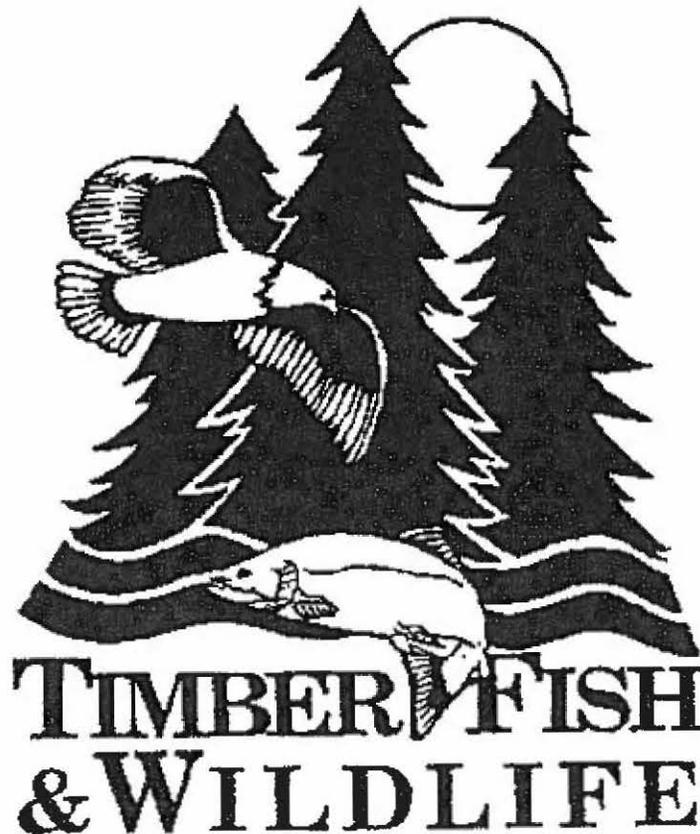


**Evaluation of Sampling Methods
for Amphibians in Headwater Basins
of Non-Fishbearing Streams:
A Preliminary Analysis
Year 2000 Annual Report**

submitted by:

**Marc P. Hayes, PhD; Timothy Quinn, PhD; Lowell Diller, PhD;
Lawrence L.C. Jones, MSc; James G. MacCracken, PhD;
Martin J. Raphael, PhD; Douglas E. Runde, PhD**



September 2001

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Executive Summary

We examined three stream-associated amphibian (SAA) sampling methods that varied in the effort required to use them. We compared two forms of a low-effort visual method (day and night spotlight surveys) to a relatively new, rapid assessment method requiring somewhat greater effort per unit area on 11 streams in the Coast Range (Stillman Creek watershed, $n = 8$) and Southern Washington Cascades (upper Cowlitz River watershed, $n = 3$) physiographic provinces.

In a preliminary evaluation, the rapid assessment method generally performed better than either form of visual method for presence/non-presence detection of Forest and Fish (FFR) SAAs in the Coast Range physiographic province (i.e., Olympic tailed frog, *Ascaphus truei*; Dunn's Salamander, *Plethodon dunni*; Columbia torrent salamander, *Rhyacotriton kezeri*). In particular, frequency of occurrence as determined by rapid assessment appeared superior than visual surveys for situations where amphibians were found in low numbers. Rapid assessment also generally resulted in higher estimates of relative abundance for FFR stream-associated amphibians, but comparisons of spotlight and rapid assessment methods to actual species densities will be required to determine whether rapid assessment is really superior for generating indices of relative abundance. Night spotlight surveys out-performed rapid assessment in detecting the presence of giant salamanders, which comprises two non-FFR amphibian species, i.e., Cope's and coastal giant salamanders (*Dicamptodon copei* and *D. tenebrosus*). Night sampling methods of some type may be required to detect amphibians whose daytime detection levels can be low (e.g., giant salamanders).

We found rapid assessment to be roughly three times as costly as either day or night spotlight surveys. These greater costs are related to moving surface objects during the survey and capturing and processing animals. However, detection advantages of rapid assessment over spotlight surveys outweigh its implementation cost.

We also sampled 55 streams in the Coast Range (Stillman Creek watershed, $n = 44$) and Southern Washington Cascades (Washougal River watershed, $n = 11$) to better understand how rapid assessment might be applied in Washington State. Analyses of the first detection distances (i.e., distance from the survey starting point to the first detection of a species in a stream) suggested that distances needed to detect amphibians with high probability ($> 80\%$) ranged from 100 m to 500 m, depending on the species. If our data approximate distances needed to detect FFR species that are *in fact* present, then the cost associated with this method for determining presence/absence surveys is roughly half to two-thirds of that needed to detect the same or equivalent taxa in California, where this method originated. Clearly, we must understand rapid assessment Type II error rates (i.e., not finding a species when in fact it is present) before we can confidently use rapid assessment. That understanding means verification of non-presence with a more rigorous method (e.g., some form of rubble-rousing).

We also explored the possibility that rapid assessment information might be used for estimating relative abundance. Relative abundance was indexed using two measures: 1) a tally of individuals of a species in the 30 m upstream from the first individual detected, and 2) a count of all individuals in the watered portion of the stream (typically 50–300 m) divided by the survey length. We found general inverse relationships between first detection distance and each of two indices of relative abundance, but the first measure had a stronger inverse relationship to first detection distance than the second. Inter-stream variation in first detection distance will be needed to determine how useful a relative abundance surrogate this metric may be.

We also found first detection distance to vary significantly with habitat conditions among streams. First detection curves appear promising in revealing amphibian responses to a suite of different habitat conditions, but fuller understanding of variation in first detection distance will be required to allow proper interpretation of such curves.

We found an especially intriguing pattern in Coast Range streams to which rapid assessment was applied: Streams harboring Olympic tailed frog (all life stages) had significantly more amphibian species than streams without tailed frogs. This preliminary pattern is promising because it suggests that Olympic tailed frog occurrence may be indicative of “hotspots” of amphibian biodiversity.

Any amphibian sampling program designed to measure the effectiveness of Type N FFR prescriptions will need to carefully consider the cost of finding suitable sampling sites. During 2000, a number of the streams we visited, currently typed as perennial non-fishbearing waters, were dry; these conditions may have resulted from the pronounced drought in the Pacific Northwest. Regardless of the cause, many of randomly selected sampling points lacked a scour channel and/or surface water. Finding streams suitable for survey required a large proportion of our effort.

1. General Introduction

This study addresses research needs for the Landscape and Wildlife Advisory Group (LWAG), which is charged with providing new information in support of adaptive management as described in the Forest and Fish Report (FFR). This study relates to two priority wildlife research and monitoring tasks outlined in the FFR (Schedule L-2):

- (1) G4 - Verification of models that address Stream-Associated Amphibians (SAAs).
- (2) G7 - Testing the effectiveness of buffer patches for amphibians in westside Type N (non-fishbearing) streams.

This study is a preliminary assessment of some potential sampling methods needed to address G4 and G7 in the sense that unbiased, precise, and efficient methods are necessary to determine habitat use and population persistence of amphibians.

This multi-year study was designed to develop sampling methods for SAAs in the relatively small headwater basins or watershed of Type N systems across different physiographic provinces of Washington State. Although these basins are relatively small, they are abundant and widespread. Data from the first year (2000) was intended to guide the design and approach in subsequent years. This report presents year 2000 results, analyses, and interpretations.

1.1 Why are amphibian sampling methods important?

Previous studies report high variability in data from SAA population surveys (e.g., Bury and Corn 1991, Kelsey 1995). Some of this variability is related to the patchy distribution of amphibians in streams (e.g., Welsh et al. 1997), which probably reflects the patchiness of habitat in streams (Pringle *et al.* 1988, Ward 1989, Downes 1990). Variability is also associated with temporal elements of sampling and counting SAAs: SAAs are small, frequently concealed, and have poorly understood daily activity patterns that may strongly influence their detectability. One fundamental concern in designing the effectiveness monitoring as outlined in the FFR is that this variability will mask changes in populations, distributions, and habitat use patterns. In addition, this variability will likely increase the costs of studies because greater effort will be needed to distinguish management effects. Without an analysis of variability and costs associated with a particular sampling method, monitoring programs run the risk of being inefficient and may result in studies with low statistical power or unnecessary replication. Furthermore, it is essential to understand how different habitats affect sampling efficiency since FFR will be applied statewide. Such efficiency analyses of amphibian sampling methods by habitat type have never been done.

Understanding the details of amphibian sampling methods is also valuable from a comparative perspective. Identifying similarities among methods can facilitate the translation of data from different studies into a common form, which is useful in comparative studies or meta-analyses to accurately depict population status, habitat use, and sensitivity to forest management practices. In addition, comparing sampling methods from different studies will help determine how data from those studies differ in information content. Such comparisons have helped refine sampling approaches for other taxonomic groups such as birds (Sallabanks and Quinn 2000), mammals (McComb *et al.* 1991) and for amphibians in terrestrial environments (McComb et al. 1993). However, comparisons of stream amphibian sampling methods have infrequently been addressed (see Bury and Corn 1991, Barr and Babbitt 2001).

1.2 Stream amphibian sampling methods

Sampling methods for SAAs can be thought of as ranging from small-scale intensive counts to larger scale less intensive surveys. The intensive end of this spectrum involves blocking stream sections

with nets or screens and removing and sifting through stream substrates (i.e., rubble-rousing) in search of animals (e.g., Bury and Corn 1991). Intensive methods typically provide occurrence and relative abundance data, but also have also been used to estimate density (i.e., enumerating all individuals in a small area using mark re-sighting or multiple removal methods). High levels of effort associated with these methods have prevented their systematic application to large areas of the stream. Rubble-rousing approaches have been applied in a variety of ways but commonly differ in the size of the sample unit (plot or belt) and the number of units sampled per stream (see Bury and Corn 1991). Tests to determine the relationship between the number of sample units and reduction in variability associated with relative abundance estimators within a stream are few (see Bury and Corn 1991, Welsh et al. 1997), and attempts to determine the effect of different habitat types on that variation are non-existent. As the application of rubble-rousing sampling has evolved, a consensus has emerged that more, smaller sample units generally reduce Type II error for estimating species occurrence and increase precision in relative abundance than fewer, larger units (B. Bury, *pers. comm.*, 2000). However, even this notion is based more on intuition (expert opinion) than on data.

At the other end of the spectrum are relatively low effort (per unit area), visual surveys that rely on opportunistic sighting of amphibians over larger areas of the stream, rather than disturbance of the streambed, (e.g., Jones and Raphael, 2001). Visual survey methods provide reliable occurrence data, but relative abundance determined by visual surveys is generally thought to be less reliable than estimates from intensive counts from small areas. This assumption has not been rigorously tested. The systematic spotlight survey methods (Jones and Raphael, 2001) is a relatively recently developed visual method that has been applied extensively in Washington State.

Lowell Diller (Wildlife Biologist, Simpson Timber Co, Korb, CA) developed a novel survey method for detecting stream-dwelling amphibians in California. As this approach was developed in part because of the need for a system for rapid assessment on landscape scales (i.e., across many Type N systems), we call this method **RAPID ASSESSMENT**. In its original form, sampling sites were selected from road and stream crossing points. In each quarter section, the first stream crossing point on the road used to access that quarter section was sampled. The stream was searched upstream of the road crossing using a light touch method, which involved turning movable surface objects judged to represent suitable habitat for the target species. The distance searched upstream differed depending on the amphibian species targeted. For southern torrent salamander (*Rhyacotriton variegatus*) and Olympic tailed frog (*Ascaphus truei*), two target taxa in California, search distances were, respectively, 300 m and 1000 m. When the first individual of the target species was found, a slightly more rigorous search of the next 30 m was conducted to determine whether additional individuals occurred nearby. If one failed to detect the target species within the search distance, the species was judged absent from that stream reach or segment. Search distances were best guess estimates based largely on locally collected data (L. Diller, *unpubl. data*). No published studies have used this method, its efficiency is poorly understood, and the relationship between this and other sampling methods is unknown. However, it holds great promise as a basis for designing efficient widespread surveys for cryptic species occupying small areas across large parcels of land.

The often untested assumption of most sampling methods that enumerate individuals is that the data provide valid estimates of relative abundance, i.e., the count data provide an index that is proportional to the total population even when the total population size is unknown. For example, counting 10 individuals in one stream and 100 over the same area in another stream reflects a population for the second stream that is an order of magnitude greater than the first. Different sampling methods that estimate relative abundance should be correlated, however, to our knowledge, testing this assumption has not been done for methods used to estimate relative abundance in SAAS.

1.3 Research Objectives, Questions, and Hypotheses

The objective of this project was to develop a reliable method of sampling SAAS that could be used to identify and monitor changes in occupancy patterns (i.e., distribution) and potentially document trends in abundance of SAAS through time. Specifically, we want to determine:

1) *the relationship between estimates of species occurrence and relative abundance among several sampling methods for SAAS.*

We chose three sampling methods for comparison that vary dramatically in effort per unit area sampled [in brackets]:

- (a) a rubble-rousing approach using 1-m belts [high];
- (b) a rapid assessment method [moderate]; and
- (c) the systematic spotlight survey visual method of Jones and Raphael (in press) [low]

We intentionally chose methods that represent the range of the sampling effort spectrum so that potential tradeoffs in cost and information content could be easily identified. We considered the high cost rubble-rousing and low cost systematic spotlight surveys to be “standard” methods because of their wide use. We included the rapid assessment method because of its promise in meeting the needs of the FFR, i.e., quick, accurate way of determining occupancy patterns as well as holding promise for comparing relative abundances among Type N systems over time. To address the relationship among sampling method for SAAS, we asked:

Question A: Do standard sampling methods provide less variable and more accurate information than a rapid-assessment method?

Measurement of accuracy can only be made against a standard, ideally one that has a very small error rates. For the purpose of this study, we used whichever method produced the highest frequency of occurrence as that standard, even though type II error rates were unknown. Since we did not have density information, we simply compared measures of relative abundance among methods. Stated in null form:

Hypothesis 1: There are no significant differences in species richness, species composition, and relative abundance of each species in type N streams as determined by three SAA sampling methods.

The 2000 data we present here addresses an initial effort at comparing spotlight surveys (one of the standard methods) to the rapid assessment method.

2) *criteria that will optimize the return for effort of a presence/non-presence rapid assessment sampling method in Washington State headwater streams.*

We chose to estimate cost benefit for rapid assessment first because this method is relatively new, has not previously been applied in Washington, and holds promise as an appropriate sampling method for FFR adaptive management.

Question B: Are rapid assessment methods (e.g., based on search distances) appropriate for amphibians in Type N systems in Washington?

Since the rapid assessment method was developed for stream-dwelling amphibians in northern California, we needed to understand its applicability to Washington State. We tested the hypothesis that:

Hypothesis 2: No significant differences in application criteria for the rapid assessment method exist between California and Washington States.

One basic focus was to understand potential regional differences in application

1.4 Criteria for Selection of Study Areas and Study Sites

Study Areas: We intentionally limited our initial effort to *Westside* Type N systems because six of the seven SAAs covered by FFR (all except the Rocky Mountain tailed frog (*Ascaphus montanus*)) occur in *Westside* systems¹. Subsequent development of this study will address Type N systems in eastern Washington. A type N system is defined as a perennial non-fish bearing stream or network of streams that has a single connection to a fishbearing water.

We sampled Type N systems in two physiographic provinces (Franklin and Dyrness 1973), the Coast Ranges (Willapa Hills region of southwestern Washington) and the Southern Washington Cascades. We focused on these two provinces because they have high SAA richness and high proportions of the Washington SAA genera (Dvornich *et al.* 1997, McAllister 1995).

Across the Coast Ranges province, we chose to focus on the Stillman Creek Watershed because substantial physical and biotic information existed for this watershed, especially when compared to other similar-sized basins in the Willapa Hills (D. Runde, Weyerhaeuser, *unpubl. data*). We viewed the quality of stream typing information (based on recent surveys of fish distribution) in the Stillman Watershed as crucial to study success.

We focused on the Washougal River Watershed in the Southern Washington Cascades province because one of the study co-operators, Longview Fibre Company, was a major landowner in this watershed. We also sampled a few sites without active forest management in the upper Cowlitz River Watershed to explore their potential use as reference sites.

Selecting Study Sites: In the Stillman Creek Watershed, we selected 375 stream crossings based on a stratified random approach from the population of road crossings of Type N streams on Weyerhaeuser ownership ($n = 1,063$), which encompasses 73% of the watershed. This population was STRATIFIED according to aspect, elevation, and geology (Table 1):

Table 1.401 – Strata for partitioning the population of road crossings of Type N streams for stream selection in the Stillman watershed, Washington, 2000

1	aspect ¹ (degrees)	NW-NE (293°-66°)		SW-SE (247°-113°)
2	elevation ² [m (ft)]	0-300 (0-986)	301-600 (987-1968)	601-900 (1969-2953)
3	geology ³	alluvial	igneous	Marine sedimentary

¹ Zero degrees is due North.

² Elevation actually reaches a maximum of 945 m [3,100 ft] on BawFaw Peak. However, the 45 m exceeding the highest elevation category covers only a tiny area that is entirely within the upper reaches of a few Type 5 systems that roads did not bisect.

³ Basic macrocategories that lump several geocodes based on Wells (1981).

Streams with east (67°-112°) or west (248°-292°) aspects were excluded from the sample because we believed that it would be easier to detect sampling method differences along a north-south axis.

¹ Stream-associated amphibians (SAAs) refer to those species of amphibians that reproduce in or near streams. At the time of its development in 2000, FFR recognized six SAAs as focal, including what was then termed the tailed frog (*Ascaphus truei*). Since that time, the tailed frog has been partitioned into two species, the Olympic tailed frog (*Ascaphus truei*), with a Washington State distribution across the Cascades axis and the Olympic Mountains, and the Rocky Mountain tailed frog (*Ascaphus montanus*), with a Washington State distribution in the Rocky and Blue Mountains. As the tailed frog taxon during the development of FFR encompassed both species, the list of focal FFR SAAs now also includes both. Thus, there are now seven, rather than six focal FFR SAAs. Of this group, the two tailed frog taxa represent the only members in eastside systems.

This reasoning was based on the fact that some SAAs are known to either favor or disfavor aspects along a north-south axis (see Wilkins and Peterson 2000), so the most extreme contribution to variability in relative abundance responses were expected along this gradient. We did not include any streams with alluvial geology because this geology type represents only a small fraction (4%) of the Stillman watershed and is restricted to the valley bottoms of large-order streams (>3) based on Strahler [1952]). We also excluded sedimentary geologies for similar reasons. We did not stratify by forest stand (stream-adjacent forest) age *per se*, but were confident that most stand age categories in this landscape were represented in our sample.

In the Washougal River Watershed, we randomly selected 78 streams from the total population of road crossings of Type N streams across two large, relatively contiguous blocks under Longview Fibre ownership (n = 117), which encompasses < 25% of the watershed. We did not stratify the population of stream crossings because of its relatively small number of sites. In other words, we expected to visit all these crossings during the scooping phase of the study to determine if they could be surveyed.

We selected 6 reference streams in the upper Cowlitz River Watershed, with assistance from the Gifford Pinchot National Forest. All reference streams had perennial flow, were first or second order (Strahler 1952) and had > 90% of their forests in stands > 110 yr old.

Our initial intent was to sample a block of streams in two physiographic provinces sufficient to perform complete analyses on each. However, logistical difficulties coupled with drought conditions required more effort than expected to find suitable streams for survey. Further, Type N systems in the Southern Washington Cascades were much larger than those in the Coast Ranges and required a much greater effort to access and sample. Consequently, sampling during 2000 was concentrated in the Coast Ranges.

2. Research Question A – Do standard sampling methods provide less variable and more accurate information than a rapid-assessment method?

Our general approach to comparing methods was to sample the same reaches with each method. Ideally, this would be done within a single season of the same year. The time spent finding suitable sites limited us to a preliminary comparison of the spotlight and rapid assessment methods in 2000.

2.1 Method

Scoping: Prior to initiating sampling, we visited each randomly selected stream crossing point to determine hydrologic condition of the stream and age of the adjacent forests (hereafter referred to as scoping). Road crossing points with streams that lacked a scour channel were not considered further. When streams had a scour channel we walked 100 m upstream of the crossing and characterized hydrologic condition using one of six categories: (1) dry, (2) moist, (3) saturated without surface water, (4) standing water, (5) flowing water, or (6) any combination of two or more of these five. We selected sampling reaches with flowing or standing water in $\geq 90\%$ of the first 100m. Since logging debris restricted access to > 75 % of channels in forests 0-15 years old, streams within stands < 15 years old were excluded from this study.

Systematic Spotlight Surveys: Spotlight surveys were done according to the method of Jones and Raphael (2001). This method involved a visual survey of a 300-m reach of target streams in a slow walk using a strong ($\geq 100,000$ candlepower) light source. One complete survey of a stream involved two samplings within a 24-hr period: a daytime sampling done between 1200 and 1600 hr and a nighttime sampling approximately 1 hour after dusk. No habitat manipulation to assist amphibian detection (e.g., turning over movable objects, altering vegetation) was done during

spotlight surveys, and no amphibians detected were handled. Amphibian data were recorded for each 10-m reach. Survey data was tape recorded and subsequently transcribed.

Rapid Assessment: Using a modified version of the rapid assessment survey method, we conducted daytime surveys of the main stream channel above a road crossing until either we reached the next road crossing or the uppermost extent of surface water. Our search approach included a “light touch” in which only the easily movable objects were overturned. Surveyors used headlamps (Wheat™ Kohler-Bright Star miner’s lamps or Mega™ Petzel headlamps) to help illuminate the streambed where low light levels limited visibility. We intentionally focused the search in the best available habitats. We handled and recorded data on most² amphibians, and measured the distance from the road crossing to each amphibian. All streams that were spotlight surveyed were rapid assessed within two weeks following their spotlight survey.

Amphibian Data: We determined genus (for most giant salamanders only) or species (listed in Appendix I), life stage (as egg, larvae, metamorph, juvenile, or adult), and body size (as snout-vent length [SVL] or total length [TTL]) for all amphibians observed during both survey methods. During rapid assessment, we measured body size or total length for individuals that could be captured. For individuals not captured and those observed during spotlight surveys, we determined genus (for most giant salamanders only) or species, and total body length was visually estimated to the nearest 5 mm. We developed TTL-SVL regressions using data collected during the rapid assessment to facilitate comparisons between methods. Individuals collected during the rapid assessment for which the species or life stage identification was difficult were brought to the laboratory for examination. These individuals were subsequently released at the capture location. We used counts per meter of stream length surveyed to determine indices of abundance for all methods

Analyses: We used standard statistical procedures (Zar 1996), but we relied predominantly on descriptive statistics at this preliminary stage. We frequently provided the mean (\bar{x}), standard deviation (s), standard error of the mean (se), and range to describe the data.

We used Fisher’s Exact test on all two-way contingency tables. Results of all non-parametric tests were corrected for tied ranks as needed. Data were analyzed using Statview 5.0 (SAS Institute, Inc.) software.

For analyses involving species richness we used two groups: One composed of only FFR target species and the other composed of all stream-associated amphibians taxa (FFR species plus members of the giant salamander genus *Dicamptodon*). We excluded stillwater breeding species (e.g., northwestern salamanders (*Ambystoma gracile*), newts (*Taricha granulosa*), and other frogs (*Hyla regilla*, *Rana* sp.)) despite the fact that they may be seasonally associated with streams, because their detection frequency was very low.

Lastly, although we discuss statistical significance based on $\alpha = 0.05$, we believe it is useful to look at probabilities as a guide of what to expect as more data become available.

2.2 Results

Scoping: Scoping for site selection required substantial effort. Two surveyors could visit between 8 and 14 streams ($\bar{x} = 11$) in one day and the 338 road crossing points in the Stillman ($n = 260$) and Washougal ($n = 78$) watersheds required about two person months to scope.

We visited 69% (260 of 375) of Type N stream crossings available based on selection criteria (see Section 1.4) within the Stillman watershed (Table 2.201). Of these, 23% (61 of 260) lacked any evidence of a visible scour channel. Another 58% (151 of 260) had a visible scour channel, but were

² A few amphibians were not handled because they evaded capture.

either dry during the scoping period (August-September; 30%: 79 of 260) or lacked sufficient water (28%: 72 of 260) to qualify for survey (Table 2; see Scoping section). Only 19% (48 of 260) of the road crossings had a channel with enough water to qualify for survey. Forty-four of these 48 reaches (92%) were sampled with at least one survey method in 2000.

We visited two-thirds (78 of 117) of road crossings of Type N streams in the Washougal River watershed under Longview Fibre Company ownership. Of these, 20% (16 of 78) lacked any evidence of a scour channel. Another 58% (45 of 78) had a visible scour channel, but were either dry during the scoping period (August-September) 32% (25 of 78) or lacked enough water ~26% (20 of 78) to qualify for survey (see Scoping section). Only 22% (17 of 78) of road crossings had a channel with enough water to qualify for survey. We sampled 11 of these 17 reaches using the rapid assessment method in 2000.

Hydrologic conditions above road crossing were similar between physiographic provinces. We scoped a similar proportion (about two-thirds) of road crossings within each watershed (Fisher's Exact test: $\chi^2 = 0.295$, $p = 0.6480$). The proportion of hydrologic conditions (i.e., lacking a scour channel; dry; lacking enough water to qualify for a survey; or with enough water to qualify for a survey) did not differ significantly between watersheds (Fisher's Exact test: $\chi^2 \leq 0.429$ and $p \geq 0.5151$ for all four).

Table 2.201 – Characteristics of small headwater stream reaches at 375 road-crossing points, Stillman watershed, Washington, 2000

Reach Category	Stratum Categories							Totals	
	Elevation	0-300 m		301-600 m		601-900 m			
	Aspect ¹	North	South	North	South	North	South		
Qualifying ²	$n_q =$	38	25	109	106	43	54	$N_q = 375$	
	% of N_q	10.1	6.7	29.1	28.3	11.5	14.4	100.0	
Scoped ³	$n_s =$	21	17	82	71	23	46	260	
	% of N_q	5.6	4.5	21.9	18.9	6.1	12.3	69.3	
No Channel	$n_{nc} =$	3	2	18	16	8	14	61	
	% of N_q	0.8	0.5	4.8	4.3	2.1	3.7	16.3	
Channel Present	Dry	$n_{dc} =$	4	5	31	19	6	14	79
		% of N_q	1.1	1.3	8.3	5.1	1.6	3.7	21.1
	< 90% Water ⁴	$N_{<w} =$	4	1	25	23	6	13	72
		% of N_q	1.1	0.3	6.7	6.1	1.6	3.5	19.2
	≥ 90% Water ⁵	$n_{>w} =$	10	9	8	13	3	5	48
		% of N_q	2.7	2.4	2.1	3.5	0.8	1.3	12.8

¹ North = NW-NE and South = SW-SE as defined in Table 1.

² Based on selection criteria (see Section 1.4).

³ Based on scoping approach (see Scoping subsection).

⁴ Includes all channel categories except dry that had < 90% flowing or standing water (see Scoping subsection)

⁵ Channel category with ≥ 90% flowing or standing water.

Comparison of Survey Methods: We found amphibians in 38 of 45 (84%) streams in the Stillman watershed using the rapid assessment method. Of these 38 streams, 8 (21%) also were surveyed using the spotlight survey method, and we found amphibians in all eight. The other 23 streams

could not be effectively spotlight surveyed because dense vegetation and woody debris accumulations (over 20% of the reach) precluded using that survey method.

We found amphibians in 8 of 11 (73%) streams in the Washougal River watershed using the rapid assessment method. Proportion of sampled reaches in which we recorded amphibians did not differ significantly from that in the Stillman watershed (Fisher's Exact test: $\chi^2 = 0.827$, $p = 0.3933$). Of these 8 streams, only 2 had conditions that allowed a spotlight survey. Because the sample was so small, we elected not to spotlight survey these two streams until a larger sample of streams was available.

Estimates of species richness varied between methods (Table 2.202). For streams in the Stillman watershed, we detected between 0-2 FFR species per stream using spotlight surveys, with the nighttime survey average slightly lower than daytime survey average. We found between 0-3 FFR species per stream using rapid assessment, but detected 1-3 additional FFR species in 4 of 8 streams when compared to the spotlight survey method. All methods detected the same number of species in the remaining four streams; this included one stream on which no detections were made. Similarly, we found 1 to 3 SAA species per stream with spotlight surveys. Richness of SAA species for day and night surveys was similar, but rapid assessment was more effective at determining the occurrence of SAA species as spotlight surveys in 6 of 8 streams.

Table 2.202 – Estimates of amphibian species richness as determined by three survey methods in Stillman watershed streams, 2000

Stream	FFR Amphibian Species			All Stream-Associated Amphibian Species ¹		
	Spotlight		Rapid Assessment	Spotlight		Rapid Assessment
	Day	Night		Day	Night	
STL11040313	1	0	2	2	2	4
STL11041011	1	1	2	3	3	4
STL12042120	1	1	1	1	2	3
STL12043108	2	2	2	2	2	3
STL12043226	1	1	2	1	2	4
STL12043322	1	1	1	2	2	1
STL12043407	1	0	3	2	1	4
STL12043417	0	0	0	1	1	0
Mean	1.0	0.8	1.6	1.8	1.9	2.9
Standard Deviation	0.5	0.7	0.9	0.7	0.6	1.5
Standard Error ²	0.2	0.3	0.3	0.3	0.2	0.5

¹ This includes FFR Amphibian species plus giant salamanders (*Dicamptodon* spp.).

² Standard error of the mean.

We found significant differences ($p = 0.0244$) in median richness of FFR amphibians among the three sampling methods (Table 2.203). Although we lacked the power to show differences between pairs of methods (i.e., individual contrasts) values of the q statistic indicated that the largest differences were between rapid assessment and each of the spotlight surveys (Table 2.203). No significant differences were found using a comparison among sampling methods in richness of SAAs (Friedman test: $\chi^2_r = 3.630$, $p = 0.1629$).

Species richness data for the three reference sites in the Cowlitz River watershed appeared less variable than that for the Stillman watershed (Tables 2.202 and 2.204). Rapid assessment and both types of spotlight surveys were equally effective at determining FFR species occurrence. When all SAAs were included, night spotlight surveys detected more species than the day surveys. Night spotlight surveys and rapid assessment gave similar results except that one additional non-FFR SAA was detected with night spotlight surveys in one stream.

Table 2.203 – Results of Friedman Test comparison of amphibian species richness in Stillman watershed as determined by three survey methods, 2000

Groups	χ^2_r ¹	Probability ²	Individual Contrasts		q value ²	critical q
FFR Species	7.429	0.0244	Spotlight Day	Spotlight Night	0.707	3.314
			Spotlight Day	Rapid Assessment	1.768	
			Spotlight Night	Rapid Assessment	2.475	

¹ The test statistic for a Friedman comparison is a tie-corrected Chi-square (χ^2_r).

² Emboldened probabilities or q values are significant.

Table 2.204 – Estimates of amphibian species richness as determined by three survey methods in upper Cowlitz River watershed reference sites, 2000

Stream	FFR Amphibian Species			All Stream-Associated Amphibian Species ¹		
	Spotlight		Rapid Assessment	Spotlight		Rapid Assessment
	Day	Night		Day	Night	
COW09081701	2	2	2	2	4	3
COW10071701	1	1	1	1	3	3
COW11090901	1	1	1	2	3	3
Mean	1.3	1.3	1.3	1.7	3.3	3.0
Standard Deviation	0.6	0.6	0.6	0.6	0.6	0.6
Standard Error ²	0.3	0.3	0.3	0.3	0.3	0.3

¹ This includes FFR Amphibian species plus giant salamanders (*Dicamptodon* spp.).

² Standard error of the mean.

Species Composition: Overall, we detected FFR species as, or more, frequently with the rapid assessment method as with either spotlight survey (Table 2.205). Spotlight surveys did not detect the Olympic tailed frog in three streams from which we recorded it using rapid assessment. Similarly, spotlight surveys did not detect Dunn's salamander in two streams where it was recorded with rapid assessment. In contrast, our ability to detect the presence of Columbia torrent salamander was identical between the day spotlight surveys and rapid assessment. Columbia torrent salamanders were detected less frequently with night spotlight surveys than either day spotlight or rapid assessment methods. Overall, detection of giant salamanders that we could identify as Cope's was most frequent with rapid assessment, but Cope's was detected in one stream exclusively during a night spotlight survey. Detection of both giant salamander species during spotlight surveys occurred more often at night than during the day. Night spotlight surveys were most effective at detecting giant salamanders that we could identify as coastal giant salamanders.

In contrast to the Stillman watershed, we found no differences in detection of FFR amphibian species among methods in three reference streams in the upper Cowlitz River watershed (Table 2.206). However, spotlight surveys for giant salamanders seemed to be much more effective at night than during the day based on the number of individuals found.

Table 2.205 – Estimates of amphibian species composition as determined by three survey methods in Stillman watershed, 2000

Stream	FFR Amphibian Species ¹									Other Stream-Associated Amphibian Species					
	ASTR			PLDU			RHKE			DICO			DITE		
	Spotlight ²		RA ³	Spotlight		RA	Spotlight		RA	Spotlight		RA	Spotlight		RA
	D	N		D	N		D	N		D	N		D	N	
STL11040313			+				+		+		+		+	+	+
STL11041011						+	+	+	+	+	+	+	+	+	+
STL12042120							+	+	+		+	+			+
STL12043108	+	+	+				+	+	+			+			
STL12043226			+	+	+	+	+	+	+			+		+	+
STL12043322							+	+	+				+	+	
STL12043407			+			+	+		+					+	+
STL12043417													+	+	

¹ A plus (+) indicates species detection. Species: ASTR = Olympic tailed frog, PLDU = Dunn’s salamander, RHKE = Columbia torrent salamander. DICO = Cope’s giant salamander. DITE = coastal giant salamander.

² Day (D) and night (N).

³ Rapid assessment (RA).

Table 2.206 – Estimates of amphibian species composition as determined by three survey methods in upper Cowlitz River Watershed reference streams, 2000

Stream	FFR Amphibian Species ¹						Other Stream-Associated Species					
	ASTR			RHCA			DICO			DITE		
	Spotlight ²		RA ³	Spotlight		RA	Spotlight		RA	Spotlight		RA
	D	N		D	N		D	N		D	N	
COW09081701	+	+	+	+	+	+		+	+		+	+
COW10071701	+	+	+					+	+		+	+
COW11090901	+	+	+	Not Present? ⁴				+	+	+	+	+

¹ A plus (+) indicates species detection. Species: ASTR = Olympic tailed frog, PLDU = Dunn’s salamander, RHKE = Columbia torrent salamander. DICO = Cope’s giant salamander, DITE = Pacific giant salamander.

² Day (D) and night (N).

³ Rapid Assessment (RA).

⁴ Cascades torrent salamanders are not known from north of the Cowlitz River.

Relative Abundance: Relative abundance data (individuals per length (in meters) of stream surveyed) were quite variable. Coefficients of variation (standard deviation/mean) were frequently

> 1 for all species in the data examined.

FFR SAA SPECIES: Variation in relative abundance appeared to be method- and region-specific.

Olympic tailed frog: Estimates of relative abundance for Olympic tailed frog were low in the Stillman watershed (Table 2.207). Using rapid assessment, we detected Olympic tailed frogs ca. seven times as frequently as with spotlight surveys. Nevertheless, tailed frogs were detected infrequently using rapid assessment; ≤ 2 individuals were found per 300 m stream for all streams except one in which 11 tailed frog life stages were observed. Most important, tailed frogs were detected in 4 streams with rapid assessment, but in only 1 of those 4 were Olympic tailed frogs found during spotlight surveys.

Table 2.207 – Detections (individuals per 300 m of stream) of Olympic tailed frog (*Ascaphus truei*) by life stage using three sampling methods in the Stillman watershed, 2000

Stream	SPOTLIGHT SURVEYS								RAPID ASSESSMENT			
	DAY				NIGHT				L	M	P	T
	L ¹	M	P	T	L	M	P	T				
STL11040313	0	0	0	0	0	0	0	0	0	0	1	1
STL11041011	0	0	0	0	0	0	0	0	0	0	0	0
STL12042120	0	0	0	0	0	0	0	0	0	0	0	0
STL12043108	0	0	1	1	0	0	2	2	10	0	1	11
STL12043226	0	0	0	0	0	0	0	0	0	2	0	2
STL12043322	0	0	0	0	0	0	0	0	0	0	0	0
STL12043407	0	0	0	0	0	0	0	0	1	0	0	1
STL12043417	0	0	0	0	0	0	0	0	0	0	0	0
Life Stage Totals	0	0	1	1	0	0	2	2	11	2	2	14
Mean	0.0	0.0	0.1	0.1	0.0	0.0	0.3	0.3	1.4	0.3	0.3	1.9
Standard Deviation	0.0	0.0	0.4	0.4	0.0	0.0	0.7	0.7	3.5	0.7	0.5	3.8
Standard Error²	0.0	0.0	0.1	0.1	0.0	0.0	0.3	0.3	1.2	0.3	0.2	1.3

¹ Life stage: larvae (L), metamorph (M), postmetamorph (P), and total (T). Postmetamorphic category includes juveniles and adults. Total is the sum of all life stage categories.

² Standard error of the mean.

In reference streams in the upper Cowlitz River Watershed, detection of Olympic tailed frog was frequent (≥ 46 individuals per 300 m of stream for the method with the most detections; Table 2.208). On average, we detected Olympic tailed frogs using rapid assessment slightly more than half as frequently than when night spotlight surveys were used, but over twice as frequently as when the day spotlight surveys were used. Olympic tailed frog was uniformly detected more frequently with rapid assessment than with day spotlight surveys, but detected less frequently with rapid assessment than with night spotlight surveys in two of three streams.

Columbia torrent salamander: In the Stillman watershed, detection of Columbia torrent salamander was variable, ranging from no detections to extremely frequent (up to 219 individuals per 300 m of stream for the method with the most detections; Table 2.209). However, on average, torrent salamander detections were frequent (>50 individuals per 300 m of stream) for the method with the most detections; Table 2.209). We found significant

differences among survey method in ability to detect torrent salamanders (Table 2.210). Although we lacked the power to show differences between pairs of methods (i.e., individual contrasts), values of the *q* statistic suggested that the largest differences were between rapid assessment and each of the spotlight surveys. Rapid assessment detected Columbia torrent salamander over six times as frequently as either spotlight survey method. Further, day spotlight surveys detected Columbia torrent salamanders over three times as often as

Table 2.208 – Detections (individuals per 300 m of stream) of Olympic tailed frog (*Ascaphus truei*) by life stage using three survey methods in reference streams in the upper Cowlitz watershed, 2000

Stream	SPOTLIGHT SURVEYS								RAPID ASSESSMENT			
	DAY				NIGHT				L	M	P	T
	L ¹	M	P	T	L	M	P	T				
COW09081701	3	0	1	4	46	0	7	53	35	0	0	35
COW10071701	16	0	0	16	211	0	0	211	64	0	0	64
COW11090901	53	0	2	55	29	28	8	65	94	0	0	94
Life Stage Totals	72	0	3	75	286	28	15	329	193	0	0	193
Mean	24.0	0.0	1.0	25.0	95.3	9.3	5.0	109.7	64.3	0.0	0.0	64.3
Standard Deviation	25.9	0.0	1.0	26.7	100.5	16.2	4.4	88.0	29.5	0.0	0.0	29.5
Standard Error²	15.0	0.0	0.6	15.4	58.0	9.3	2.5	50.8	17.0	0.0	0.0	17.0

¹ Life stage: larvae (L), metamorph (M), postmetamorph (P), and total (T). Postmetamorphic category includes juveniles and adults. Total is the sum of all life stage categories.

² Standard error of the mean.

Table 2.209 – Detections (individuals per 300 m of stream) of Columbia torrent salamander (*Rhyacotriton kezeri*) by life stage using three survey methods in the Stillman watershed, 2000

Stream	SPOTLIGHT SURVEYS								RAPID ASSESSMENT			
	DAY				NIGHT				L	M	P	T
	L ¹	M	P	T	L	M	P	T				
STL11040313	0	0	4	0	0	0	0	0	14	17	11	42
STL11041011	17	1	1	19	10	0	0	10	78	10	22	110
STL12042120	5	0	0	5	5	1	0	6	7	2	1	10
STL12043108	3	0	1	4	2	0	1	3	34	2	0	36
STL12043226	20	0	16	36	9	0	7	16	137	70	12	219
STL12043322	1	0	3	4	1	0	3	4	2	0	0	2
STL12043407	1	0	2	3	0	0	0	0	9	0	1	10
STL12043417	0	0	0	0	0	0	0	0	0	0	0	0
Life Stage Totals	47	1	27	71	27	1	11	39	281	101	47	429
Mean	5.9	0.1	3.4	8.9	3.4	0.1	1.4	4.9	35.1	12.6	5.9	53.6
Standard Deviation	8.0	0.4	5.3	12.5	4.1	0.4	2.5	5.7	48.5	24.0	8.2	75.9
Standard Error²	2.8	0.1	1.9	4.4	1.5	0.1	0.9	2.0	17.1	8.5	2.9	26.8

¹ Life stage: larvae (L), metamorph (M), postmetamorph (P), and total (T). Postmetamorphic category includes juveniles and adults. Total is the sum of all life stage categories.

² Standard error of the mean.

night spotlight surveys. In two streams in which Columbia torrent salamanders were infrequently detected during the day spotlight surveys, they went undetected during night spotlight surveys. Although differences in detection among the three methods were large, detection levels from different methods were generally correlated (Table 2.210). Columbia torrent salamander is restricted to the Coast Range physiographic province, so Cascades data are unavailable for this species.

Cascades torrent salamander: We lacked sufficient data to provide an indication of how Cascades torrent salamander detection might vary among methods. We found Cascades torrent salamanders in one of the three reference streams we examined in the upper Cowlitz system (COW09081701). One metamorphic and one postmetamorphic Cascades torrent salamander were found during the rapid assessment survey of this stream. We found one larval and three postmetamorphic Cascades torrent salamanders during the night spotlight surveys, and six postmetamorphic Cascades torrent salamanders during the day spotlight survey. Cascades torrent salamanders were detected in only two Washougal system streams (Appendix IVc), which we did not spotlight survey (Section 2.2 under Comparison of Survey Methods). Cascades torrent salamander is restricted to the Southern Washington Cascades physiographic province, so Coast Range data are unavailable for this species.

Table 2.210 – Friedman Test and Spearman Rank correlation comparisons of Columbia torrent salamander (*Rhyacotriton kezeri*) detections (individuals per 300 m of stream) for three survey methods in Stillman watershed streams, 2000

Friedman Test		Comparison		q value ²	Spearman Rank Correlation	
χ_r^2 ¹	Probability ²				rho (ρ)	Probability ²
6.462	0.0395	Spotlight Day	Spotlight Night	1.061	0.975	0.0099
		Spotlight Day	Rapid Assessment	2.121	0.594	0.1161
		Spotlight Night	Rapid Assessment	3.182	0.565	0.1353

¹ The test statistic for a Friedman comparison is a tie-corrected Chi-square (χ_r^2).

² Emboldened probabilities or q values are significant. The critical value of q at $\alpha = 0.05$ for multiple pairwise comparisons among methods was 3.314.

Dunn's salamander: Detection of Dunn's salamander was infrequent in the Stillman watershed using any of the methods (Table 2.211). Rapid assessment detected Dunn's salamanders at slightly higher rates than when either spotlight method was used. Dunn's salamander is restricted to the Coast Range physiographic province, so no Cascades data are available for this species.

Van Dyke's salamander: No Van Dyke's salamanders were found in this study.

NON-FFR SAA SPECIES: Giant salamanders were the only non-FFR SAAs for which enough data were collected to permit some level of comparison. We could distinguish larger individuals of the two species, Cope's and coastal giant salamanders, but not the smaller larval forms. Thus, data for the two taxa were lumped.

Giant salamanders: Giant salamanders were detected at low to moderate rates in the Stillman watershed (Table 2.212). We found significant differences among survey methods in detection of giant salamanders (Table 2.213). Post hoc comparisons indicated that day spotlight surveys and rapid assessment detection rates were significantly different ($p = 0.0470$). Day and night spotlight surveys were significantly positively correlated ($p = 0.0393$) with each other, while rapid assessment was

poorly and moderately correlated, respectively, with day and night spotlight survey detection rates.

Table 2.211 – Detections (individuals per 300 m of stream) of Dunn’s salamander (*Plethodon dunnii*) by life stage as determined by three survey methods in the Stillman watershed, 2000

Stream	SPOTLIGHT SURVEYS						RAPID ASSESSMENT		
	DAY			NIGHT			J	A	T
	J ¹	A	T	J	A	T			
STL11040313	0	0	0	0	0	0	0	0	0
STL11041011	0	0	0	0	0	0	2	0	2
STL12042120	0	0	0	0	0	0	0	0	0
STL12043108	0	0	0	0	0	0	0	0	0
STL12043226	1	0	0	1	0	0	5	0	5
STL12043322	0	0	0	0	0	0	0	0	0
STL12043407	0	0	0	0	0	0	0	1	1
STL12043417	0	0	0	0	0	0	0	0	0
Life Stage Totals	1	0	1	1	0	1	7	1	8
Mean	0.1	0.0	0.0	0.1	0.0	0.0	0.8	0.1	1.0
Standard Deviation	0.4	0.0	0.0	0.4	0.0	0.0	1.8	0.4	1.8
Standard Error ²	0.1	0.0	0.0	0.1	0.0	0.0	0.6	0.1	0.6

¹ Life stage: juvenile (J), adult (A), and total (T). Total is the sum of all life stage categories.

² Standard error of the mean.

Table 2.212 – Estimates of relative abundance (measured as individuals per 300 m of stream) of giant salamanders (*Dicamptodon* sp.) by life stage comparing different sampling methods in the Stillman watershed, 2000

Stream	SPOTLIGHT SURVEYS								RAPID ASSESSMENT			
	DAY				NIGHT				L	M	P	T
	L ¹	M	P	T	L	M	P	T				
STL11040313	1	0	0	1	5	0	0	5	3	0	0	3
STL11041011	5	0	0	5	10	0	1	11	30	0	0	30
STL12042120	0	0	0	0	1	0	0	1	3	0	0	3
STL12043108	0	0	0	0	0	0	0	0	1	0	0	1
STL12043226	0	0	0	0	7	0	0	7	9	0	0	9
STL12043322	1	0	0	1	4	0	5	9	0	0	0	0
STL12043407	0	0	0	0	1	0	0	1	3	0	0	3
STL12043417	1 ²	0	0	0	4	0	0	0	0	0	0	0
Life Stage Totals	7	0	0	7	28	0	6	34	49	0	0	49
Mean	0.9	0.0	0.0	0.9	3.5	0.0	0.8	4.3	6.1	0.0	0.0	6.1
Standard Deviation	1.7	0.0	0.0	1.7	3.7	0.0	1.8	4.4	10.1	0.0	0.0	10.1
Standard Error ³	0.6	0.0	0.0	0.6	1.3	0.0	0.6	1.5	3.6	0.0	0.0	3.6

¹ Life stage: larvae (L), metamorph (M), postmetamorph (P), and total (T). Larval category includes neotenes (aquatic reproductive individuals with larval characteristics). Postmetamorph category includes juveniles and adults. Total is the sum of all life stage categories.

² Dead individual; not included in total.

³ Standard error of the mean.

Table 2.213 – Friedman Test and Spearman Rank correlation comparisons of giant salamander (*Dicamptodon* sp.) relative abundance data (measured as individuals per 300 m of stream) for sampling methods in Stillman watershed streams, 2000

Friedman Test		Individual Contrasts		q value ²	Spearman Rank Correlation	
χ^2_r ¹	Probability ²				rho (ρ)	Probability ²
7.185	0.0275	Spotlight Day	Spotlight Night	2.475	0.779	0.0393
		Spotlight Day	Rapid Assessment	3.359	0.248	0.5116
		Spotlight Night	Rapid Assessment	0.884	0.528	0.1624

¹ The test statistic for a Friedman comparison is a tie-corrected Chi-square (χ^2_r).

² Emboldened probabilities or q values are significant. The critical value of q at $\alpha = 0.05$ for multiple pairwise comparisons among methods was 3.314.

Other species: Six other species were detected in low to moderate numbers during the two categories of spotlight surveys and rapid assessment surveys (Appendix II). All were found at one stream except for the western red-backed salamander (*Plethodon vehiculum*), which was found at two streams.

Cost differences among methods: Significant cost differences existed among methods and a large proportion of those differences was attributable to variation among sites. The effort required for one spotlight survey, regardless of whether it was during the day or at night varied from a low of 1.2 surveyor-hours (surv-hr; see footnote in Table 2.214) to a high of 10.8 surv-hr among sites (Table 2.214). In contrast, rapid assessment varied from a low of 9.6 surv-hr to a high of 37.6 surv-hr among sites.

We found significant differences in effort among survey methods (Table 2.215). Rapid assessment costs significantly more than either day or night spotlight surveys, but the two spotlight survey methods did not differ significantly from each other. In the Stillman watershed, no obvious trend in cost was evident even though day spotlight surveys were always done before night spotlight surveys in the same stream; among the 8 streams sampled, night spotlight surveys required more time in 3 streams, day spotlight surveys took more time in 4 streams, and day and night spotlight surveys took the same amount of time in the remaining stream. In the Cowlitz watershed, night spotlight surveys always took more time than daytime surveys; night spotlight surveys had consistently over three-times the number of detections than day spotlight surveys (see Tables 2.208 and 2.212). Effort among methods was poorly correlated ($-0.330 \leq \rho \leq 0.330$; Table 2.215). We also found no significant difference in effort between physiographic provinces for day spotlight surveys and rapid assessment surveys (Mann-Whitney U: $p > 0.4$ for both), but we found a significant effort difference for night spotlight surveys between the Stillman and Cowlitz streams (Mann-Whitney U: $U = 0$, $U' = 24$, $p = 0.0139$).

2.3 Discussion

We were unable to use the spotlight methods in nearly three-fourths of streams to which rapid assessment was applied because brushy undergrowth associated with stream channels effectively limited visibility, and spotlight methods do not allow alteration of stream structure (either substrate or vegetation) to enhance detection (Jones and Raphael 2001). Rapid assessment is not so restricted. The limited number of streams to which either spotlight survey method could be effectively applied

in the Stillman watershed would make it a poor method for landscape characterization of SAAs in this watershed. Thick understory riparian vegetation appears to be a common occurrence in the

Table 2.214 – Comparisons of effort for three survey methods in the Stillman watershed and upper Cowlitz watershed streams, 2000

Stream	Spotlight Surveys						Rapid Assessment		
	Day			Night			hr	surv	surv-hr
	hr ¹	surv	surv-hr	hr	surv	surv-hr			
STL11040313	1.2	2	2.4	1.3	2	2.6	10.2	2	20.4
STL11041011	2.5	2	5.0	2.3	2	4.6	11.1	2	22.2
STL12042120	0.6	2	1.2	0.7	2	1.4	4.8	2	9.6
STL12043108	1.2	2	2.4	1.0	2	2.0	9.9	2	19.8
STL12043226	1.2	2	2.4	1.1	2	2.2	18.8	2	37.6
STL12043322	1.5	2	3.0	1.0	2	2.0	9.3	2	18.6
STL12043407	0.8	2	1.6	1.3	2	2.6	10.2	2	20.4
STL12043417	1.7	2	3.4	1.7	2	3.4	4.2	2	8.4
Mean	1.3		2.7	1.3		2.6	9.8		19.6
Standard Deviation	0.6		1.2	0.5		1.0	4.5		8.9
Standard Error	0.2		0.4	0.2		0.4	1.6		3.2
COW09081701	1.3	2	2.6	5.1	2	10.2	7.6	2	15.2
COW10071701	0.8	2	1.6	5.4	2	10.8	15.7	2	31.4
COW11090901	1.3	2	2.6	2.4	2	4.8	12.3	2	24.6
Mean	1.1		2.3	4.3		8.6	11.8		23.7
Standard Deviation	0.3		0.6	1.7		3.3	4.1		8.1
Standard Error	0.2		0.3	1.0		1.9	2.3		4.7

¹ Units: hours (hr), surveyors (surv), surveyor-hours (surv-hr). Surveyor-hours are hours multiplied by the number of surveyors.

Table 2.215 – Friedman Test and Spearman Rank correlation comparisons of effort for three survey methods in Stillman watershed and upper Cowlitz Watershed streams, 2000

Friedman Test		Individual Contrasts		q value ²	Spearman Rank Correlation	
χ^2_r	Probability ²				rho (ρ)	Probability ²
17.070	0.0002	Spotlight Day	Spotlight Night	0.603	0.271	0.3917
		Spotlight Day	Rapid Assessment	5.276	0.330	0.2974
		Spotlight Night	Rapid Assessment	4.673	-0.150	0.6350

¹ The test statistic for a Friedman comparison is a tie-corrected Chi-square (χ^2_r).

² Emboldened probabilities or q values are significant. The critical value of q at $\alpha = 0.05$ for multiple pairwise comparisons among methods was 3.314.

Coast Range physiographic province and we expect that this issue will limit opportunities to apply spotlight surveys in other provinces as well.

Preliminary data suggested that rapid assessment is better than both day and night spotlight surveys for detecting FFR SAAs in the Stillman Watershed. This is especially true for Olympic tailed frog and Columbia torrent salamander, and possibly for Dunn's salamander. However, we expect that both of these sampling methods applied during the mid- to late summer will be of limited use in detecting Dunn's salamander because it frequently remains concealed at that time of year (L. Jones, M. Hayes, *unpubl. data*).

We have too little data to contrast methods for presence/non-presence detection of the FFR SAAs in the Cascades. Preliminary results suggested that night spotlight surveys might be the best method to assess relative abundance for Olympic tailed frog in the southern Washington Cascades. However, if it cannot be used in areas with thick vegetation, its utility for FFR adaptive management may be low. A nocturnal survey method of some type may be required to reach acceptable detection levels for certain species (or life stages) that are difficult to detect during daylight.

Our data suggested that giant salamanders might be easier to detect using a nocturnal sampling method as opposed to a daylight sampling method. However, a great deal of variation existed in frequency of occurrence and detection rates among methods. We believe that much of this variation may arise from the fact that it was difficult to distinguish between the two species of giant salamanders and that species-specific differences in behavior exist. Efforts are underway to distinguish all life stages of both species using morphological criteria, but this approach is not yet ready for field application (L. Jones, *unpubl. data*).

The spotlight method is considerably less costly if day and night surveys are considered separately. In both watersheds we studied, rapid assessment was roughly six times as costly per unit area as a single (day or night) spotlight survey. If both a day and night spotlight survey is conducted, rapid assessment is about three times as costly. Greater survey cost for rapid assessment mostly reflects capturing and processing animals, and moving surface objects to help find animals. We expect that the reduced detectability of some species during spotlight surveys will outweigh its cost advantages. Differences in cost for night surveys between Stillman and Cowlitz streams may reflect greater effort for access and survey of steeper streams, greater detections, or both.

3. Research Question B – Are rapid assessment methods (e.g., based on search distances) appropriate for amphibians in Type N systems in Washington?

Rapid assessment was developed to facilitate landscape-level detection of SAAs using a relatively low level of effort. One important assumption underlies this method:

The search distance is long enough to ensure a high probability of detecting the species that are present.

We consider this assumption to be critical to the use of rapid assessment. Underestimates of the length of stream searched will result in Type II errors (concluding the species is absent when it is in fact present) in species detection, affecting its acceptability among FFR stakeholders. Conversely, effort expended beyond an acceptable level of Type II error will unnecessarily increase the cost of surveys. As interpretation of an acceptable level of Type II error would almost certainly vary among FFR stakeholders, we selected a mode of evaluation that would show how Type II error varied with effort, providing stakeholders with the choice of where to set an acceptable level of error (or an acceptably high probability of detecting the species present).

Rapid assessment was originally developed to detect southern torrent salamander (*Rhyacotriton variegatus*) and Olympic tailed frog (*Ascaphus truei*) in northern California. There, search distances

required were 300 m for the salamander and 1000 m for the frog (L. Diller, *unpubl. data*). For the initial work in 2000, we needed to determine the appropriate search distances for the Olympic tailed frog and the Columbia torrent salamander (*R. kezeri*) in Washington that would reliably detect occurrence without wasting effort.

Since rapid assessment is based on using the appropriate (most cost effective) search distance, conditions that influence variation in that distance are of special interest. We needed to: (1) better understand the error associated with application of the method so that that variation could be minimized, and (2) determine whether SAA species responses to habitat variation may be better understood by examining habitat-specific variation in detection distances.

3.1 Method

Scoping: We scoped streams for selection in a manner identical to that for Research Question A in the Stillman and Washougal watersheds (see Section 2.1). The Stillman watershed streams used in this analysis were a larger set that encompassed all the streams used in Research Question A.

Rapid Assessment: We sampled streams using a modified rapid assessment method. We included light touch sampling as described in Section 2.1, recording the first detection of target species, and recording the second and subsequent detections of the same amphibian taxa to the end of surface water (including spatial intermittent reaches). Our method differed from Diller's application in that we sampled streams from the randomized selection of road-Type N stream crossings as previously described (see Section 1.4) rather than using a quarter section-based choice (L. Diller, *unpubl. data*), and we sampled each stream beyond the next 30 m following the first detection. For Stillman watershed Type N reaches, we continued recording the target amphibians until, as previously noted, water disappeared from the channel or another road crossing was encountered. We initially used this approach in the Washougal River watershed, but soon modified it to searching a reach length of 500 m because of the extent of Type N systems in this watershed. We also recorded all amphibians encountered, not just target taxa, in the course of obtaining rapid assessment data.

Analyses: Initially, we provide descriptive data on numbers of reaches in which each species of amphibian was either found or undetected. For the Stillman watershed, we had sample sizes large enough to perform contingency analyses across aspect, elevation, and stand age strata (see Section 1.4). Fisher's Exact test was used for all two-way contingency analyses. We could not distinguish species of giant salamander for all individuals, so giant salamander detections were pooled into one category.

To evaluate application of the rapid assessment technique, we developed cumulative frequency distributions for the sets of streams in which each amphibian species was detected. We arrayed first detection distance in 10-m increments on the x-axis and the cumulative percentage of the streams sampled in which the species was detected over those distance increments on the y-axis. We created distributions only for those species found in ≥ 5 streams in each of the Stillman and Washougal River watersheds. We compared cumulative frequency distributions among stratum categories using Kolmogorov-Smirnov tests (Zar 1996).

We used Spearman Rank correlation analyses to compare the distances to first detection with relative abundance estimates for that species in both the next 30 m following first detection and the longest stream segment (45-100 m) from which we could obtain relative abundance data, which included the 30 m reach immediately above the first detection. We standardized relative abundance data for survey distance by dividing the number of individuals found by the length of stream sampled. We performed these analyses using Stillman watershed data for species that were detected in at least 10 streams.

Where applicable, results of all non-parametric tests were corrected for tied ranks. Data were analyzed using Statview 5.0 (SAS Institute, Inc.) software. We discuss significance in terms of $\alpha = 0.05$, but believe that looking at probabilities can guide what to expect with more data.

3.2 Results

Detection Patterns in the Stillman Watershed: During 2000 sampling, we completed rapid assessment in 45 streams in the Stillman watershed (Table 3.201). Overall, we detected amphibians in 84% (38 of 45) of sampled streams and FFR target amphibians in 71% (32 of 45) of streams. We found three FFR amphibians: Columbia torrent salamander, Dunn's salamander, and Olympic tailed frog. Of FFR taxa, Columbia torrent salamanders were most frequently recorded; we found them in two-thirds (30 of 45) of sampled streams.

The two other FFR target amphibians, Dunn's salamander and Olympic tailed frog, were each found in fewer than 16% of sampled streams (Table 3.201).

Seven non-FFR target amphibian species were detected in 64% (29 of 45) of sampled streams (Table 3.201), and included Cope's giant salamander, northern red-legged frog, northwestern salamander, coastal giant salamander, Pacific treefrog, rough-skinned newt, and western red-backed salamander. Giant salamanders were the most frequently detected non-FFR taxon; giant salamanders were found in slightly over 33% (16 of 45) of streams (Table 3.201). Western red-backed salamander was the only other species recorded at moderate frequencies, about 25% (11 of 45) of sampled streams. All other non-FFR target amphibians were found in < 12% of streams.

Table 3.201 – Amphibian species detected during rapid assessment of streams in the Stillman watershed, 2000

Stream Number	FFR SPECIES ¹				OTHER SPECIES ¹							Total All Spp	
	ASTR	PLDU	RHKE	TOTAL	AMGR	Disp	HYRE	PLVE	RAAU	TAGR	TOTAL		
1	11040205												
2	11040221			+	1							1	
3	11040303												
4	11040308												
5	11040313	+		+	2		+		+		2	4	
6	11040405		+		1				+		1	2	
7	11040411							+			1	1	
8	11040517												
9	11040522							+			1	1	
10	11040814			+	1							1	
11	11040825	+		+	2							2	
12	11040901	+		+	2		+		+		2	4	
13	11040916			+	1		+				1	2	
14	11041008			+	1		+				1	2	
15	11041719			+	1	+	+				+	3	4
16	12040708			+	1		+				1	2	
17	12041708		+	+	2		+				1	3	
18	12041720			+	1		+		+		2	3	
19	12041731			+	1							1	
20	12041738								+		1	1	
21	12041741								+		1	1	
22	12041906			+	1		+				1	2	
23	12042005	+			1		+			+	2	3	
24	12042107			+	1							1	
25	12042120			+	1		+				1	2	
26	12042323			-	1				+	+	2	3	
27	12042330			-	1				+	+	2	3	
28	12042332			+	1							1	
29	12042712			+	1							1	
30	12042903			+	1							1	
31	12042918			+	1	+					1	2	
32	12043007					+					1	1	
33	12043108	+		+	2		+				1	3	
34	12043114												
35	12043206												
36	12043223			+	1		+				1	2	
37	12043226	+	+	+	3		+				1	4	
38	12043308			+	1							1	
39	12043316			+	1	+					1	2	
40	12043322			+	1	+		+			2	3	
41	12043403								+		1	1	
42	12043407	+	+	+	3		+			+	2	5	
43	12043410			-	1				+		1	2	
44	12043421												
45	12043503		+	+	2		+		+		2	4	
Detection (n)		7	5	30	32	5	16	3	11	4	1	29	38
% (ⁿ / ₄₅ *100)		15.6	11.1	66.7	71.1	11.1	35.6	6.7	24.4	8.9	2.2	64.4	84.4

¹ Species codes correspond to the list in Appendix I.

We found no significant associations between aspect, elevation (see Table 1.401 for categories), or stand age (16-39 yr, 40-55 yr) categories, and the occurrence of any amphibian species. We also found no significant relationship between either FFR amphibian species richness or overall

amphibian species richness and the occurrence of any amphibian species except Olympic tailed frog. Overall species richness was higher in streams with tailed frogs (Table 3.202).

Table 3.202 – Relationship between amphibian species richness and presence of Olympic tailed frog (*Ascaphus truei*) in Stillman watershed streams, 2000

CATEGORY	FFR AMPHIBIAN SPECIES DETECTED		OVERALL AMPHIBIAN SPECIES DETECTED	
	0-1	2	0-2	3-4
ASTR DETECTED	5	2	3	4
NO ASTR DETECTED	36	2	31	7
FISHER'S EXACT TEST RESULT ¹	$\chi^2 = 3.965$		$\chi^2 = 4.799$	
	$p = 0.1082$		$p = 0.0496$	

¹ Significant probabilities are emboldened.

Detection Patterns in the Washougal River Watershed: We sampled 11 streams in the Washougal River watershed (Table 3.203). We detected amphibians in 73% (8 of 11) of sampled streams. Cascades torrent salamander was the only FFR amphibian species found, occurring in 18% (2 of 11) sampled streams. The only taxon observed with some frequency was giant salamanders, which we detected in almost two-thirds of the streams (Table 3.203). Small sample sizes precluded use of statistical comparisons but amphibian species richness in Washougal watershed appeared to be substantially lower than in Stillman Basin.

Distance to First Detection Analysis: For Columbia torrent salamanders in 30 Stillman watershed streams in which they were found, the survey distance required to achieve 100% detection was 200 m (Figure 3.201). We achieved 90% detection at 115 m, and 80% detection at 70 m.

For Olympic tailed frog, the survey distance needed to achieve 100% detection for all life stages in the 7 streams in which this species was found was 480 m (Figure 3.202). We achieved a 90% detection level at 470 m, and an 80% detection level at ~260 m. When we considered only larval and metamorphic stages, the survey distance needed to achieve 100% detection in the 5 streams in

Table 3.203 – Amphibian species occurring in streams of the Washougal watershed as determined by rapid assessment, 2000

Stream Number	FFR SPECIES ¹				OTHER SPECIES ¹							Total All Spp
	ASTR	PLVA	RHCA	TOTAL	AMGR	Disp	HYRE	PLVE	RAAU	TAGR	TOTAL	
1 02050430			+	1								1
2 02050127						+					1	1
3 02050431						+					1	1
4 02050506						+					1	1
5 02050518												
6 02050525			+	1		+					1	2
7 02050529						+					1	1
8 02050617												
9 02051040						+	-				1	1
10 03052607						+			+		2	2
11 03053229												
Detection (n)	0	0	2	2	0	7	0	1	0	0	7	8
% ($n/11 * 100$)	0.0	0.0	18.2	18.2	0.0	63.6	0	9.1	0	0	63.6	72.7

¹ Species codes correspond to the list in Appendix I.

Figure 3.201 - Cumulative distribution of first detection distances for Columbia torrent salamanders in the Stillman Creek watershed using a rapid assessment method

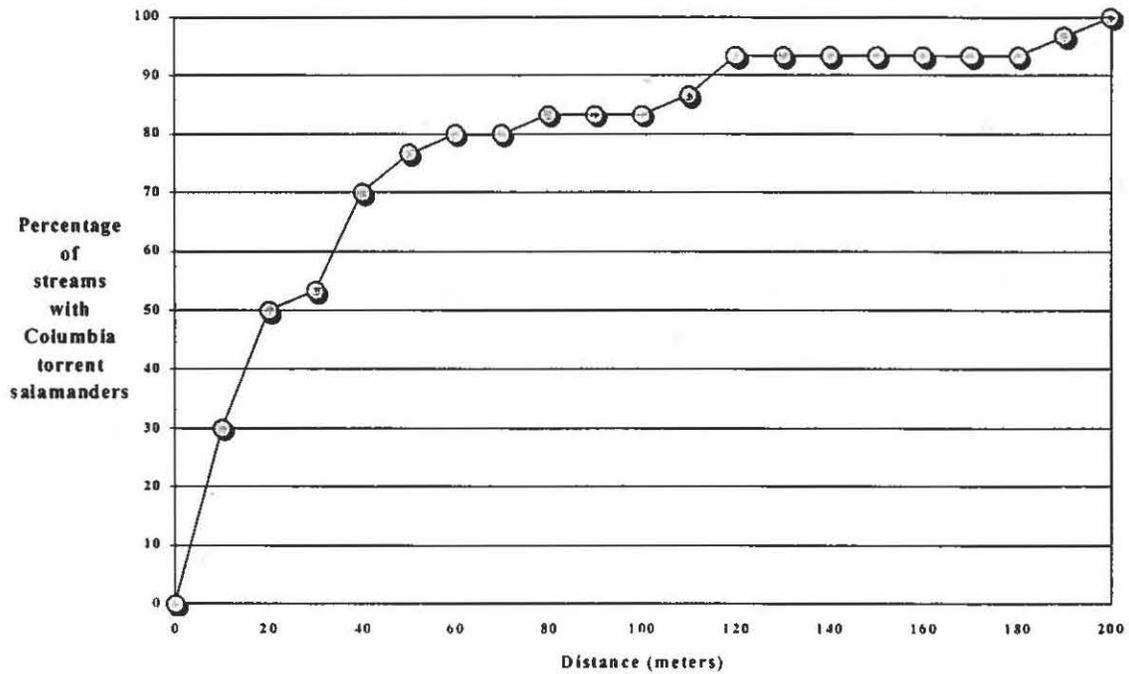


Figure 3.202 - Cumulative distribution of first detection distances for Olympic tailed frog in the Stillman Creek watershed using a rapid assessment method

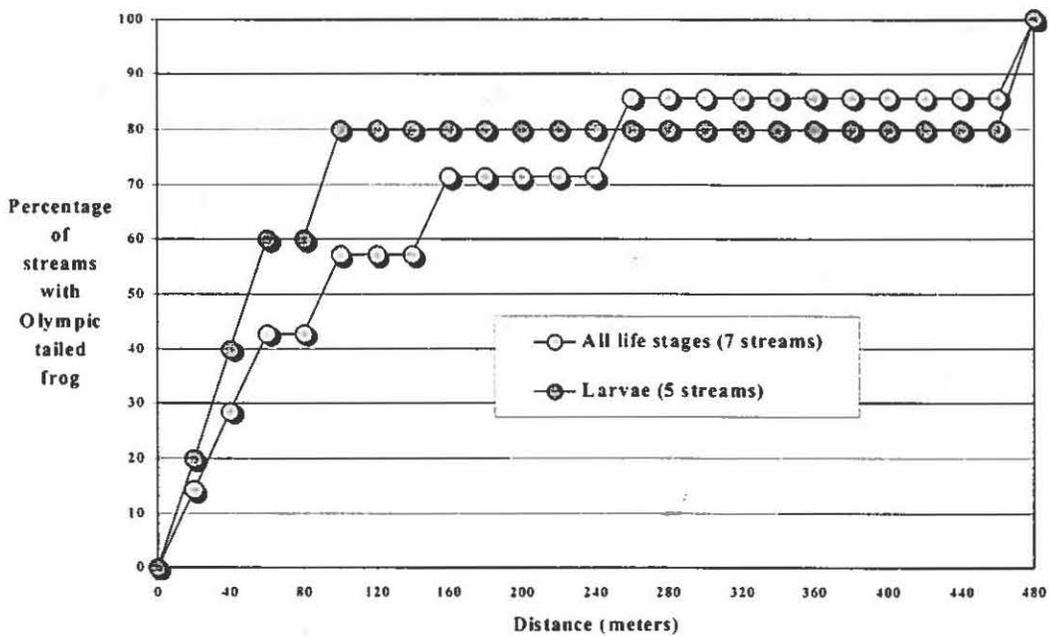
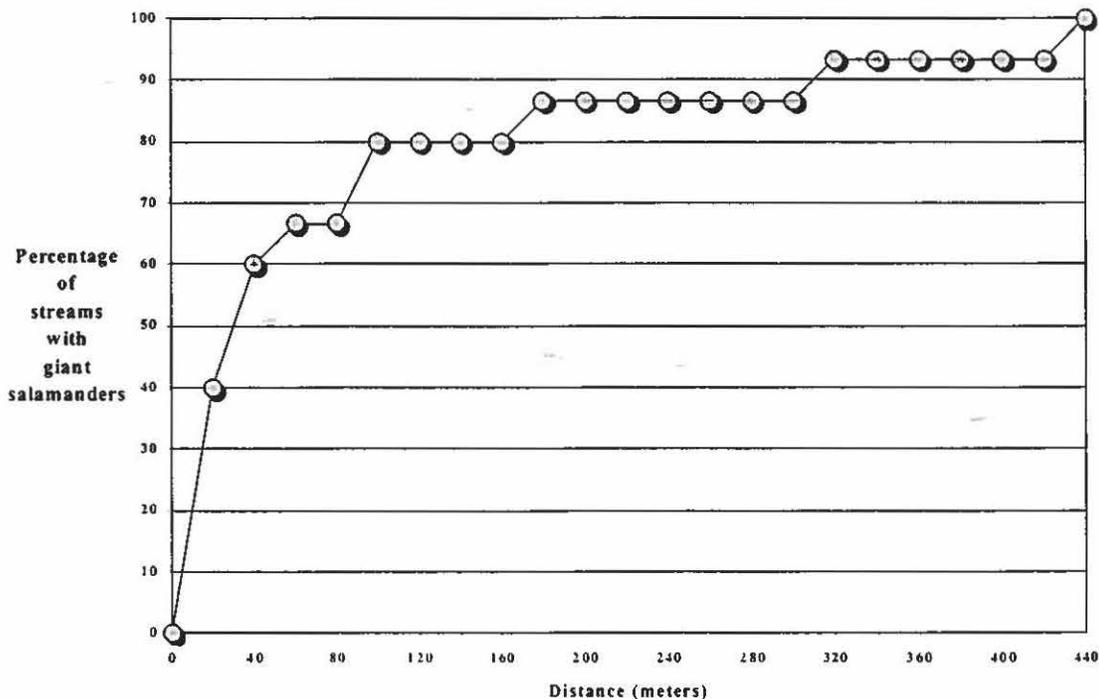


Figure 3.203 - Cumulative distribution of first detection distances for giant salamanders in the Stillman Creek watershed using rapid assessment

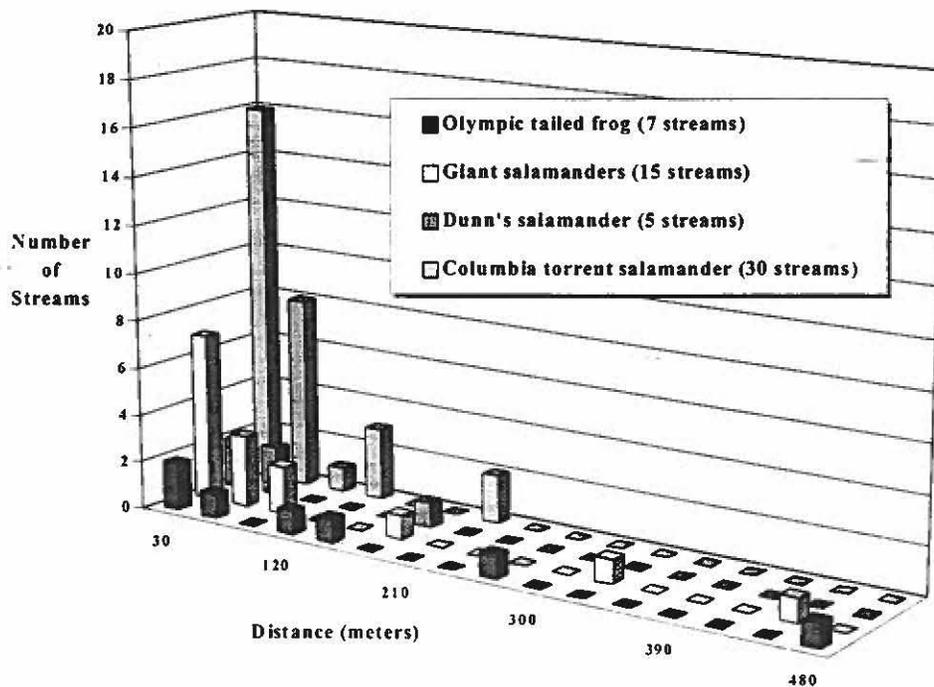


which this species was found was also 480 m. The 90% detection level was attained at 466 m, and the 80% detection level at 100 m. These curves were significantly different from each other (Kolmogorov-Smirnov Test: $df = 2$, maximum difference = 0.440, $\chi^2 = 9.7$, $p = 0.0158$).

For giant salamanders in the Stillman watershed, the survey distance need to achieve 100% detection in the 15 streams in which these taxa were found was 440 m (Figure 3.203). We achieved a 90% detection level at 310 m, and a 80% detection level at 100 m.

In the Stillman watershed, 84% (48 of 57) of first detections of SAAs occurred at distances of ≤ 120 m. If only in-stream life stages of FFR target species were considered, that percentage rose to 90% (36 of 40).

Figure 3.204 - Distribution of first detection distances for stream-associated amphibians in the Stillman Creek watershed, 2000

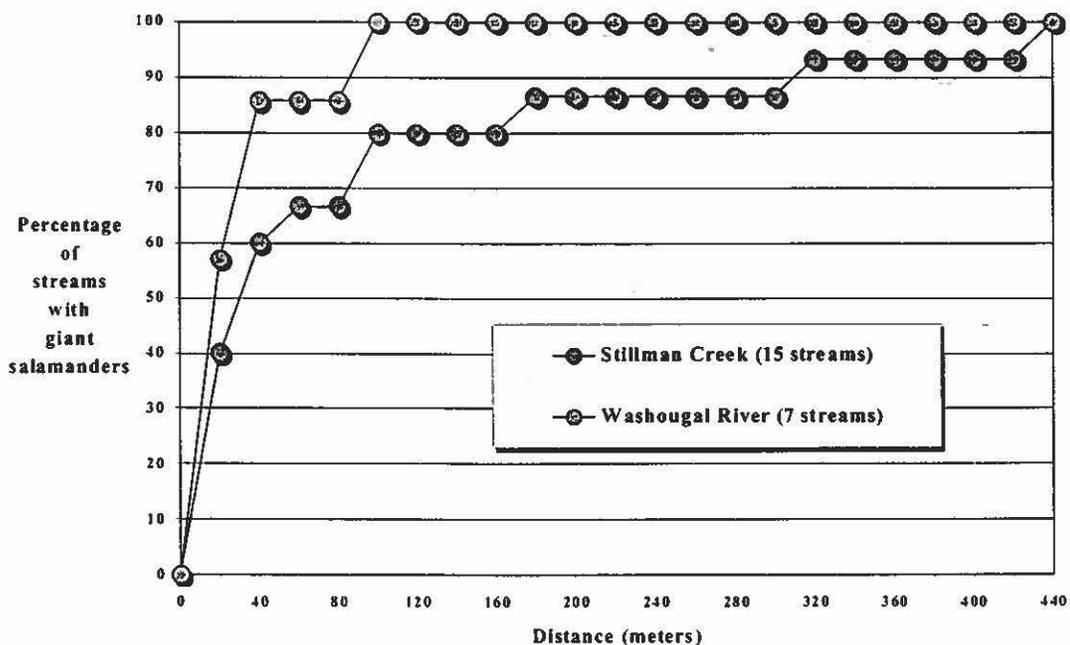


No FFR amphibians were detected in large enough numbers in the 11 Washougal River watershed streams to perform first detection analyses. We found Cascades torrent salamander, the only FFR species detected, in only two streams. The first detection distances for this species in these two streams were 2 m and 87 m (see Appendix IV). These first detection distances fall within the range of first detection distances we obtained for the Columbia torrent salamander in the Stillman watershed (Appendix IV; see also Figures 3.201 and 3.204), but data are too few to determine whether first detection patterns between the two species differ.

In the Washougal River watershed, the only SAAs for which we had enough data to develop a preliminary first detection curve were giant salamanders (Figure 3.205). The survey distance needed to achieve 100% detection in the 7 streams in which giant salamanders were found in the Washougal River watershed was 100 m (Figure 3.205). The 90% detection level was reached at 86 m, and the 50% detection level at 18 m. These distances were less than half of that needed to detect giant salamanders at a similar level in the Stillman watershed (Figure 3.205), a significant difference (Kolmogorov-Smirnov Test: $df = 2$, maximum difference = 0.676, $\chi^2 = 31.1$, $p < 0.0001$).

Comparison of First Detection Data to Measures of Relative Abundance: In the Stillman watershed, first detection distances were generally inversely correlated with measures of relative abundance (Table 3.204). Olympic tailed frog was the only taxon for which first detection distance was significantly inversely correlated with measures of relative abundance. The next 30 meter

Figure 3.205 - Comparison of cumulative distributions of first detection distances for giant salamanders between the Stillman Creek and Washougal River watersheds using a rapid assessment method, 2000



measure of relative abundance was more strongly correlated with first detection distances than the index of relative abundance based on total survey distance.

Table 3.204 – Spearman rank correlation comparison of first detection distance with measures of relative abundance in the Stillman watershed, 2000

Categories Compared		AMPHIBIAN SPECIES ¹							
		ASTR (n = 7)		Disp (n = 16)		PLDU (n = 5)		RHKE (n = 30)	
		rho (ρ) ²	p ³	rho (ρ)	p	rho (ρ)	p	rho (ρ)	p
1 st Detection Distance	Next 30 m Count	-0.896	0.0281	-0.474	0.0763	-0.112	0.8231	-0.306	0.0933
	Total Survey Distance Index ⁴	-0.612	0.1336	-0.474	0.0761	0.000	>0.9999	-0.251	0.1768

¹ Species codes in Appendix I. The two giant salamanders species are collectively included in Disp.

² Spearman rank correlation coefficient.

³ Probability. Emboldened probabilities are significant.

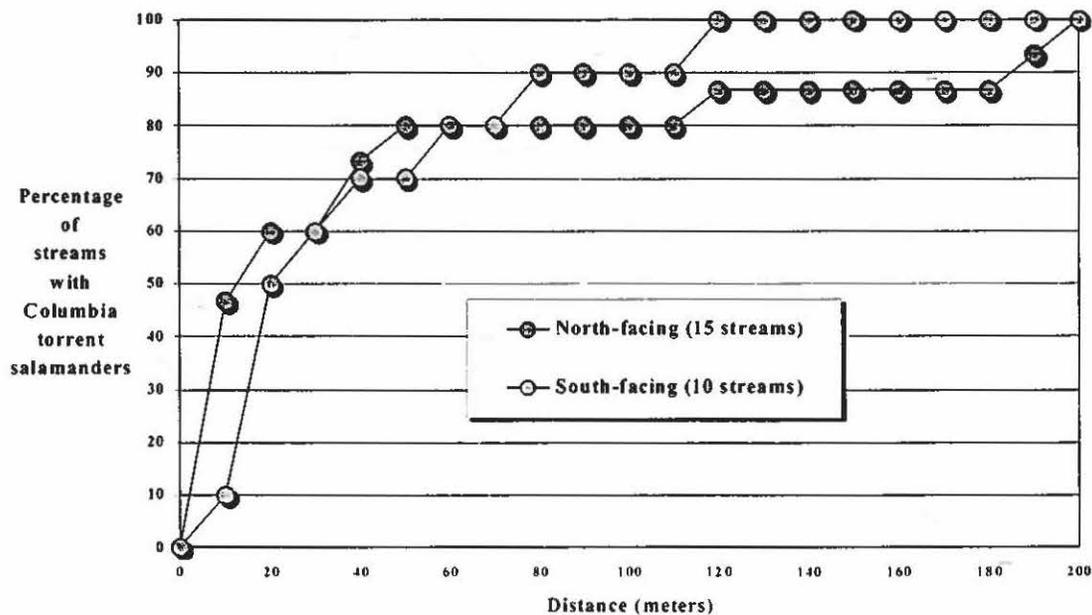
⁴ Next X m Index = standardized relative abundance value, i.e., individuals/survey distance (see methods section).

For giant salamanders in Washougal River watershed, we found no significant correlation between first detection distance and either of these measures of relative abundance (Spearman Rank correlation: $\rho \leq 0.270$, $p \geq 0.5079$ for both).

Variation in First Detection Distance with Habitat Conditions: Columbia torrent salamander and giant salamanders were the only taxa with sample sizes large enough to allow comparison of first detection distances between different landscape strata.

We found a significant difference in the curves for north- and south-aspects streams for the Columbia torrent salamander (Kolmogorov-Smirnov test: $df = 2$, maximum difference = 0.524, $\chi^2 = 11.5$, $p = 0.0063$), although those detection curves seemed similar in shape (Figure 3.206). The curve describing south-facing streams crossed the curve for the north-aspect streams at 60-70 m and reached the 100% detection level at 120 m, well before the south-facing curve.

Figure 3.206 - Comparison of cumulative distributions of first detection distances for Columbia torrent salamanders between aspect categories in the Stillman Creek watershed using a rapid assessment method



We found no significant difference in Columbia torrent salamander first detection curves between younger (16-39 yr) and older (40-55 yr) managed stands (Figure 3.207; Kolmogorov-Smirnov test: $df = 2$, maximum difference = 0.333, $\chi^2 = 4.7$, $p = 0.1939$).

We found significant differences between Columbia torrent salamander first detection curves among elevation categories (Figure 3.208). In particular, we found significant differences between the low (0-300 m) and high (601-900 m), and mid and high (601-900 m) elevation categories (Kolmogorov-Smirnov test: $df = 2$, maximum difference > 0.714, $\chi^2 > 21.4$, $p < 0.0001$ for both). The 100% detection distance for the high elevation category (40 m) was roughly one-fifth the 100% detection distance for the remaining elevation categories. The low versus mid elevation difference was not significant (Kolmogorov-Smirnov test: $df = 2$, maximum difference = 0.381, $\chi^2 = 6.1$, $p = 0.0949$).

Figure 3.207 - Comparison of cumulative distributions of first detection distance for Columbia torrent salamanders between stand age categories in the Stillman Creek watershed using rapid assessment

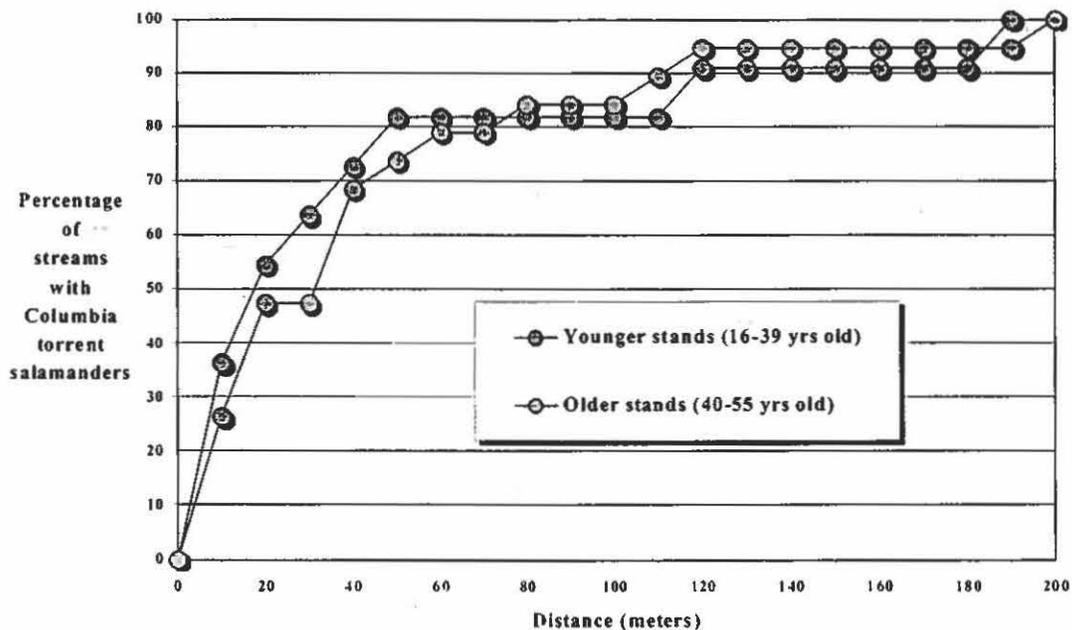
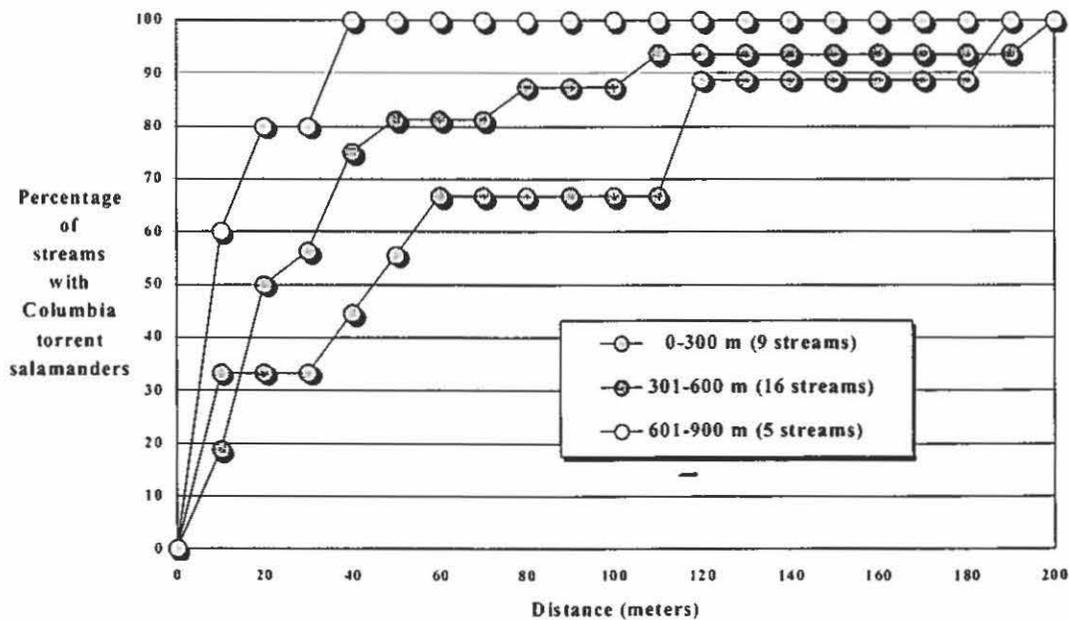


Figure 3.208 - Comparison of cumulative distributions of first detection distances for Columbia torrent salamanders among elevation categories in the Stillman Creek watershed using a rapid assessment method



For giant salamanders, we found a significant difference in the curves for north- and south-aspect streams (Figure 3.209; Kolmogorov-Smirnov test: $df = 2$, maximum difference = 0.739, $\chi^2 = 25.1$, $p < 0.0001$). The curve for south-facing streams reached the 100% detection level in 100 m, or less than one-fourth the distance of the curve for north-aspect streams (440 m).

We also found a significant difference in giant salamanders curves between younger and older managed stands (Figure 3.210; Kolmogorov-Smirnov test: $df = 2$, maximum difference = 0.739, $\chi^2 = 25.1$, $p < 0.0001$). Distance for the 100% detection level in older stands was roughly one-third that of younger stands.

The giant salamander curves for elevation categories also revealed significant differences (Figure 3.211). We found significant differences between the low and mid, and low and high elevation categories (Kolmogorov-Smirnov test: $df = 2$, maximum difference ≥ 0.739 , $\chi^2 = 25.1$, $p < 0.0001$). However, we found no significant difference between the mid and high elevation categories (Kolmogorov-Smirnov test: $df = 2$, maximum difference = 0.139, $\chi^2 = 0.7$, $p > 0.9999$).

Figure 3.209 - Comparison of cumulative distributions of first detection distances for giant salamanders between aspect categories in the Stillman Creek watershed using a rapid assessment method

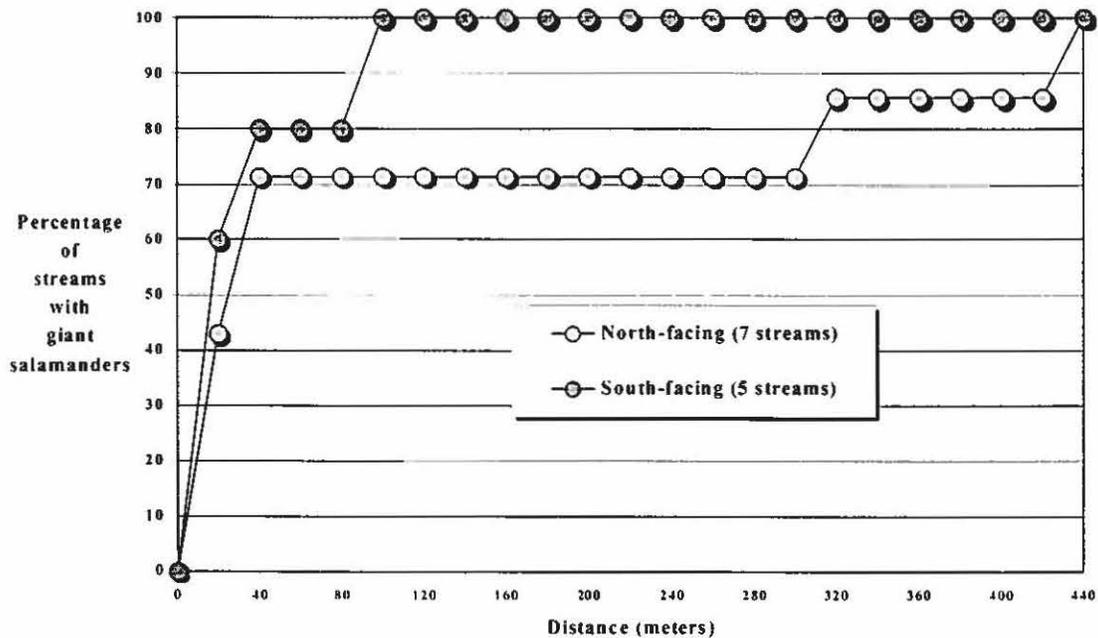


Figure 3.210 - Comparison of cumulative distributions of first detection distance for giant salamanders between stand age categories in the Stillman Creek watershed using a rapid assessment method

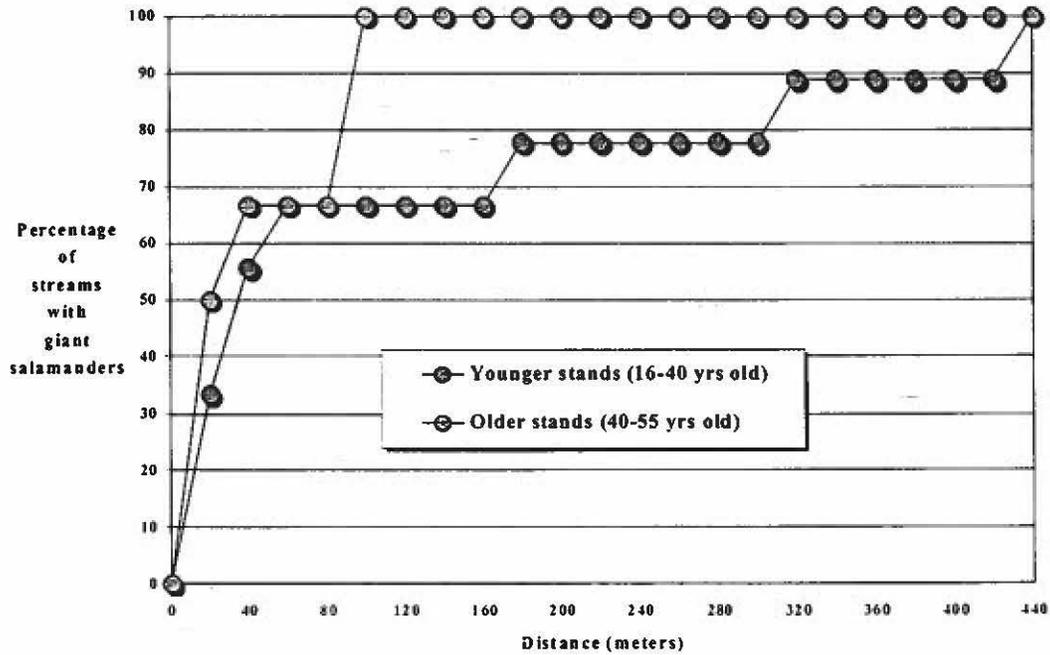
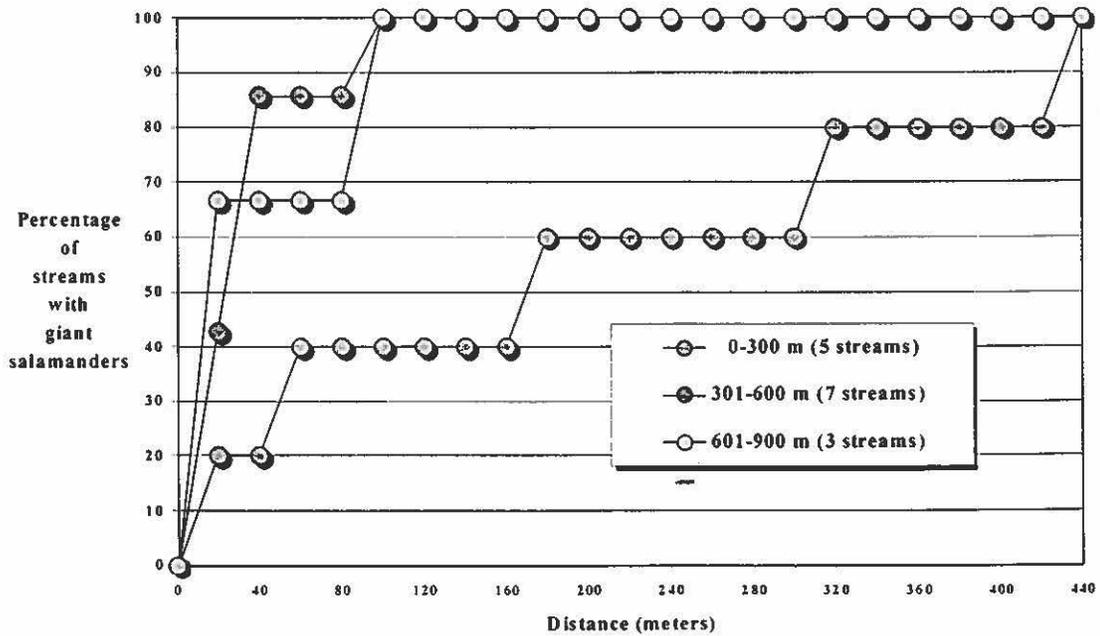


Figure 3.211 - Comparison of cumulative distributions of first detection distances for giant salamanders among elevation categories in the Stillman Creek watershed using a rapid assessment method



First detection data are provided in Appendix IV.

3.2 Discussion

Results from this preliminary study suggest that rapid assessment in the Coast Range and Southern Washington Cascades physiographic provinces appears promising. We expect that distances needed to detect FFR SAAs at near the 100% level will be significantly shorter than what is required for the equivalent taxa in northern California. Notably, detection of all the SAAs we examined except for the in-stream life stages of Olympic tailed frog had high detection levels (80-100%) over distances less than 100 m. Approaching a 100% detection level will be relatively costly for some species, but it appears that distances required to approach 100% detection in Washington may still be half (for Olympic tailed frog) to two-thirds (for Columbia torrent salamander) of that required for the same or equivalent taxa in California. Of course we have not yet determined the reliability of this method for determining occupancy. This phase of the study, scheduled for year 2, will require a comparative approach using a more rigorous sampling method such as rubble-rousing. If rapid assessment proves reliable, then one can choose a desired detection level and express results probabilistically.

The utility of first detection distance curves to identify habitat variation also seems promising. Again, understanding sources of error and increasing the sample sizes will be necessary to show how habitat affects first detection distance. Greater amphibian species richness at sites with Olympic tailed frog is a pattern that needs further elucidation. If this pattern is real, then the Olympic tailed frog might be useful as an indicator for SAA species richness.

As determined by rapid assessment, distance to first detection was inversely correlated with relative abundance. However, only the distance to first detection for Olympic tailed frog was significantly inversely correlated with relative abundance based on counts 30 m upstream of that first detection. While larger sample sizes may help demonstrate correlations where we found none, other alternative explanations exist. The simplest is that distances to first detection are simply not correlated with relative abundance. Alternatively, counts of individuals above the first detection point may not provide reasonable relative abundance estimates. Clearly, understanding the relationship between first detection distance and relative abundance is important. Moreover, we suggest that the relationship among all SAAs sampling methods and relative abundance needs to be further explored. Finally, rapid assessment must be compared with other sampling methods in estimating species composition, especially if we use presence/absence as an indicator of FFR effectiveness.

4. Key Findings and the Direction of Future Research

These first study key findings are preliminary:

- Systematic spotlight surveys are a **low** cost method, but application of this visual method is **highly restricted** by structural features that interfere with visibility, such as dense, brushy vegetation. As a consequence, its application is **limited** in some physiographic provinces and some forest structural stages, such as the Coast Ranges of southwestern Washington and stands with an open tree canopy.
- Rapid assessment methods appear to perform better than spotlight surveys for determining **presence/non-presence** of FFR SAAs in the Coast Range physiographic province. Detection differences appear to be **pronounced** where target amphibians occur in **low numbers**.
- Of the two methods, rapid assessment may perform **better** than spotlight surveys in assessing **relative abundance** in the Coast Range physiographic province, but the definitive test will be comparing both methods to a standard, i.e., the rubble-rousing approach.
- Nighttime systematic spotlight surveys may **outperform** rapid assessment surveys for **giant**

salamanders.

- Rapid assessment distances required to detect torrent salamanders and Olympic tailed frog at **high levels** ($\geq 80\%$) in the Coast Ranges and Southern Washington Cascades physiographic provinces are **considerably less** than distances used to detect these or the equivalent taxa in northern California. Thus, application of rapid assessment may be done at a **relatively low cost compared to California**. However, the most important cost analysis will be in comparing the rapid assessment method with the rubble-rousing technique.
- Rapid assessment surveys suggest that streams with Olympic tailed frogs have a **higher amphibian species richness** than streams in which the Olympic tailed frog was not detected.
- First detection distance curves may be **useful to detect responses** of amphibians to **differences in habitat**. Preliminary curves suggest that Columbia torrent salamanders respond to elevation or a co-variate of elevation, and giant salamanders responses are related to aspect, elevation, and stand age or co-variates of these variables.

These issues led us to suggest priorities for the direction of future research. In order of descending importance:

- A potentially significant portion of the error associated with the first detection distances obtained with rapid assessment method is unknown. We suspect that a major contribution to variation in first detection distance is the relationship between the point where sampling started and the distance upstream to the stream origin. Standardizing starting points relative to initiation points of water may help limit first detection distance variation.
- We need to compare results of rubble rousing and rapid assessment methods to determine if these methods can provide equivalent relative abundance information. This comparison would also help determine which method is better at estimating species occurrence.
- We should continue to explore why the Olympic tailed frog appears to be correlated with SAA species richness. Its presence may be indicative of forest quality that benefits various amphibians.

5. Acknowledgments

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Appendix I

Amphibian Species Known to Occur in the Cowlitz, Stillman and Washougal Watersheds, Washington, 2000. Only native species are listed. Data come from The Weyerhaeuser Company (D. Runde, *unpubl. data*), Longview Fibre Company (J. MacCracken, *unpubl. data*), and The Washington Department of Fish and Wildlife database.

Scientific Name	Common Name
Anura	Frogs and Toads
<i>Ascaphus truei</i>	Olympic tailed frog
<i>Bufo boreas</i>	Western toad
<i>Hyla regilla</i>	Pacific treefrog
<i>Rana aurora aurora</i>	Northern red-legged frog
Caudata	Salamanders
<i>Ambystoma gracile</i>	Northwestern salamander
<i>Ambystoma macrodactylum</i>	Long-toed salamander
<i>Dicamptodon copei</i>	Cope's giant salamander
<i>Dicamptodon tenebrosus</i>	Pacific giant salamander
<i>Ensatina eschscholtzii</i>	Ensatina
<i>Plethodon dunni</i> ¹	Dunn's salamander
<i>Plethodon larselli</i> ²	Larch mountain salamander
<i>Plethodon vandykei</i> ³	Van Dyke's salamander
<i>Plethodon vehiculum</i>	Western red-backed salamander
<i>Rhyacotriton cascades</i> ²	Cascades torrent salamander
<i>Rhyacotriton kezeri</i> ¹	Columbia torrent salamander
<i>Taricha granulosa</i>	Rough-skinned newt

¹ Known only from the Willapa Hills region in Washington State.

² Known only from the Cascades in Washington State.

³ Not known from the Stillman Watershed, although recorded elsewhere in the Willapa Hills.

Appendix II

Other Amphibians Recorded During Method Comparison Surveys in the Cowlitz and Stillman Watersheds, 2000

This appendix summarizes data on the 6 non-FFR amphibian species for which we collected too few data for analysis:

- (1) northwestern salamander (*Ambystoma gracile*: AMGR),
- (2) ensatina (*Ensatina eschscholtzii*: ENES),
- (3) Pacific treefrog (*Hyla regilla*: HYRE),
- (4) western red-backed salamander (*Plethodon vehiculum*: PLVE),
- (5) northern red-legged frog (*Rana aurora aurora*: RAAU), and
- (6) roughskin newt (*Taricha granulosa*: TAGR).

Within the matrix, a two-part alphanumeric describes:

- (1) the number of individuals and life stage (as larva (L), juvenile (J), adult (A), postmetamorph (P)), and
- (2) the survey methods (as day spotlight surveys (DSS), night spotlight surveys (NSS), and rapid assessment (RA)).

Streams	Species					
	AMGR	ENES	HYRE	PLVE	RAAU	TAGR
STL11040313				5J RA		1P DSS
STL11041011				1J RA		
STL12042120						
STL12043108				1A NSS		
STL12043226						
STL12043322	55L RA	1A NSS	29L RA			
STL12043407					1A RA	
COW09081701						
COW10071701						
COW11090901						

Appendix III

Characteristics of Sampled Reaches in the Cowlitz, Stillman, and Washougal River Watersheds

This appendix describes characteristics of sampled reaches of streams within the Cowlitz, Stillman and Washougal River Watersheds. Descriptions of column headings, left to right, are:

- I. **Stream Number:** We identified streams with an eight-digit number. Each pair of the first six digits designated the **Township, Range, and Section**, respectively. In the Stillman watershed, the remaining two digits indicated a unique road crossing number from the pool of Type N road crossings within the **Section** numbered from north to south. In the Washougal River Watershed, the remaining two digits indicated a unique road crossing within each **Township** block of Longview Fibre ownership. In the Cowlitz Watershed, the remaining two digits specifies the order in which reaches were sequentially sampled within that **Section**.
- II. **Aspect:** Aspect was in octants: **N** (338°-22°), **NE** (23°-66°), **E** (67°-112°), **SE** (113°-157°), **S** (158°-202°), **SW** (203°-247°), **W** (248°-292°), and **NW** (293°-337°).
- III. **Elevation:** Elevation of the channel at the road crossing point.
- IV. **Road Above?:** Whether (**yes**) or not (**no**) the reach ends in another road crossing.
- V. **Stand Age:** The stand age or range of stand ages associated with each reach.
- VI. **Geology:** Geocode as provided in Appendix V.
- VII. **Water Start:** Starting point of water within the reach above the road crossing start point.
- VIII. **Water End:** Specifies the end point of water within channel in meters. A “dv” specifies that the end point of water could not be specified unambiguously because of dense vegetation; an “ns” indicates that the reach was not surveyed to the end of water; and an “re” indicates that recorder error resulted in insufficient data being collected on the end of water point.
- IX. **Continuous Flow?:** Indicates whether (**yes**) or not (**no**) continuous flowing or standing water existed along the entire channel length. A “dv” specifies that the end point of water could not be specified unambiguously because of dense vegetation; and an “re” indicates that recorder error resulted in insufficient data being collected on hydrologic condition of the channel.

Appendix Table IIIa
Characteristics of Reaches Sampled in the Stillman Watershed

I	II	III	IV	V	VI	VII	VIII	IX
Stream Number	Aspect	Elevation	Road Above ?	Stand Age	Geology	Water Start	Water End	Continuous flow?
	octants	meters		years		geocode	meters	
11040205	SW	1156	Yes	39	Tib	0.0	125.0	No
11040221	NE	740	Yes	44	Tib	0.0	250.0	No
11040303	N	667	Yes	41	Tib	0.0	129.0	Yes
11040308	N	965	No	45	Tib	0.0	175.0	n/a
11040313	N	707	Yes	35	Tib	0.0	1191.0	n/a
11040405	SE	765	No	45	Tib	0.0	161.0	n/a
11040411	SE	1510	Yes	44	Tib	n/a	n/a	n/a
11040517	S	1570	Yes	51	Tib	0.0	161.0	n/a
11040522	S	1527	No	45	Tib	1.0	n/a	n/a
11040814	NE	2108	No	49	Tcr	0.0	100.0	No
11040825	NE	2019	No	49	Tcr	256.0	n/a	n/a
11040901	N	1621	No	53	Tib	0.0	109.0	No
11040916	SW	1741	No	43	Tib	0.0	108.0	No
11041008	NE	1745	No	48	Tcr	17.0	175.0	No
11041719	SE	2184	Yes	33	Tib	0.0	n/a	No
12040708	E	869	Yes	18	Tcr	0.0	n/a	n/a
12041708	N	816	Yes	21	Tig	0.0	488.0	n/a
12041720	NE	936	Yes	18	Tig	0.0	447.0	No
12041731	E	957	No	39	Tig	8.0	198.0	No
12041738	E	776	No	47	Tig	48.0	100.0	n/a
12041741	E	856	No	42	Tig	30.0	200.0	n/a
12041906	NE	1515	Yes	41	Tcr	30.0	n/a	n/a
12042005	E	1535	No	44	Tig	9.0	n/a	n/a
12042107	N	1212	No	44	Tig	0.0	n/a	n/a
12042120	N	1380	No	16	Tig	0.0	261.0	No
12042323	NW	696	No	45	Tig	0.0	n/a	n/a
12042330	SE	495	No	45	Tig	56.0	84.0	n/a
12042332	SE	547	No	45	Tig	4.0	155.0	No
12042712	SE	1304	No	48	Tib	0.0	45.0	No
12042903	N	1810	Yes	39	Tcr	0.0	n/a	n/a
12042918	NE	1908	Yes	52	Tbt	0.0	n/a	n/a
12043006	N	2134	Yes	39	Tcr	n/a	n/a	n/a
12043108	E	2209	Yes	53	Tib	0.0	n/a	n/a
12043114	SE	2148	No	43	Tib	0.0	n/a	n/a
12043206	SW	2779	No	46	Tib	0.0	62.0	n/a
12043223	SE	2068	Yes	35	Tib	0.0	n/a	n/a
12043226	S	1492	Yes	39	Tib	12.0	448.0	n/a
12043308	E	1538	Yes	47	Tib	0.0	154.0	No
12043316	N	1608	No	47	Tib	187.0	274.0	n/a
12043322	SE	1573	Yes	47	Tib	0.0	458.0	No
12043403	SE	1249	No	46	Tib	0.0	n/a	n/a
12043407	SE	1169	Yes	55	Tib	0.0	572.0	No
12043410	SE	1139	No	50	Tib	0.0	99.0	No
12043421	S	855	No	50	Tib	0.0	38.0	n/a
12043503	E	565	Yes	38	Tib	0.0	715.0	n/a

Appendix Table IIIb

Characteristics of Reaches Sampled in the Washougal River Watershed

I	II	III	IV	V	VI	VII	VIII	IX
Stream Number	Aspect	Elevation	Road Above	Stand Age	Geology	Water Start	Water End	Continuous flow?
	octants	meters	?	years	geocode	meters	meters	
02050430	N	366	No	36	To	0.00	49.0	No
02050127	NW	213	Yes	59	QTb,To	0.00	n/a	No
02050431	N	366	Yes	58,36	To	0.00	n/a	Yes
02050506	NE	427	No	21,63,32	To(f)	0.00	139.0	Yes
02050518	NW	305	Yes	21,5	To(f)	0.00	115.0	No
02050525	N	366	No	?,36	To(f)	0.00	759.0	No
02050529	NE	366	Yes	21,43	To(f)	0.00	375.0	Yes
02050617	SE	305	No	17	Ti,To(f)	0.00	n/a	n/a
02051040	NE	305	No	31,24,60,32	QTb,To	0.00	n/a	n/a
03052607	NW	670	No	37,27	To,QTb	0.00	n/a	n/a
03053229	SE	457	No	42,35	Ti,To	0.00	17.0	n/a

Appendix Table IIIc

Characteristics of Reaches Sampled in the upper Cowlitz River Watershed

I	II	III	IV	V	VI	VII	VIII	IX
Stream Number	Aspect	Elevation	Road Above	Stand Age	Geology	Water Start	Water End	Continuous flow?
	octants	meters	?	years	geocode	meters	meters	
090817	NW	1097	No	387	Tcb	0.0	n/a	Yes
100717	W	811	No	271	Tvt3,Tva3	0.0	n/a	Yes
110909	SW	732	No	225	Toh	0.0	n/a	Yes
120804	SW	914	No	110	Tva2	0.0	n/a	Yes
140908	W	914	No	114	Tgh2	0.0	n/a	Yes

Appendix IV

First Detection Distance and Relative Abundance Data for the Stillman, Cowlitz River, and Washougal River Watersheds, 2000

This appendix provided the raw data on first detection distances, abundance tallies (within the next 30 m and X m of first detection), and survey distances (for X m from first detection) for streams sampled in the Stillman, Washougal River, and Cowlitz River Watersheds. Descriptions of column headings, left to right, are:

- I. **Stream Number:** We identified streams with an eight-digit number. Each pair of the first six digits designated the **Township, Range, and Section**, respectively. In the Stillman Creek watershed, the remaining two digits indicated a unique road crossing number from the pool of Type N road crossings within the **Section** numbered from north to south. In the Washougal River Watershed, the remaining two digits indicated a unique road crossing within each **Township** block of Longview Fibre ownership. In the Cowlitz Watershed, the remaining two digits specify the order in which reaches were sequentially sampled within that **Section**.
- II. **First Detection Distance (m):** Distance from the road crossing to the first individual of the indicated species detected.
- III. **Tally Next 30 meters:** Tally of individuals of the same species from the point of first detection through the next 30 meters. Excluding the individual first detected.
- IV. **Tally Next X meters:** Tally of individuals of the same species from the point of first detection distance through the next X meters.
- V. **Next X meters Survey Length (m):** Survey distance over which individuals of a species were tallied (i.e., **Tally Next X meters**); either 100 m or the remaining lesser channel distance.

Appendix Table IVa
First Detection, Relative Abundance, and Survey Distance Data
for the Stillman Watershed

Stream Number	First Detection Distance (m)				Tally Next 30 meters				Tally Next X meters				Next X meters Survey Length (m)			
	ASTR	Disp	PLDU	RHKE	ASTR	DISP	PLDU	RHKE	ASTR	Disp	PLDU	RHKE	ASTR	Disp	PLDU	RHKE
11040205																
11040221				4				6				6				100
11040303																
11040308																
11040313	34	423		5	0	1		1	0	2		1	100	100		100
11040405			39				0				0				46	
11040411																
11040517																
11040522																
11040814				4				22				27				96
11040825	257			1	0			35	0			96	100			100
11040901	54	6		50	1	4		2	0	15		4	100	100		100
11040916		9		16		1		2		7		4		100		100
11041008		20		19		2		33		28		42		100		100
11041719		2		2		5		4		16		9		100		100
12040708		169		49		0		0		0		0		100		100
12041708		8	2	1		0	3	1		0	3	1		100	100	100
12041720		319		182		0		0		0		0		100		100
12041731				10				0				0				100
12041738																
12041741																
12041906		30		36		3		2		16		9		100		100
12042005	148				0				0				62			
12042107				7				1				1				100
12042120		34		5		1		8		2		9		100		100
12042323				3				12				12				100
12042330				57				3				3				100
12042332				114				86				86				50
12042712				32				47				47				57
12042903				14				1				1				72
12042918				38				1				1				100
12043007																
12043108	2	86		37	5	0		3	10	0		30	100	55		100
12043114																
12043206																
12043223		19		19		0		1		0		5		57		57
12043226	23	34	43	25	1	1	1	94	0	3	3	147	100	100	100	100
12043308				109				4				4				45
12043316				191				1				1				100
12043322				19				0				1				100
12043403																
12043407	95	86	175	79	0	1	0	0	0	2	0	1	100	100	100	100
12043410				12				5				6				100
12043421																
12043503		57	1	40		1	0	0		1	0	0		100	100	100

Appendix V

Geology Data from the Cowlitz, Stillman, and Washougal River Watersheds, Washington, 2000

This appendix describes the geocode map units occurring in portions of the Cowlitz, Stillman, and Washougal River watersheds in which sampling occurred. The descriptions are abbreviated from (Fiksdal 1978, Wells 1981).

<u>Map Code</u>	<u>Description</u>
1) QTb	PLIOCENE-PLEISTOCENE VOLCANIC ROCKS: Quaternary basalts greater than 690,000 years of age.
2) Tcb	CRESCENT FORMATION (lower and lower middle Eocene): Pillow flows, massive and columnar jointed flow interiors, pillow breccia, lapilli tuff breccia, and filled lava tubes of tholeiitic and alkalic basalt, basalt groundmass altered to green and brown clays; zeolite and calcite fracture fillings are ubiquitous; contains minor amounts of mudflow breccia, basaltic sandstone, and interbedded laminated siltstone.
3) Tgn₂	GRAND RONDE BASALT: Upper flows, normal magnetic polarity.
4) Tidi	DIORITE INTRUSIONS (Miocene): Diorite dikes, sills, or plugs, fine to medium grained phaneritic texture; age uncertain, but cuts Eocene rocks of the Puget Group and Northcraft Formation (unit Tnog).
5) Tig	GABBRO AND INTRUSIVE ROCKS (early or middle Eocene): Massive to blocky jointed and columnar jointed, fine to very coarse-grained gabbro sill complex; marginal facies are basalt and have well-developed columnar jointing, while interiors are very coarse-grained to pegmatitic; gabbro and basalt are vesicular and typically flow banded, a result of planar concentrations of vesicles and/or crystal sorting; interstitial glass is generally altered to green clays and vesicles are filled with clay, calcite, or zeolite.
6) Tml	McINTOSH FORMATION, LOWER MEMBER (lower and middle Eocene): Massive to thin bedded and laminated very fine grained to coarse grained basaltic sandstone, arkosic sandstone and laminated tuffaceous siltstone; sandstone commonly shows graded bedding.
7) To (f)	OHANAPECOSH FORMATION: Chiefly pyroclastic and epiclastic debris with interbedded andesite and basalt lava flows (f). Pyroclastic and epiclastic tuffs and sandstones were deposited in aqueous and sub-aqueous environments. Abundant ash and glass has been altered to clay and zeolite secondary mineralization has occurred. Rock particles found are predominately andesite to rhyodacite.

Appendix V (continued)**Geology Data from the Cowlitz, Stillman, and Washougal River Watersheds,
Washington, 2000**

- 8) **Toh** OHANAPECOSH FORMATION: Volcaniclastic-dominated unit composed of a series of undifferentiated volcanic breccias, conglomerates, sandstones, and lava flows interbedded with shale; rocks vary widely in color but are chiefly green and grayish-green and consists of andesitic to basaltic lithic breccia, tuff, tuff breccia, and volcanic siltstone, sandstone, and conglomerate; interbedded with basalt and andesite flows and rare dacite to rhyolite flows and tuffs.
- 9) **Tva₂** BASALTIC-ANDESITE AND BASALT FLOWS (Upper Oligocene): Dark gray, basaltic-andesite and basalt, aphyric to augite-plagioclase phyrlic; commonly contains fine-grained, holocrystalline groundmass; forms thick, dense, blocky- to platy-jointed flows or sills; locally contains interbeds of dark-colored mafic tuff or basaltic sandstone and conglomerate.
- 10) **Tva₃** LOWER MIOCENE ANDESITE FLOWS: Chiefly dark-colored augite-hypersthene andesite flows restricted to the Alder Lake-Mineral Lake area; fresh-looking, platy, non-vesicular flows occasionally displaying columnar jointing; interbedded with tan to dark brown basaltic andesitic clast- and matrix-supported volcanic breccia.
- 11) **Tvc₂** UPPER OLIGOCENE VOLCANICLASTIC ROCKS: Volcaniclastic rocks (upper Oligocene through lower Miocene). Light gray to greenish-gray lithic-pumice-crystal lapilli tuff, tuff breccia, and andesitic to dacitic to sandstone, conglomerate and siltstone; commonly massive to thickly-bedded; contains numerous thin, discontinuous intrusive rocks (sills and dikes) or lava flows.
- 12) **Tvt₃** LOWER MIOCENE TUFF AND TUFF BRECCIA: Tuff; light gray to greenish-gray lithic-pumice-crystal lapilli tuff, tuff breccia, and andesitic to dacitic sandstone, conglomerate and siltstone; commonly massive to thickly-bedded; contains numerous thin, discontinuous intrusive rocks (sills and dikes) or lava flows.