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# Determinants of the Tailed Frog's Range in British Columbia, Canada

## Abstract

The tailed frog is the only stream-breeding frog in Canada. Due to its highly specialized habitat requirements and its vulnerability to habitat degradation, it is of concern through much of its range in the Pacific Northwest. The purpose of this study was to determine the range of the tailed frog in British Columbia, and to generate hypotheses for its current distribution. The tailed frog is a resident of steep mountain streams. Along the coast, other than its absence from Vancouver Island and Haida Gwaii, the tailed frog's distribution coincides closely with the Coastal Western Hemlock (CWH) biogeoclimatic zone. In the interior, an area with a continental climate, its distribution is allied with the Engelmann Spruce/Subalpine Fir (ESSF) biogeoclimatic zone. However, streams in the ESSF are likely only suitable to tadpoles if a thick blanket of snow buffers them from winter freezing. Thus, drier subzones of the ESSF are less likely to support tailed frogs. This close association with moist biogeoclimatic zones may reflect the species preference for a humid temperate climate regime. The tailed frog's distribution may also be associated with geology: in contrast to streams underlain by competent plutonic rocks (e.g., granite), which typically have coarse gravel beds with locked boulder steps, areas with highly fractured or weak rock types (e.g. shale) have a finer and more mobile stream bedload, leading to unstable channel conditions. These streams provide less favorable habitat for tadpoles. Along the coast, the presently documented northern distribution lies at the Nass River, and the factors limiting northward dispersal are not apparent. In the interior of British Columbia, northward advancement appears to be limited in part both to underlying rock type and climate.

## Introduction

Aside from a small population of Pacific giant salamander (*Dicamptodon ensatus*) in the extreme southwest of British Columbia, the tailed frog (*Ascaphus truei*) is the only stream-breeding amphibian in Canada (Cook 1984). The tadpole stage may last one to four years during which it is subject to stress or mortality from natural or anthropogenic events that may affect the natal stream channel. Typical mountain streams which support tailed frogs are characterized by a step-pool morphology (see Chin 1989). Step-pool systems have stable bedforms over time spans of 5 years or more, with reorganization occurring during infrequent, extreme events (Chin 1998). This represents long-term stability from the tadpole's point of view. Negative influences include debris flows or flooding (Metter 1964), or increased sedimentation from logging and other land use practices (Corn and Bury 1989; Wahbe 1996; Welsh and Ollivier 1997; Dupuis and Steventon 1999). In Montana, adults appear to recolonize degraded areas relatively slowly (Daugherty and Sheldon 1982). Since it is sensitive to land-use practices, the tailed frog is designated "at risk" in British Columbia, "of concern" in Washington, Oregon, and of special concern in California. Prior to 1990, the Canadian range of the tailed frog was thought to be largely restricted to the southern coast of British Columbia, with some records from the Kitimat/Terrace area on the north coast (Green and Campbell 1984). Based on a 1958 record by J. Grant, confirmed by S. Orchard in 1983, a separate population was assumed to occur in southeastern British Columbia, but its status and extent was unknown.

Because the species is vulnerable to habitat disturbances and is designated "at risk", delineating its current range was important for conservation measures. Based on extensive surveys, we report the range of the tailed frog in British Columbia, and hypothesize on the factors which might affect its current distribution. Although some preliminary tests have been conducted on our database (Sutherland and Bunnell 1999), these hypotheses wait to be explicitly tested.

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## Survey Areas

During 1995, 1996 and 1998, field surveys were conducted along 519 creeks in British Columbia. Surveys began at the 49th Parallel and extended to 58° N, a distance of about 1,815 kilometers. Sixty percent of the creeks surveyed were located in the Coast Ranges, from the Sunshine Coast to the Stikine River, in northern British Columbia. Because numerous records were available from the populous, southern coastal portion of the province, extra search effort was focused where historical records were scarce: the mid, northern and eastern portions of the Coast and Mountains Ecoprovince (refer to Demarchi (1993) for an overview of the ecoregions of British Columbia). Given the remote nature of the mainland coast, surveyors had to fly into active logging camps and use logging road access to systematically search every road-accessible permanent creek in the area. The remainder of the surveys (40%) were carried out in southeastern British Columbia between the Akamina-Kishinena and Moyie Rivers. Road access in the east part of the study area was good so all permanent creeks within a 2,000 $km^2$ area of the single confirmed record (Storm Creek) were searched to delineate the species' northern and western range boundaries in the East Kootenays. Searches of all permanent creeks were also carried out west of the dry Rocky Mountain Trench, within the southern portion of the McGillivray Ranges (1300 $km^2$ area) because of its proximity to existing populations in northwestern Montana. Additional creeks were surveyed in the adjacent Southern Columbia Mountains.

## Methods

### Reconnaissance Surveys

Time-constrained searches (TCS) are the most effective technique for determining the presence or absence of a species in an area because they involve no set-up costs, allow for large areas to be covered, and focus on the most suitable microhabitats (Corn and Bury 1990). Time-constrained searches involve hand-raking gravel, uplifting cobbles, sweeping boulder surfaces and scanning the banks for a specific time limit.

### Detailed Searches

Area-constrained searches are ideal for determining species density, because they involve the thorough search of a stream segment (e.g., Dupuis and Steventon, 1999). In this study, tadpole density within a creek was estimated by counting all the individuals encountered during an active search of one 10-m segment of stream.

### Stream Characterization

A series of physical parameters, following Bury and Corn (1991), were measured to characterize the habitat of each creek. These parameters included aspect, elevation, stream gradient (%), wet and bank widths (m), water temperature (°C), canopy closure (%), understory cover (%) and substrate composition (%). Substrate was classified visually into four categories: sand (<2 mm), pebbles (2-64 mm), cobbles (64-256 mm), and boulders (>256 mm) in accordance with the Udden-Wentworth size classification (Pettijohn et al. 1972). Regional variables included local climate (Meidinger et al. 1997; Meidinger and Pojar 1991), physiography and bedrock geology (Holland, 1976), and landscape units as defined by ecological and topographical parameters (Demarchi 1993).

### Compilation of Existing Observations

The final inventory method involved the collection and compilation of existing records (n = 235) from provincial and federal government agencies, academic groups, consultants, naturalists, and museums. Government agencies in Whitehorse, Yukon Territory (Department of Fisheries and Oceans) and Juneau and Ketchikan, Alaska (Department of Fish and Game, U.S. Fish and Wildlife, Tongass National Park) also contributed information. These observations had been collected by various means, including electroshocking, trapping, active searches and opportunistic sightings.

## Results

A total of 398 twenty-minute surveys were conducted for a reconnaissance of the remote coast and the southeastern Kootenay Region. This data is summarized in Table 1, for comparable estimates of relative abundance in British Columbia (given the lack of TCS surveys along the south coast, secondary observations for this region are also included in Table 1 for a frequency of occurrence comparison). In addition, 47 reconnaissance surveys were done in which searching ceased after the first detection (absence was

TABLE 1. Frequency of occurrence and relative abundance (mean and range of TCS) of the tailed frog in various parts of its range in British Columbia

| Location | No. Creeks Sampled | Occurrence (%) | Mean No. Tadpoles per 20 minutes (range) |
|---|---|---|---|
| Kootenays | 188 | 9 | 3 (1 - 16) |
| North Coast | 110 | 15 | 10 (1 - 34) |
| Mid Coast | 100 | 36 | 10 (1 - 34) |
| South Coast | 93* | 54 | N/A |

* secondary observations with no relative abundance data

assumed after 20 minutes). A total of 74 area-constrained searches were conducted near the northern edge of the tailed frog range (n = 53) and in the southeastern corner of the province (n = 21), where specific questions about density were asked.

Tailed frogs were present in 285 of 733 sites searched. Tadpoles were present in approximately 40% of the permanent creeks sampled in central and southern coastal British Columbia (Table 1). Tadpole numbers ranged from 1 to 34 tadpoles per 20-minute search along the mid-coast (Table 1). Occurrence was less common, and relative densities were lower in the northern and eastern portions of their range.

### Coast Mountains

The tailed frog's distribution along British Columbia's coast is mostly continuous through the Coast and Mountains Ecoprovinces as far north as the Nass River Basin, from which the species was absent (Figure 1). The most northerly records were along the northwest shore of Kitsemkalum Lake, on the leeward side of the Coast Mountains. Elsewhere in the coastal portion of its range, the distribution of the tailed frog is largely congruent with the distribution of the Coastal Western Hemlock zone (CWH), and associated biogeoclimatic zones at higher elevations (e.g., Mountain Hemlock, Engelmann Spruce-Subalpine Fir, Alpine Tundra). North of the Nass River, tailed frogs were not detected in the Coastal Western Hemlock zone between Greenville and Stewart, or in the isolated pockets of CWH along the Stikine River. Discussions with Alaskan agencies revealed no evidence of the species (e.g., within federal and state parks, and in streams surveyed for fish by means of electroshocking). Thus, it appears that the present range of the tailed frog lies south of Portland Canal and the Nass River.

The most westerly records were found on islands of the mid- and northern-coast of British Columbia: Princess Royal Island and Gribble Island at the mouth of Douglas Channel, and King Island west of Bella Coola. Tailed frogs were also documented as far west as Namu and Boswell Inlet on the eastern edge of the Hecate Lowlands. The most easterly coast records were found in the Cayoosh Ranges between Pemberton and Lillooet, Spius Creek (northeast of Boston Bar), and Cathedral Park (south of Princeton)(Figure 1). These areas fall just beyond the Coast and Mountains ecoprovince, within the Southern Interior Ecoprovince (Demarchi 1993).

### East Kootenays

Tailed frogs occurred in 9% of 188 creeks sampled in the East Kootenays (Table 1), and are limited to a few southern drainages of the Southern Interior Mountains Ecoprovince (Figure 1). In 1996 and 1998, the species was found in ten tributaries that flow into the Flathead Drainage near the Montana border. Tailed frogs were also encountered in six tributaries to Yahk River, in the Columbia Basin. These occurrences coincide with the Border and McGillivray Ranges, respectively, which are separated by the Rocky Mountain Trench. Tadpoles and adults were found at high elevations (1380 to 1770 m), within the Engelmann Spruce/Sub-alpine Fir (ESSF) biogeoclimatic zone (Meidinger and Pojar 1991).

Green and Campbell (1984) and Nussbaum et al. (1983) provide two records further north in eastern British Columbia, near Shuswap Lake. These records are false (Green, pers. com. 1999) and likely propagated amongst general amphibian field guides that made use of the same databases.

## Discussion

During the last glaciation (ca. 29,000-10,000 $C^{14}$ years B.P.; Clague 1989), the Cordilleran ice sheet extended just south of the 49th parallel into parts of Washington, Idaho, and Montana. Thus, the present distribution of tailed frog populations in British Columbia represents northward migration from southern refugia. Although coastal refugia existed in British Columbia during glaciation (e.g. Brooks Peninsula and parts of Haida Gwaii), the habitats available in these refugia (e.g., nunataks and coastal plain; see Clague 1989; Josenhans et

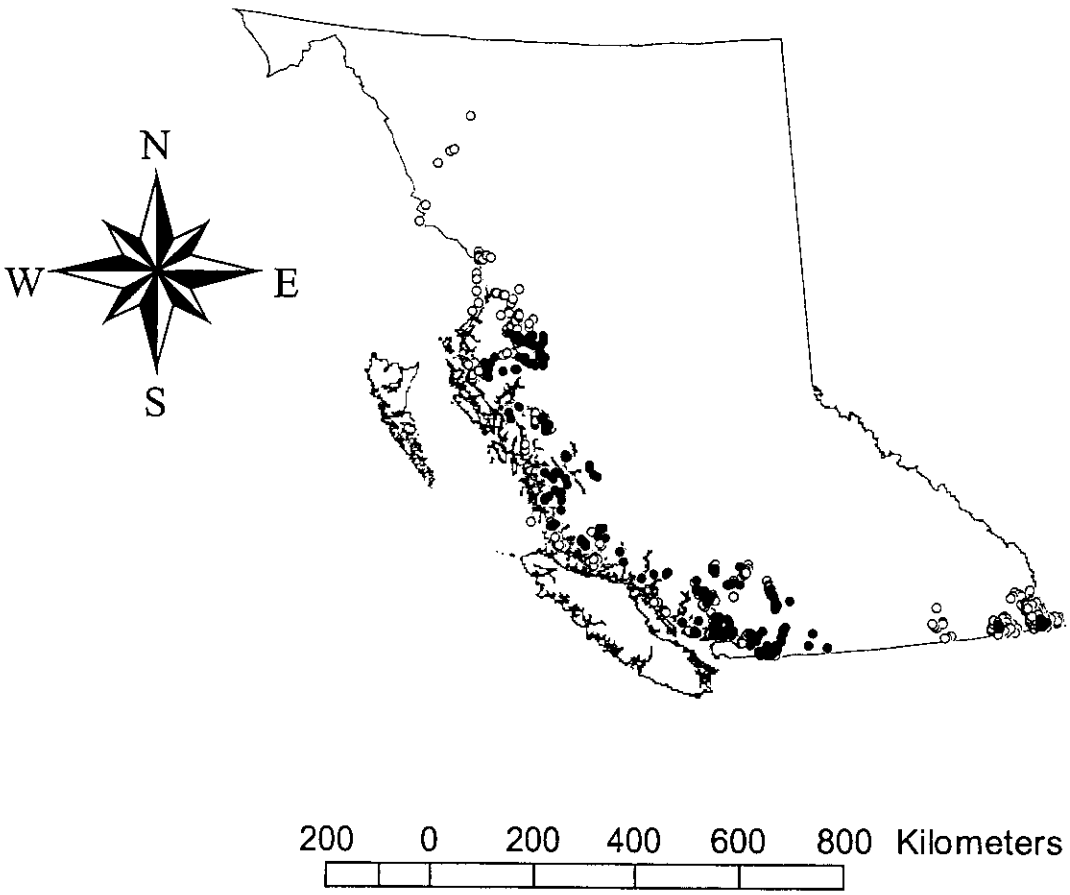


Figure 1. Distribution of the tailed frog in British Columbia; solid dots depict their presence and hollow dots represent searches in which they were undetected.

al. 1997) would not have been suitable to the tailed frog because they lacked permanent, fast-flowing streams in a favorable (temperate) climate. The populations in British Columbia represent northward migration from founding populations in the American Coast Mountains in the west and the Bitterroot and Rocky Mountains in the east. Nowhere in its range is the species found in low relief basins and plateau country, especially if occupied by grassland. Since the climate of the early Holocene (ca. 10, 000 - 7, 000 $C^{14}$ years B.P.) was warm and dry (Mathewes 1985), grasslands of the central interior plateau were more extensive (Hebda 1982), representing a greater barrier than today. Therefore, in British Columbia, coastal and interior populations have probably been geographically isolated for at least 10 000 years. Geographic isolation of coastal and interior populations in the United States has probably been considerably longer.

Other than its apparent absence from Vancouver Island and Haida Gwaii (Corkran and Thoms 1996), the range of the tailed frog in British Columbia coincides closely with the distribution of the Coastal Western Hemlock (CWH) zone and with scattered occurrences in the neighboring zones. This close association is directly related to the species' preferred habitat. The tailed frog breeds in cool, swift flowing headwater streams (Leonard et al. 1993; Corkran and Thoms 1996). Since tadpoles in British Columbia require 3-4 years to develop, suitable streams must be perennial. The CWH zone receives abundant precipitation (Table 2), providing numerous perennial first and second order streams, with enough snow

TABLE 2. Climate regimes associated with tailed frog occurrence.

| BGC[1] Zone | Elevation (M) | MAP[2] (mm) | MWP[3] (mm) | MAS[4] (mm) | MAT[5] (°C) | Tailed Frog Occurrence |
|---|---|---|---|---|---|---|
| CWH | 0-900 | 836-4400 | 695-3313 | 204-841 | 4.0-10.7 | Throughout |
| IDF | 122-1330 | 276-1199 | 117-1022 | 81-507 | 1.5-9.6 | Wetter portions |
| MH | 400-1800 | 1700-5000 | 1200-3000 | 700-3000 | -1.4-5.0 | Scattered |
| ESSF | 770-1945 | 414-2169 | 170-1607 | 198-1974 | -3.1-3.8 | Scattered |

[1] BGC = biogeoclimatic zones: Coastal Western Hemlock (CWH), Interior Douglas Fir (IDF), Mountain Hemlock (MH), Interior Cedar Hemlock (ICH), Montane Spruce (MS) and Engelmann Spruce-Subalpine fir (ESSF).
[2] MAP = Mean Annual Precipitation
[3] MWP = Mean Winter Precipitation
[4] MAS = Means Annual Snow (water equivalent)
[5] MAT = Mean Annual Temperature
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cover that many of these streams do not freeze during winter.

Inland from coastal British Columbia, precipitation diminishes and the climate becomes more continental: small streams are fewer and many freeze in the winter. Sampling across the Duffey Lake and Hurley Pass roads, which cross from the coast to the interior, revealed a marked decline in occurrence of tailed frogs at the transition from CWH to ESSF forest. In general, the ESSF zone is cold (Table 2) and shows marked variability in precipitation with most falling as snow (Meidinger and Pojar 1991). Tailed frogs were found at a few sites (n = 9) in the ESSF (near Princeton, Cranbrook, and in Kootenays), suggesting that where the snow blanket is sufficient to permit flowing water, the species can survive in cold climates. The Alpine Tundra zone which lies above the CWH and ESSF was not searched; however, G. Hazelwood (1993) reported adults from alpine meadows above mountain hemlock forests on the windward side of the Coast Mountains. As in the ESSF, distribution in the Mountain Hemlock and Alpine Tundra zones are likely determined by depth of insulating snow cover during winter. The climate regimes associated with tailed frog occurrences are summarized in Table 2.

Although precipitation is essential, extreme rainfall may be detrimental. This notion derives from sampling along a latitudinal transect across the northern Coast Mountains, in the vicinity of Prince Rupert, in a region of similar bedrock geology and local relief. On the windward side, populations were small and scattered (e.g., Scotia River) whereas on the leeward side, they were larger and widespread (e.g., Kitimat River). The change in tadpole densities coincides with a marked shift in precipitation levels, which are twice as high on the windward side of the Coast Mountains (e.g. 4400 versus 2300 mm as measured at valley bottom stations; Meidinger and Pojar 1991). Higher precipitation levels correlate with more frequent and intense rainfall, which may subject tailed frog tadpoles to more frequent and extreme bedload transport events, therefore limiting the viability of tadpole populations in northern coastal watersheds.

Tailed frog distribution is also influenced by geology (Sutherland and Bunnell 1999). Underlying geology influences the character of stream substrates. Massive, competent rock types (e.g., granitic) generally produce coarser substrates that are optimal habitats (Altig and Brodie 1972; Hawkins 1988), while fractured or brittle rock types (e.g., sedimentary) produce abundant fine gravel and sand, which is suboptimal (Dupuis and Steventon 1999; Welsh and Ollivier 1997; Wahbe 1996). Other factors (precipitation, relief) being equal, coarser substrates tend to be more stable and massive bedload transport events are fewer. Coarse substrates also provide greater interstitial habitat and refugia in the face of channel disturbance events. Thus, habitat is better and mortality may be lower in streams underlain by competent rocks.

In British Columbia, competent granitic and metamorphic rocks of the Coast Plutonic Complex underlie the main ranges of the Coast Mountains. Thus, in general the Coast Mountains provide good stream substrate; however, local bedrock structure, such as faults or intense fracturing, may reduce viability of specific streams. East and west of the intrusive spine of the Coast Mountains are older volcanic and sedimentary rocks. These areas provide less suitable substrates. In the East Kootenays, bedrock consists primarily of sedimentary rock, and stream channels are typically underlain by fine gravel composed of angular clasts (rubble). This sediment is readily mobilized and channel substrates are unstable. The Nass Basin, also underlain by fine sedimentary rock (argillitte) is devoid of tailed frogs and may present a barrier to northeastward migration of the species.

In summary, the tailed frog's range in British Columbia appears to be associated with past and current climatic and geological conditions. These geoclimatic factors interplay to produce the patchy distribution of tailed frog populations seen within British Columbia today. In general, the combination of mountainous terrain, plutonic rocks, and maritime climate on the coast provides an extensive region with optimal habitat conditions, while interior habitats with continental climate and sedimentary rock types are considered marginal.

## Acknowledgements

We thank Krista Wilson, Bruce Watkinson, and Natasha Slik for help with the Kootenay surveys and Elke Wind, Leo Frid, Tanya Wahbe, and Mike Wiley for conducting searches in the Coast Ranges. Many individuals and agencies in B.C., the Yukon Territory, and Alaska contributed information. Forest Renewal British Columbia, British Columbia Ministry of Environment, Lands, and Parks (Nelson Region), and Wildlife Habitat Canada provided funding. Logistical support was provided by Ministry of Forest districts (Kalum, Port McNeill, Mid-Coast, Squamish and Lillooet) and by industry (Elko, Shushardi Bay, Frank Beban Logging, Bear Creek Contracting, Interfor, Western Forest Products, and MacMillan Bloedel). Jim Pojar reviewed climate data in Table 2.

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*Received 9 July 1998*
*Accepted 17 February 2000*

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