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Distribution of Red-legged Frog (*Rana aurora aurora*) Breeding Habitat in the Jordan River Watershed, Vancouver Island, British Columbia

Final

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EXECUTIVE SUMMARY

The Red-legged Frog is vulnerable to habitat perturbations and degradation throughout its range. In recent years urban sprawl and continued land development have led to a decline of this species in certain areas. On a large scale, industrial operations such as forestry and mining can affect unclassified wetland habitats that are not currently afforded protection under BC provincial law. These habitats are often used by pond-breeding amphibians like Red-legged Frogs. Large-scale habitat alteration and/or loss have also been attributed to BC Hydro resulting primarily from impoundments, which have flooded river valleys, wetlands, and uplands forests throughout the province.

Under the auspices of the Bridge Coastal Restoration Program, an evaluation of the suitability and distribution of Red-legged Frog breeding habitat was conducted in the Jordan River Watershed on southwestern Vancouver Island. Jordan River and Bear Creek were impounded in the early 1900's creating Diversion and Bear Creek reservoirs. A third headpond was created in the late 1960's. The cumulative effects of impounding the Jordan River and its tributaries decreased productivity and habitat connectivity for species like the Red-legged Frog, which is currently threatened in BC and is a COSEWIC species of Special Concern.

In 2004 and 2005, Red-legged Frog presence and distribution was assessed using time-constrained searches in suitable habitat (including upland forest), frog auditory surveys, and road surveys. Red-legged Frogs were detected both inside and outside the Jordan River watershed boundary with most detections in the watershed occurring outside of BC Hydro's area of operation. In addition to Red-legged Frogs, Rough-skinned Newts, Long-toed Salamanders, Northwestern Salamanders, Pacific Treefrogs, Ensatina, and Western Redbacked Salamanders were detected.

Red-legged Frogs were not detected in either Diversion or Bear Creek reservoir and it is apparent that suitable Red-legged Frog breeding habitat is not currently available in either reservoir. Through impoundment and reservoir creation up to 20 km of shoreline habitat was created. However, the shoreline habitat created is not suitable for Red-legged Frogs due to a lack of shallow shoreline areas with emergent vegetation. These habitats are not forming within the shoreline of either reservoir because of fluctuating water levels. Furthermore, the presence of fish in each reservoir could be precluding Red-legged Frogs. Diversion Reservoir is the primary storage reservoir, and as such can undergo a maximum draw down of 18 m annually. During the critical period for Red-legged Frogs, water levels have fluctuated by as much as 9.6 m. The magnitude of those fluctuations makes it impossible for emergent and submergent vegetation to take hold and for wetland habitats to develop. Associated with the fluctuating water levels in Diversion Reservoir is the deposition of large woody debris along the shoreline in areas that could be used for breeding. The presence of the woody material in Diversion Reservoir does not necessarily preclude Red-legged Frogs from breeding. However, the large fluctuations in water level cause these large blockades of woody material to move, and that movement would almost certainly dislodge any attached egg masses. Conversely, water levels in Bear Creek Reservoir are more stable (i.e., have limited fluctuation) so that edge habitats may be suitable for Red-legged Frogs; however, specific components of Red-legged Frog breeding habitat are missing, namely submergent and emergent vegetation, which have not become established because of fluctuating water levels.. This is most noticeable along the west and south shoreline of Bear Creek Reservoir.

It is likely that the impoundment of the Jordan River and its tributaries resulted in a net loss of approximately 90 ha of suitable breeding habitat; 60 ha along Bear Creek and 30 ha along the upper Jordan River. Impoundment and reservoir creation may have also decreased habitat connectivity around Bear Creek and Diversion Reservoirs. Despite this, Red-legged Frogs are breeding in the Jordan River Watershed, including some areas within the area of operation of the

hydroelectric facility; however, the population is likely depressed relative to pre-impoundment conditions.

Restoration projects, such as the construction of perched wetlands within specific areas of both Diversion and Bear Creek reservoirs would increase the connectivity and productivity of the Jordan River Watershed for Red-legged Frogs and other wetland-associated species. Overall, this project speaks to the primary objective of the Bridge Coastal Restoration Program, which is to address impacts on natural resources in the Bridge Coastal System. Additionally, this project has filled a data gap for rare and endangered species in the Jordan River Watershed, as recommended by the Jordan River Water Use Plan. Additionally, recommendations in this report provide some direction as to how affected habitats could be restored to increase the productivity of the Jordan River Watershed for Red-legged Frogs and other wetland-associated species.

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1 INTRODUCTION

1.1 Background

River floodplains are disturbance-dominated ecosystems where floods are major regulators of both aquatic and nearby terrestrial communities (Ward et al. 1999; Cogălniceanu and Miadu 2003). With damming and river regulation, the predictable cycling of high and low water is replaced with the maintenance of relatively steady (lower) flows with periodic flood events associated with the release of water. Flow regulation by dams has disrupted the natural pulse flow regime of most rivers and has altered the processes that sustain biodiversity (Junk et al. 1989; Ward and Sanford 1995).

Downstream effects of regulation can be quite variable. However, there are several changes that appear to occur in most regulated systems such as 1) the decrease of peak flood flows with lower year-round flows (Ligon et al. 1995), 2) the concentration and suspension of sediments decreases substantially for many kilometres downstream and the bed material typically becomes more coarse (Williams and Wolman 1984; Ligon et al. 1995), and 3) the areal extent of riparian vegetation increases below dams as a direct result of the reduced flows and lack of scouring associated with normal flood events (e.g., annual freshet) (Petts 1984; Johnson 2002). Associated with the downstream changes to hydrologic function within a regulated river system are the effects on riverine fauna, including invertebrates, fish, birds, mammals, amphibians, and reptiles (Trayler 2000). These include loss of important habitat, reduced productivity, reduced survival and fitness, and modification of population structure within and among species groups (Trayler 2000). In a recent study, Richter et al. (1997) found that hydrologic regime alteration and streambed sediment load changes (including siltation) were the most important stressors leading to species decline, along with habitat destruction, channel or shoreline changes in morphology or bed structure, and changes in nutrient loading. The direct and indirect impacts of each of these stressors on species and genera have been well-reported for certain groups (e.g., fish; invertebrates; see Ward et al. 1999) but less so for others (e.g., amphibians; see Lind et al. 1996).

In North America, the regulation of rivers (i.e., damming and diversion of water) has been implicated in the decline of many native frogs (Moyle 1973; Hayes and Jennings 1986; Jennings 1988), but most implications have been anecdotal and the effects of dams and river regulation on amphibians have not been quantitatively evaluated (Lind et al. 1996). With the exception of one published study (Lind et al. 1996), empirical data on the effects of river regulation and impoundment on amphibians are nonexistent. Lind et al. (1996) documented habitat alteration resulting from river regulation as having significantly negative impacts on the Foothill Yellow-legged frog (*Rana boylii*), a stream-breeding amphibian. Specifically, they cited changes in river morphology leading to degradation and loss of suitable breeding habitat. They also pointed to unseasonably high flows within the regulated river channel resulting in the loss of entire cohorts of *R. boylii*. The combination of habitat alteration and the loss of entire cohorts have contributed to the decline of this species in a regulated river. The data presented by Lind et al. (1996) represents the only published account on the relationship between a riverine frog species and river regulation that could be obtained. Because amphibians are frequent inhabitants of floodplain and riparian habitats, the cumulative effects of impoundment and regulation can be detrimental to a species that relies on these habitats to fulfill important life requisites. For example, many amphibian species use riparian corridors for seasonal migrations and/or for dispersal (e.g., Red-legged Frogs (*Rana aurora aurora*) on Vancouver Island; Chan-McLeod 2003).

In British Columbia, the impoundment and subsequent regulation of riverine systems has resulted in the loss of lowland and upland forests, wetlands, and ponds. The loss of wetland and pond habitat has likely had direct significant (negative) impacts on pond-breeding amphibians, such as the Red-legged Frog. Throughout British Columbia habitat degradation and loss are the primary threats to Red-legged Frogs, with introduced species a secondary threat (Waye 1999; Ovaska and Sopuck 2004). The Red-legged Frog appears to be most common at elevations below 500 m (Ovaska and Sopuck 2004) which coincides with areas of intense urban and agricultural development in the Lower Mainland and on south-eastern Vancouver Island. Forestry activities at low elevations can affect the movements of Red-legged Frogs (Chan-McLeod 2003; Ovaska and Sopuck 2004) and river impoundment appears to have disrupted the connectivity of breeding habitats across certain landscapes (this study). Habitat altering activities create barriers to movement, resulting in habitat fragmentation and the isolation of populations, which makes the species particularly vulnerable to, for example, disease, an increasing issue with native amphibians that can rapidly destroy populations (e.g. Ranids in the PNW; Ovaska and Sopuck 2004).

Like many amphibian species, it is likely that the Red-legged Frog exhibits philopatry to natal breeding or overwintering sites and their ability to use alternate sites is unknown (Berven and Grudzien 1990). The sedentary nature of amphibians coupled with the philopatry to breeding and overwintering sites increases the vulnerability of Red-legged Frog populations to loss and degradation of their habitats (Biolinx Consulting and E.Wind Consulting 2003). Other factors that could increase this species' vulnerability include increased water temperature resulting from reduction in stream flow, which could adversely affect the development of eggs (Hayes and Jennings 1986; COSEWIC 2002).

To assess whether or not river impoundment and regulation have affected Red-legged Frog populations in the Jordan River Watershed on Vancouver Island, a study investigating the distribution of suitable breeding habitat within the Jordan River Watershed was conducted. The area investigated was limited to the Area of Operation, or the area immediately adjacent to lands inundated by flooding, or affected by dam construction and river regulation. Tributaries to Jordan River were also assessed as a means to compare unregulated systems with regulated ones to determine if Red-legged Frogs were breeding in areas not affected by regulation. Other areas not within the area of operation, but that appeared to provide breeding opportunities for Red-legged Frogs were investigated because of their ability to serve as sources for frogs. The current assumption is that impoundment of Jordan River and Bear Creek has resulted in a net-negative habitat loss scenario and that the Red-legged Frog population associated with the area of operation is depressed relative to unregulated areas within the watershed and to pre-impoundment conditions. The water use plan for Jordan River indicates that significant wetland habitat was lost when Bear Creek was flooded and it is likely that these wetlands were used extensively by pond-breeding amphibians, like the Red-legged Frog during the breeding season, although data on ore-impoundment conditions are nonexistent.

1.2 Statement of Need

The ***Bridge-Coastal Fish and Wildlife Restoration Program Strategic Plan Volume 1: Strategy and Overview*** provides a description of the wildlife species of conservation concern that occur in the Jordan River Watershed. Included in this table is the Red-legged Frog. The primary objective of the Bridge Coastal Fish and Wildlife Restoration Program is to address fish and wildlife impacts as identified in the Strategic Plans in 15 watersheds affected by BC Hydro generation facilities in the Bridge Coastal Generation region. This region includes Vancouver Island, Coastal BC, Bridge River, Shuswap River and Fraser Valley. The Jordan River Watershed on Vancouver Island occurs within the Bridge Coastal Generation Region and. According to the Jordan River Watershed Plan (BC Hydro 2000b), river impoundment and regulation, as well as inundation of wetland and upland habitats, have been implicated as having negatively impacted local wildlife populations. Of the ten impacts listed, eight are indicated as negative and are confounded by the following limiting factors:

- Habitat change
- Loss of habitat
- Reduced productivity
- Impediments to wildlife migration
- Diversions resulting in mortality

Habitat Changes: Regulation can affect the productivity of riparian zones, and can therefore affect the distribution of suitable Red-legged Frog breeding habitats adjacent to regulated rivers. River regulation can also create changes to the distribution, abundance, and occurrence of riparian-associated tree and shrub species and can drastically affect the quality and availability of suitable breeding habitat.

Loss of Habitat: The loss of wetlands in flooded valley bottoms (Bear Creek) represents a net loss of suitable Red-legged Frog breeding habitat in the Jordan River Watershed. The reduction of available habitat for Red-legged Frogs and other amphibians needs to be addressed.

Reduced Productivity: The effects of river regulation on the availability and abundance of suitable Red-legged Frog breeding habitats need to be investigated. Given that the damming of the Jordan River and Bear Creek likely resulted in a net-loss of wetland and marsh habitats associated with Bear Creek and Jordan River, the net productivity (i.e., reproductive success) of Red-legged Frogs has also likely decreased. It is unlikely that the ratio of males to females has changed as a result of impoundment. However, breeding success likely has. A direct comparison of Red-legged Frog breeding productivity (relative number of males to females now vs. then) is not possible; however, an assessment of the distribution of suitable breeding habitats currently available within the area of operation is possible.

Based on the limiting factors and their direct or indirect effects on wildlife, the Jordan River Water Use Plan (BC Hydro 2000a) has identified six wildlife restoration objectives for the Jordan River Watershed:

- Objective 1: Reduce erosion or drying of riparian and riverine habitats
- Objective 2: Rehabilitate reservoir drawdown zones to enhance productivity and wildlife habitat
- Objective 3: Reduce barrier effects of diversions on wildlife
- Objective 4: Conserve riparian and wetland habitats in the Jordan River Watershed
- Objective 5: Create elk winter range
- Objective 6: Improve the knowledge base on rare, endangered and threatened species and habitat utilization in the Jordan watershed.

Of these 6 objectives, objectives 1, 2, 4 and 6 relate directly to the current study. The need for this study is based on the following statements:

Objective 1: Reduce erosion or drying of riparian and riverine habitats:

Red-legged Frogs use riparian habitats extensively during their life to fulfill their food, cover, thermal, and reproductive life requisites. The persistence of these habitats is essential to the persistence of this species in a given area. The degradation of riparian habitats has been indicated in the local extirpation of this species in other areas. The distribution of Red-legged Frogs in the Jordan River Watershed has not been documented, at least not downstream of Jordan Meadows. Therefore, a need exists to determine the distribution of Red-legged Frogs relative to the riparian zones within the area of operation (i.e., floodplain of affected watercourses).

Objective 2: Rehabilitate reservoir drawdown zones to enhance productivity and wildlife habitat

Edges of ponds, lakes, and reservoirs can provide suitable breeding habitat for Red-legged Frogs. The nature or quality of edge habitat can be used as a predictor of Red-legged Frog presence. For example, female frogs use relatively shallow, gently sloping shoreline areas containing submergent and emergent vegetation as attachment sites for their egg masses. Edge habitat substrate can also affect the suitability of habitat for Red-legged Frogs. Because Bear Creek Reservoir was created by flooding a previously existing wetland, an assumption has been made that the wetland represented highly suitable Red-legged Frog habitat. An evaluation of existing conditions is required to determine if, through the creation of reservoirs, any habitat creation has occurred.

Objective 4: Conserve riparian and wetland habitats in the Jordan River Watershed

The Red-legged Frogs' need for riparian and wetland habitats for the fulfillment of life requisites is paramount for the persistence of Red-legged Frogs (and other amphibian species) in the Jordan watershed. Furthermore, the value of wetlands and riparian areas for other wildlife species (e.g., elk, raptors, small mammals, bats) is high, and these habitats are needed to preserve and maintain wildlife diversity and productivity in the watershed. Identification of habitat suitability within the area of operation is useful so that recommendations can be made to foster sound management practices.

Objective 6: Improve the knowledge base on rare, endangered and threatened species and habitat utilization in the Jordan watershed.

In general, there is a paucity of information on the effects of regulating rivers on wildlife populations and their habitats in British Columbia. An understanding of the requirements of rare, endangered and threatened species is required to ensure that restoration plans do not result in diminished abundance of these species. The Red-legged Frog, when present, can be locally abundant. However, it is generally patchily distributed throughout its range and appears to be declining in numbers for reasons that are not well understood. Determination of this species presence in the Jordan River Watershed will provide useful information on the distribution of this species relative to its range on southern Vancouver Island and will help determine if river impoundment and regulation has affected suitable Red-legged Frog habitat

2 PURPOSE AND OBJECTIVES

The purpose and objectives of this study were:

- to evaluate the effects of river impoundment and reservoir creation on the distribution and abundance of the Red-legged Frog,
- to investigate how regulation affects the distribution and persistence of breeding habitat within the floodplain of the river, and
- to determine if the cumulative effects of impoundment resulted in a negative net loss or gain of suitable breeding habitat.

3 STUDY AREA

This project was conducted in the Jordan River Watershed on the southwestern edge of Vancouver Island, British Columbia, approximately 85 km northwest of Victoria (Figure 1). Jordan River drains a watershed of approximately 165 km^2 and the watershed has been impacted by hydroelectric development, mining, and logging (Wright and Guimond 2003).

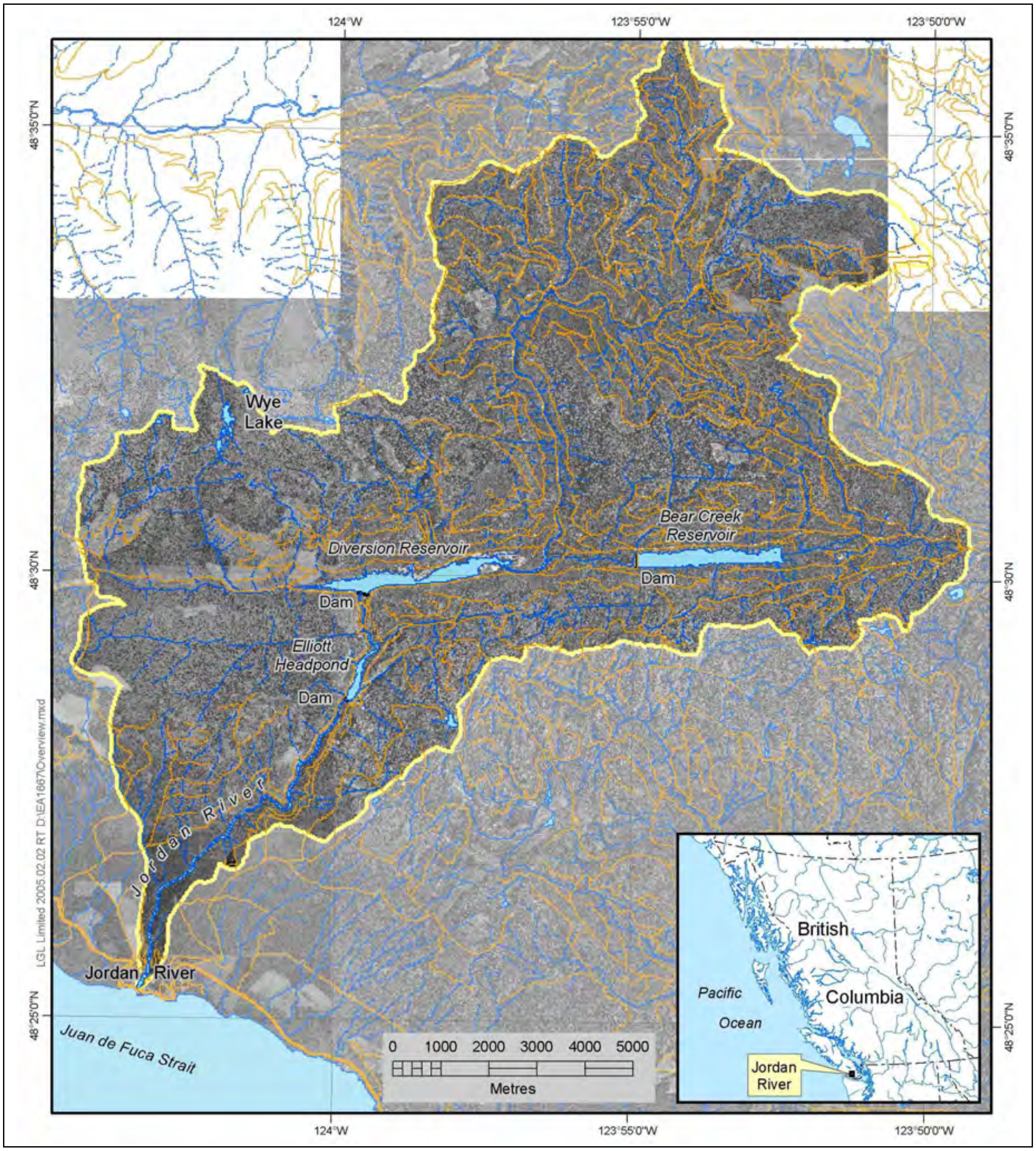


Figure 1. Location of Jordan River Watershed relative to British Columbia and Vancouver Island.

Jordan River is a steep, incised watercourse with several barriers to fish migration. High water inflows from snowmelt occur between May and July, with August and September generally very dry. Heavy rain can cause immediate high flows between October and March. Between 1909 and

1911, the Old Jordan Forebay Dam was constructed and in 1913 two reservoirs were created (Bear and Jordan [=Diversion]) with a headpond created in 1971 (Elliot). Coincident with the construction of Elliot headpond in 1971, the old powerhouse, forebay and wooden penstock were taken out of service. The additive effects of reservoir and head pond creation resulted in the inundation of 193 hectares of mostly upland and stream channel habitat (BC Hydro 2000b). The creation of Diversion and Bear Creek Reservoirs and Elliot Head pond also resulted in the development of 20 new kilometres of shoreline habitat. According to BC Hydro, 8 km of Jordan River have been potentially affected by diversion, which includes the mainstem of Jordan River downstream of Diversion Dam to its confluence with the ocean. The total surface area of two reservoirs and headpond is 271.7 ha (Diversion: 179.8 ha; Bear Creek: 75.9 ha; Elliot headpond: 16 ha). The specifications for the facilities and reservoirs are presented in Table 1.

Table 1. Specifications for facilities and reservoirs associated with Jordan River.

DAM	**Bear Creek**	**Diversion**	**Elliot**
Nameplate Capacity (MW)	0	0	150
Dependable Capacity (MW)	-	-	170
Dam Function	Storage	Storage / Diversion	Storage / Diversion
Date Constructed	1911	1911	1969
Date Operational			1971
Date Reconstructed	1969; 1985	1969	2004
Height (m)	19	39.9	27.4
Length (m)	337	232	270
Fishway at dam	No	No	No
Historic anadromous fish presence	No	No	No
RESERVOIR	**Bear Creek**	**Diversion**	**Elliot**
Cleared / Not cleared	Not cleared		
Present Area (ha)	75	193	16
Watershed Area (km^2)			165
Present elevation a.s.l (m)	411	386	336
Normal Drawdown Range (m)	8	18.3	10.7
Mean Depth (m)	15	40	27.4
Storage (million m^3)			28.4
Mean annual discharge (m^3/s)			12 – 13.7
DIVERSION	**Bear Creek**	**Diversion**	**Elliot**
Structure Type			Tunnel: 5.3 km Penstock: 1.6 km
Licensed flow (m^3/s)			10.4
Fish flow release (m^3/s)	0	0	0
Mainstem Length diminished (km)			9

Water quality data for Bear Creek were collected in the 1980's by the Ministry of Water, Land and Air Protection (Hirst 1991). Bear Creek Reservoir has a surface area of 75 ha, a maximum depth of 15 m and a mean depth of 6 m. The impoundment is ultra-oligotrophic, with total dissolved solids content of only 18 mg/l and a pH of 6.9; total dissolved phosphorus content is about 3 µg/l, total nitrogen 23 mg/l, ammonia nitrogen 7 µg/l and nitrate/ nitrites 2 µg/l (measurements made in 1983, Ministry of Environment, lake survey data). The reservoir contains considerable amounts of debris, although the area was apparently logged prior to initial impoundment. The surrounding terrain has been extensively logged. Dissolved oxygen content ranges from 8 to 8.5 mg/l throughout the water column, except near the bottom where the content is only 2.5 mg/l (Ministry of Environment, lake survey data) suggesting the likelihood of stagnation and decomposition in the hypolimnion. Bear Creek Reservoir only has minor tributaries, most of which dry in late summer (Hirst 1991). Similar information for Diversion Reservoir was not obtained.

The Jordan River Watershed is part of the Coast and Mountains Ecoprovince, the Western Vancouver Island Ecoregion, and the Windward Island Mountains Ecosection (Demarchi 1996). Within the Windward Island Mountains Ecosection, the project area is contained within 4 variants of the Coastal Western Hemlock (CWH) biogeoclimatic zone, which covers much of Vancouver Island:

Table 2. Biogeoclimatic zones, subzones, and variants occurring within the Jordan River Watershed.

Label	Zone	Subzone	Variant
CWHvm1	Coastal Western hemlock	Very wet maritime	submontane
CWHvm2	Coastal Western hemlock	Very wet maritime	monatne
CWHmm1	Coastal Western hemlock	Moist maritime	submontane
CWHmm2	Coastal Western hemlock	Moist maritime	monatne

The CWH is characterized by cool summers and mild winters and the highest average rainfall of all biogeoclimatic zones (Pojar et al. 1991). Within the CWH, western hemlock is the dominant coniferous tree species with Douglas-fir being widespread. Amabalis fir and yellow-cedar are also common. Big-leaf maple, red alder and cottonwood species are common in riparian zones throughout the CWH (Pojar et al. 1991). Characteristic floristic features of zonal ecosystems in the CWH are:

a) the prominence of western hemlock;

b) the sparse herb layer;

c) the predominance of several moss species (especially ***Hylocomium splendens*** [step moss] and ***Rhytidiadelphus loreus*** [lanky moss]).

The riparian zone of Bear Creek between the two reservoirs is dominated by red alder with a well developed understory of shrubs and herbs (V. Hawkes, pers. obs). Riparian vegetation associated with Jordan River includes deciduous and coniferous tree species including red alder, Douglas-fir and western redcedar. In some areas, it appears that riparian vegetation is starting to encroach into floodplain habitats.

Within the watershed, surveys for Red-legged Frogs and potential frog breeding habitat occurred in:

- The mainstem of Jordan River upstream of Diversion Dam, downstream of Diversion Dam to Elliot Headpond, and downstream from Elliott Headpond,
- Portions of Wye, Walker, Tripp, Valentine, Bear, Rough, Alligator, and Sinn Fein Creeks,
- Portions of Jordan River downstream of Elliot Headpond,
- Shoreline habitats associated with Diversion and Bear Creek Reservoir and Forebay Headpond

Figure 2 shows the portions of the Jordan River Watershed that were sampled during this study. In general, the areas sampled were within the floodplain of the Jordan River and its tributaries and around the edges of the three main reservoirs: Diversion and Bear Creek Reservoirs, and Elliott Headpond. Some small ponds and lakes (e.g., Forslund Lake; Forebay Headpond) were also assessed for their suitability as Red-legged Frog breeding habitat. These areas were included because of their potential to serve as sources for Red-legged Frogs in the project area.

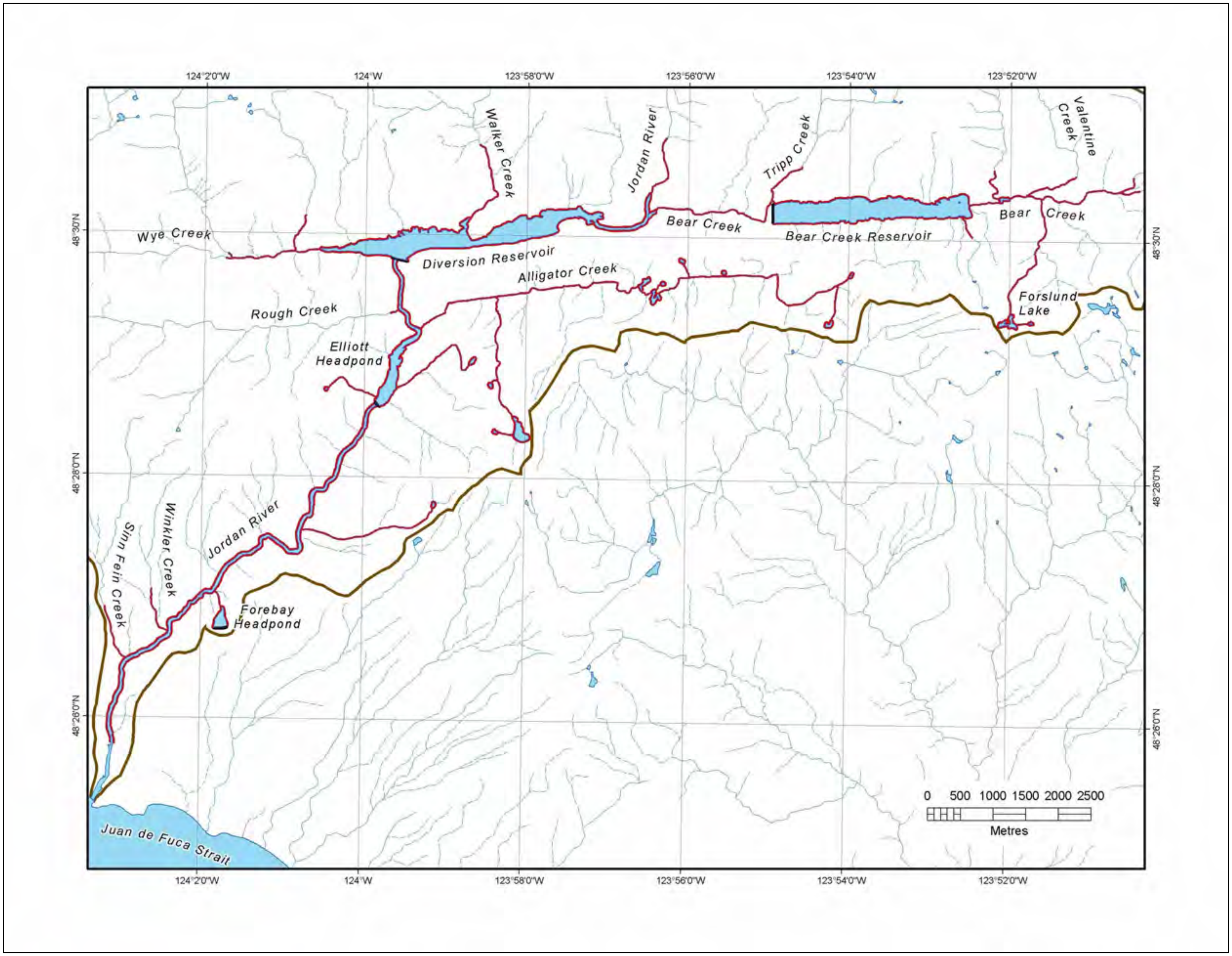


Figure 2. Overview of the Jordan River project area showing the primary area of interest (outlined in red).

4 METHODS

Red-legged Frog surveys were conducted during late spring and early summer 2004 and late winter 2005 following RISC (1998a). All data were recorded on either the ***Animal Observation Form - frog Auditory Survey, Animal Observation Form - Pond-Breeding Amphibians Road Survey*** or the ***Animal Observation Form - Pond-Breeding Amphibians/Painted Turtle Search –*** Adult (RISC 1998b). The ***Animal Observation Form - Pond-Breeding Amphibians/Painted Turtle Search –*** Adult form was modified slightly to allow for the recording of wet and dry bulb temperature (°C) for the calculation of relative humidity.

In spring and summer 2004 (June and July), time-constrained searches (TCS) were conducted and in late winter 2005 (February and March), TCS as well as frog auditory surveys (FAS) were conducted. Frogs (and other amphibians) were also searched for on forestry roads (Road Survey [RS]) within the project area to detect amphibians travelling to breeding ponds. Prior to conducting field surveys, aerial photographs and topographical maps of the Jordan River Watershed were evaluated for the presence and distribution of potential Red-legged Frog breeding habitats. Specifically, ponds, wetlands, backwaters, and creeks with riparian forests dominated by deciduous tree species were identified and flagged for on-the-ground follow-up surveys.

Time-constrained surveys were conducted in semi-aquatic and aquatic habitats throughout the area of operation, which was defined as the area approximately 30 m beyond the high water mark along each bank of the Jordan River mainstem, and within 15 m of the high water mark of associated tributaries. Time-constrained searches were conducted in aquatic and terrestrial habitats and the study area was visited eight times between September 2003 and March 2005. Most areas were sampled on each visit with some sites being visited only once to assess habitat suitability. The edges of Diversion and Bear Creek Reservoirs were searched, as was the Old Forebay pond. The edges of Elliot Headpond were not searched in 2004 because it had been drained to accommodate maintenance work on the dam. Other areas searched included ponds, lakes, and wetlands within Jordan River Watershed, including areas outside the 30 m or 15 m zones around the mainstem and tributaries. During TCS, biotic and abiotic data were recorded for each area searched (RISC 1998a).

When amphibians were captured, they were placed in a clean plastic bag and weighed using a Pesola® Scale to the nearest 0.25 gram. Snout-vent length (SVL) and total length (TL) were recorded to the nearest millimetre for salamanders and snout-urostyle length (SUL) was recorded for frogs. Where possible, sex and life form were recorded. Captured amphibians were released at the site of capture and the capture location was obtained using a Garmin GPS 12 handheld unit. Frog capture was permitted under Wildlife Sundry Permit Number V104-1476.

To facilitate the production of a habitat suitability map for the Red-legged Frog, a Wildlife Habitat Ratings approach was used (RISC 1999) in which habitats were rated as probable breeding, confirmed breeding, or potential breeding (with restoration) with particular attention paid to the availability, distribution, and suitability of breeding habitat within the area of operation. Breeding habitats were identified on the ground during field work and were assessed for the potential to serve as breeding sites for Red-legged Frogs. The criteria used to assess breeding habitats were:

- Pond permanence
- Edge habitat with emergent and submergent vegetation and/or woody material
- Water depth
- Presence of Red-legged Frogs
- Water temperature (4 – 21 °C; Licht 1971).

A 4-class rating system suitable for mapping at either 1:50,000 or 1:20,000 is suggested by RISC (1999). However, there are problems with developing a wildlife habitat suitability map for the Red-legged Frog because Provincial Benchmarks have not been described for this species and attributes available in forest cover or TRIM data sets do not capture the habitat attributes required by this species during the breeding season. Furthermore, suitable (i.e., useable) breeding habitat can occur in ditches along a roadside, in rock crevasses within a riverine floodplain, or in small forest wetlands not identifiable through conventional methods (such as aerial photograph interpretation) (Wind 2002). Although it may be possible to identify areas of deciduous forests associated with creeks, lakes, or ponds, small forested wetlands occurring under coniferous canopy are not identifiable, resulting in a constant under-estimation of Red-legged Frog breeding habitat availability in forested landscapes. Therefore, although the wildlife habitat ratings methodology can be applied to this species, it was not possible to develop a suitability map that is useful for comparisons to other regions. The map developed can only be used to assess the suitability of Red-legged Frog breeding habitat within the project area. Consequently, the polygons on the habitat suitability map were digitized from hand drawn polygons. For much of the project area, polygon development was resulted from field investigations. However, the ratings for a small proportion of polygons included in the maps were predicted based on probable similarities in habitat-type. Similarly, upland forested habitats were not evaluated for the presence of small wetlands given the primary objective of this project to evaluate the suitability and distribution of Red-legged Frog breeding habitats associated with BC Hydro's area of operation. Because habitat suitability is related to habitat connectivity, the distribution of Red-legged Frog breeding habitats was evaluated using information on average and maximum movement patterns of Red-legged Frogs around and away from breeding ponds (Gomez and Anthony 1996; Hayes et al. 2001).

Edge habitat and substrate composition of water bodies is important to Red-legged Frogs, especially for breeding habitat. The impoundment of Jordan River and Bear Creek created up to 20 km of new edge habitat. To evaluate the potential for either Diversion or Bear Creek Reservoir to provide breeding habitat for Red-legged Frogs, water level data for each reservoir were obtained from BC Hydro for the period 1994 - 2004. Similar data were obtained for the release of water from the Hollow Cone Valve situated at Diversion Dam. Environmental data (temperature and precipitation) were obtained from BC Hydro and Western Forest Products and those data were used to estimate the onset of Red-legged Frog breeding for the same period. Fluctuating water levels can affect the suitability and extent of Red-legged Frog breeding habitat and seasonal water level fluctuations within each reservoir could preclude breeding. To assess the suitability of reservoirs for breeding, the magnitude of water level fluctuation was plotted and the timing of Red-legged Frog breeding was indicated to determine if fluctuating water levels would adversely affect the reproductive success of Red-legged Frogs.

5 RESULTS

In 2004 and 2005 amphibians were sampled using several techniques. Table 3 shows level of effort for each of the survey types used. Time constrained searches were conducted in May and July 2004 and in February and March 2005. Frog Auditory Surveys (FAS) were conducted during February and mid-March 2005. During FAS, roads were surveyed for animals migrating to breeding areas.

Table 3. Level of effort used to sample amphibians in the Jordan River watershed.

Date	Survey Type	Duration (hours or Kms)	People	Total Effort
11 May 2004	TCS	4 Hr 55 min	3	14 Hr 45 min
12 May 2004	TCS	5 hr	3	15 Hr
22 Jul 2004	TCS	4 hr	2	8 Hr
02 Mar 2005	TCS	4 Hr	2	8 Hr
08 Mar 2005	TCS	6 Hr	2	12 Hr
			TOTAL	**57 Hr 45 min**
16 Feb 2005	FAS	2 Hr	2	4 Hr
09 Mar 2005	FAS	2.5 Hr	2	5 Hr
			TOTAL	**9 Hr**
16 Feb 2005	RS	14.56 Km	2	14.56 Km
09 Mar 2005	RS	22.7 Km	2	22.7 Km
			TOTAL	**37.3 Km**

Survey efforts resulted in the detection of seven amphibian species in the Jordan River Watershed (Table 4;; Map 1). Terrestrial forms of all species were detected with the exception of the Long-toed salamander whose presence was determined by egg masses only. Information gleaned from BC Hydro personnel and other reports did not increase the number of species known to occur in the Jordan River Watershed (see below), although others species are probably present (e.g., Clouded salamander and Western Toad). With the exception of three egg masses encountered in Bear Creek, all amphibians and egg masses encountered were identified or attributed to a particular species.

Table 4. Species and life forms of amphibians detected in the Jordan River Watershed in 2004 and 2005.

	Life Form[1]							
Species	**Adult**	**Subadult**	**Juvenile**	**Tadpoles[2]**	**Metamorphs**	**Egg Masses**	**Unclassified**	**Total**
A. gracile	1					16		17
A. macrodactylum						45		45
T. granulosa		2	16					18
*H. regilla**	134			500				634
R. aurora	8	10	17		10		2	47
E. eschscholtzii	2							2
P. vehiculum	5		1					6
Egg Masses							3	3
Total	150	12	34	500	10	61	5	772

[1] Life Form assigned using snout to vent r snout to urostyle length. See Section 5.2.
[2] Number approximated
* Includes approximately 130 calling males

Amphibians breed in the Jordan River Watershed, including some areas within the area of operation. For example, amphibians bred in portions of Bear Creek (Pacific Treefrog, Red-legged Frog, and Northwestern Salamanders) (Photo 1) and in several small wetlands and ponds in 2005

(Map 1). Beauchesne and Cooper (2004) reported that Rough-skinned newts were breeding in the Forebay pond in 2003 and both Pacific Treefrogs and Red-legged Frogs may use the Forebay pond for breeding. Furthermore, in 2003 and 2004 amphibian tadpoles (*Hyla regilla*; Photo 2), metamorphosing froglets of *Rana aurora* (Photo 3) and juvenile Rough-skinned newts (Photo 4) were encountered in an area just below the spillway at Diversion Dam. This area consists of many small pools in the crevasses of rocks, many of which had numerous (> 200) Pacific Treefrog tadpoles in them in both 2003 and 2004 (animals observed in 2003 were observed during a reconnaissance visit to the field site). In some areas, the development of tadpoles appeared to be delayed because the pools were heavily shaded, reducing water temperature and protracting the time to metamorphosis. Other pond-breeding amphibians that are breeding in the Jordan River Watershed include the Long-toed Salamander (Photo 5) and Northwesten Salamander. The Western Toad may be a resident breeder. Additionally, Rough-skinned Newts and Red-legged Frogs (adults) were documented from Elliot Headpond in 2004 after the headpond had been drawn down for maintenance (Al Maclean and Eva Wichmann pers comm.).

Photo 1. Northwestern salamander egg mass encountered in Bear Creek, May 2004.

Photo 2. Pacific Treefrog tadpole captured in a pool below Diversion Dam.

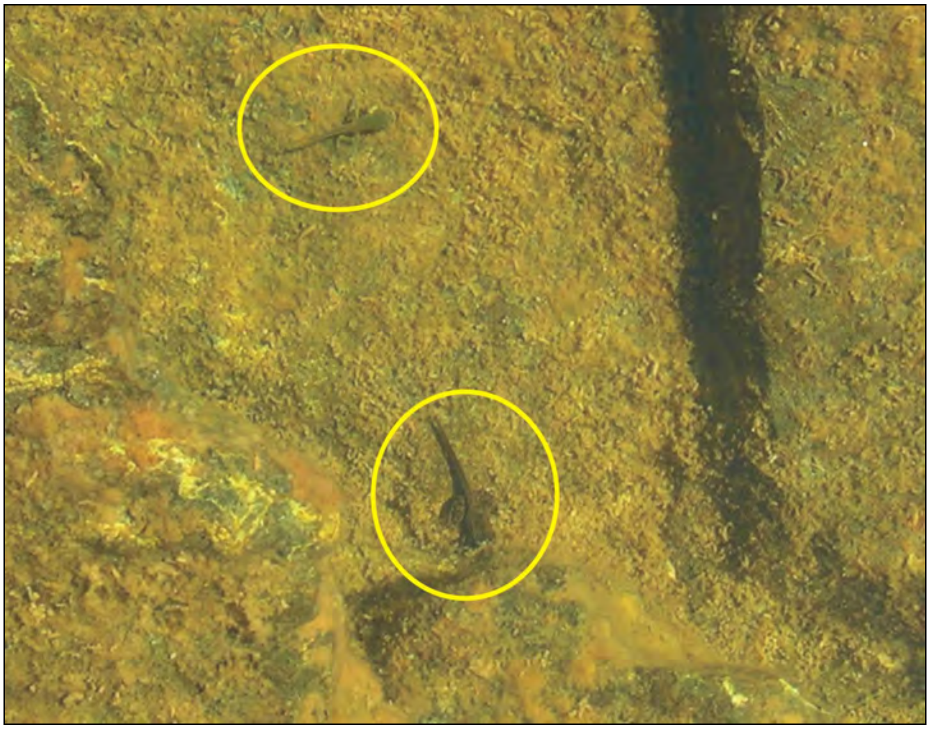


Photo 3. Metamorphosing Red-legged Frog tadpoles with well developed fore and hind legs and large tails in pools below Diversion Dam.

Photo 4. Juvenile Rough-skinned newts in pools below Diversion Dam.

Photo 5. Long-toed salamander breeding habitat.

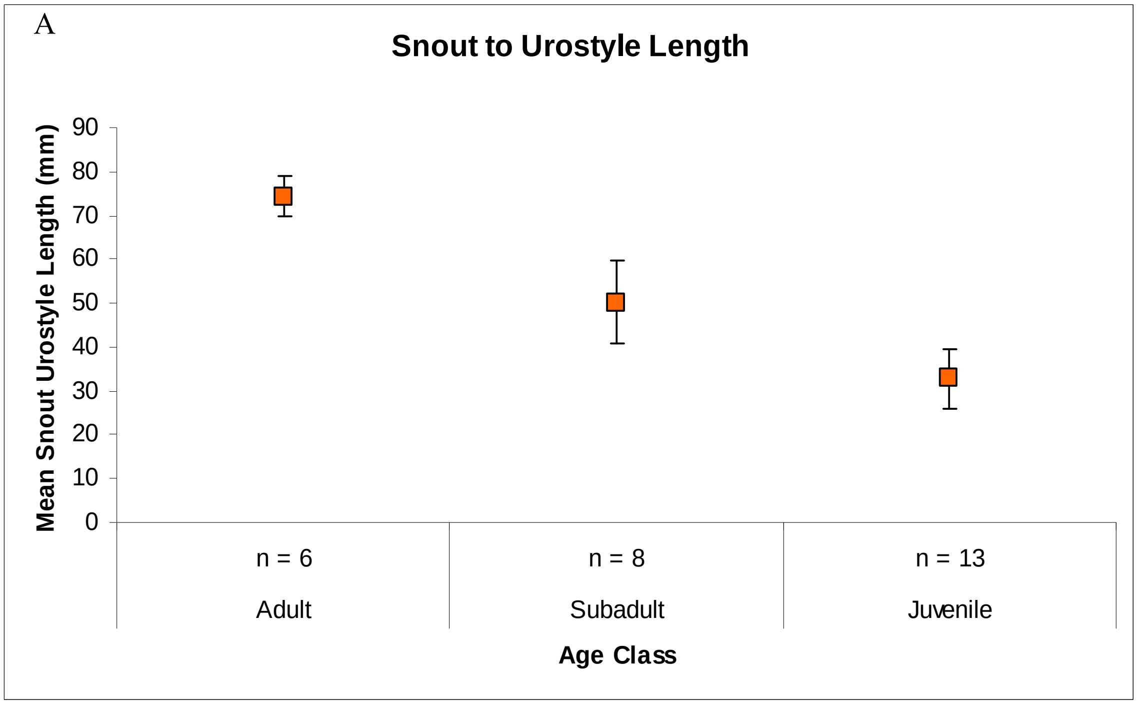
Photo 6. Amphibian breeding pool located below Diversion Dam on the east side of Jordan River. Pond measures approximately 10 m X 10 m.

Map 1. Habitat suitability and distribution of amphibians detected in the Jordan River Watershed during 2004 and 2005.

5.1 Red-legged Frogs: Distribution

Red-legged Frogs were encountered throughout the Jordan River Watershed (Map 1) and were encountered in ponds and ditches along East Main from the southern end of the watershed north to Bear Creek. Red-legged Frogs were also detected in the vicinity of Diversion and Bear Creek Reservoirs, at the west end of Bear Creek Reservoir and in Bear Creek (Map 1). BC Hydro personnel documented Red-legged Frog presence in the vicinity of Elliot Headpond in 2004 and Beauchesne and Cooper (2004) reported the presence of Red-legged Frogs in and around the Forebay pond in September 2003. During a reconnaissance trip to the area in 2003, Red-legged Frog metamorphs were documented from pools immediately below Diversion Dam (Photo 3). Red-legged Frogs were also encountered in the mainstem of Jordan River downstream of Diversion Dam to the confluence of Alligator Creek with Jordan River and in and adjacent to the lower reaches of Alligator Creek (Map 1). Several of the locations documented on Map 1 are from information obtained from BC Hydro personnel and from Beauchesne and Cooper (2004).

Although only a small number of Red-legged Frogs were encountered in the project area (n = 47), all life forms were represented (Figure 3 and Table 4). Only a few emerging metamorphs (n = 10) were documented in the Jordan River Watershed, with all of those occurring in the rocky pools below Diversion Dam (Photo 6). A small juvenile was detected in 2005 in the south end of the watershed in a small roadside wetland. This individual likely emerged last summer/fall and over-wintered as a juvenile.



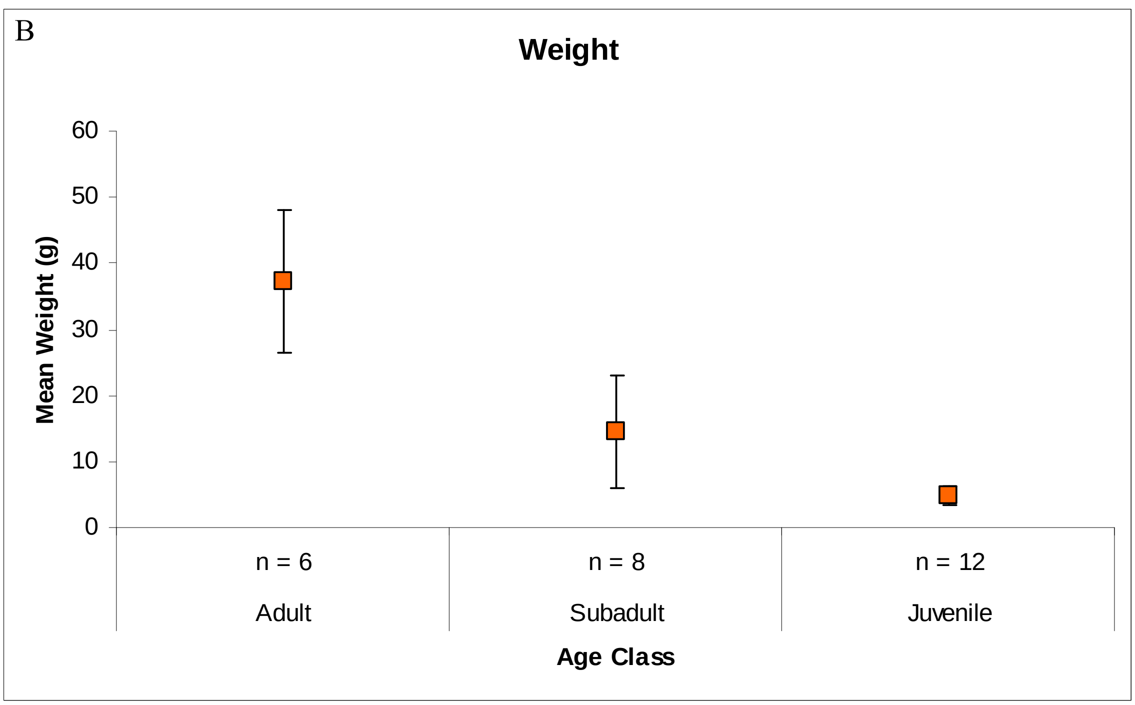


Figure 3. Mean ± 95% CI for A) snout-urostyle length (mm) and B) weight (g) of Red-legged Frogs captured in the Jordan River Watershed.

5.2 Red-legged Frogs: Life Forms

Life form distribution of Red-legged Frogs in the Jordan River Watershed was determined by measuring the snout to urostyle-length (SUL) of captured animals. In some areas (e.g., Washington State) SUL is correlated with both sex and maturation (i.e., reproductive or not). In Washington State (Puget lowlands), females reach a maximum SUL of 95-96 mm and males 75-76 mm. During the breeding season reproductive males are readily identified by the presence of nuptial pads. Identifying mature animals during the remainder of the year can be based on SUL, with males reaching maturity at approximately 50 mm and females at 60 mm. Based on Washington State information, 9 of 42 Red-legged Frogs captured in this study were sexually mature individuals; the majority of animals captured were subadults (Figure 4). Because all were captured outside of the breeding season, or just as they emerged from winter dens, it was not possible to determine if the mature animals caught were males or females. What is certain is that breeding does occur in the Jordan River Watershed based on the presence of metamorphs near Diversion Dam and the juvenile detected in 2005.

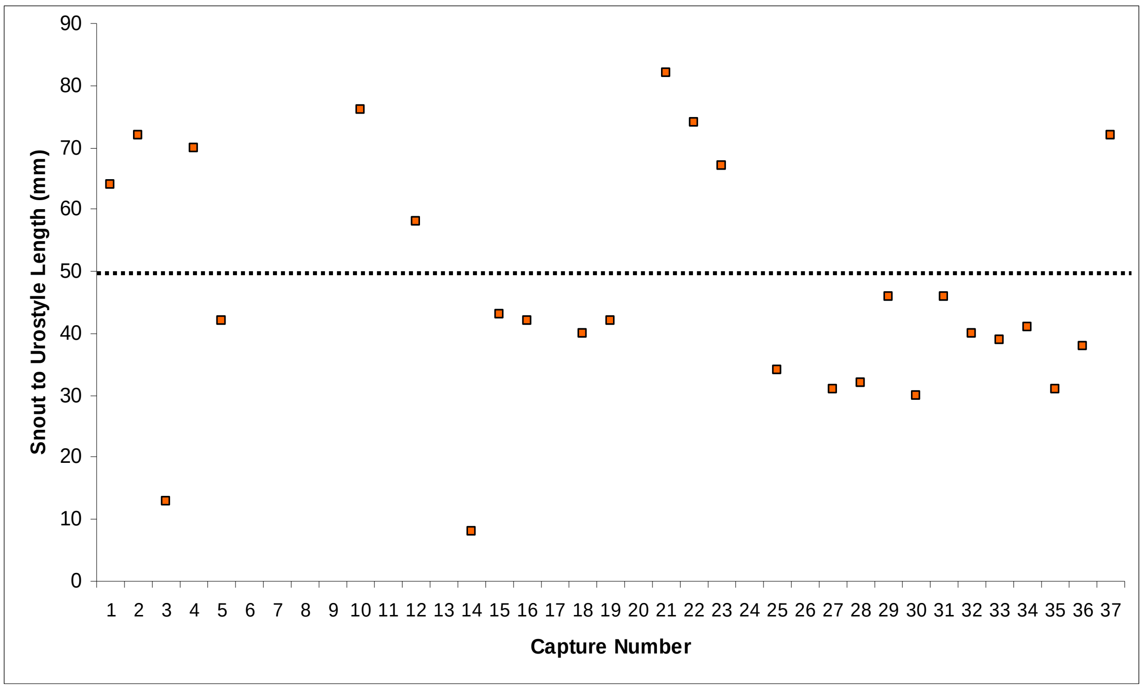


Figure 4. Distribution of SVL measurements for Red-legged Frogs caught in the Jordan River Watershed. Individuals > 50 mm SVL are considered sexually mature.

5.3 Reservoirs

The reservoirs created by impounding Jordan River and Bear Creek do not provided suitable breeding habitats for Red-legged Frogs. In 2004 and 2005, Red-legged Frogs were not documented in either Diversion or Bear Creek Reservoir; however, one adult Red-legged Frog was collected in the vicinity of Elliot Headpond in 2004 when it was drained for maintenance (Eva Wichmann pers comm.). This individual could have been using pools in the mainstem of the Jordan River as security and/or thermal habitat.

Reservoir water level data for the period 1994 through 2004 were obtained for both Bear Creek and Diversion Reservoirs. Average weekly water level were plotted to show the fluctuation of water level throughout the year (Figure 5; Figure 6) to determine if the magnitude of fluctuation would preclude frog breeding in each reservoir. Information pertaining to the timing of Red-legged Frog breeding and tadpole development, including metamorphosis is indicated on each figure. Breeding typically begins approximately 2 weeks after males become active and male activity corresponds to the period when the ambient air temperature has averaged at least 5°C for one week (Figure 7).

Water levels in Bear Creek Reservoir do not vary substantially during the year relative to Diversion reservoir. The average weekly water level at bear Creek reservoir fluctuated approximately 80 cm with a maximum of 1.4 m (Figure 5) compared to an average of 9.7 m and a maximum of 15.1 m at Diversion reservoir (Figure 6). Even small daily water fluctuations can negatively impact amphibians, including Red-legged frogs. Red-legged Frogs typically breed in relatively stable water bodies and females attach their egg masses to submergent or emergent vegetation or woody debris at depths of 30 – 90 cm, it is critical that breeding pond water levels do not drop, especially during the period of egg deposition and egg hatching (approximately 20 February – 1 May) exposing eggs to climatic extremes. If water levels drop and egg masses are stranded they will not develop and hatch into tadpoles, reducing the reproductive success for that year.

To assess how reservoir water levels varied during the critical period of egg development and hatching, daily water levels were plotted for each reservoir for the period 20 February – 1 May for the years 1994 – 2004, inclusive (Figure 8; Figure 9). In general, the daily variation in water levels in Bear Creek Reservoir would not likely affect a large proportion of Red-legged Frog egg masses. The largest daily change occurred in 2002 resulting in a decrease in water levels of approximately 2 m. This event was preceded by an increase in water levels, with the 2.0 m reduction bringing water levels down to slightly below average. However, the overall net change in water levels would not likely affect Red-legged Frog egg masses, which would have been deposited at a minimum depth of 30 cm (approx 410. 9 m A.S.L) (Figure 8). Furthermore, 2002 water levels remained at a level that would not have caused egg mass stranding. In all years, water level fluctuations would probably not have affected Red-legged Frog egg masses if they were deposited in Bear Creek Reservoir (Figure 8), although this would depend on the depth and substrate to which the eggs were attached..

Water levels in Diversion Reservoir varied much more than in Bear Creek Reservoir (Figure 9). Unlike Bear Creek Reservoir, it is unlikely that Red-legged Frogs could successfully breed in Diversion Reservoir. However, it is likely that frogs could attempt to breed in certain portions of the reservoir, such as the at the east end near the outlet of Bear Creek and possibly at the west end near the outlet of Wye Creek. The major problem facing Red-legged Frogs in Diversion Reservoir is the magnitude of water level fluctuation. For example, although the average fluctuation in water level over the period 20 February – 01 May may be as little as 45 cm and as much as 1.05 m, which would seemingly be suitable for frogs, the daily fluctuation can range from a maximum increase of 5.8 m in 1999 to a maximum decrease of 9.6 m in the same year (Figure 9). Based on water level fluctuations, only 1995 and 2004 would have provided stable breeding opportunities for Red-legged Frogs (Figure 9). For all other years, the frequency of variation was either too great or the magnitude of the change was too high to provide stable breeding opportunities for Red-legged Frogs.

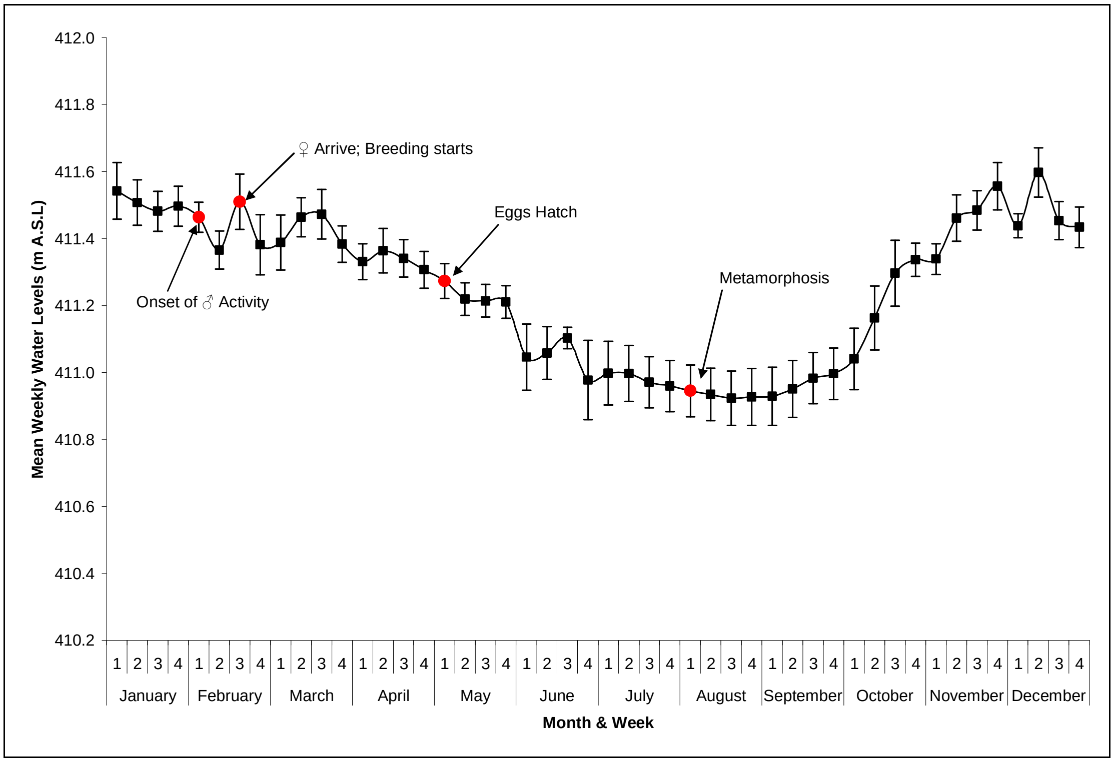


Figure 5. Red-legged Frog breeding, egg development, hatching and metamorphosis relative to weekly water levels (mean ± SE) for Bear Creek Reservoir 1994 - 2004.

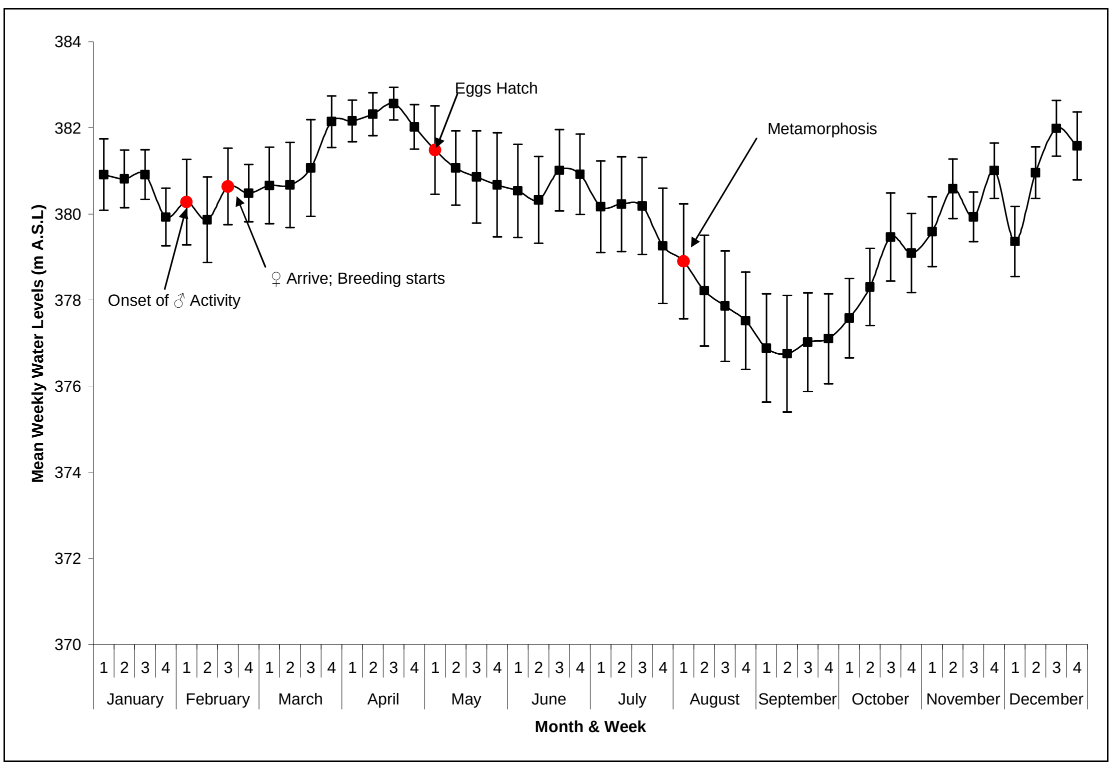


Figure 6. Red-legged Frog breeding, egg development, hatching and metamorphosis relative to weekly water levels (mean ± SE) in Diversion Reservoir, 1994 - 2004.

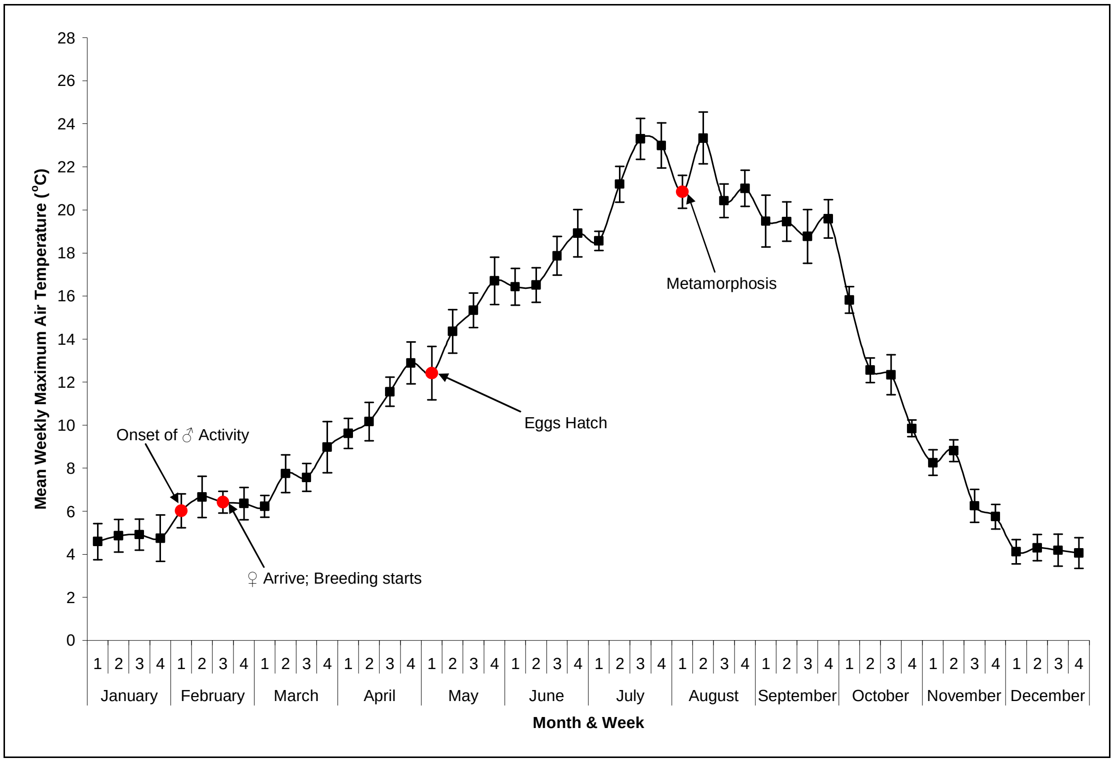


Figure 7. Mean weekly maximum temperature (± SE) for the period 1994 – 2004. Temperature data were collected from a weather station at Bear Creek Reservoir.

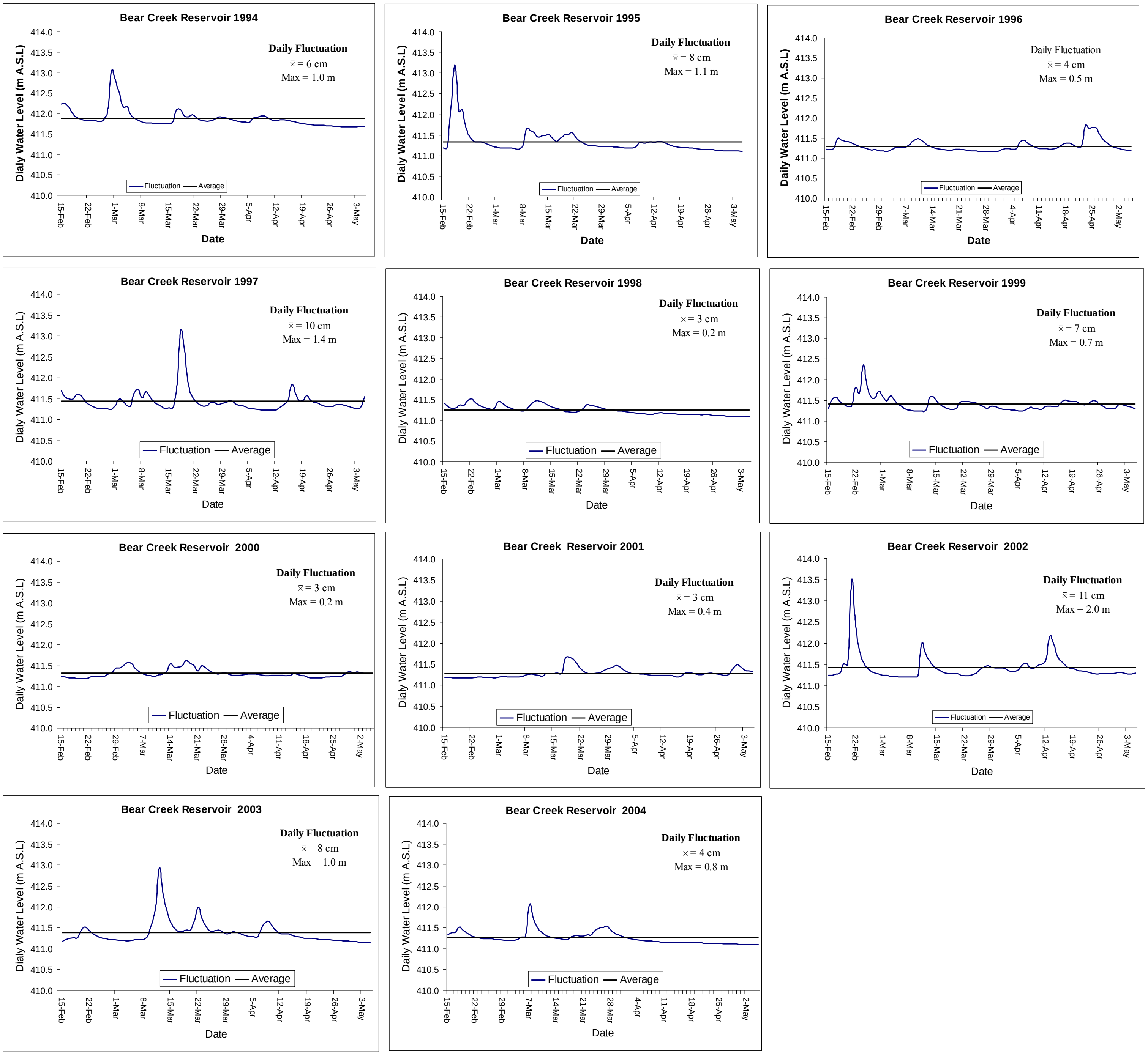


Figure 8. Daily water level variation at Bear Creek Reservoir between 15 February and 5 May for the period 1994 – 2004.

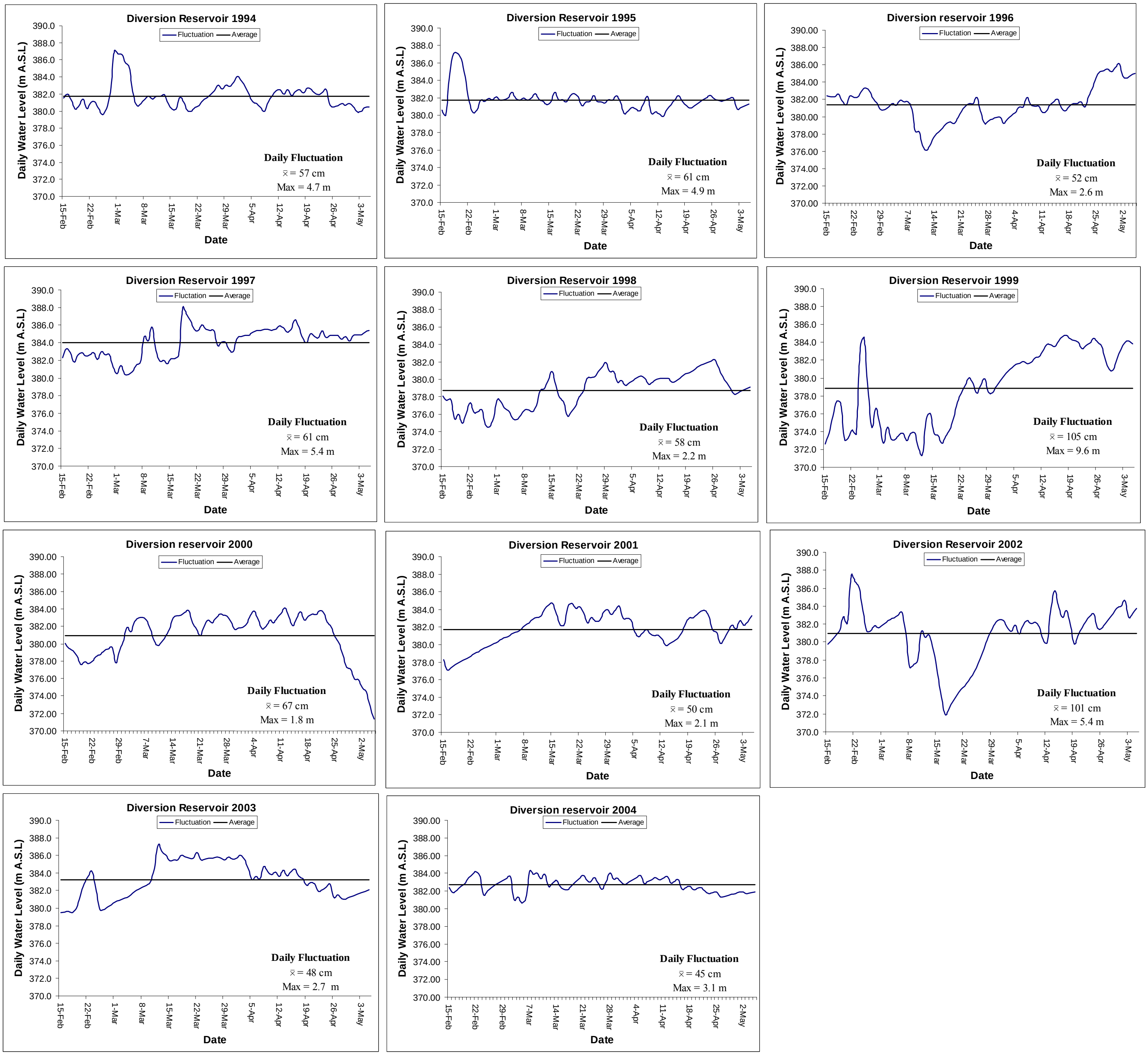


Figure 9. Daily water level variation at Diversion Reservoir between 15 February and 5 May for the period 1994 – 2004.

5.4 Habitats & Habitat Mapping

Red-legged Frogs were detected in a variety of habitats ranging from streams to rock piles. For the most part, Red-legged Frogs were always detected within 10 m of aquatic habitats, with most frogs detected in or immediately adjacent to (0 – 1.2 m) aquatic habitat. Frogs were found under rocks, in shallow pools, in roadside ditches, in riparian and upland forest, and under coarse woody debris. Aquatic habitats were characterized as having little to no flow, cool temperatures ($\bar{x}$ = 15 °C), presence of emergent or submergent vegetation and woody debris, and usually shaded by trees (both deciduous and coniferous). Water depth varied from 5 cm to over 1 m. The majority of habitats occupied by Red-legged Frogs could be characterized as suitable security and thermal habitat, with most providing shade from the sun and immediate access to escape habitats (water, mud, or decaying organic material). However, dispersing subadults tended to be captured in sub-optimal habitats. For example, several subadults were captured in small pools associated with the Jordan River mainstem downstream of Diversion Dam. While these small pools and rocky habitats may provide some opportunity for feeding and assist in thermoregulation, they are not optimal as they are highly exposed areas where frogs could be more readily preyed upon.

Determination of habitat suitability in the Jordan River Watershed was based on in-the-field observations and aerial photograph interpretation. A habitat rating scheme of confirmed, probable, or potential breeding habitat was developed (Map 1). Polygons were drawn onto orthophotos and then digitized in a GIS. Table 5 shows the total area of confirmed, probable, and potential breeding habitat for areas within and adjacent to the Jordan River Watershed. With the impoundment of Jordan River and Bear Creek, two reservoirs and two headponds were created covering 198.94 ha of wetland, riverine, and upland habitats (Table 5). Within the Jordan River Watershed, 48.45 ha are confirmed as Red-legged Frog breeding habitat, which represents 13% of the total area rated. Outside the watershed boundary, 158.1 ha are confirmed breeding habitat, all of which occur in the Jordan Meadows / Weeks Lake complex. The amount of probable breeding habitat both within and outside the watershed boundary was assessed primarily from aerial photo interpretation and frogs may not occur in all water bodies.

Table 5. Total confirmed, probable, and potential breeding habitat delineated for areas within and outside the Jordan River Watershed.

Area	Description	Hectares	Sites Mapped	Sites Searched	Area Searched (ha)
Jordan River Watershed	Confirmed Breeding	48.45	3	2	8.1
Jordan River Watershed	Probable Breeding	270.73	23	8	88.52
Jordan River Watershed	Potential - with restoration	52.98	5	0	
	TOTAL	**372.16**	**31**	**10**	**96.62**
Outside watershed boundary	Confirmed Breeding[1]	158.1	4	0	
Outside watershed boundary	Probable Breeding[2]	129.39	11	0	
	TOTAL	**287.49**	**15**		

[1] Dr. P.T. Gregory, pers. comm. And Davis and Gregory (2003).
[2] Based on aerial photograph interpretation and field visits to similar sites within the watershed boundary.

Despite the fact that suitable breeding habitat appears to be well represented, the amount of breeding habitat currently available is probably lower than before Diversion and Bear Creek Reservoirs were created. To assess habitat loss for frogs in the area of operation, pre-impoundment conditions were compared to current conditions (Table 6). Prior to flooding (i.e., in 1908), suitable breeding habitat would have totalled approximately 134.4 ha (Table 6). Following impoundment (ca. 1911) approximately 44.4 ha of suitable breeding habitat remained in the area of operation, with an additional 8.3 ha becoming suitable sometime after 1911. For example, the Forebay pond has not been used since 1971, creating a stable body of water that over time has become suitable for Red-legged Frogs (Table 6). In 2005, the Forebay pond will be drained and 7 of the 8.3 ha gained will be lost, resulting in a total loss of approximately 88.2 ha since impoundment. The habitat loss calculations are based on the following assumptions:

1. Areas outside of Bear Creek Reservoir, Diversion Reservoir, Elliot Headpond, and the Forebay pond that are assessed as probable breeding habitats (Map 1) would have been used by Red-legged Frogs in pre-impoundment times.
2. There were suitable breeding habitats associated with Bear Creek (i.e., where Bear Creek Reservoir occurs) and within portions of Jordan River where Diversion Reservoir was created. This would have totalled approximately 90 ha (Table 6).
3. Impoundment and reservoir creation have not provided suitable breeding habitats for Red-legged Frogs (see section 6.2).
4. The Forebay pond has been subtracted as suitable breeding habitat because of plans to drain the pond in 2005[1].

Table 6. Habitat loss calculation for suitable Red-legged Frog breeding habitat in the Jordan River Watershed.

		Hectares							
	Year	**Water bodies[a]**	**Jordan River[1]**	**Bear Creek[2]**	**Forebay[3]**	**Diversion**	**Total**	**Percent**	**Net Loss**
Pre-impoundment	1908	44.4	30	60			134.4	100%	0
Post-impoundment	1911	44.4					44.4	33%	-67%
Post-impoundment	no date	44.4				1.8	46.2	34%	-66%
Post-impoundment	1971	46.2			7		53.2	40%	-60%
Post-impoundment	2005	53.2			7		46.2	34%	-66%

[a] Indicate areas not created by impoundment or road building (e.g. ditches).

[1] Pre-impoundment breeding habitat in Diversion Reservoir is an estimate based on topography and the likelihood that off-channel and backwater habitats would have been used by Red-legged Frog s for breeding. There is also a large area at the outlet of Wye Creek that may have been used.

[2]The total length of Bear Creek Reservoir was multiplied by the width of the confirmed breeding polygon in Bear Creek (MAP) to estimate pre-impoundment habitat available to Red-legged Frogs for breeding.

[3] Water levels in the Forebay pond have been stable for approximately 34 years (See footnote 1, this page).

5.5 Habitat Connectivity

A map of current habitat connectivity (Map 2) was derived by creating 300, 500 and 1000 m buffers around all probable and potential breeding areas and was based on what is known about the movements of aquatic-breeding anurans (see Map 1). The various buffers were chosen to reflect 1) the average movement of an adult Red-legged Frog away from a breeding pond, 2) a likely movement by a Red-legged Frog away from a breeding pond (500 m), and 3) a longer-distance movement of a Red-legged Frog away from a breeding pond under ideal conditions (1000 m). Habitats appear to be relatively well connected in the Jordan River Watershed; however, only areas labelled as 'A' are truly well-connected. These areas are characterized as large wetland / lake complexes that are completely enclosed by a 300 m contour. These areas provide ample opportunity for individual frogs and dispersing juveniles to maintain connectivity among populations. Areas identified as 'B' have some areas enclosed by the 300 m contour, but a significant portion of the total areas is enclosed by a 500 m contour. Similarly, areas identified with 'C' have some breeding areas enclosed by the 500 m contour, but a large portion is

[1] The Forebay pond will be drained in 2005; however, habitats for Red-legged Frogs will be retained within the current footprint of the pond.

contained within the 1000 m contour. Areas identified with 'X' are not well connected and have little potential for frogs to disperse from that breeding area into new habitats. The effects of impoundment on habitat connectivity are most noticeable in Bear Creek Reservoir where much of the habitat is categorized as 'B' or 'C'. Map 3 shows how, with restoration, the connectivity of breeding areas around Diversion and Bear Creek reservoirs can be increased thereby increasing the productivity of the area of operation for Red-legged Frogs. Similarly, restoration at the west end of Diversion Reservoir would increase connectivity and increase the total area encompassed by the 300 m contour. The largest increase in connectivity is associated with the 500 m contour and overall, there is a 6% increase in connectivity for all contours. While this may not seem like a significant increase, it represents and increase of just over 800 hectares of habitats that would be connected if restoration occurred in all areas delineated on Maps 1, 2, and 3. Furthermore, because Red-legged Frogs generally remain within 300 m of suitable habitat and it is likely that the Red-legged Frog exhibits philopatry to natal breeding or overwintering sites, the establishment of suitable habitats on each reservoir could potentially result in the establishment of new populations of Red-legged Frogs in the Jordan River Watershed. Additionally, once new populations are established, animals could disperse into unoccupied (but suitable) habitats, further increasing the connectivity and productivity of the Jordan Rive Watershed for Red-legged Frogs.

Table 7. Total area (ha) contained within each contour on Maps 2 and 3 to represent the potential increase in habitat connectivity after restoration in areas on Bear Creek Reservoir and Diversion Reservoir.

	hectares		Increase	
Contour	**Current**	**Potential**	**Hectares**	**%**
300	3363	3600	237	7.0%
500	2764	2984	220	8.0%
1000	7196	7542	346	4.8%
Total	13323	14126	803	6.0%

Map 2. Red-legged Frog breeding habitat distribution and connectivity in the Jordan River Watershed: current conditions.

Map 3. Red-legged Frog breeding habitat distribution and connectivity in the Jordan River Watershed: potential with restoration.

6 DISCUSSION

The impoundment of Jordan River and Bear Creek in the early 1900’s resulted in a significant modification to the Jordan River Watershed that affected many species of wildlife. Paramount among those affected were animals that are relatively sessile or that are tied to specific habitat features that are not widespread across the landscape. For example, organisms associated with riparian zones or wetlands were likely negatively affected when Diversion and Bear Creek reservoirs were created. The water use plan for Jordan River indicates that significant wetland habitat was lost when Bear Creek was flooded and it is likely that these wetlands were used extensively by pond-breeding amphibians, like the Red-legged Frog during the breeding season, although data on ore-impoundment conditions are nonexistent. The loss of such habitats throughout the range of the Red-legged Frog in British Columbia has been implicated in the decline of this species in certain areas, including Vancouver Island (COSEWIC 2002). Furthermore, from a conservation perspective, the Red-legged Frog is a good example of a declining amphibian, especially in the southern portion of its range (Davidson et al. 2002; Shaffer et al. 2004).

Footprint impacts on Red-legged Frogs in the Jordan River Watershed have resulted in a significant reduction in the availability of suitable breeding habitat. For example, backwaters and ponds associated with the floodplain of Jordan River that would have filled annually (after the spring freshet) likely no longer occur. This occurred when Bear Creek, and to a lesser extent, when Jordan River were flooded to create Diversion Reservoir. The areas downstream of Diversion Dam were also affected, but not to the same degree.

Although Red-legged Frogs occur near the area of operation (e.g., Bear Creek between Bear Creek Reservoir and Diversion Reservoir) and all life forms were observed (juveniles, sub-adults, and adults), it is apparent that suitable Red-legged Frog breeding habitat is not currently being provided by either Diversion or Bear Creek reservoirs. Diversion Reservoir is the primary storage reservoir, and as such can undergo a maximum draw down of 18 m annually. During the critical period for Red-legged Frogs, water levels have fluctuated by as much as 9.6 m (Figure 9). The magnitude of those fluctuations makes it impossible for emergent and submergent vegetation to take hold and for wetland habitats to develop. Associated with the fluctuating water levels in Diversion Reservoir is the deposition of large woody debris along the shoreline in areas that could be used for breeding (Photo 7). The presence of the woody material in Diversion Reservoir does not necessarily preclude Red-legged Frogs from breeding. However, the large fluctuations in water level cause these large blockades of woody material to move, and that movement would almost certainly dislodge any attached egg masses. Conversely, water levels in Bear Creek Reservoir are more stable (i.e., have limited fluctuation) so that edge habitats may be suitable for Red-legged Frogs; however, specific components of Red-legged Frog breeding habitat are missing, namely submergent and emergent vegetation, which have not become established because of fluctuating water levels.. This is most noticeable along the west and south shoreline of Bear Creek Reservoir.

The effects of impoundment on pond-breeding amphibians remains poorly studied and only one published journal article on the effects of impoundment on a river-breeding amphibian could be found (Lind et al. 1996). However, the categories of effects of impoundment on pond-breeding amphibians are likely similar to the effects of impoundment on other groups (e.g., fish, birds, mammals) (Trayler 2000). Impoundment effects for amphibians can be spatial or temporal in nature, and become complicated by interactions with other known stressors. For example, in California, California Red-legged Frogs have vanished downstream from reservoirs due to an interaction between habitat changes and the introduction of exotic species (e.g., bullfrogs). The precise factor inducing the effect is uncertain; regardless, along the Sierra Nevada foothills, many populations have become extirpated so that highly disparate isolates exist today in certain regions (Dr. Marc Hayes, pers. comm.). The effects of impoundment on Red-legged Frogs can be related to one-of-three categories:

1. Downstream effects
2. Reservoir effects, and
3. Habitat fragmentation

Photo 7. Woody debris clogging shoreline / willow habitat in Diversion Reservoir.

1. Downstream effects: Downstream effects will have the greatest impacts on habitats used for oviposition and rearing. Changes to riparian-associated habitat will also be apparent, and will generally include an increase in vegetated cover associated with an expansion of riparian vegetation into the floodplain. For Red-legged Frogs, the most vulnerable stages will be eggs and larvae, and if water velocities exceed 5 cm^{-sec}, the waterbody will likely be avoided and not used for breeding (Klaus Richter, unpublished data). Oviposition and rearing habitats will be affected over longer time scales through off-channel habitat changes from annually wetted to rarely-wetted. Back-water and off-channel habitats that received annual influxes of water associated with the annual freshet no longer receive those waters because of river regulation. While unstudied for Red-legged Frogs, downstream effects of the loss of off-channel habitats have been investigated for fish. In general, there has been a net-reduction in habitat quality, species density, and species diversity with off-channel habitat loss (Poddubny and Galat 1995; Richter et al. 1997; Trayler 2000; Reid 2004).

2. Reservoir effects: Reservoir effects likely had the greatest impact on Red-legged Frogs in the Jordan River Watershed, especially the Bear Creek Reservoir. The effects are primarily related to habitat loss and potential impacts at the population level; metapopulation dynamics may have also been affected. Fluctuating water levels in Diversion Reservoir prohibit aquatic vegetation (emergent and submergent) from becoming established, which directly affects the suitability of the reservoir for breeding. This also applies to Bear Creek Reservoir; however, water levels are more stable in Bear Creek Reservoir than Diversion Reservoir (Figure 8; Figure 9).

3. Habitat fragmentation: Fragmentation of Red-legged Frog habitat in impounded watersheds is unstudied. At larger scales (e.g., watershed scale), the loss of small wetlands can affect metapopulation dynamics of pond-breeding amphibians and increase the probability of extirpation of populations in the remaining wetlands (Gibbs 1993, 2000; Semlitsch 1998). Although small wetlands do not comprise a large portion of the land base, they are often numerically dominant to large wetlands. For example, Semlitsch and Bodie (1998) observed 46% of wetlands in the southeastern Atlantic coastal plain were <1.2 ha. Over 97% of all wetlands surveyed on the west side of Vancouver Island were <0.1 ha (Beasley et al. 2000); Red-legged Frogs were present in 26% of these wetlands. The loss of unclassified wetlands not only decreases the number of aquatic breeding sites, reducing the abundance or density of organisms, it also increases the nearest neighbour distance between sites, promoting source-sink processes (Gibbs 1993, 2000; Semlitsch 1998). For a number of species of ranid frogs, the occupancy of wetlands is related to the proximity of other breeding ponds (Laan and Verboom 1990; Gulve 1994; Pope et al. 2000). These results suggest nearby population sources are important in maintaining metapopulations of pond-breeding amphibians. Little is known about the metapopulation dynamics of Red-legged Frogs, but studies on other ranids suggest that these processes may be important.

6.1 Red-legged Frog Breeding

Red-legged Frogs are most common in habitat sites with shallow slopes and southerly aspects (Adams, 1999). They are found in streams, ponds, marshes, or in moist forests. They tend to be restricted to lower altitudes and prefer forests with an abundance of leaf litter. Outside of the breeding season, they are often found at considerable distances from water (≥ 300m) (Waye 1999).

Red legged frogs breed in cool ponds or lake margins, slow moving streams, bogs or swamps or other habitats with shallow water with emergent and submergent vegetation. Females will only lay their eggs in water above 6^{o}C. On average, females lay 680 eggs in one mass on water grasses (including *Juncus*) or on underwater branches. The eggs are usually laid at a depth of 30 to 90 cm but can be laid as deep as 3m. Because Red-legged Frogs breed in water, the eggs are protected from direct sunlight and thermal extremes which could be damaging.

Breeding lasts from 2 to 4 weeks, finishing at the end of March and eggs hatch in early May Tadpoles begin to metamorphosize in late July or early August. While the developmental rate of the embryos is considered slow for frogs, they hatch at a larger size, which may improve survival during dry summer conditions. Frogs are sexually mature after the third year following metamorphosis and it is assumed that adult females breed every year. Some males may not find a mate every breeding season while others will engage in multiple matings (Nussbaum et al., 1983).

6.2 Reservoirs: Breeding Potential

The most critical period for Red-legged Frogs is the period of egg development between approximately 20 February and 1 May (Figure 7). During this time, water levels need to remain relatively constant to prevent desiccation of egg masses. Because eggs are deposited at a minimum depth of 30 cm and typically no more than 90 cm (although up to 5 m is possible) water fluctuations during this critical period should not exceed 30 cm.

In all years, there was an increase in water levels of at least 1 m approximately half way through the breeding season. Based on site visits to Bear Creek Reservoir, there is some potential for Red-legged Frogs to breed in habitats along the edge of the reservoir, especially at the east end. If frogs had bred and females had deposited eggs early in the breeding season (i.e., before 5 March) and the eggs were secure and not deposited in >3m of water, the increase in water level would likely not have affected eggs. After approximately the end of March, egg deposition has occurred and eggs would be developing into tadpoles, a process that requires approximately 6 - 8 weeks. During this time, water levels in Bear Creek Reservoir are relatively constant, creating a stable environment for Red-legged Frog eggs to develop in.

In contrast, water levels in Diversion Reservoir fluctuate between 0.5 - 7 m during the period of egg deposition and development (Figure 6). These large fluctuations would greatly reduce or remove any potential for Red-legged Frog eggs to either remain attached to submergent or emergent vegetation or to develop into tadpoles. Because conditions in Diversion Reservoir vary significantly during the period of egg deposition and development, even areas that show some potential as suitable Red-legged Frog breeding habitat would not be used. If Red-legged frogs did deposit their eggs in Diversion Reservoir, the probability of those eggs developing into tadpoles is low to none. If egg deposition had occurred later in the year, around 15 April, any eggs laid in 1 – 3m of water have been left dry in both 2003 and 2004 due to relatively large decreases in water levels in late May 2003 and mid June 2004 (Figure 6).

7 RECOMMENDATIONS

Impoundment has affected the suitability and connectivity of Red-legged Frog breeding habitat in the Jordan River Watershed. Therefore, habitat restoration is recommended for the Jordan River Watershed in specific areas within the area of operation to increase the availability of wetland habitat to compensate for habitats that were lost when Bear Creek and Jordan River were impounded. Habitat restoration and/or replacement will undoubtedly increase the productivity of the Jordan River Watershed for Red-legged Frogs and other pond-breeding amphibians. In fact, because wetlands are used by many species of wildlife, wetland creation will likely increase the productivity for many species.

The following sections outline several recommendations regarding restoration activities for the Jordan River Hydroelectric System. The intention of these restoration activities is to enhance habitats for more than the Red-legged Frog. The implementation of the recommendations outlined below will benefit a variety of wildlife such as pond-breeding amphibians, waterfowl, songbirds, semi-aquatic mammals, ungulates, invertebrates, and fish. The Best Management Practices (BMP) for Amphibians and Reptiles (Biolinx Consulting and E.Wind Consulting 2003) were consulted for management strategies for pond-breeding amphibians. Management information relevant to Red-legged Frogs and other pond-breeding amphibians has been included where it is applicable to the Jordan River Watershed.

7.1 Habitat Restoration

The majority of the impacts to amphibians and other wildlife in the Jordan River Watershed are associated with a reduction in riparian and wetland habitats. Because of drawdown and the creation of Diversion and Bear Creek Reservoirs, as well as Elliot Headpond, wetland and riparian habitat that was flooded through impoundment was lost and not replaced.

The Peace Water Use Plan identifies some of the effects of reservoir drawdown on foreshore habitats and the wildlife that use those habitats (BC Hydro Project Team and the Peace Water Use Plan Committee 2003). Effects are categorized as primary and secondary with primary effects related to the unproductive drawdown zone that is exposed annually. The unproductive drawdown zone eliminates effective riparian habitat and associated wildlife at all levels except full pool. Additional primary effects are related to drawdown timing, which may have adverse impacts on foreshore nesting waterfowl. Secondary effects are related to debris scour of the shoreline habitats that inhibits establishment of riparian vegetation as well as accelerating erosion. While these impacts have been determined for the Williston Reservoir, they are also applicable to Diversion Reservoir, and to a lesser extent, Bear Creek Reservoir in the Jordan River Watershed.

To alleviate some of the problems associated with drawdown and unproductive foreshore and riparian habitats, engineered wetlands have been proposed by BC Hydro for other regions (e.g., Williston Reservoir). Specifically, the concept of building a perched wetland (Figure 10) has been proposed for certain areas to increase the area of wetland habitat available to wildlife, including amphibians. Perched wetlands have been suggested for the creation of wetland habitat along some reservoir shorelines. Candidate areas are those where physical barriers like berms can be easily created to trap water after drawdown. Site selection needs to consider all species of wildlife that would benefit from the creation of wetlands (e.g., amphibians, birds, mammals, and fish).

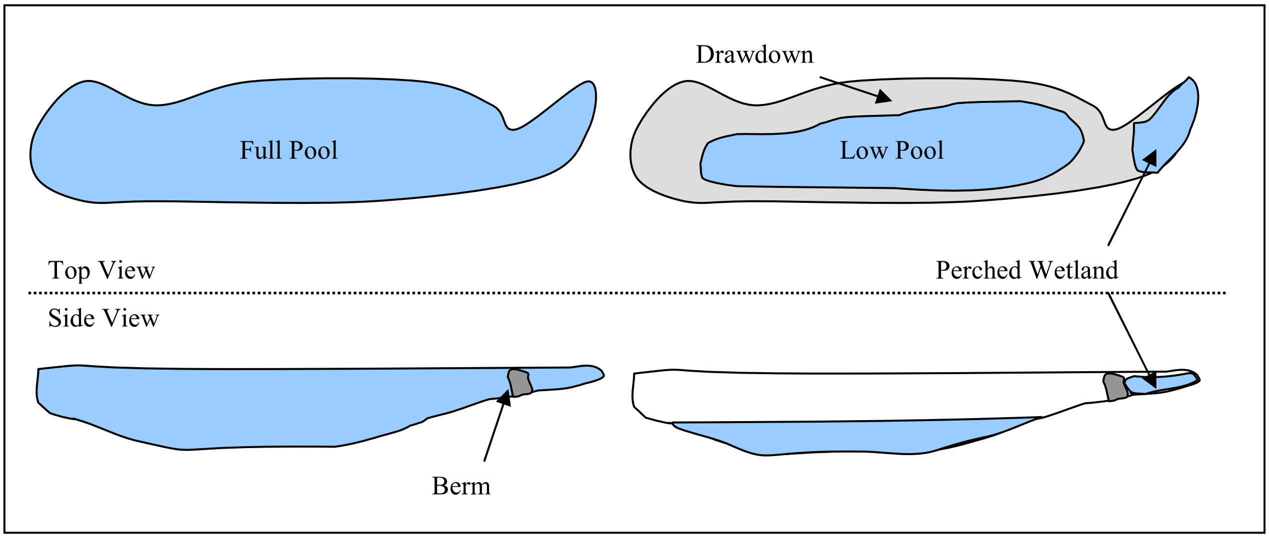


Figure 10. Schematic of a perched wetland created by placing a berm in an opportunistic location to create wetland habitat that would be maintained during the drawdown period. Figure adapted from the Peace Water Use Plan.

Perched wetlands provide stable wetted areas that permit the development of functional riparian zones complete with shoreline vegetation and submergent and emergent aquatic vegetation. These shallow, vegetated wetlands provide suitable habitat for many species of wildlife including pond-breeding amphibians, waterfowl, semi- aquatic mammals, and potentially by ungulates such as elk.

In the Jordan River Watershed steps have been taken to increase reservoir productivity at Bear Creek and Diversion Reservoirs. For example, the Jordan River Water Use Plan Consultative Committee Report (n.d.) outlined several operating constraints for the Jordan River Hydroelectric System. These operating constraints were developed primarily to maximize resident fish populations, anadromous fish populations, and to optimize littoral habitat in reservoirs and riparian habitat along streams for wildlife. These procedures may be beneficial to the Red-legged Frog as well, especially in Bear Creek Reservoir, where it may be possible for riparian and foreshore vegetation communities to become established, or for planted vegetation to persist. The expected outcome of implementing the recommended operating constraints on Bear Creek Reservoir is that it would be maintained as a lake. This would primarily benefit fish that are stocked in Bear Creek. The maintenance of Bear Creek Reservoir as a lake does not compensate for the wetland and back channel habitats that were lost when Bear Creek was impounded. Although, maintaining relatively stable water levels in Bear Creek is important for pond-breeding amphibians, additional restorative actions that should be taken for Bear Creek Reservoir to enhance the productivity of the foreshore zone. These include:

1. planting of emergent and submergent vegetation;
2. seeding and planting of native riparian vegetation; and
3. removing of large floating woody debris.

Recommended operating constraints have also been developed for Diversion Reservoir for different times of the year. For example, a minimum normal elevation of 376 m ASL for the period 1 July through 30 September and 372 m ASL for 1 October through 30 June has been recommended. These constraints were developed for reservoir productivity and reduced fish stress. Maintenance of the reservoir at higher levels is believed to provide better temperature and oxygen conditions for fish. These constraints do not represent a compensatory action for pond-breeding amphibians or any other species of wildlife that would have been displaced when Jordan River was impounded. Establishing a minimum normal elevation for water levels does not remove the potential for large daily fluctuations during the Red-legged Frog breeding period.

Perched wetlands would increase the productivity of the area of operation and the entire watershed for Red-legged Frogs and other pond-breeding amphibians, as well as other wildlife groups (ungulates, birds, bats) and would address several of the principles of the Bridge Coastal Restoration Program: to restore habitats within a watershed context using an ecosystem approach that coordinates with the water use plan and with fish and wildlife management agencies. The restoration strategy also indicates that habitat-forming processes and habitat development should be considered for watersheds within the Bridge Coastal System – a perched wetland would adequately address these considerations in the Jordan River Watershed. Additionally, effectiveness monitoring and evaluation should be conducted to determine the efficacy of restoration efforts.

7.2 Restoring Habitat Connectivity

Associated with the development of replacement habitat in the Jordan River Watershed is the maintenance and expansion of habitat connectivity. Habitat connectivity is important for the long-term viability of amphibian populations and the following practices may be implemented to achieve connectivity in fragmented environments.

- Restoration activities may involve increasing connectivity to allow for dispersal and migratory movements of amphibians. However, careful planning is required to ensure that nonnative species such as fish or bullfrogs do not use new corridors to invade wetlands. Furthermore, perched wetlands should be designed so that they dry out in the fall to help avoid bullfrog establishment. Strategic location of perched wetlands will increase the connectivity of areas identified in Maps 2 and 3.
- Restoration efforts should focus on habitats that were naturally continuous rather than to create travel routes where none existed before development. Wetland creation in Bear Creek would replace wetland habitat that occurred prior to impoundment and the creation of new wetlands would restore the habitat connectivity that occurred prior to impoundment.
- A radio-tracking study of Red-legged frog movement would increase our understanding of Red-legged Frog distribution and habitat use in the Jordan River watershed. Similarly, a mark-recapture study of Red-legged Frog metamorphs could be conducted at different ponds to see how far they disperse. Either of these projects would enhance the development of habitat connectivity maps for the Jordan River watershed and provide valuable habitat relationship data.

7.3 Restoration of the Forebay Pond

The Forebay pond will be drained in 2005.However there is potential for retaining several small ponds within the footprint of the Forebay pond after it has been drained. Amphibians use wetlands across a spectrum of pond-permanence for different life-history phases and activities. Temporary wetlands include vernal pools, floodplain pools, and other shallow depressions that undergo a periodic, annual pattern of filling and drying. Amphibians that breed in temporary water bodies avoid predation by fish and other aquatic or semi-aquatic animals that have poor overland movement abilities. Semi-permanent and permanent wetlands include marshes, ponds, lakes, excavated dugouts, and beaver ponds. Permanent water bodies are essential for amphibians that require multiple years for aquatic larval development. Edges of ponds between 20 and 90 cm deep with submergent and emergent vegetation will be used by pond-breeding amphibians during the breeding season provided these ponds are connected to upland forest.

While retaining several small ponds in the footprint of the Forebay pond is valuable, it will be important to consider the following:

- The quality of riparian vegetation adjacent to wetlands can be improved by removing invasive, introduced plants. Restoring shallow water zones with native, emergent and submerged vegetation helps to restore natural ecosystem processes.
- Habitat complexity of wetlands can be increased by re-contouring eroded or modified shorelines using irregular or undulating patterns.

Areas with a diversity of terrestrial and aquatic habitats tend to support the greatest diversity of amphibians. While the aquatic habitat retained in the Forebay pond is critical for breeding Red-legged Frogs, adjacent habitats are also important. Some key components of successful restoration include:

- Control exotic, weedy plants, especially in small habitat patches that are susceptible to invasion. As the Forebay pond is dewatered, the newly dried area should be revegetated using native forbs and grasses.
- Maintain or restore important habitat features for amphibians including downed logs, bark, and other coarse woody debris, especially large-diameter pieces, in various stages of decay. The addition of large pieces of coarse woody debris to sites from where it has been removed or depleted is also an option. Where practical, large woody debris should be retained at the site and well distributed throughout the site.

8 CONCLUSIONS

This project speaks to the primary objective of the Bridge Coastal Restoration Program: to address impacts on wildlife and fisheries resources in the Bridge Coastal System. Additionally, this project has filled a data gap for rare and endangered species in the Jordan River Watershed, as recommended by the Jordan River Water Use plan.

Impoundment of Jordan River and Bear Creek has affected Red-legged Frogs in several ways. Foremost is the net-loss of breeding habitat associated with Bear Creek and Jordan River. Impoundment also resulted in the loss of wetland habitat and the creation of permanent waterbodies with fluctuating water levels and unsuitable shoreline habitats for breeding. The connectivity of breeding habitat also likely decreased in these areas, especially within the vicinity of Bear Creek Reservoir and Diversion Reservoir, potentially affecting metapopulation dynamics. Perched wetlands are recommended as a means of replacing some of the habitat that has been lost. These wetlands will likely increase the productivity of the Jordan River Watershed for Red-legged frogs and other wetland-associated species.

9 ACKNOWLEDGMENTS

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11 APPENDICES

Appendix 1. Financial Statement

BC Hydro Fish and Wildlife Bridge Coastal Restoration Program

Project No. 04.W.Jo.1

FINANCIAL STATEMENT FORM

	BUDGET		ACTUAL	
INCOME	**BCRP**	**Other**	**BCRP**	**Other**
Total Income by Source				
Grand Total Income		$32,545.00		$32,545.00
(BCRP + other)				
EXPENSES				
Project Personnel				
Wages		$29,965.00		$29,633.98
Consultant Fees				
Technicians		$1,380.00		$1,380.00
MATERIALS & EQUIPMENT				
Equipment Rental				
Materials Purchased		$150.00		$149.98
Permits				
ADMINISTRATION				
Office Supplies				$54.52
Photocopies & Printing		$50.00		$49.73
Postage				
Travel & Living		$1,000.00		$1,276.79
TOTAL EXPENSES				
Grand Total Expenses (BCRP + other)	$32,545.00		$32,545.00	
BALANCE (Grand Total Income - Grand Total Expenses)	$0.00		$0.00	

Appendix 2. Performance Measures – Actual Outcomes

Appendix 3. Confirmation of BCRP Recognition

The Bridge Coastal restoration Program was referred to using the BCRP logo and colours at the following:

1. April 2005. Oral Presentation at the BCRP Annual General Meeting, Vancouver, BC
2. July 2005: Poster presentation to be shown at the 2005 Joint Meeting of Ichthyologists and Herpetologists, Tampa, Florida, USA.