811-823.

Sutherland, G., M. Hayes, T. Quinn, L. Dupuis, T. Wahbe, D. Rundle, and J. Richardson. 2001. Predictive habitat models for the occurrence and abundance of the Olympic Tailed Frog, *Ascaphus truei* Stejneger 1899 and the Rocky Mountain Tailed Frog, *Ascaphus montanus* (Mittleman and Myers) 1949: A pilot meta-analysis. Dep. Nat. Resour., Olympia, WA.

Sutherland, G. 2008. Bayesian Belief Networks for effectiveness monitoring under the Forest and Range Evaluation Program (FREP): Prototypes for Wildlife Habitat Areas (WHAs) and their context, designed for Tailed Frogs, BBN Version 1.0a (alpha-level). BC Ministry of Environment, Victoria BC.

Todd, M. and C. Johnson. 2014. Terrestrial habitat requirements of post-metamorphic Coastal Tailed Frogs in northwest British Columbia. Habitat Conservation Trust Fund Annual Report, 2013/14. Proj. 6-224. Unpublished report.

Todd, M., C. Johnson, and L. Turney. 2015. Terrestrial habitat requirements of post-metamorphic Coastal Tailed Frogs in northwest British Columbia. Habitat Conservation Trust Fund Annual Report, 2014/15. Proj. 6-224. Unpublished report.

Todd, M., C. Johnson, P. Govindarajulu, D. Steventon, B. Murray, L. Turney, L. Rach, K. Paige, A. Hetherington, and L. Vanderstar. 2014a. The spatial ecology of Coastal Tailed Frogs in northwestern BC. B.C. Min. For., Lands Nat. Resour. Ops. Coast Area and Skeena Res. Sect. 2014/15 Wildlife Research Project Summary. Unpublished report. <http://a100.gov.bc.ca/appsdata/acat/documents/r42787/2014ProgressSummaryTailedFrogProjectBC29Maydraft_1402502200547_2501445295.pdf> [Accessed September 2, 2015]

Todd, M., K. Paige, P. Govindarajulu, A. Hetherington, L. Turney, L. Rach, C. Johnson, A. McEwan, B. Millard-Martin, and D. Steventon. 2014b. Research and monitoring protocols for the spatial ecology of coastal tailed frogs (*Ascaphus truei*) in northwestern BC. Version 5.0. B.C. Min. For., Lands Nat. Resour. Ops., Forest Sciences Research Project. Unpublished report.

Tripp, D.B., P.J. Tschaplinski, S.A. Bird and D.L. Hogan. 2009. Protocol for evaluating the condition of streams and riparian management areas (Riparian Management Routine Effectiveness Evaluation). Forest and Range Evaluation Program, B.C. Min. For. Range

and B.C. Min. Env., Victoria, BC. https://www.for.gov.bc.ca/ftp/hfp/external/!publish/frep/indicators/Indicators-Riparian-Protocol-2009.pdf

Tschaplinski, P. 2010. State of stream channels, fish habitats, and their adjacent riparian areas: resource stewardship monitoring to evaluate the effectiveness of riparian management, 2005–2008. B.C. Min. For. Mines, Lands., For. Prac. Invest. Br., Forest and Range Evaluation Program, Victoria, B.C. FREP Report No. 27. <https://www.for.gov.bc.ca/ftp/hfp/external/!publish/FREP/reports/FREP_Report_27.pdf > [Accessed August 4, 2015]

Thomas, K.D., P.G. Comeau, and K.R. Brown. 2000. The silviculture of hybrid poplar plantations. B.C. Min. For., Res. Br., Victoria, BC. Exten. Note No. 47. <https://www.for.gov.bc.ca/hfd/pubs/docs/en/en47.pdf> [Accessed August 4, 2015]

Van Hinte, T., G.I. Gunton, and J.C. Day. 2007. Evaluation of the assessment process for major projects: a case study of oil and gas pipelines in Canada. Impact Assess. Proj. Appr. 25(2):123–137. <http://www.tandfonline.com/doi/pdf/10.3152/146155107X204491> [Accessed August 4, 2015]

Vanlarr, W.G.M., K.E. Gunson, S.W. Brown, and R.D. Robertson. 2012. Wildlife-vehicle collisions in Canada: a review of the literature and a compendium of existing data sources. Traffic Injury Research Foundation and Eco-Kare International, Ottawa, ON. <http://tirf.ca/publications/PDF_publications/WildlifeVehicle_Collision_Deliverable1_Eng_6.pdf> [Accessed August 4, 2015]

Wahbe, T.R., F.L. Bunnell, and R.B. Bury. 2004. Terrestrial movements of juvenile and adult tailed frogs in relation to timber harvest in coastal British Columbia. Can. J. For. Res. 34:2455–2466.

Wahbe, T., C. Ritland, F. Bunnell, and K. Ritland. 2005. Population genetic structure of tailed frogs (*Ascaphus truei*) in clearcut and old-growth stream habitats in south coastal British Columbia. Can. J. Zool. 83:1460–1468.

Welsh, H.H. 1990. Relictual amphibians and old-growth forests. Conserv. Biol. 4:309–319.

Welsh, H.H. 1993. A hierarchical analysis of the niche relationships of four amphibians from forested habitats of northwestern California. Ph.D. dissertation. Univ. Calif., Berkeley, CA.

Welsh H.H. Jr., and A.J. Lind. 2002. The stream amphibian assemblage of the mixed conifer–hardwood forests of northwestern California and southwestern Oregon: relationships with forest and stream environments. J. Wildl. Manag. 66:581–60.

Welsh, H.H., Jr., and L.M. Ollivier. 1998. Stream amphibians as indicators of ecosystem stress: a case study from California's redwoods. Ecol. Appl. 8(4):1118–1132.

Wilkins, R.N. and N.P. Peterson. 2000. Factors related to amphibian occurrence and abundance in headwater streams draining second-growth Douglas-fir forests in southwestern Washington. For. Ecol. Manag. 139:79–91.

Wind, E. 2009. Coastal Tailed Frog inventory and habitat assessment. BC Hydro, Lillooet, BC.

Winker, K., J.H. Rappole, and M.A. Ramos. 1995. The use of movement data as an assay of habitat quality. Oecologia 101:211–216.

Wondzell, S.M. and J.G. King. 2003. Postfire erosional processes in the Pacific Northwest and Rocky Mountain regions. For. Ecol. Manag. 178(1–2):75–87.

Wong, C., H. Sandmann, and B. Dorner. 2004. Historical variability of natural disturbances in British Columbia: a literature review. FORREX–Forest Research Extension Partnership, Kamloops, BC. FORREX Series No.12. <http://www.forrex.org/sites/default/files/forrex_series/FS12.pdf> [Accessed August 4, 2015]

Zevit, P. and B. Matsuda. 2010. BC's Coast Region – Species and ecosystems of conservation concern: Pacific Tailed Frog (*Ascaphus truei*). South Coast Conservation Program, Vancouver, BC. <http://www.geog.ubc.ca/biodiversity/factsheets/pdf/Ascaphus_truei.pdf> [Accessed August 4, 2015]

Personal Communications

Pierre Friele, Geomorphologist, Cordilleran Geoscience, 2015.

Debra Lacroix, Biologist, Ecofish, 2014.

Josh Malt, Ecosystem Biologist, B.C. Ministry of Forests, Lands and Natural Resource Operations, 2013.

Volker Michelfelder. Ecosystems Biologist, Ministry of Environment. 2010.

Connie Miller-Retzer, Ecosystem Biologist, B.C. Ministry of Forests, Lands and Natural Resource Operations, 2015.

Lisa Nordin, Senior Ecosystem Biologist, B.C. Ministry of Forests, Lands and Natural Resource Operations, 2015.

Kathy Paige, Ecosystem Biologist, B.C. Ministry of Environment, 2015.

Brad Pollard, Biologist, McElhanney Consulting Services, 2015.

Lars Reese-Hansen, Fisheries Sensitive Watershed Biologist, Ministry of Forest, Lands, and Natural Resources. 2015

Len Vanderstar, Senior Ecosystems Biologist, B.C. Ministry of Environment, 2014, 2015.