Using amphibians to monitor the effectiveness of variable retention harvesting systems on Vancouver Island

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Abstract

Forest harvesting has been identified as major threat to amphibian populations. Many studies have shown that amphibian species richness and abundance are reduced in clearcuts versus forests. This is likely due to exposure to climatic extremes, which effectively decreases available habitat and imposes barriers to movement. Variable retention harvesting systems may ameliorate these effects.

In 2000, we started a study with Weyerhaeuser Company (now Western Forest Products and Island Timberlands) on Vancouver Island to investigate how aquatic-breeding amphibians might be used to evaluate and monitor the effectiveness of variable retention harvesting systems. Amphibians were studied in terrestrial and aquatic environments. The relative abundance of amphibians detected during visual surveys and pitfall trapping in terrestrial habitats was low and highly variable across sites. Despite this, more amphibians were captured in forest versus VR sites, especially fully terrestrial salamanders. Some aquatic-breeding amphibian species were relatively common in some VR sites, but their abundance and distribution were linked to retention patches and wet areas within the block and evidence suggests that smaller individuals may be excluded from these habitats in summer. Monte Carlo simulation precision analyses found that sampling amphibians terrestrially was not cost-effective in terms of a long-term VR monitoring program. In contrast, local amphibians can be effectively monitored at small wetland habitats (< 1 ha), which are affected by timber harvesting. Although amphibian larvae were more common in small wetlands in forest versus VR ponds, larvae in VR ponds were often larger than those in forest. Current legislation provides limited riparian protection for these habitats. However, Weyerhaeuser's group retention harvesting system often anchors forest patches over small wetland habitats, which may inadvertently protect amphibian habitat. As a result, we are designing and implementing a pre- and post-harvest study to investigate the efficacy of buffers around small wetland habitats to maintain hydroperiod for amphibian populations.

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Introduction

A recent study of the 5,743 known amphibian species in the world has determined that 32% are threatened with extinction, compared to 12% of birds and 23% of mammals (Stuart et al. 2004). Habitat loss and degradation are by far the greatest threat to amphibians, followed distantly by pollution, invasive species, and disease, the latter of which has resulted in numerous rapid declines in the Americas (Stuart et al. 2004). The Pacific Northwest has been identified as an area with a high proportion of threatened or endangered amphibians, especially among frog and toad species (Doyle 1998). Habitat loss and degradation, resulting from agriculture, urban development, and forestry, increasingly isolates and fragments populations, raising stress levels and susceptibility to other limiting factors (Wake 1998).

The majority of the world's amphibians inhabit forests (almost 5,000 species; Stuart et al. 2004). Many studies have found reduced abundance of amphibians in clearcuts compared to forest habitats (see review by deMaynadier and Hunter 1995).

Sensitivity of wildlife and plants to extreme climatic conditions, and the potential impacts on recruitment, is one of the reasons for a recent shift to a variable retention (VR) approach to forest management. Weyerhaeuser BC Coastal Group has adopted this approach and is supporting its implementation with an Adaptive Management Program. The program uses selected focal species as one of three linked elements as a means of assessing ecological effectiveness (e.g., ecological representation, habitat structure, and species). Amphibians are being evaluated through pilot studies as one candidate species group.

Methods

The amphibian pilot study was initiated on Vancouver Island in 2000 and is on-going. Amphibians have been studied both in terrestrial and aquatic habitats.

In terrestrial environments, amphibians were sampled using visual surveys and through pitfall trapping. For the time and area constrained visual surveys, four 100-m transect lines were installed at each of 12 sites in 2000: 4 older forest sites (80+ years) and 8 recently logged sites harvested using VR ($\leq$ 2 years old). Visual surveys were conducted along each transect line four times from June to July, twice during the day and twice at night. Each 2-m wide search area along each transect was searched for 60-person minutes. At two of the VR sites that had paired forest sites, four pitfall trap arrays were installed in each habitat type (e.g., 8 arrays in forest and 8 in VR). In the two VR sites, two arrays were placed in retention patches and two were put in the cutover matrix. Both visual surveys and pitfall trapping were conducted in summer 2000; pitfall trapping was repeated in spring 2001. For all amphibians encountered, the location along the transect line or pitfall trap was recorded, they were identified to species, their weight and body length were measured, and they were released more than two metres from the capture location

Aquatic habitat use was investigated by sampling amphibian larvae and adults using funnel traps and visual surveys at ponds in both forest and VR. During presence / not detected visual surveys, most or all of the perimeter of a wetland was walked searching for amphibians in the water and along the shoreline. For all amphibians encountered, species and life stage were recorded. Funnel trapping was used for repeat surveys conducted at three wetlands with different amounts of canopy cover (unbuffered, retention patch pond, and in forest), to compare the growth rate of larval amphibians. In addition, all small wetlands < 1 ha were mapped from Weyerhaeuser's North and South Island Divisions on eastern Vancouver Island that have base mapping at a scale of

1:5,000 (approximately 300,000 ha) and a sub-sample were ground truthed, to determine the accuracy of mapping and to identify potential experimental study sites.

Results

The capture and recapture rates of amphibians during terrestrial surveys was low and highly variable across sites. For example, only 82 amphibian detections occurred at the 12 sites during summer visual surveys in 2000 (0-37 detections per site). As well, there were only 35 captures in 1536 pitfall trap nights in 2000 (0-18 captures per site). Recapture rates in 2001 were low (4 to 5%).

Despite the low capture rates and variability, amphibians were detected more often in forest than in VR harvest units, both terrestrially and aquatically. However, the results varied across techniques, sites, and species. For example, terrestrial-breeding salamanders (e.g., completely terrestrial salamanders of the family Plethodontidae) were consistently more abundant in forest sites versus VR harvest units compared to aquatic-breeding species, from both visual surveys (Fig. 1) and from pitfall trapping (Fig. 2). The results varied for aquatic breeding species like the Rough-skinned newt (*Taricha granulosa*) and Red-legged frog (*Rana aurora*), which were more abundant in VR than in forest from the pitfall data (Fig. 2), but not from the visual surveys (Fig. 1). However, from the pitfall data, all of the newts at VR2 were captured in retention patches rather than in the matrix; this site had no wetlands within the site itself. At VR1, the arrays varied in the amount of forest cover and wetness. At this site, the majority of amphibians were captured in the two arrays closest to water and within, or close to, retention patches versus the two with little to no forest cover and far from water. In addition, individuals of some species captured in VR sites tended to be larger than those caught in forest. For example, Rough-skinned newts captured in pitfall traps in VR in spring 2001 were larger than those from the forest ($F_{1,34} = 3.34$, $p = 0.08$)—newts were not captured in pitfall traps in summer 2000. Red-legged frogs caught in pitfall traps in VR blocks were also significantly larger than those caught in forest in mid-summer (2000; $F_{1,18} = 35.9$, $p < 0.001$), but not in spring (2001; $F_{1,114} = 0.01$, $p = 0.91$).

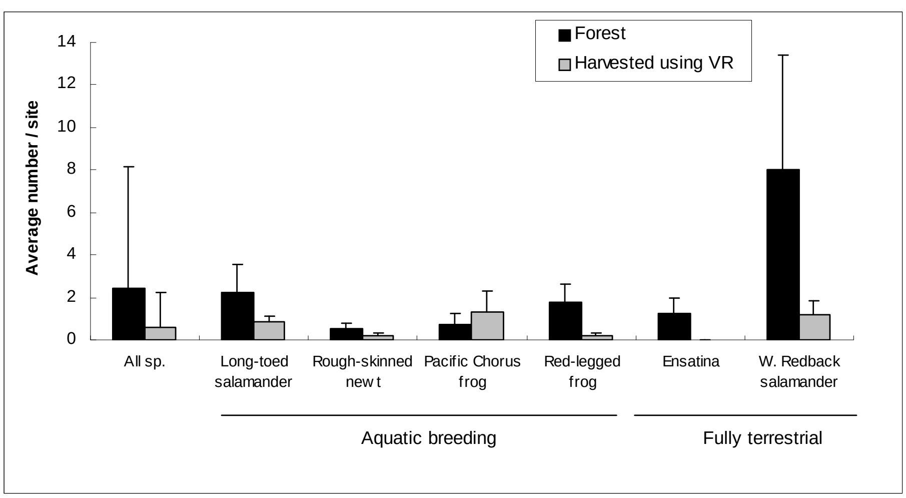

Figure 1. Average number of amphibians detected during visual surveys in 2000 at forest sites and sites harvested using variable retention (VR).

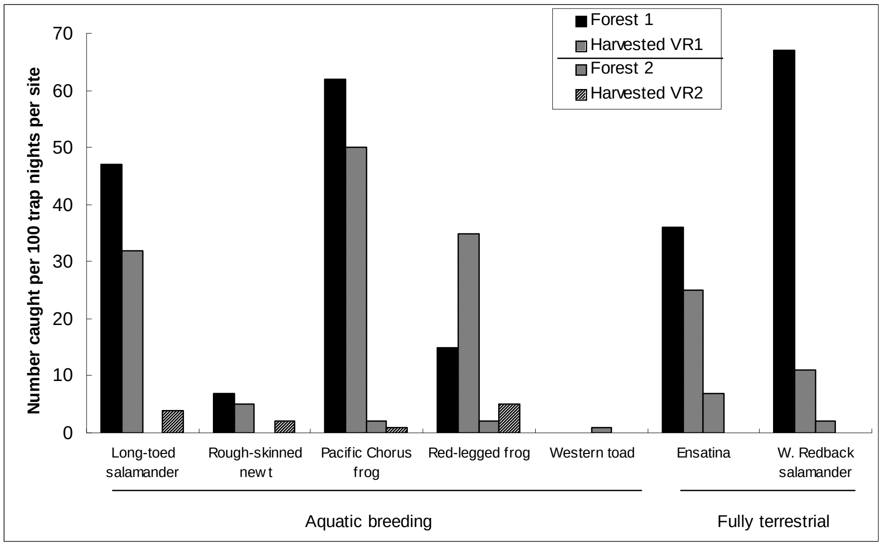

Figure 2. Number of amphibians detected per 100 pitfall trap nights per site in 2000 and 2001combined at two paired sites, each containing one forest site (Forest 1 or 2) and one harvested using variable retention (Harvested VR1 or 2).

We found evidence of breeding of all amphibian species both in wetlands located in forest as well as those situated within cutover areas, but more ponds were used in forest than in VR. Of the 98 small wetlands that contained water at the time of the surveys in 2002, 45% of forest ponds had signs of breeding versus only 28% of VR ponds ($\chi^2_1 = 2.82$, $0.10 > p < 0.05$). Larvae in VR ponds were often observed to be larger or at a later stage of development than those in forests (e.g., had limbs developing). This was consistent with observations from the three ponds sampled in 2001 with different amounts of canopy cover (Fig. 3). Pacific Chorus frog tadpoles at the retention patch pond and the unbuffered pond were detected sooner (e.g., hatched earlier) and were larger than at the forest pond, especially in spring. The unbuffered pond dried up within two weeks of the study start date, in late May, and all tadpoles perished. Later in the season, the tadpoles in the retention patch pond and forest pond were more similar in size.

Of 240 wetlands found during ground truthing surveys conducted in 55+ km of VR and forest habitats, approximately 72% (n = 171) had not been mapped. From a re-evaluation of the digital imagery using a sub-sample of 76 of the unmapped wetlands, it was determined that 16% may be detectable or were inaccurately mapped originally (many of the unmapped wetlands were found to be associated with canopy openings, indefinite drainages, and scrub habitat). It was originally estimated from the 1:5000 base maps and GIS that approximately 8,500 wetlands covering more than 900 ha occur in the 300,000+ ha area mapped. From the corrected margin of error, we estimated that close to 21,700 small wetlands covering approximately 3,451 ha occur in this area of Weyerhaeuser’s private and crown land on eastern Vancouver Island.

Discussion

Overall, we captured more amphibians in the forest than in cutover areas, which is consistent with similar studies elsewhere (see deMaynadier and Hunter 1995). The fact that amphibians were captured in VR harvest units, especially in retention patches, indicates that they utilize these areas in some capacity, but their use may be limited. Although salamanders in terrestrial habitats were less abundant in VR blocks, these trends were not consistent across species. Amphibians were captured more often in wet sites, and in or near forest or patches, suggesting a relationship between habitat use and availability. For example, they may seek out retention patches, especially areas with water, for cover from predators and extreme climatic conditions.

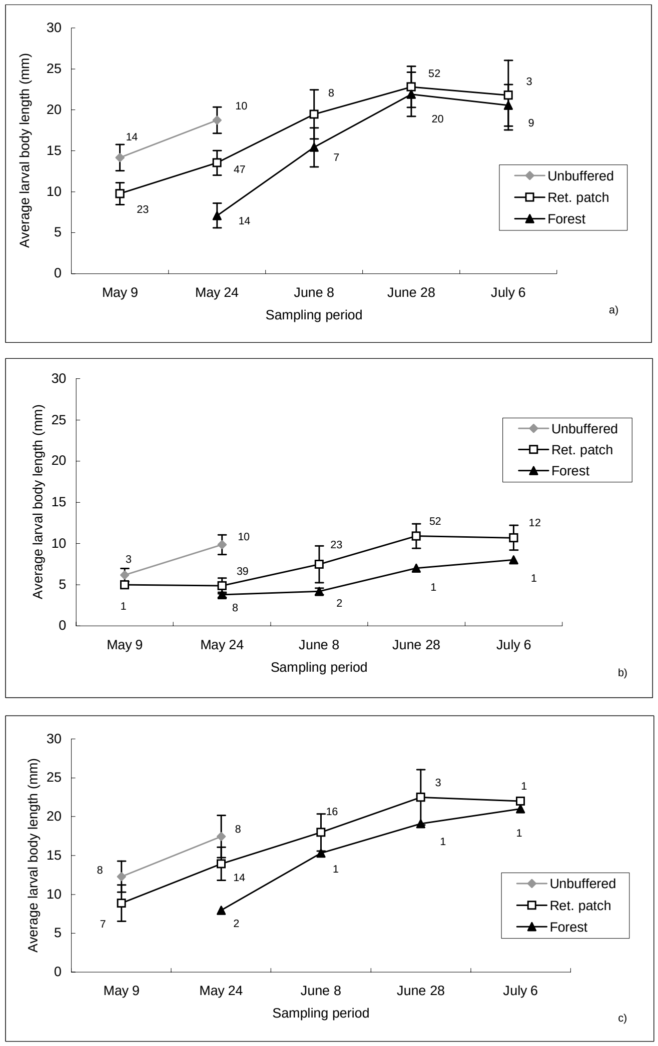

Figure 3. Average body length, standard deviation, and sample size of a) Red-legged frog tadpoles, b) Pacific Chorus frog tadpoles, and c) Long-toed salamander larvae captured from May to July at three ponds with different amounts of canopy cover; VR pond with no riparian cover (unbuffered); VR pond with partial riparian buffer (i.e., within a retention patch); and a forest pond (unharvested).

Through radio-telemetry, Chan-MacLeod (2002) found that Red-legged frogs released into VR patches moved less than those released into the matrix, and they tended preferentially use larger patches, especially those containing a stream. As with our study, she also found a relationship with body size. Red-legged frogs that ventured into clearcuts were, on average, larger than frogs that entered forests (Chan-McLeod 2003). Conserving moisture is especially important for small and/or elongated amphibians because their greater surface area-to-volume ratio makes them more susceptible to desiccation compared to larger individuals (e.g., juveniles versus adults, salamanders versus frogs) (Zug 1993; deMaynadier and Hunter 1995). These results have implications for smaller bodied species and individuals, such as newly emerged metamorphs that venture onto land in mid summer from ponds located within cutover areas.

Compared to studies in the Oregon and Washington, amphibian capture rates for terrestrial amphibians on Vancouver Island were relatively low and highly variable across sites. This variability led to high variance components and low statistical power. It was determined from Monte Carlo simulation precision analyses that sampling amphibians terrestrially was not cost-effective in terms of a long-term VR monitoring program. High spatial variability among amphibian populations is common. In our case, this was likely due to small sample sizes, both in terms of the number of sites surveyed and animals captured, but it also relates to the patchy distribution of amphibian populations that is associated with the location of ponds and moist microsites. As well, there appeared to be a high potential for bias across habitat types during visual surveys (e.g., slash-covered VR versus forest); this technique is better suited for inventories or comparisons across similar habitat types. As a result, our limited pitfall data likely more closely reflects abundance across habitat types but its interpretation is limited due to the low number of replicate study sites.

Given the incompatibility of clearcuts to amphibian populations terrestrially, it is interesting that all species breed in ponds in cutover areas. This is important because amphibians breeding in cutover ponds may be at greater risk of reproductive failure. Many amphibians are highly philopatric to natal breeding sites and may continue to use sites after harvesting (Gill 1978; Berven and Grudzien 1990). In addition, some species may also be attracted to ponds with reduced canopy cover due to the increased solar radiation that warms ponds earlier in spring. The rapid development of larvae that we observed under open-canopy conditions has been noted elsewhere (Halverson et al. 2003), and is likely advantageous for survival. It may reduce predation pressure (e.g., through gape limitations, speed of escape), increase the likelihood that larvae will metamorphose before temporary ponds have dried, or increase their fitness by extending the period spent in terrestrial environments before overwintering. Although larvae in cutover ponds may have an early competitive size advantage, they are exposed to greater risk of desiccation from pre-mature pond drying than those in forest ponds. Most larvae in this geographic area and elevation metamorphose in late June or July, so ponds that dry before then could become reproductive sinks, such as the VR pond we studied. The effect of forest harvesting on the hydrology of small, temporary ponds has received little study in this region.

We determined that a large number of small wetland habitats occur on eastern Vancouver Island. These areas, whether Crown or Private tenure, do not require any specific protective measures under the *Forest and Range Practices Act* or the *Private Forest Land Association* regulations within BC. Although these wetlands comprise a small proportion of the overall land base (1.1%), they cover close to 3,500 ha. The number of wetlands in a landscape is important because it directly relates to biodiversity, maintaining both species and genetic diversity (Semlitsch and Bodie 1998). Many of these small wet areas are likely ephemeral, and play an important role in the survivorship of amphibian populations because they offer relatively predator-free breeding sites (Snodgrass et al. 2000). They also serve as stepping stones between larger areas, by playing a vital role in the metapopulation dynamics of amphibian populations (Gill 1978; Gibbs 1993), and providing vital rehydration and foraging sites during seasonal movements.

The margin of error we found in the mapping small wetlands on eastern Vancouver Island was due to both limitations in traditional mapping techniques (e.g., photo interpretation) and the priorities of forest companies inventories. Photogrammeterists primarily map landscape features that help identify merchantable timber, as well as attributes that aid in orientation on the ground (e.g., canopy openings, drainages, large trees; see Wind 2003). They also map features that require protection under the *Forest and Range Practices Act* or *Private Forest Land Association* regulations, such as wildlife trees, fish bearing streams, and large lakes and wetlands. As a result, many small wetlands are not recorded, or if they are, they are not necessarily included on maps produced for forest engineers responsible for laying out block boundaries and identifying reserve areas. Unless these areas are given priority for protection, changes to current mapping practices and guidance to their conservation are unlikely. As a result, small wetlands will continue to be at risk of being degraded and lost during forest harvesting.

Harvesting methods that use a variable retention approach offer a unique opportunity to protect small wetland habitats. For example, Weyerhaeuser uses small wet areas as anchor points when deciding where group retention patches should be located within a block. This buffering may be beneficial to the wetland and to amphibian populations. However, the effect of buffering these small wetlands has not been studied. As a result, we have initiated an experiment to investigate the effects of buffering small wetland habitats on hydroperiod and amphibian reproductive success. We collected pre-harvest data at 71 wetlands in three forest sites near Nanaimo in 2004. These wetlands will be divided into similar groupings and randomly allocated to one of three treatments: 1) unbuffered, 2) narrow buffer (normally administered), and 3) wide buffer (2x the narrow). Group retention harvesting is slated to begin in fall 2004, and post-harvest data collection is expected to begin in spring 2005.

Conclusions

Amphibians are sensitive to forest harvesting and variable retention systems may retain forest patch refugia that provide moist, moderate climatic conditions aiding amphibian recruitment in the harvested matrix. However, refugial effects are difficult to monitor because the location of amphibian populations is closely tied to that of wet areas, which results in a patchy distribution. Alternatively, amphibians are an excellent group to monitor in aquatic environments and retention systems are often used to provide protection for their small wetland habitats. In this way, aquatic-breeding amphibians may be utilized as indicators of the health of aquatic habitats within the terrestrial environment and the effectiveness of variable retention approaches. Important issues that need to be addressed regarding wetland buffers, amphibian conservation, and cost-effective harvesting include: 1) the number of wetlands that require buffers (e.g., all or priority areas); 2) perimeter extent that requires buffers (e.g., all or partial buffers); and 3) effective buffer width.

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