Rocky Mountain Tailed frog - Conservation Analysis

Project No. 4055T10
File No. 1070-20/ASCA 05 91

Final Report

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March 16, 2005

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Background

Identified Wildlife are species or plant communities that have been determined to require special management under the Forest and Range Practices Act. The Identified Wildlife Management Strategy stipulates that Wildlife Habitat Areas (WHAs) be established to protect important habitat or landscape features for all species designated as Identified Wildlife. In order to ensure their long-term viability in B.C., conservation analyses are being conducted to determine the appropriate number and placement of WHAs, and to ascertain the proportion of each Identified Wildlife species' range that is protected through this initiative, or through other beneficial policies such as parks and protected areas. Towards this algorithms are being developed to predict where suitable habitats are located for each species of interest, and to determine the quantity and quality of habitat in: (1) legally protected areas (parks and reserves) that constitute the non-contributing land base (NCLB); and (2) the non-harvestable land base (NHLB), which includes inaccessible or unproductive areas, and sites protected under the Forest and Range Practices Act for specific species, species assemblages or ecosystems. This document reports on the habitat associations, protection status and conservation needs of the Rocky Mountain tailed frog (*Ascaphus montanus*).

Introduction

In recent years it has become increasingly clear that in order to meet the compositional, spatial and functional attributes necessary in maintaining and restoring ecosystems, one must recognize the relationship of biotic and abiotic factors over a range of spatial scales (Franklin 1993). In neglecting to do so, an array of problems can arise that span the boundaries between ecology, biogeography, population genetics and evolution (Brown 1989). The need for understanding the environmental context is particularly heightened in stream ecosystems, because complex spatial and functional interactions are intensified by dynamic and unpredictable (peak) flow events (Naiman et al. 2000; Gomi et al. 2002). At the highest level of environmental controls are independent regional parameters: climate, physiography, geology, and land use (Knighton 1984). These factors influence basin gradient, stream discharge, bank material strength, sediment inputs and texture, which in turn affect site level channel and flow variables, namely sediment transport rate, bedform geometry, stream power, hydraulic geometry (width, depth, slope), and bed material size (Knighton 1984). Thus to appreciate patterns of tailed frog distribution and abundance, one must consider site level attributes in the context of broader interacting forces (see Dupuis et al. 2000).

It is equally important to consider riparian attributes that may influence the terrestrial-bound juveniles and adults. Parameters affecting terrestrial ecosystems are difficult to quantify because they involve short-term events of various intensity (storms, fires) as well as the slow, complex and ongoing processes of stand development and nutrient cycling. These processes are affected by a multitude of factors, from a site's soil moisture retention capacity and nutrient regime to a stand's topography (e.g., open and undulating versus steep and confined) and structural diversity (e.g., amount of woody debris, degree of vegetation stratification, talus), to a watershed's physiography (e.g., aspect, slope and elevation). Riparian habitats are rendered even more complex because they are influenced by aquatic events that extend through the hyporheic zone underlying them (Naiman et al. 2000). Given that amphibians are vulnerable to desiccation (Feder 1983) and that tailed frogs have particularly low tolerance thresholds for temperature (Brattstrom 1963; de Vlaming and Bury 1970) and moisture (Claussen 1973), the exploration of forest associations should be narrowed to climate (in relation to site, watershed and region). Two B.C. trapping studies support this climate dependence: Wahbe et al. (2004) found that *A. truei* was confined to riparian zones in clearcuts but not in old growth forests, and Maxcy (2000) reported greater tailed frog movement rates in forested stream sites than in stream-buffered sites. In a radio-telemetry study of Pacific giant salamanders, Johntson and Frid (2002) reported greater movement in old growth than in clearcuts: a mean home range ten times larger in size, a mean distance-from-streams four times longer, and a refuge duration two days shorter.

Methodology

A literature review of tailed frog ecology was done, and the information was amalgamated and discussed in the context of regional and stand-level climate. With respect to terrestrial habitat associations, there is little research to rely on, and results are often controversial because they lack environmental context. Dupuis and Friele (2002, 2003, 2004a,b) developed a process-based model for understanding tailed frog aquatic habitat suitability. Their results were founded on extensive sampling within the defined ranges of *A. montanus* (see Fig. 1). They conducted timed rubble rousing searches, simplifying the substrate to eliminate cover in a roughly 50 m stream segment. To understand patterns of distribution and abundance in relation to landscape and habitat variables, sampling was conducted along vertical transects that extended from mainstems to perennial headwaters (first order streams), in basins ranging from 0.3 to 140 km^2. In addition to tailed frog data (size, sex, numbers) and general information (weather and location), several parameters were measured in the field and others were calculated or queried from maps (Table 1).

Table 1. Landscape (map-derived) and habitat (field-derived) variables relevant to tailed frogs

MAP (Landscape)	FIELD (Site or Habitat)	Derivation/description of values (units)
Basin area		Digitized map area (km^2) above sample point
Elevation		GIS-queried (m)
Relief		GIS-queried (m); height above sample
Ruggedness		[(Vertical height (m) above sample/Length above sample (m)]; expressed as a percentage
BGC zone		Biogeoclimatic subzone; GIS-queried
Aspect		Expressed as degrees
Projected Stand Age		GIS-queried; in one case where two banks differed in age, the oldest age class was used, based on positive benefits of one-sided buffers (Dupuis and Steventon 1999)
	H_2O temp	Water temperature (° C)
	Reach slope	Reach slope (%) over a distance of 50 m
	Channel unit	1=pool; 2=run; 3=rifle; 4=cascade
	Channel geometry	Bankfull depth and width; wet width and depth
	Channel condition	Evidence of floods, sediment pulses, debris flows, braiding, etc.
	Substrate lithology	Pct cover: sand, pebbles, cobbles, boulders, bedrock
	Embeddedness	0=none; 1=low; 2=moderate; 3=high
	Discharge	Stream discharge (m^3/s)
	Flow Ratio	Flashiness: bankfull versus low flow ratio
	Pct. Sand	Estimate of sand cover in 50-m sample-reach
	Logged	0=no; 1=yes; 2=partial (one-side of creek)
	Riparian cover	Percent tree cover in riparian zone (%; left bank + right bank / 2)

Principle Component Analyses

Principle Component Analysis (PCA) was employed to investigate the relationship of tailed frogs to landscape and site-level parameters. PCA tests are beneficial because they: (1) do not require normality; (2) can handle categorical and ordinal variables; (3) permit simultaneous exploration of multiple variables; and (4) integrate the many related measurements into summary components (Environmental Protection Agency 2002). Principle components were defined by the variables with the highest loadings. Those with an Eigenvalue greater than one were examined for their influence on tailed frog detection rate and abundance.

As with ecological counts in general, all life stages show a negative binomial distribution with numerous zeros (see White and Bennetts 1996). This skewness necessitates the separation of the data into two categories: (1) detected/not-detected data to be tested through logistic regressions; and (2) abundance data (zeros excluded) to be tested through linear regressions. All tailed frog data was log-transformed to meet the assumptions of normality and variance homogeneity (Krebs 1989). An alpha level of $p < 0.1$ was deemed appropriate in testing for significance of habitat variables, as it provides a more sensitive test for the detection of ecological trends (Toft and Shea 1983; Toft 1991).

Classification and regression tree-based analyses

As PCAs do not give an indication of the direction of influence parameters have on dependent variables, their results were further explored using classification and regression tree-based methods (C&RT). Originally proposed for detecting non-linear interactions among variables (Denison et al. 2002), tree-fitting methods are akin to classical cluster analysis but are easier to interpret when both continuous and categorical predictor variables are used. Moreover, they assume no specific multiplicative relationship between predictor variables so that resulting models are robust to both the shapes of frequency distributions of predictor variables, and the presence of outliers (Verbyla 1987).

C&RT models create hierarchical trees by recursive partitioning of habitat predictor variable sets into mutually exclusive subsets which are most homogeneous with respect to the biological response variable of interest (i.e. species occurrence or abundance) (Brieman *et al.* 1984). The top node of the tree contains the entire sample. The classification algorithm for splitting assumes the response variable follows a multinomial distribution. Each step in splitting the sample finds the variable most important in reducing remaining variation in the response variable of the subset. The goodness-of-split criterion used was least squares deviation.

The output tree diagram represents a nested set of ecological dependencies among habitat factors, exposing how key environmental variables can act to constrain the ranges of other variables, given the observed species response. By treating the pathway through the tree nodes from the initial node to the terminal node for each site as a set of site classification rules, one can infer how different environmental factors may combine to determine observed patterns in the response variable of interest.

Area description

The Rocky Mountain tailed frog occupies two regions of B.C.: the Yahk River watershed south of Cranbrook (Fig. 1; A), which is in the Columbia Mountains and Highlands Ecoregion, and the Flathead River watershed, southeast of Fernie (Fig. 1; B), which is in the Western Continental Ranges Eco-region (see Demarchi 1993).

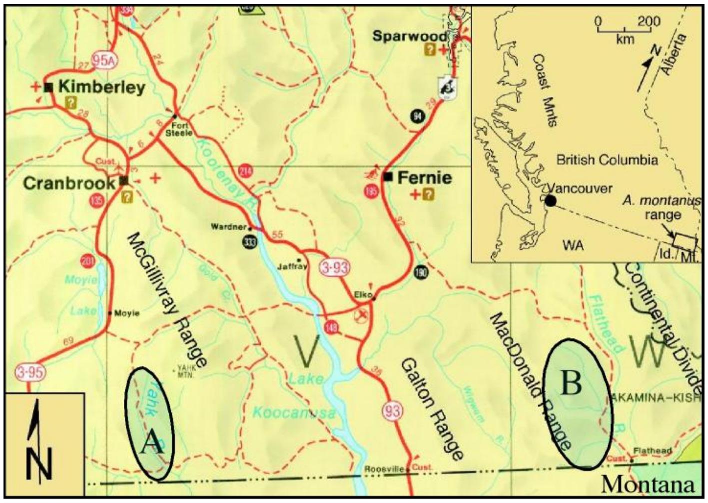


Figure 1. Location of *A. montanus* in B.C.

The two regions differ in their climate and physiography. The Yahk River mainstem flows at 1200 m elevation. Its tributaries drain forested catchments with a relief of about 600 m; channel gradients range from 3-25% along sub-basin mainstems, and 10-60% along first order reaches (Dupuis and Friele 2002). The Yahk's relatively warm, moist climate regime is reflected in two of its three predominant biogeoclimatic zones: in moist, warm Interior Cedar Hemlock (ICHmw) and Engelmann Spruce-Sub-alpine fir forests (ESSFwm) but not in dry, cool Montane Spruce (MSdk) (Meidinger and Pojar 1991). Conversely the Flathead River is higher and has greater relief. The mainstem valleys of Couldrey and Cabin Creeks flow at 1400 to 1500 m elevation. Some sub-basin tributaries drain alpine catchments with relief of up to 1100 m whereas others drain forested catchments with relief of 650 m. Although basin ruggedness is similar to the Yahk (Dupuis and Friele 2004a) the climate of Flathead River is drier and colder, supporting primarily the ESSFdk and Msdk biogeoclimatic zones (Meidinger and Pojar 1991).

Both regions contain sedimentary rock (e.g., argillite, siltstone, and quartzite; refer to Leech 1960; Holland 1976; Journeay et al. 2000) that range from reasonably hard but brittle, to poorly consolidated and very soft.

Habitat Associations

Broader environmental context

Based on principle component analyses, some regional and landscape level parameters (i.e., basin size, relief, elevation, and biogeoclimatic zone) have a significant influence on tailed frog occurrence (Logistic Regression: Wald=11.52, p=0.001) and on tadpole abundance (Anova: F=9.623, p=0.004); there were insufficient data to look at frog abundance. Classification and regression trees (C&RT) illustrate how these significant variables interact with one another to influence tailed frog detectability (all life stages combined), which is assumed to reflect occurrence frequency. CR&T analyses for abundance data are not presented: they show similar habitat association trends, but are less clear given the multitude of interacting ecological variables affecting population size. Density data would be more suitable than relative abundance data for drawing conclusions about how habitat characteristics affect different life stages; there are only 9 density estimates for *A. montanus* in B.C. (see Dupuis and Wilson 1999).

Influential regional parameters

Biogeoclimatic zone, the ultimate manifestation of basin climate and physiography, explained the majority of the variability in the overall data (Fig. 2): tailed frog were detected far more often (85%) in warm forests (ESSFwm and ICHmw) than in cooler ones (41% in ESSFdk, MSdk, ICHmk) - to some extent, this split reflects the Yahk versus Flathead regions. Warmer biogeoclimatic zones provide more productive base flows. Indeed, in regions of significant relief (i.e., colder, drier forests), water temperature is the primary factor governing distribution patterns at the site level (Dupuis and Friele 2003, 2004a); cold creeks do not support growth and development. Moisture levels also play an important role in distribution patterns. Creeks in moist forests are likely to have bigger base flows than creeks in dry ones (ESSFdk, Msdk). In support of this,

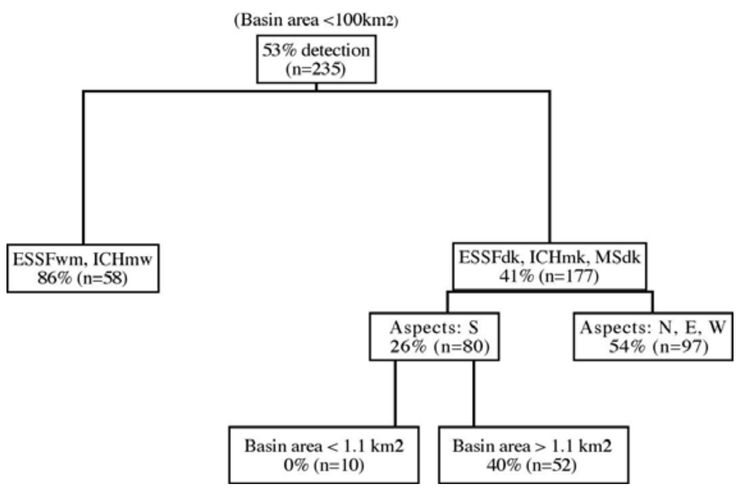


Figure 2. Regional and watershed parameters affecting tailed frogs.

tailed frogs were uncommonly encountered in south-facing (135-225°) basins of these drier forests (Fig. 2) likely because south draining tributaries are more susceptible to drying up in the summer and freezing in the winter because of their small size. For south-facing basins to house tailed frogs they must drain areas greater than 1.1 km^2 in size (Fig. 2).

On an even broader regional scale, paleo-botanical records suggest that the isolation of Coast and Interior tailed frogs occurred in response to the rise of the Cascade Mountains, and the creation of a rain shadow to the east, after glacial retreat six million years ago (during the Miocene; Nielson et al. 2001). *A. truei* and *A. montanus* did not diverge during the Pleistocene when equable, mesic forests persisted in the inland Pacific Northwest. Their divergence pattern is congruent with patterns found in several other mesic forest species. In the Interior, *A. montanus* seems to have become restricted in its northward dispersal with the xerification of valley floors during the Holocene (Nielson et al. 2001). Unless frogs in the Yahk region are in the midst of northward range expansion, environmental conditions in the matrix habitat appear to be unsuitable for dispersal. There are large distances of xeric habitat between tributaries in this rolling landscape.

Cold continental climates restrict availability of warm, productive creeks. A. *truei* migrated north of the 54th parallel (Dupuis et al. 2000) while *A. montanus* stayed no more than 25 km north of the 49th parallel. Cold, high mountains are barriers to dispersal, limiting the potential for exploiting new niches. In the lower Flathead River watershed for example, cold, steep ridges prevent movement across certain watershed divides: breeding and non-reproductive frogs are not found in small, cold headwaters draining terrain above 1800 m in elevation (Dupuis and Friele 2004a).

Geology has been found to be significant to tailed frog distribution patterns (Diller and Wallace 1999; Sutherland et al. 2001; Wilkins and Peterson 2000), but is irrelevant to the subject areas because both regions are underlain by weak to moderately weak rock types. Poor rock types are generally conducive to high bedload movement and the production of pebble and sand (fine sediment). This potential for channel instability can be offset when basin ruggedness is low (and streams are correspondingly less powerful), as in southeastern (compared to coastal) B.C. Aside from local effects, geology does not differ between the two regions and is not relevant.

Important aquatic watershed characteristics

Tailed frogs generally occupy tributaries to main rivers (basins roughly 0.3 – 100 km^2)(Fig. 3).

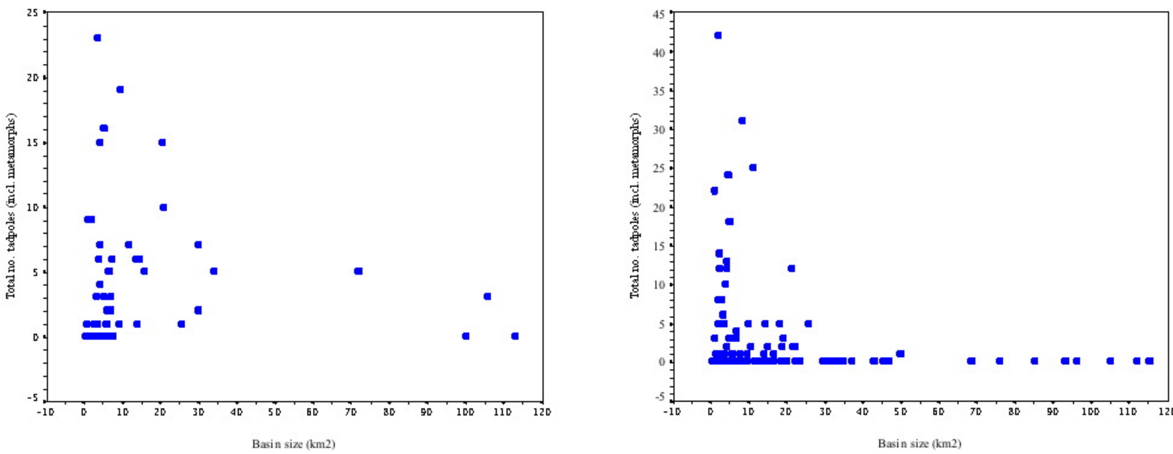


Figure 3. The distribution of tailed frogs in basins of the Yahk and Flathead River

CR&T analyses were done to clarify how basin size interacts with the other significant landscape variables to affect tailed frogs (each region was treated separately, to account for differences in physiography and climate). Based on detection rates, tailed frogs occur primarily in areas of relatively high relief in the gentle Yahk area (Fig. 4a) presumably because they provide more (a greater length of) step-pool habitat. The species is found in areas of low relief < 350 m) when basin size is greater than 1km^2, probably because smaller creeks do not provide good physical habitat (i.e., too sandy). In creeks with greater relief (> 350m) tailed frogs are most frequently found in the warm, moist biogeoclimatic zones. They are less common in the montane spruce, particularly in south aspects, because the creeks at this elevation tend to be small and susceptible to drying out in summer, and freezing in winter.

Figure 4. Watershed parameters of influence in S.E. B.C.

In the more rugged Flathead region, too much relief is unfavourable (Fig. 4b) because creeks at high elevation drain sub-alpine and alpine terrain and are too cold to support tailed frog growth and development. Where relief is less (< 575 m), tadpoles are more commonly found in basins ≥ 1.8 km², particularly on non south-facing slopes (< 135° or >225 °), perhaps because these are more likely to be perennial.

In addition to influencing channel permanence basin size exerts a strong influence on the distribution and abundance of larvae and breeding adults because it (along with precipitation levels) dictates discharge rate, process domain (Montgomery 1999), and channel morphology (Montgomery and Buffington 1997). Montane basins are characterized by steep channel slopes (≥0.03 m/m), low sediment supply relative to transport capacity, heterogeneous bed material, highly dynamic flow regimes, and periodic debris flow activity (Montgomery and Buffington 1997; Scheuerlein 1999; De Scally et al 2001). In the upper headwater reaches, colluvially-derived sediment is randomly deposited in the channel (Fig. 5). Downstream, flows transport pebbles and sand through reaches leaving coarse, armoured substrates. Stable aggregations of clasts are formed, in a succession of steps (Fig. 6). This step-pool sequence causes flows to tumble, reducing water velocity and lowering the tractive force on the bed (Scheuerlein 1999; Zimmerman and Church 2001). Step bedforms are stable over a wide range of flows (Fig. 5) but are subject to collapse at critical flows with 5-50 year recurrence intervals (Chin 1998) depending on local geomorphic conditions.

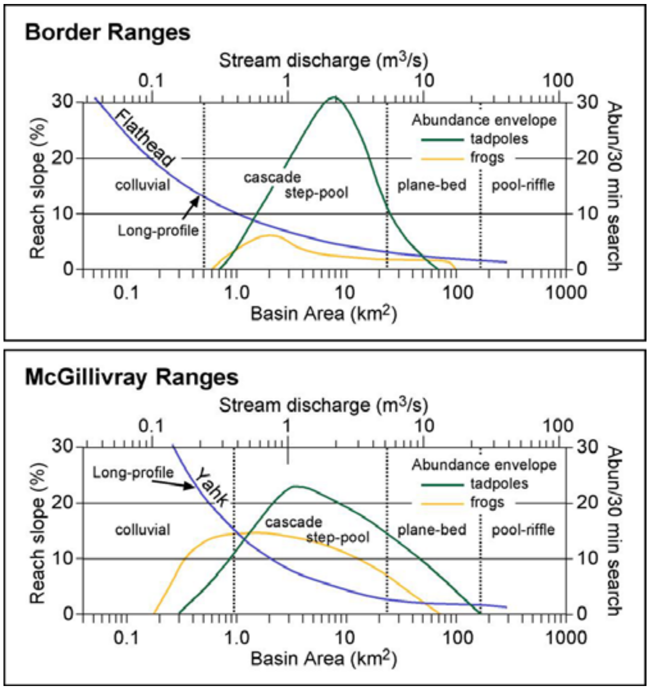


Figure 5. Tailed frog distribution patterns in relation to basin physiography.

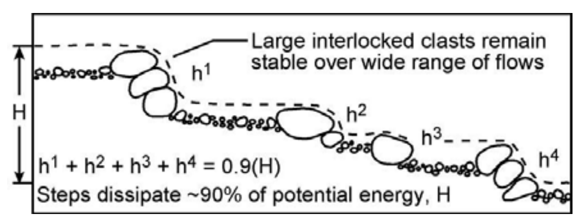


Figure 6. Drop-pool sequence of headwater systems.

Tailed frogs are strongly adapted to the stable drop-pool (cascade and step-pool) sequences of headwaters (Dupuis and Friele 2002, 2003, 2004a,b). The tadpoles possess an oral sucker that withstands high tractive forces; it enables them to move with ease through the predominantly cobble-boulder channel substrate in search of food, without risk of displacement. Eggs, yolkfeeding larvae with undeveloped suckers, and frogs, can also benefit from the matrix pores of the "armoured" steps and their associated pools as retreat zones. Although many individuals are killed through bedload movement and channel erosion during infrequently large channel events, residents of remaining, intact steps can serve as future colonists. In any case, the inherent stability of steps accommodates the lengthy aquatic development stage of most tadpoles (4 years; Daugherty and Sheldon 1982b); it also allows for one or more successful (catastrophe-free) egg laying and post-metamorph recruitment cycles in the roughly 10-year lifespan (see Daugherty and Sheldon 1982b) of a breeding adult.

Juveniles and non-breeding adults are also found in significant numbers higher up in the colluvial reaches, which are unsuitable for larvae because they risk drying up in the summer and have a greater potential for bed instability. These higher reaches may represent mating lek sites and/or dispersal routes. Farther down in the catchment basin, cascade and step-pool bedforms give way to plane bed and then pool-riffle bedforms (Fig. 5), which are characterized by lower gradients, larger discharges and modulated flows. These reaches represent third or fourth order mainstem channels, and they typically support floodplains because sediment supply exceeds transport capacity (Montgomery and Buffington 1997). Large flows and fine sediment loads make plane and pool-riffle bedforms less resilient to change. Perhaps tailed frog abundance falls off sharply in these bedforms because matrix habitat availability and channel bed stability are reduced; eggs and hatchlings in particular lack the ability to resist traction.

Based on the distribution of tailed frog in relation to the watershed characteristics discussed above, breeding (step-pool/cascade) reaches, headwater dispersal and/or mating zones (colluvial reaches), and valley bottom dispersal corridors (plane bed/pool-riffle reaches) have been mapped out (Fig. 7). Wildlife Habitat Areas (WHAs) have been proposed along most perennial reaches of tailed frog containing sub-basins (Fig. 8), to protect natal (core) areas from upslope and upstream human disturbances.

It should be noted that stream vertical profile (concave, irregular) and basin drainage pattern can also influence the distribution and abundance of tailed frogs. In streams with a concave profile, a disturbance can propagate the length of the channel whereas in streams with irregular profiles, benches can dissipate events (e.g., debris flows, large floods). Likewise, a disturbance can affect all the steps in a short channel while it might only affect the steps in the upper reaches of a longer stream, or a very localized series of steps in a dendritic network of channels.

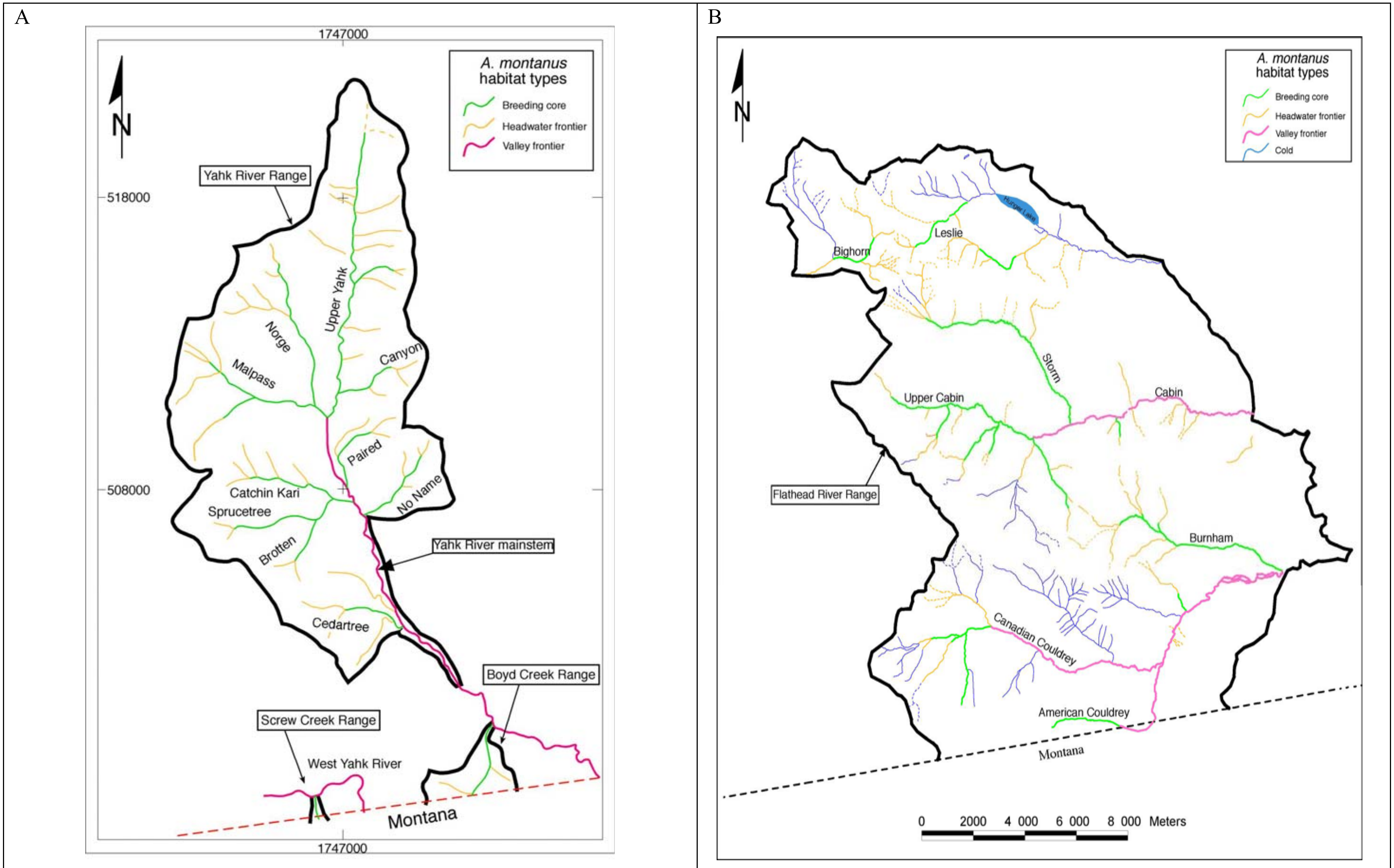
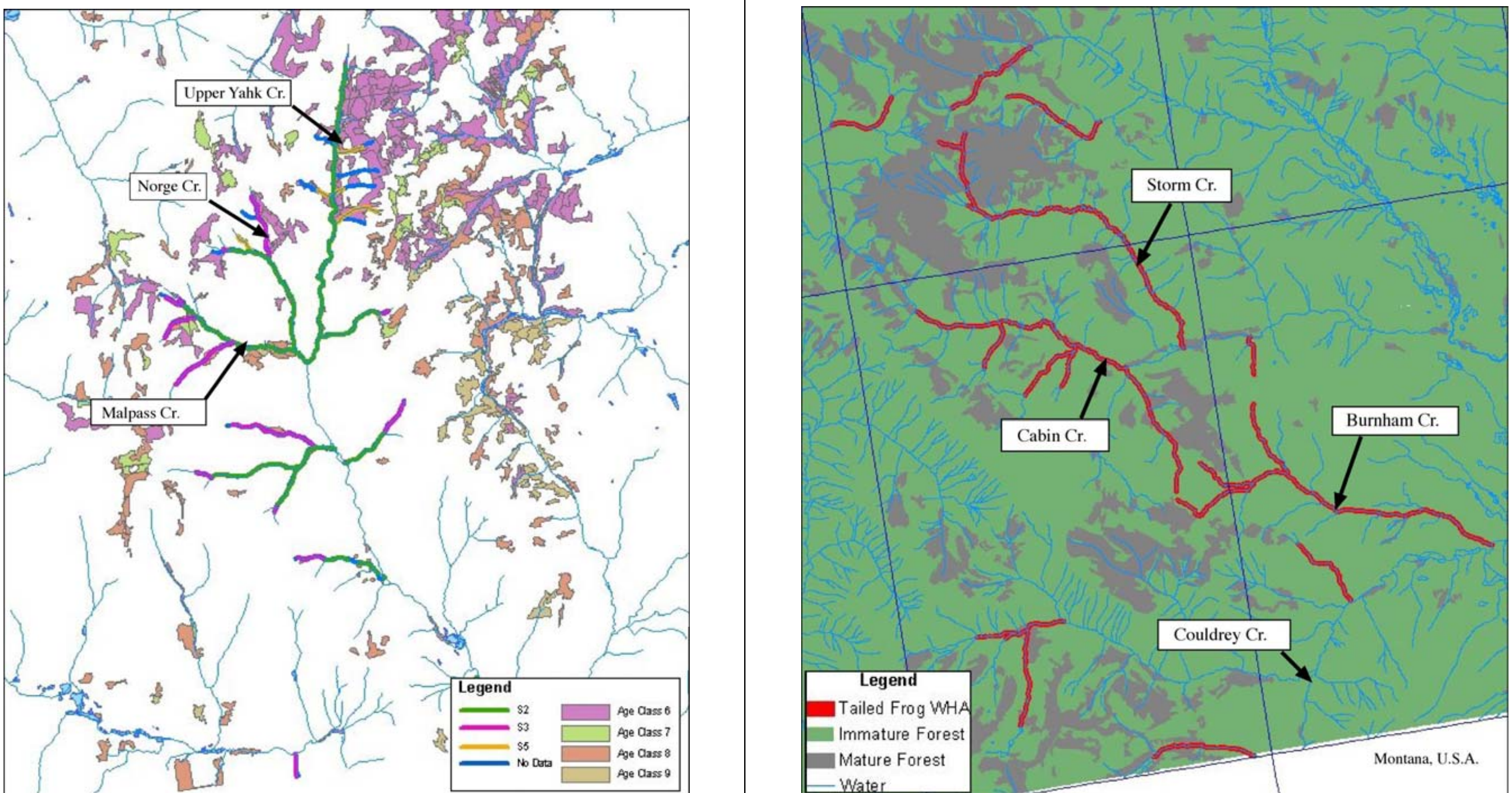


Figure 7. Distribution of tailed frog breeding and dispersal reaches in the Yahk (A) and Flathead (B) River watersheds (Modified from Dupuis and Friele 2002 and 2004a, respectively).



Yahk River Region

Flathead River Region

Figure 8. The distribution of proposed tailed frog WHAs and 100^{+} year forests in the Yahk and Flathead River watersheds (Modified from Ministry of Water, Land and Air Protection, Nelson Region 2004).

Important terrestrial watershed characteristics

Very little is known about the landscape-level requirements of post-metamorphs (juvenile and adult frogs). As previously stated, the current gene flow of *A. montanus* seems to be restricted because the warm, moist habitats it occupies are isolated from one another (Nielson et al. 2001). Physiologically, terrestrial amphibians are vulnerable to desiccation when unprotected from prolonged, hot dry conditions, because their impermeable skin is susceptible to water loss (Feder 1983; Keen 1984). Tailed frogs are especially intolerant of temperature extremes (Brattstrom 1963) and high evapo-transpiration rates (Claussen 1973). Metter (1964) clearly showed that movement of *A. montanus* is positively correlated with both air temperature (within the range of tolerance) and relative humidity.

Studies of movement and dispersal corroborate this finding; they suggest that tailed frogs move primarily along riparian zones (Landreth and Ferguson 1967; Daugherty and Sheldon 1982a; Matsuda 2001; Adams and Frissell 2001; Wahbe et al. 2004). On the coast, *A. truei* can move upland distances > 75 m when conditions are moist (Bury and Corn 1987; Wahbe et al. 2004), but the inland species is a riparian obligate (Daugherty and Sheldon 1982a; Metter 1964) because of the extreme temperature and moisture regimes associated with a continental climate. Undoubtedly, riparian corridors along permanent, intermittent and even ephemeral drainage channels, and along upslope seepages, provide critical movement corridors to *A. montanus*.

Juveniles and non-breeding adults are often found in large congregations above breeding reaches (Bull and Carter 1996; Hunter 1998; Dupuis and Friele 2002; Stoddard 2002). Some researchers suggest that tailed frogs move up and downstream along tributaries in response to seasonal water temperature and stream discharge rates (Adams and Frissell 2002) or for mating (Kelsey 1995; Stoddard 2002; Wahbe et al. 2004). Alternatively (or in addition), large numbers of *A. montanus* frogs may also accumulate upstream of natal reaches (possibly over several years) in an attempt to colonize new drainages (see Dupuis and Friele 2002, who coined these upstream reaches ‘frontier zones’). Whatever the cause, frogs have an innate drive to move upstream (Wahbe et al. 2004) and their high concentrations in first order streams imply that riparian buffers should not be restricted to breeding reaches, but should extend along upstream frontier/mating channels, and possibly ephemeral channels. Forests should even link drainages at the height of land, to form a solid network of landscape connectivity.

At higher elevations in a drainage network there is a greater drainage density, which implies that distances between basins are at their lowest. Dendritic headwater systems can accommodate more individuals than solitary channels. This is clearly exemplified in the Yahk River watershed (see Dupuis and Friele 2002), where post-metamorphs were especially numerous in complex Upper Yahk and Norge/Malpass tributary basins during mid to late summer (in the Flathead River watershed, adults and juveniles were found in most surmountable divide frontiers, all of which are dendritic; Dupuis and Friele 2004a). Meta-population dynamics are expected to be most concentrated above breeding reaches as a result of low inter-channel distances and high frog concentrations. However, there is also some movement along the valley bottom: Dupuis and Friele (2002, 2004a) found small numbers of non-reproductive frogs downstream of natal reaches, where basins did not exceed roughly 100 km^2 (see figure 5).

Tailed frogs appear to be dependent on older forests (Corn and Bury 1989; Welsh 1990; Gomez and Anthony 1996; Matsuda 2001; Biek et al. 2002; Stoddard 2002; Welsh and Lind 2002) and there is evidence to suggest that increased disturbance to terrestrial habitat at the sub-basin level can have a negative impact on tailed frog post-metamorphs (Bull and Carter 1996; Hunter 1998; Matsuda 2001; Dupuis and Friele 2002). Corn and Bury (1989), Richardson and Neill (1998) and Frid et al. (2003) found a lower incidence of tailed frog occurrence in watersheds with a history of logging, than in unlogged watersheds. Along Yahk River, tadpole and adult densities were significantly higher in the headwaters (Upper Yahk, Norge and Malpass Creeks) where the greatest proportion of mature and old forest occurs (Dupuis and Friele 2002; fig. 8). In the Flathead River watershed, upper reaches also seem to correspond to areas of significant mature forest cover (fig. 8).

Site-specific context

Aquatic microhabitat considerations

When sediment levels are low and steps are well–armoured (stable), the channel is configured for a maximum flow resistance. In these optimal conditions: (1) steps account for a high proportion (e.g., > 90%) of the total reach drop; (2) there are a relatively high number of steps per unit area; (3) scour depth in pools is greater; and (4) sediments are clean and coarse. As sediment levels increase, drop-pools become masked, thereby raising the tractive forces on the bed (Wood-Smith and Buffington 1996). When there are extreme amounts of fine gravelly sediment, step-pools can be obliterated altogether, giving rise to unstable conditions such as braided reaches or forced pool-riffle morphologies. Low tadpole densities have been documented in streams channels dominated by fine substrates (Dupuis and Friele 1996; Welsh and Ollivier 1998; Diller and Wallace 1999; Wilkins and Peterson 2000; Dupuis and Friele 2002, 2003, 2004).

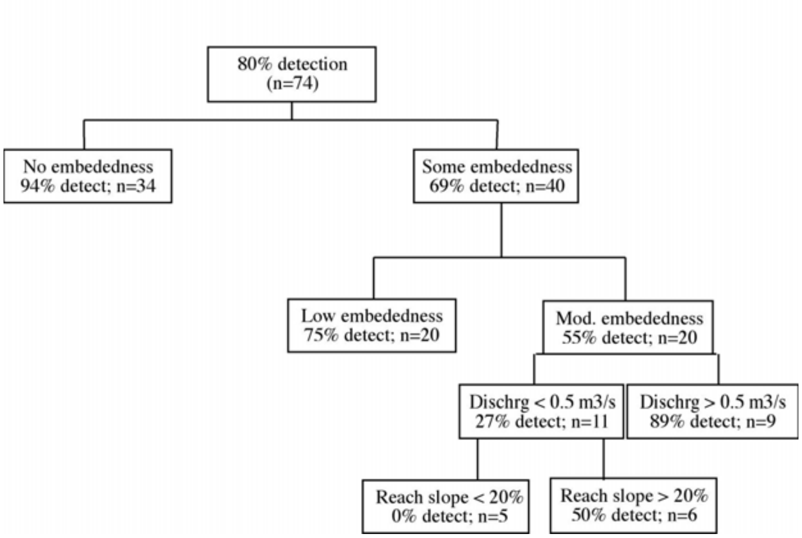


Figure 9. Influential site variables in the Yahk area.

A CR&T analysis of site variables shows that in the Yahk area, where fine sediment is generally less easily washed out of drainages because of the gentle topography, tailed frogs are most frequently detected in channels with no embededness (94%; Figure 9). Detection rate can also be high (75%) at sites with low embededness, but when embededness is moderate to high, the species seems to need sufficient reach slope (> 20%) or bankfull discharge (> 0.5 m^3/s) to flush out sand and pebbles during flood events (Fig. 9). Tadpole and frog densities are similarly affected by embededness (or percent fines).

Water temperature is also a critical factor in determining site-level aquatic habitat quality, since growth and development do not occur below 6°C. In continental climates, relief and ruggedness generally foretell cold temperatures: high ridges and steeper basins rapidly deliver runoff to lower elevations so that temperatures remain cold for the creek length. Local groundwater springs, lakes, wetlands and meadows can also influence stream temperature. Since mean annual temperature is 5°C at valley bottom, ground-water sources are cold (app. 5°C), whereas solar radiation heats up standing water bodies, thereby generating warm outflow channels (> 10°C). A CR&T analysis reveals that in the Flathead area, where cold, steep ridges, lakes wetlands and meadows

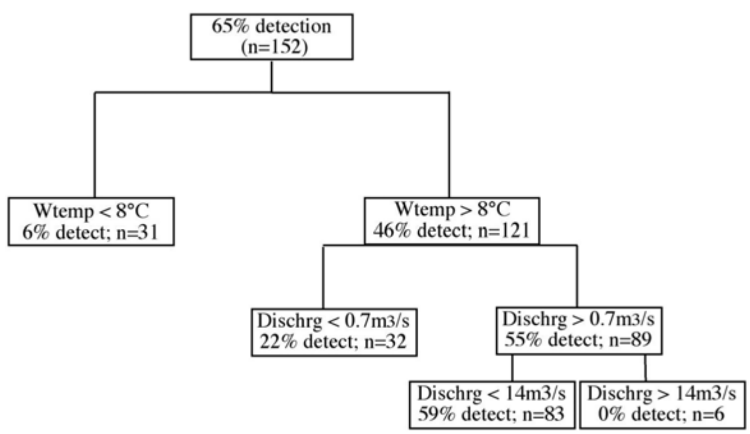


Figure 10. Influential site variables in the Flathead area

do exist, water temperature is the most important site-level variable affecting occurrence (Fig. 10) followed by basin size (channels with bankfull discharge rates of 0.7-14 km^2). Tadpole and frog density are also influenced by water temperature and basin size in the Flathead River watershed.

Terrestrial stand-level considerations

Although the fluvial environment exerts a strong influence on tailed frog distribution patterns (Dupuis and Friele 2002, 2003, 2004), the riparian environment also plays an important role in the ecology of this species. For the benefit of aquatic life stages, riparian buffers help to maintain stream temperatures (Brown and Krygier 1970), and water quality (Gilliam 1994). Riparian buffers also protect channel structure (Kelsey 1995; Dupuis and Steventon 1999) since fine tree roots provide the soil mantle with a tensile strength to resists landslides (Beschta 1978).

Streams also exert a strong influence on air temperature and relative humidity in the riparian forest, for a lateral distance of 30 to 60 m in the summer, either through direct cooling or by supplying water for evaporative cooling of vegetation (Brosofske et al. 1997; Naiman et al. 2000). The terrestrial, transformed individuals are strongly dependent on riparian habitats for survival in the dry Interior (foraging, thermal/predatory refuge, movement, mating) given their vulnerability to desiccation. Even in coastal areas, Stoddard (2002) found a positive correlation between the presence of 150 m wide stream buffers and metamorphosed tailed frogs. Terrestrial-bound amphibians in general, are known to benefit from the retention of riparian habitat during logging (Gomez and Anthony 1996; Maxcy 2000).

The cover of tall trees and understory plants helps to maintain cool, moist air and soil conditions, by reducing wind speed and solar radiation (Geiger 1971; Franklin 1988; Naiman et al. 2000). In support of this, Childs and Flint (1987) found that as solar radiation incident increased at the soil surface, soil temperatures rose throughout the soil profile, seasonal water loss was accelerated, and seedling water stress increased in clearcuts compared to shelterwoods. Older forests (> 100 years) are generally more structurally complex and their intricate vegetation layers and large amounts of downed wood make them more effective at maintaining stable climate regimes (Chen et al. 1992; Brosofske et al. 1997) and providing suitable conditions for foraging and dispersing frogs. Incipient lethal air temperatures for adult frogs are between 22-24^{o}C.

Research by Bull and Carter (1996) suggests a positive relationship between post-metamorphs and the maturity of riparian habitat, and several authors have reported strong ties to old forests in general (see Corn and Bury 1989; Welsh 1990; Gomez and Anthony 1996; Matsuda 2001; Biek et al. 2002; Stoddard 2002; Wahbe et al. 2004; Welsh and Lind 2002), presumably because these more structurally diverse forests provide a more stable climatic environment (Geiger 1971; Franklin 1988) in which to forage, and possibly more food (ecological niches) to exploit. In support of this, Wahbe et al. (2004) noted that juveniles, who are more vulnerable to desiccation and thus more limited in their foraging opportunities than adults (Feder 1983), were larger in old growth forests of south coast B.C. than in clearcuts.

Timber harvesting can have beneficial short-term effects on tailed frog populations due to the temporary increase in light penetration and stream productivity (Richardson and Neill 1998; Kim 1999); particularly where metamorphosis occurs rapidly and where summer temperatures do not become lethal. In the long-term (25-80 years) however, populations can persist in managed forests but their numbers may be reduced (Corn and Bury 1989; Aubry and Hall 1991; Corn and Bury 1991; Bull and Carter 1996; Richardson and Neil 1998; Aubry 2000; Welsh and Lind 2002). Metter (1964) reported long term absence of *A. montanus* following timber harvest in Montana, where climatic conditions are more extreme and perennial streams are less common.

Even in moist habitats amphibians lose water and seek retreats such as seepages, talus, burrows and logs, but these shelters only retain moisture and cool temperatures if adequately shaded (Heatwole 1962). Bury et al. (1991) suggest that *A. truei* typically occurs in mesic forests with high herb cover. In the drier Cascades there is a strong link to talus, high elevation, and other moisture-conducive sites (Aubry and Hall 1991). Tailed frogs appear to be dependent on the moist downed wood of late seral stages (> 200 years) in California (Welsh 1993), but not they do not appear tied to downed wood in more northern (cooler) coastal sites, even in second-growth stands (e.g., Washington; see Aubry 2000). The degree of forest fragmentation may affect microhabitat availability regardless of site-specific features. For example, Gibbs (1998) found that pond-breeding amphibians are absent from landscapes with less than 50% canopy cover.

As a closing comment on site-level terrestrial needs, the link between tailed frog abundance and stand structure, canopy cover, or forest age may not always be ascertainable. Firstly, the number of frogs in the terrestrial environments is to a large extent a function of the quality of the stream environment from which they have emerged. Streams with stable step-pools flowing through warm and moist biogeoclimatic zones, and situated in basins with optimal characteristics (e.g., basin size, relief, and aspect) will generate more frogs than less stable or productive streams. Furthermore, breeding adults of *A. montanus* are extremely philopatric but pre-reproductive individuals move relatively large distances (Daugherty and Sheldon 1982a; Bury and Corn 1987;

Wahbe et al. 2004) and may show less affinity for old forest characteristics than adults (see Wahbe et al. 2004) because of their exploratory tendencies; a behaviour typical of many juvenile animals (Sutherland et al. 2000).

Habitat suitability algorithms

Given that site characteristics are to a large extent products of watershed level controls, it is possible to predict tailed frog tadpole and post-metamorph frequency of occurrence in the landscape using map variables of significance (summarized in Table 2). Although terrestrial parameters also influence tailed frogs, they do not govern the location of breeding habitats and are considered secondary in their predictive power. Moreover, there are no solid data quantifying how various forest attributes affect tailed frog numbers because compositional, functional, and spatial elements of forests have never been properly synthesized.

Table 2. Optimal habitat for *A. montanus* in B.C.

Landscape Parameter	Ideal Range in Yahk area	Ideal Range in Flathead area
Biogeoclimatic Zone	ICHmw, ESSFwm, ICH mk	ESSFdk, Msdk,
Basin Area (km^2)*	1.0-35.0	1.5-27.0
Relief (m)	> 275	<600
Elevation (m)*	1150-1675	1500-1800

According to the PCA/CR&T analyses, relationships between the variables in Table 2 interact to affect tailed frogs. For example, in the cooler biogeoclimatic zones (ESSFdk, Msdk) basins with more than 600 m of relief are inappropriate and south-facing basins are only suitable if they have adequate discharge rates in the summer (basins with a bankfull discharge of $0.4 m^3/s$; i.e., basins $>1 km^2$). In the warmer biogeoclimatic zones (ICHmw, ESSFwm), basins must have at least 275 m of relief.

These results were used to develop algorithms that describe where tailed frogs occur and at what frequency (relative abundance data yielded less clear results). Detection data are assumed to reflect occurrence because: (1) searchers simplified channel habitats (removing all cover objects) over a limited area (50 m stream length) during timed searches, to lower the potential for escaped detections; and (2) several surveys were done in any one tributary to increase the reliability of the data to reflect presence/absence.

This habitat suitability algorithm applies to the area within the boundaries of the Rocky Mountain tailed frog's range:

(1) Basins < 120 km^2 contain tailed frogs

(2) When BGCzone=ESSFwm or ICHmw:

(i) Occurrence high (95%) if relief > 275m

(ii) Occurrence low (30%) if relief is < 275m

(iii) peak abundances are in basins ≤ 30 km^2

(3) When BGCzone=ESSFdk, Msdk, ICHmk

(a) no tailed frogs if relief > 600m

(b) tailed frogs occur if relief is ≤ 600m

(i) Occurrence low (26%) if aspect = 135-225°

(ii) Occurrence is moderate (55%) if aspect is < 135° or > 225°

(iii) peak abundances are in basins > 1 km^2, and < 30 km^2.

The Rocky Mountain tailed frog distribution pattern is now fairly well understood thus there is no need to create a GIS model to predict habitat suitability. The highest occurrence (and density; see Dupuis and Friele 2002) is in the headwaters of Yahk River (Norge, Upper Yahk) where the climate is warmer and moister, and there is enough relief (> 275m) to generate good step-pool availability. Occurrence is moderate throughout the Flathead drainage in all but the high ridge areas, where waters are too cold to support life. A south-facing aspect can be limiting in small tributaries of both regions (see yellow lines in Fig. 7).

Protected lands in the tailed frog's range

In order to evaluate the status of *A. montanus* in British Columbia, a digital (GIS) protected area layer was developed to determine how much of the species' range falls within protected areas. A digital map layer was created to reflect protected lands; it includes the: (1) non-contributing land base (NCLB), which encompasses legally surveyed provincial or federal parks, or reserves of any kind; and (2) non-harvesting land base (NHLB) set aside through the Forest and Range Practices Act, for wildlife or cultural values, or because lands are unstable, inaccessible, or unproductive. A second map layer was created to assess the extent of tailed frog occupancy in partially protected areas, namely in integrative management zones for wildlife. This map layer only includes land units in which at least 40% of the tree canopy is left intact, based on the assumption that woodland amphibians decline in forests with highly fragmented canopies (Gibbs 1998).

Tailed frog range definition

The tailed frog's range was defined following extensive tailed frog reconnaissance surveys of the area from 1996 to present (i.e., Dupuis and Bunnell 1997; Dupuis and Wilson 1999; Dupuis and Friele 2002; Dupuis and Friele 2004a; miscellaneous searches by endangered species specialist Ted Antifeau of the MWLAP Nelson Region). The geo-referenced range boundary consists of the height of land around tailed frog-bearing drainages (Figs. 7).

Fully and partially protected area definitions

There are no legally protected areas such as national/provincial parks, ecological reserves, or Indian Reserves in the Flathead or Yahk areas. These lands represent the non-commercial land base (NCLB). NHLB data included in the protected area layer for the tailed frog conservation analysis are listed in Table 2, as are relevant integrative management units. Data were obtained from the Kootenay Region office of the Ministry of Sustainable Resource Management (see MSRM 2002) or from the Cranbrook Timber Supply area (see Forsite Consultants Ltd. 2004). Data exclude areas above 1800 m in elevation (sub/alpine habitats).

Table 3. Data sources used in creating a protected area layer of benefit to A. montanus

Flathead Region	Yahk Region
Non-harvestable land base (NHLB)	
Riparian reserve zones; reconstructed from TSR3 for S1-S3 streams	Riparian reserve zones; reconstructed from TSR3 for S1-S3 streams
Tailed frog WHA reserves (30 m); S4-S6 streams	Tailed frog WHA reserves (30 m); S4-S6 streams
Old growth and mature management areas: AOGMA, POGMA, MAT, and OGMAs proposed by WLAP, Nelson	Old growth and mature management areas: AOGMA, POGMA, MAT, and OGMAs proposed by WLAP, Nelson
Environmentally Sensitive Areas (ESA) for wildlife	Environmentally Sensitive Areas (ESA) for wildlife
Wildlife Tree Patches (WTP)	Wildlife Tree Patches (WTP)
High value grizzly bear habitat	N/A
Integrative Management areas	
Riparian management zones; reconstructed from TSR3 for S1-S3 streams	Riparian management zones; reconstructed from TSR3 for S1-S3 streams
Tailed frog WHA management zones (20 m); S4-S6 streams	Tailed frog WHA management zones (20 m); S4-S6 streams
Ungulate winter range (UWR): mesic and moist management forest polygons	Ungulate winter range (UWR): whitetail and moose polygons in deep snow

Non-harvestable land base (NHLB) units

Stream classification information (from 1:50,000 maps) was transferred to a TRIM base (1:20,000 scale), and buffered with fish reserve and management zones according to the Riparian Guidebook (Ministries of Forests and Environment 1995a). Riparian reserve zones are excluded from the harvestable land base and vary in width with stream classification (Table 4).

Table 4. Riparian reserve and management zones (Riparian Guidebook; MOF/E 1995 a)

Stream classification	Reserve width (m)	Management zone width (m)	Management zone tree retention (%)	Effective Width (m) *
S1	50	20	50	60
S2	30	20	50	40
S3	20	20	50	30
S4	0	30	25	8
S5	0	30	25	8
S6	0	20	5	1

* Effective width = reserve width + (management zone width x retention)

Wildlife Habitat Areas (WHAs) are being established under the Forest and Range Practices Act, for Identified Wildlife (species recognized under FRPA as being at risk from forest and range management practices). Thus smaller streams (S4-S6) that are tailed frog-bearing are now fully protected by the 30-m reserve zone of WHAs that were established to protect all of their known breeding and adjacent foraging habitats. There are no other Identified Wildlife species within the tailed frog's range at the present time, though a 'threatened' grizzly bear population unit in the Yahk River watershed may receive protection in the future (Ted Antifeau, pers. com.).

Environmentally sensitive areas (ESAs), delineated in 2002 during the last forest cover inventory, are a broad classification of places that appear to be sensitive because of unstable soils, forest regeneration problems, snow avalanche risks, or high water values, or they can be areas of significant value for other resource uses (Forsite Consultants Ltd. 2004). For this project, only wildlife ESAs are included as potentially relevant.

Wildlife tree patches (WTPs) have been excluded from current timber harvesting activities. A WTP is expected to remain on the landscape for at least one rotation, and will be replaced by an equivalent area of mature forest when harvested (Forsite Consultants Ltd. 2004).

Old growth management areas (OGMAS) and their future recruits (mature management areas – MAT) are retained to ensure that all seral stages of all biogeoclimatic zones are adequately represented in the landscape. For ESSF, mature and old forests should make up at least 19% of the forest area within a landscape unit, and they should comprise more than 54% of the forest area where biodiversity values are high (see Biodiversity Guidebook, MOF 1995b). For ICH, mature and old forests should consist of 17 to 51% of the forest area within a landscape unit, depending on whether the biodiversity emphasis is low or high; 14 to 39% is recommended for MS. Established old growth management areas in the SRMMP area that encompasses the Flathead watershed (AOGMA), OGMAs proposed by MWLAP for the benefit of tailed frogs in the Yahk watershed, and other proposed old growth management areas for the Cranbrook TSA (POGMA) are included in the NHLB layer.

Grizzly bear habitat is considered a high biodiversity priority in the Flathead valley, with respect to old and mature forest retention targets. Denning and foraging sites (except avalanche chutes) are likely to be picked up in the OGMA and MAT data layer, but are included as a separate layer for thoroughness. There are no other areas of high archaeology or biodiversity value within the tailed frog's range that are currently protected.

Lands that are inaccessible, unstable or unproductive are also part of the NHLB. With the exception of steep (>70%) forested slopes, these are not deemed beneficial to tailed frogs because they lack a suitable microclimate (e.g., avalanche chutes and bedrock outcrops, gravel pits, swamps, unproductive (dry) forests or scrub).

Integrative Management units

Ungulate winter ranges were mapped in 1998 (KBLUP – implementation strategy) for four species (mule deer, white tail deer, elk and moose) so that they could be integrated into forest development plans (Table 5; from Forsite Consultants Ltd. 2004). In more recent years, UWRs have been based on predictive ecosystem mapping (PEM) with objectives for both landscape and stand level management (Table 5).

With the official release of the Southern Rocky Mountain Management Plan (SRMMP) on August 28, 2003, the new PEM based ungulate winter range mapping became policy in that area (Foresite Consultants Ltd. 2004). Thus PEM based UWRs were used in the Flathead watershed, which is part of the SRMMP area; only mesic polygons were included because tailed frogs are generally not associated with wetter or drier conditions. KBLUP-IS based UWRs were used in the Yahk area (deep snow zones of ESSF, ICH and MS). Only whitetail deer and moose polygons were included since aquatic amphibian abundance appears to decline in forest stands with less than 50% canopy (Gibbs 1998). The threshold was lowered to 40% to account for the fact that younger trees may be left on site as well, and the values in Table 5 represent minimums.

Table 5. KBLUP-IS ungulate winter range forest cover requirements (crown forested areas)

KBLUP – IS ungulate winter range strategy		
Snow Depth	Species	Forest cover objective (crown forest areas)*
Deep Snow Zone (defined as all BEC zones but PP and IDF)	Moose Whitetail Mule Elk	Min. 50% > 120 yrs Min. 40% > 100 yrs Min. 35% > 100 yrs Min. 30% > 100 yrs
Shallow Snow Zone (defined as PP and IDF biogeoclimatic (BEC) zones)	Whitetail Elk Mule Moose	Min. 30% > 100 yrs Min. 25% > 100 yrs Min. 25% > 100 yrs Min. 40% > 81 yrs
PEM ungulate winter range strategy		
Open forest or range	All species	None
Managed forest – dry	All species	10% > 100 yrs
Managed forest - transitional	All species	20% ≥ 60 yrs (w/ 10% ≥ 100 yrs); 10% < 31 yrs
Managed forest – mesic	All species	30% ≥ 60 yrs (w/ 20% ≥ 100 yrs); 10% < 31 yrs
Managed forest – moist	All species	20% ≥ 60 yrs; 10% < 31 yrs
Managed forest - wet	All species	30% ≥ 60 yrs;10% < 31 yrs

* The most limiting forest cover requirements apply to polygons with multiple ungulate species

Given that some timber harvesting is allowed in the management zone of riparian buffers and tailed frog WHAs (e.g., to windfirm the reserve zone edge) this landscape unit is considered one of integrative management rather than of the NHLB.

Additional management initiatives that could benefit tailed frogs include community or domestic watersheds, and visual quality objectives along scenic corridors. None of these attributes exist within the Rocky Mountain tailed frog's range. Connectivity corridors can also be valuable but priorities for this linkage initiative include non-contributing land base polygons (parks and miscellaneous reserves), which are absent within the range of the tailed frog, and constraints of the timber-harvesting land base that are irrelevant to tailed frogs, or already incorporated in the NHLB map layer.

Summary of protected areas in tailed frog range

NHLB coverage

Based on GIS queries, the NHLB makes up 6.4% (25, 406 km^2) of the *A. montanus* range area. Riparian/tailed frog WHA reserve areas make up the bulk of the NHLB, followed by old growth management areas. There are no ESAs or grizzly bear management areas. Within the Yahk watershed, 8% (9,494km^2) of the tailed frog's range overlaps with the NHLB. In the Flathead area, 6% (15,962 km^2) of the tailed frog's range occurs within the NHLB, though 10,000 ha of forest (a large proportion mature and old) burned along the north fork of Bighorn, Storm and Leslie Creeks recently (summer 2003).

Integrative management area coverage

Integrative management lands offer partial protection to 3.4% of the total tailed frog range (7% in the Yahk; 2% in the Flathead area). In the lower Flathead River watershed, all restrictive logging is in the form of management zones along riparian reserves of fish and tailed frog bearing creeks (Fig. 14). Along Yahk River, riparian management zones are the dominant form of integrative management, but there is also a large ungulate winter range in the valley bottom (Fig. 13).

Conservation analysis

Given that *A. montanus* is confined to creeks and riparian zones, its conservation status may be more effectively evaluated by looking at the total length of stream flowing through Integrative Management lands and the NHLB. There are 658 km of creeks within the Rocky Mountain tailed frog's range in B.C., 45% (294 km) of which constitute suitable breeding or non-breeding habitat. The NHLB overlaps with 35% of the overall stream length, and 29% of the tailed frog reaches. The integrative management lands buffer all of the NHLB riparian reserve zones, and offer partial protection to an additional 4% of unprotected creeks (creeks not represented in the Ministry of Sustainable Resource Management's digital 1:50,000 stream classification data).

Below is a detailed synthesis of how the NHLB and Integrated management lands help protect tailed frogs in their breeding and non-breeding habitats. Habitat information was derived from Dupuis and Friele (2002, 2004a) and essentially reflects basin size (see Fig. 5). Basins of roughly 1-35 km^2 contain suitable breeding habitat whereas smaller basins (< 1km^2) are fitting for non-breeding frogs; large basins generally contain drifting tadpoles and dispersing frogs (see Fig. 7).

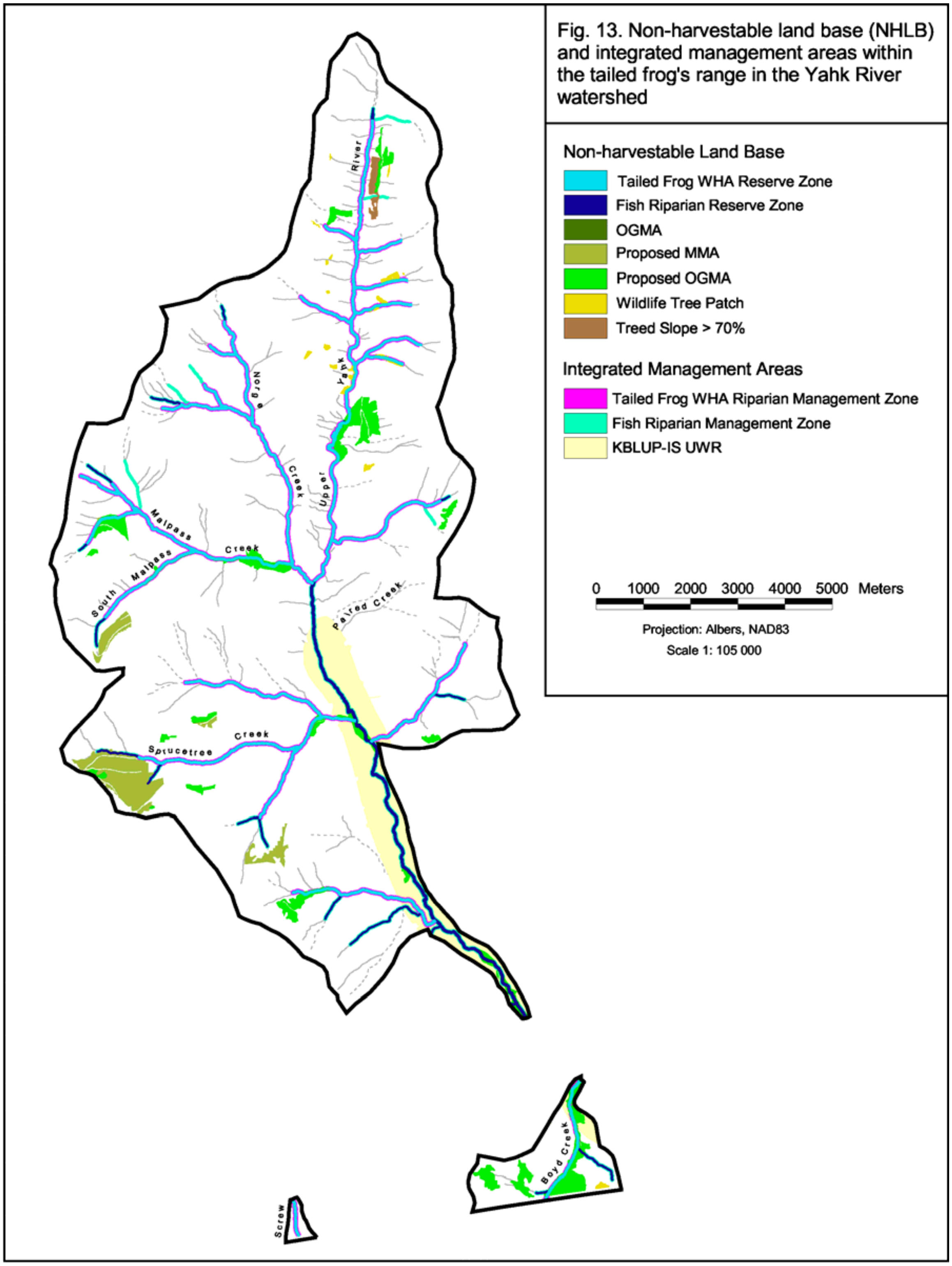
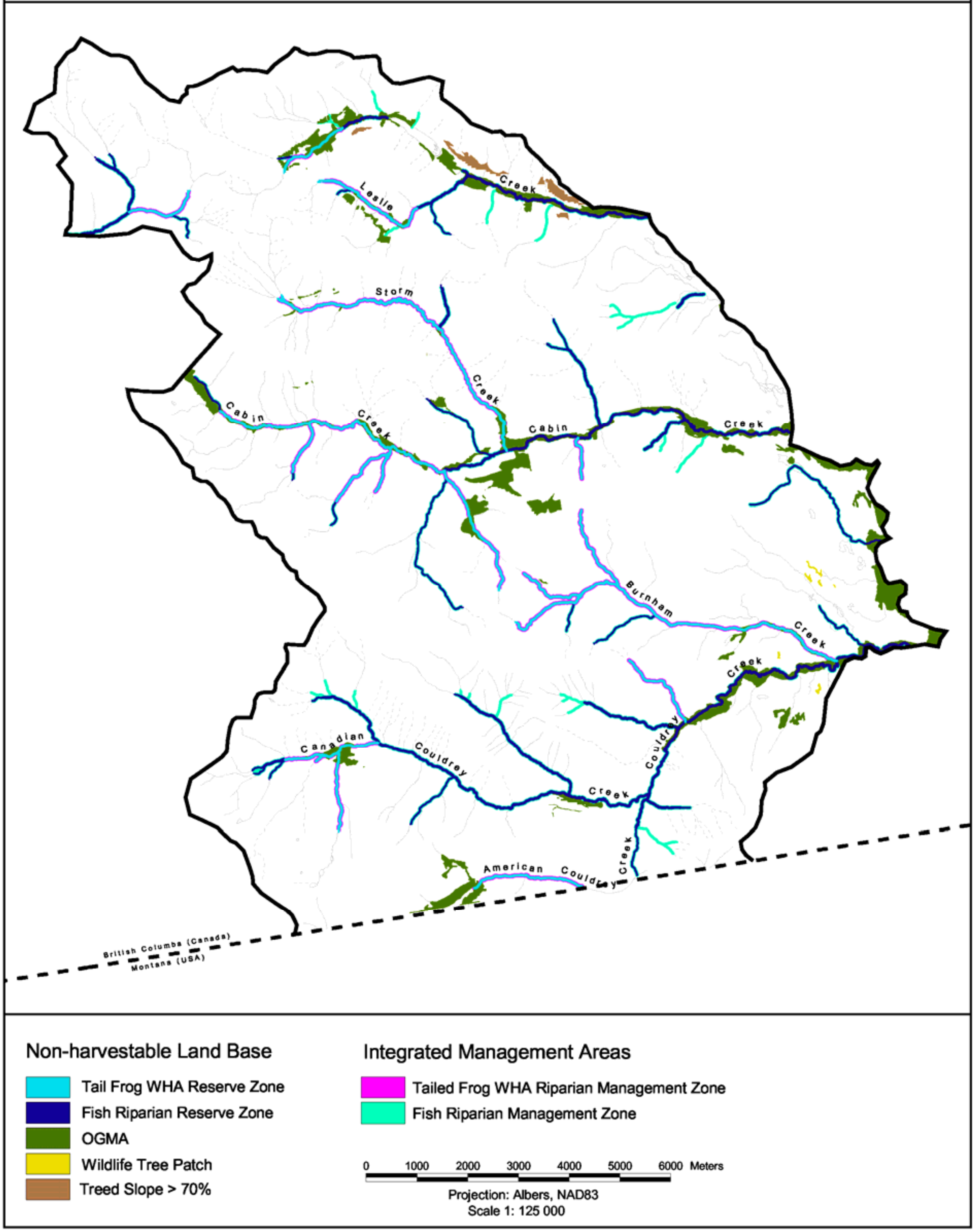


Fig. 13. Non-harvestable land base (NHLB) and integrated management areas within the tailed frog's range in the Yahk River watershed

Fig. 14. Non-harvestable land base (NHLB) and integrated management areas within the tailed frog's range in the lower Flathead River watershed



Yahk River watershed

Overview

Assuming that all proposed WHAs become established, a total of 68% of the Yahk tailed frog habitat is protected by the NHLB, and there is additional partial protection along 10% of the non-breeding reaches above natal areas (Table 6). Boyd Creek is the most protected as it has (1) riparian buffers along its length in Canada – it is very remote in the U.S. and unlikely to have been logged; (2) old growth forest next to the entire river right's riparian management zone; (3) two additional OGMAs and one WTP within its small range area; and (4) part of a UWR at its confluence with Yahk River, in which at least 40% of the forest is to be retained. The Upper Yahk tributary is the second most protected area; in addition to the riparian buffers, it has an elongated patch of inaccessible (steep) forest, some OGMAs, and a cluster of wildlife tree patches, nearly half of which abut the riparian/WHA management zones (Fig. 13). All Yahk River sub-basins have some OGMAs next to the tailed frog WHA boundaries, except Norge and Screw Creeks (the latter is comprised of pine forest; low priority for OGMA protection).

Breeding habitat protection

With the current proposed WHA design, breeding reaches and adjacent foraging habitats are 95% protected by the NHLB (Table 6; Map 1). This protection is largely a function of the 30-m reserve area and 20-m management zone of tailed frog WHAs (only Paired Creek lacks WHA protection; the channel has suboptimal habitat and though tailed frog breeding is suspected here, it has never been confirmed). Three percent of breeding reaches lacking reserve protection have a fish riparian management buffer (Table 6). By bordering buffers along creeks, OGMAs contribute to the protection of riparian microclimates and increase terrestrial habitat availability.

Non-breeding habitat protection

Forty percent of reaches above natal areas are protected; WHA boundaries do not extend along all small headwaters used by juveniles and non-breeding frogs. OGMAs offer additional protection to upper reaches or tributaries in the Sprucetree, South Malpass and Cedartree sub-basins (Map 1). Some headwater mating/dispersal reaches of Upper Yahk are bordered by WTPs, OGMAs, and/or steep forested slopes (refer to Fig. 13, Map 1). Ten percent of unprotected headwaters (two in Upper Yahk, two in Norge, and one in Malpass; Fig. 13) have fish riparian management zones (S5, S6 designations; see Table 4). There is no protection of ephemeral channels and of forests above the stream network at the height of divide, where distances between drainages are minimal. However, inter-drainage movement is possible in the valley bottom because the mouths of North, Malpass and Upper Yahk are relatively close together. Further downstream, travel via the Yahk mainstem is plausible because its basin is small enough (~ 120 km^2) to have tolerable peak flow discharges for drifting tadpoles, juveniles and adults (refer to Fig. 5).

Valley bottom linkages are fully protected (Table 6; Map 1) by riparian buffers along Yahk River; an S2 watercourse with a 30-m reserve and 20-m management zone (see Table 4). An ungulate winter range borders the length of Yahk River to Paired Creek (see Fig. 13), which implies that there is at least 40% canopy through most of the valley bottom.

Table 6. Degree of protection afforded to *A. montanus* breeding and non-breeding habitats

Habitat type	TOTAL stream length (km)	NHLB length (km) (% protected)	% in Integrative Management units length (km) (% protected)*
Yahk River watershed			
Breeding	49.7	47.0 (95%)	1.6 (3%)
Headwater, non-breeding	61.5	24.8 (40%)	6.4 (10%)
Valley bottom, non-breeding	11.6	11.6 (100%)	0.0 (0%)
TOTAL tailed frog stream length	122.8	83.4 (68%)	8.0 (7%)
Unclassified (ephemeral)†	79.5	8.9 km (11%)	3.6 km (5%)
TOTAL STREAM LENGTH	202	92.3 (46%)	11.6 (6%)
Lower Flathead River watershed			
Breeding	48.5	46.4 (96%)	0.03 (0%)
Headwater, non-breeding	91.2	30.3 (33%)	3.6 (4%)
Valley bottom, non-breeding	31.6	30.9 (98%)	0.04 (0%)
TOTAL tailed frog stream length	171.3	107.6 km (63%)	3.7 (2%)
Unclassified (ephemeral, unstable floodplain)	193.7	29.1 (15%)	8.0 (4%)
Cold-limiting	91.2	23.1 (25%)	5.3 (6%)
TOTAL STREAM LENGTH	456.2	159.8 (35%)	17 (4%)

* In addition to the 100% overlap of riparian management zones with riparian reserves
† 'Unclassified' refers to creeks that creeks not considered tailed frog habitat

Ephemeral creeks are categorized as unclassified (see Table 6); they are unlikely to accommodate tailed frogs during late summer but may be used by dispersing frogs during snowmelt periods (spring, early summer) and in wet, early falls. Sixteen percent of these temporary watercourses are partially or fully protected.

Lower Flathead River watershed

Overview

Assuming that all recommended WHAs are established, a total of 63% of the Flathead tailed frog habitat is protected by the NHLB, which is made up primarily of fish and tailed frog WHA riparian reserves (Fig. 14). There are some small OGMAs and these are mostly situated next to creeks (Fig. 14). A relatively large amount of inaccessible (>70% steep) forest is found on lower Leslie Creek's river left. A cluster of WTPs is situated in the Flathead River floodplain, north and south of Burnham Creek. The integrative management land base is comprised entirely of riparian management zones, which occur along the length of the aforementioned riparian reserves, and extend along 4% of unprotected, upstream, non-breeding reaches (Table 6); there are no ungulate winter ranges in the area of interest.

Breeding habitat protection

Based on the current proposed WHA design for the Lower Flathead River watershed, the NHLB protects virtually all breeding (96%), and adjacent foraging areas of the Flathead region (Table 6, Map 2). This protection is primarily in the form of tailed frog WHA reserve areas (see Fig. 14), which are in turn buffered by WHA management zones. OGMAs offer a little additional upslope protection around the natal reaches of: (1) Leslie Creek's south fork (which is marginal habitat); (2) the Storm Creek confluence with Cabin creek; (3) the main south tributary of Cabin Creek leading to Burnham Creek (OGMA is midslope); (4) upper Cabin Creek; (5) Canadian Couldrey headwaters; and (6) the Frozen Lake outlet (top of American Couldrey Creek). These OGMAs increase foraging opportunities for breeders, which maintain terrestrial territories.

Non-breeding habitat protection

Non-breeding reaches below natal areas are well protected (98%; Table 6), lacking known riparian buffers only along a small segment of American Couldrey Creek as it flows through Montana (100% protected within B.C.). There is also significant old growth forest retention along these lower reaches, extending the full protection status to upslope habitats (Map 2). Valley bottom dispersal of tailed frogs is limited in the Flathead however, because the section of Flathead River adjoining Couldrey and Cabin Creeks is too large (S1) for tadpoles and frogs to cope with (bankfull discharge exceeds 140 m^3/s).

One third of non-breeding reaches upstream of natal areas are protected by the NHLB (33%;

Table 6). Aside from a small OGMA above the Cabin Creek natal area, this protection consists of riparian buffers (NHLB riparian reserves; riparian management zones of the integrative management area). Most of the unprotected upstream reaches (the other 67%) occur between the headwaters of Storm, Leslie and Bighorn Creeks; some occur low in the Cabin and Couldrey Creek watersheds near the Flathead River floodplain, and a few are found in the smallest order tributaries of the Cabin and Canadian Couldrey drainages (Map 2). The lack of protection along (1) some of the small perennial channels; (2) ephemeral headwaters; and (3) at the crest of sub-basins may pose a threat to this species' meta-population dynamics since tailed frogs cannot easily disperse through the valley bottom. Upstream dispersal is particularly critical between Burnham Creek and the main south tributary of Cabin Creek nearest to it: this is the only area linking sub-populations north of Inverted Ridge (in Cabin, Storm and Leslie Creeks) with those of the south (in Couldrey Creek). Another critical, unprotected linkage is between Storm Creek and the Leslie and Bighorn headwaters. Dispersal beyond the Storm headwaters is necessary to maintain (and possibly expand) satellite populations at the northern range limit.

Streams labeled 'unclassified' in the Flathead region (see Table 6) refer to ephemeral channels as well as sandy, floodplain creeks. Just as temporary watercourses can be useful during wet seasons, the sluggish creeks of the valley bottom may be valuable to dispersing frogs even if they do not contain step-pool or cascade habitats. Fifteen percent of 'unclassified' creeks flow through the NHLB, and 4% are partially protected by riparian management zones. Cold-limiting creeks, which do not support tailed frog activity, growth and development, overlap with 25% of the NHLB and 6% of the integrated management land base.

Summary Remarks

Progress to date

A significant proportion of *A. montanus* habitat is protected by the NHLB: (1) all aquatic breeding reaches; (2) all potential valley bottom movement corridors; and (3) a quarter to a third of small headwater tributaries above natal zones. Beneficial NHLB units include tailed frog WHA reserve areas, fish riparian reserves, and OGMAs (some minor WTP and steep forest polygons at limited sites). Riparian forest is protected by the watercourse management zones of the integrative management land base, and to a lesser extent by an ungulate winter range in the Yahk.

This exceptional level of protection can be attributed to Tembec Industry and the Ministry of Water, Land and Air Protection (MWALP, Nelson Region), who prompted research into tailed frog distribution patterns. The species' range and habitat associations were defined and Wildlife Habitat Areas (WHAs) were established in every tailed frog-bearing sub-basin of the Yahk and Flathead Rivers.

The WHA boundaries extend to the top of main perennial headwaters above natal areas because juveniles and adults congregate here, and because it has been recognized that streams are part of an energy continuum. That is, upstream disturbances have downstream consequences and tadpole populations can only be maintained if channels are stable and armoured; a condition that cannot be established when sedimentation issues are chronic (such as in areas of poor surface water management). High reaching WHA boundaries further contribute to the well being of local tailed frog population because the dendritic first order streams are a key sources of water, nutrients and organic matter for channels downstream.

Further conservation needs

There is no safeguard against habitat loss along and above ephemeral reaches, which implies that dispersal and metapopulation dynamics are vulnerable to human-imposed impasses. The potential lack of connectivity is concerning in the Flathead River watershed, where inter-drainage dispersal occurs primarily at the height of land. Burnham Creek is the species pool for the Storm Creek population. Storm Creek makes possible northern range expansion: it is the basis for all northern satellites. Isolation and harsh climate promote genetic divergence in these marginal settlements (Jones et al. 2001), and this genetic differentiation is key to future adaptability to environmental change (e.g., global warming).

In the Yahk River watershed, inter-drainage movement seems possible through the valley bottom and at divides, though lack of mature or old forests between the existing range and neighbouring sub-basins would make it less likely for the Yahk tailed frog population to successfully colonize new drainages (such as Gilnockie) in the future. The only conservation need within the Yahk River watershed, is the retention of some mature or old forest in the Norge Creek drainage. It is a well-established fact that tailed frogs are dependent on old forests. Two well protected, neighbouring drainages (Norge and Upper Yahk) are a better assurance of long-term population viability.

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