Evaluation of Sampling Methods for Amphibians in Headwater Basins of Non-Fishbearing Streams: A Preliminary Analysis

Year 2001 Annual Report

submitted by:

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Executive Summary

We examined 4 stream-associated amphibian (SAA) sampling methods that varied in effort required to use them. We compared two forms of a low-effort visual method (day versus night spotlight surveys); a relatively new method (rapid assessment) requiring an intermediate level of effort; and a rubble-rousing method requiring a high level of effort in a mix of combinations on 31 streams in the Coast Range (Stillman Creek watershed) over two field seasons (2000-2001).

Similar to that for 2000, 2001 data showed that the rapid assessment method generally performed better than either form of visual method for presence/non-detection of Forest and Fish (FFR) SAAs in the Coast Range physiographic province (i.e., Pacific tailed frog, *Ascaphus truei*; Dunn's Salamander, *Plethodon dunni*; Columbia torrent salamander, *Rhyacotriton kezeri*). In particular, rapid assessment was superior to visual surveys for species detection where amphibians were infrequently encountered, and thus, generally resulted in higher estimates of species richness. Rapid assessment also resulted in higher estimates of relative abundance for FFR stream-associated amphibian species. The only taxon for which rapid assessment did not consistently outperform spotlight surveys was giant salamanders, which comprises 2 non-FFR amphibian species, Cope's and coastal giant salamanders (*Dicamptodon copei* and *D. tenebrosus*). Ambiguity in performance may arise from treatment of the 2 giant salamander species as one.

As anticipated, rapid assessment required about 5 times the effort of either day or night spotlight surveys. Greater costs are related to moving surface objects during the survey and capturing and processing animals, but detection advantages of rapid assessment over spotlight surveys outweigh its implementation cost.

Interestingly, rapid assessment also outperformed 10 1-m belt rubble-rousing samples (i.e., excavation of all removable stream substrates) per stream, the "gold standard" of instream surveys, for species richness or relative abundance. The observed differences in detection between methods likely result from sampling error associated with the reduced longitudinal coverage (i.e., along the stream length axis) of rubble rousing. At this level of effort, rubble rousing has a relatively high likelihood of missing habitat patches with different amphibian species and high density patches of amphibians. Increasing the number of belts should allow rubble-rousing sampling to approach rapid assessment in performance. However, the effort required for rubble rousing in 10 1-m belts is already 10-50% greater than that for a 300-m application of rapid assessment, so increased effort for rubble rousing is unlikely to result in an advantage. Greater effort required for rubble rousing seems to be primarily related to moving and replacing instream material during searches.

We also sampled 116 streams in the Coast Range (Stillman Creek watershed, n = 62 in 2000, n = 48 in 2001) and Southern Cascades (Washougal River watershed, n = 11 in 2000) to better understand how rapid assessment might be applied in Washington State. Analyses of 1st-detection distances (i.e., distance from the survey starting point to the 1st detection of a species in a stream) suggested that distances required to detect amphibians with high probability (≥ 80%) ranged from 50 m to 690 m, depending on the species. If our data approximate the distances needed to detect FFR species that are *in fact* present, then the cost of this method is about one-third to two-thirds of that needed to detect the same or congeneric taxa in California (variation in cost differential depending on the

species involved), where this method was developed. We must further our understanding of rapid assessment rates of errors of omission (i.e., not finding a species when in fact it is present) before we can use it with confidence. Over the ≤ 300-m reach scale at which we applied our sampling methods, 10 1-m belt rubble rousing should not be used as the standard to which alternative methods are compared. Increasing search effort in streams in which rapid assessment did not detect particular species will be needed to better understand rates of error of omission.

We also explored rapid assessment data as a method for estimating relative abundance. Relative abundance was indexed using two measures: 1) the density of individuals (#/m^2) of a species in the 30 m upstream from the 1st individual detected, and 2) the density of individuals of a species in the 100 m (or remaining stream distance, if < 100 m) upstream from the 1st individual detected. First detection distance was generally poorly correlated to relative abundance indices, which indicates that this metric would not be a particularly useful relative abundance surrogate.

We found 1st-detection distance to vary significantly with the landscape variables we used to stratify streams (e.g., aspect, elevation). This suggests that curves that describe detection distance could reveal amphibian responses to different strata. To use detection distance curves as such a tool, fundamental understanding of variation in 1st-detection distances, including inter-year variation, will be required.

We reconfirmed the intriguing pattern found in 2000 for Coast Range streams to which rapid assessment was applied: Streams harboring Pacific tailed frog (all life stages) were significantly richer in amphibian species than streams without Pacific tailed frogs. Thus, Pacific tailed frog presence would be a useful amphibian biodiversity indicator, at least at a local scale in the Coast Range of Washington. What stream characteristics that reflect a richer amphibian assemblage are linked to Pacific tailed frog presence and whether tailed frog might be useful as a biodiversity indicator on a broader geographic scale or for taxa other than amphibians need exploration.

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 2000-2001, a number of the streams we visited, currently typed as perennial non-fish-bearing waters, were dry; this condition may have resulted from a general drought in the Pacific Northwest. Regardless of the cause, many of our randomly selected sampling points lacked a scour channel and/or surface water. We spent a large proportion of our effort locating streams suitable for survey.

1. Background

This study addresses research needs for the **L**andscape and **W**ildlife **A**dvisory **G**roup (**LWAG**), the Scientific Advisory Group of the **C**ooperative **M**onitoring **E**valuation and **R**esearch (**CMER**) Committee that is charged with providing new information in support of **F**orest and **F**ish **R**eport (**FFR**: http://www.wa.gov/dnr/htdocs/fp/fpb/forests&fish.html) adaptive management. In particular, this study relates directly to two priority wildlife research and monitoring tasks outlined in Schedule L-2 (Appendix I), the schedule that focuses more precisely on priority tasks identified in FFR Schedule L-1 (see website above):

(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.

This multi-year study was designed to develop sampling methods for SAAs in the small headwater basins or watersheds of Type N systems across different physiographic provinces of Washington State. Unbiased, precise, and efficient methods will be necessary to address G4 and G7, that is, to determine habitat use, presence, and population persistence of amphibians. These basins are relatively small, but they are abundant and widespread. Data from 2000 and a report from that year of study (Hayes *et al.* 2001) helped guide data collection in 2001. This report presents year 2001 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), a notion pervasive across amphibian population literature (e.g., Hyde and Simons 2001, Lowe and Bolger 2002, Marsh 2001). Some variability is related to the patchy distribution of amphibians in streams (e.g., Welsh et al. 1997), which likely reflects the patchiness of habitat in streams (Pringle *et al.* 1988, Ward 1989, Downes 1990). Variability is also associated with spatial and temporal elements of sampling and counting SAAs: SAAs are small, often concealed, and have incompletely understood activity patterns that may strongly influence the probability that they are detected. One basic concern in designing the effectiveness monitoring as outlined in the FFR is that 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. However, these notions have not been rigorously tested.

Understanding the details of 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, a requirement for 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 the information content of data from those studies differs. 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, the comparison of stream amphibian sampling methods has rarely been addressed (e.g., Bury and Corn 1991, Barr and Babbitt 2001).

1.2 Stream amphibian sampling methods

Sampling methods for SAAs can be viewed 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 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 extensive stream areas. 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 errors of omission for estimating species occurrence and increase accuracy of relative abundance estimates compared to a few, larger units (B. Bury, *pers. comm.*, 2000). However, even this notion is based more on 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 streambed disturbance (e.g., Jones and Raphael 2001). Visual survey methods may 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.

Coauthor Lowell Diller developed a novel survey method for detecting stream-dwelling amphibians in California. This method was developed in part because of the need for a system to rapidly assess habitat on landscape scales (as in the case of Washington State, across many Type N systems), hence this method is called **RAPID ASSESSMENT**. In its original form, sampling sites were selected from road and stream crossing points. In each section, the first stream crossing point on the road used to access that section was sampled. The stream was searched upstream of the road crossing using a light touch method, which involved turning easily moved surface objects judged to represent suitable habitat for the target species. The distance searched differed depending on the target species. For southern seep or torrent salamander (*Rhyacotriton variegatus*) and Pacific tailed frog (*Ascaphus truei*), two of the stream taxa focused on in California, effective search distances, respectively, were 500 m (Diller and Wallace 1996) and 1000 m (Diller and Wallace 1999). When the first individual of the target species was found, a slightly

more rigorous search of the next 30 m was done to determine whether more individuals occurred nearby. If one failed to detect the target species within the entire search distance, the species was deemed to be absent from that stream reach or segment. Effective search distances were best guess estimates based largely on locally collected data (L. Diller, *unpubl. data*). Few published studies have used this method (Diller and Wallace 1996, 1999), its efficiency is not well 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. Thus, if different sampling methods provide valid estimates of relative abundance, their estimates should be strongly correlated. To our knowledge, examining 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 occurrence patterns (i.e., distribution) and potentially document trends in abundance of SAAs through time. Specifically, we want to determine:

Objective 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 substantially 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 (2001) [low]

We intentionally chose methods that represent the range of the effort spectrum so that potential tradeoffs in cost and information content could be easily compared. We considered the high-cost rubble rousing and low-cost systematic spotlight surveys to be "standard" methods. 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 and the potential for comparing relative abundances among Type N systems over time. To address the relationship among sampling method for SAAs, we asked:

Question A: Do the 2 standard sampling methods provide data with greater precision and less bias than a rapid-assessment method?

Technically, for bias estimation, determination of accuracy for a sampling method can only be made with knowledge of the true value that the samples are trying to estimate. Yet, in most if not all cases, true values are not known. This conundrum as applied to amphibians requires that sampling methods results be tested against a standard, which is in turn based on a series of samples. For this study, we used

whichever method gave the highest frequency of occurrence as that standard, even though error rates associated with not detecting a species when they are present were not known. Estimating such omission error rates for species detection in such a standard is difficult, but can be done with greater effort focused on sample units in which detections with the standard were not made. Thus, our hypothesis in null form is:

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

Objective 2) ***To develop 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 whether the length of stream searched would change for its potential application in Washington State. We tested the hypothesis that:

Hypothesis 2: *No significant differences in application criteria exist for the rapid assessment method as currently used when contrasted to the form that may be required for application in Washington State.*

A 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 restricted our initial efforts to *Westside* Type N systems because 6 of the 7 SAAs covered in FFR (all except the Rocky Mountain tailed frog (*Ascaphus montanus*)) occur in *Westside* systems[1]. 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 fish-bearing (Type F) waters.

In 2000, we sampled Type N systems in 2 physiographic provinces (Franklin and Dyrness 1973), the Coast Ranges (Willapa Hills region of southwestern Washington) and Southern Washington Cascades. In 2001, we also began sampling the Central Cascades physiographic province. We addressed the former 2 provinces first because they are rich in SAAs, with the highest proportions of SAA genera in Washington State (Dvornich *et al.*

[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 6 SAAs as focal, including what was then termed the tailed frog (*Ascaphus truei*). Since that time, the tailed frog has been partitioned into 2 species, the Pacific 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 7, rather than 6 focal FFR SAAs. Of this group, the 2 tailed frog taxa represent the only members in eastside systems, and Rocky Mountain tailed frog is the only one exclusive there.

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. In 2000, we began work on the Washougal River Watershed in the Southern Washington Cascades province because a study cooperator, Longview Fibre Company, was a major landowner in this watershed. In 2000, the Forest Service, a study cooperator, also sampled 6 sites without active forest management in the Cowlitz River Watershed to explore their potential use as reference sites. In 2001, work in the Central Cascades physiographic province was begun in the Wilkeson Creek watershed because another important study cooperator, Plum Creek Timber Company, was major landowner in this watershed.

Our original target was to sample enough streams to complete an analysis on each physiographic province in any one year. This was unrealistic. Logistical difficulties coupled with drought conditions required significantly more effort than expected to find suitable streams in 2000. Moreover, more severe drought conditions existed in 2001. As important, Type N systems in the Washington Cascades were found to be 3-10 times larger than those in the Coast Ranges, requiring greater effort to access and sample not only because of their size, but because access roads were frequently more remote from Type N channels. Consequently, after the 2000 season, we concentrated sampling in the Coast Ranges to move toward the completion of sampling comparisons on an igneous lithology on a reasonable timetable. Based on the data collected in 2001, completion of a sampling comparison on an igneous lithology in the Coast Ranges will require one more field season (2002). We have collected some data toward model development on igneous lithologies in the Central and Southern Washington Cascades, but beyond a small sample size upon which we have already reported for the Southern Washington Cascades (Hayes *et al.* 2001), the data are too few for analyses. Further analyses of these data are deferred until larger sample sizes are available for analysis from these physiographic provinces.

Selecting Study Sites: In 2001, we selected 198 more stream crossings in the Stillman Creek Watershed based on a stratified random pattern from the road crossing population of Type N streams on Weyerhaeuser ownership (n = 1,063), which encompasses 73% of the watershed. We had selected 375 stream crossings to sample in 2000. As in 2000, this population of stream crossing was stratified based on aspect and elevation (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, 2000-2001

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)

[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.

Our original stratification was also based on geology (lithology). However, as geology of the Stillman watershed was overwhelmingly igneous, we only selected igneous sites. This constraint was supported by the finding that amphibian abundance was significantly

greater on igneous substrates than those of marine sedimentary origin (Wilkins and Peterson 2000), the only other lithology of significance in the Stillman watershed.

In 2000, 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. This rationale was based on the finding that some SAAs seem 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. In 2001, we continued site selection based on these aspect criteria until all sites were targeted for sampling or eliminated due to other criteria (no channel), but we ran out of selections falling under these criteria mid-season, we continued a random selection pattern on stream crossings with an east or west aspect. 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.

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, development of a sufficient sample size for such a comparison would be done within a single season of the same year, but this was not logistically possible given constraints of funding and the low-flow sampling time window. In 2000, the time spent finding suitable sites limited us to an initial comparison of spotlight and rapid assessment methods. In 2001, we added a comparison between rapid assessment and rubble rousing and augmented sample size on the spotlight-rapid assessment comparison. We anticipate that at least one more year will be need to increase sample sizes to make all comparisons robust for the sampling model on an igneous lithology in the Coast Range physiographic province.

2.1 Method

Scoping: Prior to initiating sampling, we visited each randomly selected stream crossing point to determine hydrologic condition of the stream; in some cases, adjacent forest age; and in 2001, to measure selected physical variables (see below). Hereafter, we call this process scoping. If swales or streams at road crossing points lacked a scour channel, we did not consider them further. Logging debris restricted access to > 95 % of channels in forests 0-15 years old (see also Jackson *et al.* 2001), so streams with substantial area in stands ≤ 15 years old were not addressed in this study.

In 2000, when a scour channel was visible at the stream crossing point, we walked 100 m upstream of the crossing and characterized hydrologic condition as 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 categories. We selected reaches for sampling with flowing or standing water in ≥ 90% of the first 100 m.

In 2001, we sampled all reaches with a scour channel visible at the stream crossing point, including those that did not meet the ≥ 90% rule. Scoping in 2001 consisted of delimiting the stream in 10-m bands. Within each 10-m band, we measured channel gradient from the ends of the band in the upstream direction (always positive), and if water was present, average wetted channel width was estimated and water temperature was taken. We also scored a more refined description of channel moisture and type patterned after data collected for perennial initiation point (PIP) studies (Appendix II).

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 (≥ 100,000 candlepower) light source. Jones and Raphael (2001) regarded the 2 samplings (one day and one night) as one complete stream survey, but our approach treated day and night surveys as different methods (see Analysis Section). Our reasoning was that the combined day and night spotlight surveys really represent 2 samplings of the same system (the other 2 methods each represent but one sampling; see descriptions that follow). Thus, data from a day versus night spotlight survey are not independent and cannot be combined into single values with meaning for comparison to the other two methods. We further reasoned that although mode of survey was the same in each, conducting surveys during the day versus at night affected several aspect of logistics for surveyors, and for that reason alone, should be considered different.

Moreover, since major differences in day and night responses exist for some amphibians (Nussbaum et al. 1983), such treatment was well justified.

We completed the day and night surveys on each stream within a 24-hr period similar to Jones and Raphael (2001). Daytime sampling was completed between 1200 and 1600 hr and nighttime sampling typically done one hour after dusk, but always between 2200 hr to 0200 hr the following morning. In 2001, day surveys were always completed prior to night surveys; in 2000, survey order was sometimes reversed. No habitat manipulation was done to help detect amphibians (turning movable objects, altering vegetation) during spotlighting, and no amphibians were handled. We recorded data on each 10-m band using hand-held tape-recorders for later transcription.

In 2000, spotlighted streams were selected from the pool of streams in which we recorded amphibians based on rapid assessment, but in 2001, save one stream resurveyed from 2000, we selected the remaining streams for spotlighting to ensure a range of variation from no to frequent amphibian presence based on an earlier rapid assessment result.

Rapid Assessment: Using a modified version of the rapid assessment survey method (see Section 1.2), 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 was 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 light the streambed where shade limited visibility. We handled and recorded data on most[2] amphibians, and recorded the distance from the road crossing to each amphibian. All spotlighted streams were rapid assessed within two weeks following their spotlight survey.

Rubble Rousing: We used a modified form of a standard rubble-rousing procedure (see Bury and Corn 1991). The ends of the sampled units, termed belts, were first delimited with block nets. Belts were then searched by removing all of the movable substrate from the wetted channel to a 30-cm depth, and encountered animals were captured, processed (see amphibian data below), and released at the point of capture. After searching a belt, removed substrate was replaced in the wetted channel. In our form of this method, we attempted to sample a randomly selected 1-m belt every 30 meters over a 300-m stream reach. However, based on our selection of road crossing start points, many streams had < 300 meters that could be surveyed. In those cases, we compressed the distance over which our 1-m belts were randomly selected to $^{1}/_{10}$ the overall reach distance available for survey. We conducted all rubble-rousing surveys during the daytime and similar to rapid assessment surveys, moved in an upstream direction along the main stream thread until we either reached another road crossing or the uppermost extent of visible channel.

In 2000, rubble-roused streams were selected from the pool of streams that we also rapid assessed to ensure sufficient range of variation in stream length and channel condition.

Amphibian Data: We determined genus (for most giant salamanders only) or species (listed in Appendix II), 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 SVL and TTL for animals that were captured. For individuals not captured (e.g., animals recorded during spotlight surveys), we determined genus (for most giant salamanders only) or species,

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

and TTL was visually estimated to the nearest 5 mm. We developed TTL-SVL regressions using data collected during the rapid assessment to aid comparisons between methods. Individuals collected during rapid assessment for which the identification of species or life stage was problematic were brought to the laboratory to verify identification. These animals were subsequently released at the capture location.

Analyses: We used standard statistical procedures (Zar 1996), but relied predominantly on non-parametric statistics for preliminary analyses. Results of all non-parametric tests were corrected for tied ranks as needed. We provided varying descriptive statistics based on different descriptive requirements from among the mean, median, standard deviation (s), standard error of the mean (se), and range to describe the data. Data were analyzed using Statview 5.0 (SAS Institute, Inc.) software.

We excluded data on the initial 10-m reach above road crossing for all comparisons even thought we had recorded data from this interval to reduce the possibility of influence of the road. Animals recorded in this interval as well as individuals found outside of the survey protocols for any method were viewed as incidental and not used in analyses.

We analyzed species richness with FFR amphibian species only, with all SAA taxa (FFR amphibians plus giant salamanders [genus *Dicamptodon*]), and with all amphibian species (including non-SAA taxa) except those incidentally detected. We compared methods in pairwise fashion for these different richness metrics and the occurrence of individual species using a Wilcoxon signed rank test (Zar 1996). For relative abundance comparisons between methods, we used density data for individual species and evaluated it with a two-tailed paired t-test. We assessed the degree of correlation between methods for overall species richness and relative abundance using Spearman rank correlations.

We used a Spearman rank correlation to examine the relationship between selected richness metrics and numbers of 10-m intervals sampled or numbers of 10-m intervals sampled with significant water. Significant water refers to any 10-m interval with ≥ 20% of its length having flowing or standing water.

Significant indicates statistical significance based on $\alpha = 0.05$, which was conservatively adjusted to address experiment-wise error rates where > 1 test was performed. Still, we believe it useful to simply look at probabilities as a guide to likely importance of results.

2.2 Results

Scoping: Scoping for site selection required a large effort. In 2000, 2 surveyors visited 8-14 reaches (based on road crossings) in one day. Scoping the 260 reaches examined over the Stillman watershed in 2000 required 1.7 person-months. In 2001, a more thorough scoping procedure, which included delineating 10-m stream sections and measuring their physical parameters, resulted in 2 surveyors being able to scope 1-2 reaches in one day, and the 62 reaches scoped in the Stillman watershed required 2 person-months.

In 2000, we visited 69% (260/375) of Type N stream crossings that were available based on selection criteria (see Section 1.4) within the Stillman watershed (Table 2.201). Of these, 23% (61/260) lacked evidence of a visible scour channel. Another 58% (151/260) had a visible scour channel, but were either dry (30%: 79/260) during the scoping period (August-September) or lacked sufficient water (28%: 72/260) to qualify for survey (Table 2.201; see Scoping in Section 2.1). Based on the ≥ 90% watered distance criterion, 19% (48/260) of the road crossings had a channel with sufficient water to qualify for survey. In 2000, all 48 of these reaches were rapid assessed, and 17% (n = 8) were also sampled

Table 2.201 – Characteristics of small headwater stream reaches at 533 road-crossing points with north or south aspects in the Stillman watershed, Washington, 2000-2001

Reach Category		Stratum Categories														
		Year 2000							Year 2001							
		Elevation	0-300 m		301-600 m		601-900 m		2000 Totals	0-300 m		301-600 m		601-900 m		2001 Totals
		Aspect[1]	N	S	N	S	N	S		N	S	N	S	N	S	
Qualifying[2]		n_q =	38	25	109	106	43	54	375	32	5	74	20	14	13	158
		% of Totals	10.1	6.7	29.1	28.3	11.5	14.4	100.0	20.3	3.2	46.8	12.7	8.9	8.2	100.0
Scoped[3]		n_s =	21	17	82	71	23	46	260	11	2	23	7	3	5	51
		% of Totals	5.6	4.5	21.9	18.9	6.1	12.3	69.3	7.0	1.3	14.6	4.4	1.9	3.2	32.4
No Channel		n_n =	3	2	18	16	8	14	61	21	3	51	13	11	8	107
		% of Totals	0.8	0.5	4.8	4.3	2.1	3.7	16.3	13.3	1.9	32.3	8.2	7.0	5.1	67.7
Channel Present	Dry	n_d =	4	5	31	19	6	14	79	0	0	0	0	0	1	1
		% of Totals	1.1	1.3	8.3	5.1	1.6	3.7	21.1	0	0	0	0	0	0.6	0.6
	< 90% Water[4]	$n_{<w}$ =	4	1	25	23	6	13	72	0	0	7	2	0	1	10
		% of Totals	1.1	0.3	6.7	6.1	1.6	3.5	19.2	0	0	4.4	1.3	0	0.6	6.3
	≥ 90% Water[5]	$n_{>w}$ =	10	9	8	13	3	5	48	11	2	16	5	3	3	40
		% of Totals	2.7	2.4	2.1	3.5	0.8	1.3	12.8	7.5	1.3	10.1	3.2	1.9	1.9	25.4

[1] North = NW-NE and South = SW-SE as defined in Table 1.401.
[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.

with both spotlighting methods.

In 2001, using the more thorough scoping procedure, we scoped 31% (62/198) of Type N crossings, as 69% (136/198) of the crossings were excluded because a scour channel was not present (Tables 2.201 and 2.202). We rapid assessed 76% (n = 47) of reaches scoped. Eight of the reaches that we rapid assessed were spotlight surveyed, but logistic problems resulted in only 7 reaches being spotlighted at night. One stream that was spotlight surveyed both day and night was a stream that had been surveyed in 2000 using both rapid assessment and day and night spotlighting. Of rapid assessed reaches, 18 were also surveyed using rubble rousing, which included all reaches that were spotlighted in 2001.

Table 2.202 – Characteristics of small headwater stream reaches at 40 road-crossing points selected with east or west aspects in the Stillman watershed, Washington, 2001

Reach Category		Stratum Categories							
		Elevation	0-300 m		301-600 m		601-900 m		Totals
		Aspect[1]	E	W	E	W	E	W	
Qualifying[2]		n_q =	6	1	22	0	11	0	40
		% of 2001 Totals	15.0	2.5	55.0	0	27.5	0	100.0
Scoped[3]		n_s =	2	0	5	0	4	0	11
		% of 2001 Totals	5.0	0	12.5	0	10.0	0	27.5
No Channel		n_n =	4	1	14	0	7	0	26
		% of 2001 Totals	10.0	2.5	35.0	0	17.5	0	65.0
Channel Present	Dry	n_d =	0	0	0	0	0	0	0
		% of 2001 Totals	0	0	0	0	0	0	0
	< 90% Water[4]	$n_{<w}$ =	0	0	3	0	1	0	4
		% of 2001 Totals	0	0	7.5	0	2.5	0	10.0
	≥ 90% Water[4]	$n_{<w}$ =	2	0	2	0	1	0	5
		% of 2001 Totals	5.0	0	5.0	0	2.5	0	12.5

[1] North = NW-NE and South = SW-SE as defined in Table 1.401.
[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: Species Richness: With giant salamander taxa treated collectively, we recorded 0-3 FFR amphibian species and 0-4 SAA species across sampled streams using different sampling methods (Table 2.203). We found important differences in species richness when we compared results of different sampling methods on the same stream (Table 2.204). Notably, our rapid assessment approach nearly always returned species richness values that were greater than or equal to the other 3 methods (Table 2.203). In particular, of 15 streams sampled with both daytime spotlighting and rapid assessment, only 1 had a higher FFR species richness value with spotlighting; 53% (n = 8) of the streams had a higher species richness with rapid assessment and the remaining 6 streams had identical values with both methods. Similarly, of 14 streams that had been

Table 2.203 – Estimates of amphibian species richness for FFR amphibians and all SAAs using 4 survey methods in Stillman watershed streams, Washington, 2000-2001

Stream	Year	10-meter Intervals[1]		FFR Amphibian Species				All Stream-Associated Amphibian Species[2]			
				Spotlight		Rapid Assessment	Rubble Rousing	Spotlight		Rapid Assessment	Rubble Rousing
		Total	Watered	Day	Night			Day	Night		
STL11040313	'00	30	30	1	0	2	-	2	2	3	-
STL11041011	'00	30	30	1	1	2	-	3[4]	3[4]	3[4]	-
STL12042120	'00	30	26	1	1	1	-	1	2	3	-
STL12043108	'00	30	14	2	2	2	-	2	2	3	-
STL12043226	'00	30	30	1	1	3	-	1	2	4	-
STL12043226	'01	30	30	3	1[3]	3	3	4[4]	2	4[4]	4[4]
STL12043322	'00	30	30	1	1	1	-	2	2	1	-
STL12043407	'00	30	30	1	0	3	-	2	1	4	-
STL12043417	'00	20	8	0	0	0	-	1	1	0	-
STL11040512	'01	26	26	2	0	3	1	2	1	4	1
STL11041713A	'01	12	10	1	1	2	1	1	1	2	1
STL11041713B	'01	19	2	0	0	1	0	0	1	2	0
STL12042121	'01	30	19	2	3	2	2	3[4]	4	3	3
STL12042213	'01	12	11	0	0	2	0	1	1	3	1[4]
STL12042214	'01	26	10	0	1	1	1	0	1	1	1
STL12043225	'01	23	20	3	-	2	1	3	-	2	1
STL11040218	'01	4	0	-	-	0	0	-	-	0	0
STL11040513	'01	10	9	-	-	1	1	-	-	1	1
STL11040519	'01	15	6	-	-	1	1	-	-	1	1
STL11040602	'01	9	0	-	-	0	0	-	-	0	0
STL11040607	'01	9	0	-	-	0	0	-	-	0	0
STL11040703	'01	7	0	-	-	0	0	-	-	0	0
STL11040709	'01	23	5	-	-	2	0	-	-	2	0
STL11041716	'01	5	0	-	-	0	0	-	-	0	0
STL12041741	'01	17	4	-	-	0	0	-	-	0	0
STL12043501	'01	30	30	-	-	1	0	-	-	1	1
Sample Sizes	Year 2000			8	7	8	0	8	7	8	0
	Year 2001			8	8	18	18	8	8	18	18
	Overall (2000+2001)[5]			15	14	25	18	15	14	25	18

[1] Approximate distances in 10-m intervals of stream sampled (Total) and of stream sampled with flowing or standing water (Watered).
[2] This includes FFR amphibian species plus giant salamanders (*Dicamptodon* spp.).
[3] This stream was sampled on 4 October, the last day of the sample season in 2001, when a significant drop in nighttime temperature occurred; night spotlighting species richness may be biased.
[4] Actual species richness was one greater than indicated since both Cope's (*D. copei*) and coastal giant (*D. tenebrosus*) salamanders were identified.
[5] Overall sample size for each of the spotlight surveys and rapid assessment do not equal the sum of the two years because one stream sampled in 2000 was repeated in 2001 (in blue).

night spotlight surveyed and rapid-assessed, only 1 had a higher species richness value with spotlighting; 50% (n = 7) of these streams had a higher species richness using rapid assessment and the remaining 6 streams had identical values.

Of 18 streams that were rapid-assessed and rubble-roused, none returned higher species richness values for the rubble-rousing method; one-third (n = 6) of the streams had a higher species richness with rapid assessment and the remaining 12 streams returned identical values. Notable in the latter analysis is that 5 of the streams sampled were short (≤ 9 10-m intervals), none had significant water (Table 2.203), and no amphibians were detected in them with either method.

Table 2.204 – Wilcoxon signed rank comparison for amphibian species richness between pairs of combinations for 4 survey methods in Stillman watershed streams, Washington, 2000-2001

	FFR Amphibians[1]				Stream-Associated Amphibians			
Survey Method	**Spotlight Survey Day**	**Spotlight Survey Night**	**Rapid Assessment**	**Rubble Rousing**	**Spotlight Survey Day**	**Spotlight Survey Night**	**Rapid Assessment**	**Rubble Rousing**
Spotlight Survey Day		0.2342	***0.0126***	0.4142		0.7630	***0.0213***	0.4142
Spotlight Survey Night	SSD>SSN		***0.0098***	0.4142	SSN>SSD		***0.0300***	> 0.9999
Rapid Assessment	***SSD<RA***	***SSN<RA***		***0.0152***	***SSD<RA***	***SSN<RA***		***0.0256***
Rubble Rousing	SSD>RR	SSN<RA	***RA>RR***		SSD>RR	SSN=RR	***RA>RR***	

[1] Numbers above the diagonal in the table are probabilities associated with the Wilcoxon signed rank test statistic for each comparison; directionality of the result or lack of it is below the diagonal. Experiment-wise error-adjusted α for 6 tests in each group was 0.0085; no test was significant, but values and test directions approaching significance are emboldened and italicized.

Day and night spotlight surveys returned similar richness values. For FFR amphibians, 3 streams had higher values with day spotlight surveys, whereas 3 other streams had higher values for night spotlight surveys; the other 8 streams had an identical species richness value with each type of spotlight survey (Table 2.203). When all SAA species were considered, 6 streams had higher values with night spotlighting, 2 streams had higher values with day spotlighting, and species richness was identical in the remaining 6 streams using either of the spotlight survey types.

Rubble rousing also returned species richness values similar to spotlight surveys, whether FFR amphibians or all SAA species were compared. However, this comparison involved the fewest streams, 8 for the comparison with day spotlighting and 7 for the comparison with night spotlighting (Table 2.203), and thus represents the least robust analysis.

Comparisons in species richness among survey methods did not change substantially when we considered all amphibian species (Table 2.205). Rapid assessment and night spotlight surveys scored a maximum of 6 taxa across the collective sample, but rubble rousing and day spotlight surveys scored maxima of 5 and 4, respectively. The difference between rapid assessment and day spotlight surveys diverged, as rapid assessment scored higher species richness values than day spotlight surveys in 75% (n = 12) of reaches, was equal in richness in 2 streams, and had a richness value of only one less than that of day spotlight surveys on only 2 streams. The only differences among methods that were statistically significant or approaching significance were all combinations that involved

Table 2.205 – Estimates of amphibian species richness for all amphibians and numbers of incidentally detected species using four survey methods in Stillman watershed streams, Washington, 2000-2001

Stream	Year	10-meter Intervals[1]		All Amphibian Species[2]				Incidentally Detected Amphibian Species[3]			
				Spotlight		Rapid Assessment	Rubble Rousing	Spotlight		Rapid Assessment	Rubble Rousing
		Total	Watered	Day	Night			Day	Night		
STL11040313	'00	30	30	2	2	5	-	1	0	0	-
STL11041011	'00	30	30	3[4]	3[4]	4[4]	-	0	0	1	-
STL12042120	'00	30	26	1	2	2	-	0	0	0	-
STL12043108	'00	30	14	2	2	3	-	0	1	0	-
STL12043226	'00	30	30	1	2	4	-	0	0	0	-
STL12043226	'01	30	30	4[4]	2[5]	6[4]	5[4]	0	0	0	0
STL12043322	'00	30	30	2	2	1	-	0	1	2	-
STL12043407	'00	30	30	2	2	5	-	0	0	0	-
STL12043417	'00	20	8	1	1	0	-	0	0	0	-
STL11040512	'01	30	26	2	1	5	1	0	0	0	1
STL11041713A	'01	12	10	1	1	2	1	0	0	0	0
STL11041713B	'01	19	2	1	2	2	0	0	0	0	0
STL12042121	'01	30	19	3[4]	6	3	3	0	0	2	0
STL12042213	'01	12	11	1	1	5	1[4]	0	0	0	0
STL12042214	'01	26	10	0	1	2	1	0	0	0	0
STL12043225	'01	23	20	3	-	3	1	0	-	0	0
STL11040218	'01	4	0	-	-	0	0	-	-	0	0
STL11040513	'01	10	9	-	-	1	1	-	-	0	0
STL11040519	'01	15	6	-	-	1	1	-	-	0	0
STL11040602	'01	9	0	-	-	0	0	-	-	0	0
STL11040607	'01	9	0	-	-	0	0	-	-	0	0
STL11040703	'01	7	0	-	-	0	0	-	-	0	1
STL11040709	'01	23	5	-	-	4	0	-	-	0	0
STL11041716	'01	5	0	-	-	0	0	-	-	0	0
STL12041741	'01	17	4	-	-	0	0	-	-	0	0
STL12043501	'01	30	30	-	-	2	1	-	-	1	0
Sample Sizes	Year 2000			8	7	8	0	8	7	8	0
	Year 2001			8	8	18	18	8	8	18	18
	Overall (2000+2001)[6]			15	14	25	18	15	14	25	18

[1] Approximate distances in 10-m intervals of stream sampled (Total) and of stream sampled with flowing or standing water (Watered).
[2] This includes all amphibian species found during the established protocol for the method.
[3] This includes any additional species found incidental to the established protocol for the method.
[4] Actual species richness was one greater than indicated since both Cope's (*D. copei*) and coastal giant (*D. tenebrosus*) salamanders were identified.
[5] This stream was sampled on 4 October, the last day of the sample season in 2001, when a significant drop in nighttime temperature occurred, so the night species richness was probably biased.
[6] Overall sample size for each of the spotlight surveys and rapid assessment do not equal the sum of the two years because one stream sampled in 2000 was repeated in 2001 (in blue).

rapid assessment and another method (Table 2.206). Night spotlight surveys and rubble rousing each performed only marginally better than day spotlight surveys.

Table 2.206 – Wilcoxon signed rank comparisons for amphibian species richness based on all amphibian species detected with four survey methods in Stillman watershed streams, Washington, 2000-2001

Survey Method	Spotlight Survey Day	Spotlight Survey Night	Rapid Assessment	Rubble Rousing
Spotlight Survey Day		0.3805	**0.0045**	0.4795
Spotlight Survey Night	SSD>SSN		***0.0367***	0.7855
Rapid Assessment	**SSD<RA**	***SSN<RA***		**0.0069**
Rubble Rousing	SSD>RR	SSN>RR	**RA>RR**	

Note: Numbers above the diagonal in the table are probabilities associated with the Wilcoxon signed rank test statistic for each comparison; directionality of the result or lack of it is below the diagonal. Experiment-wise error-adjusted α for 6 tests in each group was 0.0085; significant values are emboldened, and values approaching significance are emboldened and italicized.

No species richness patterns were evident when we considered the few incidentally detected amphibian species.

Species richness was positively correlated with the number of intervals sampled and with the number of intervals with significant water for most sampling methods (Table 2.207). The relationship was significant for all categories for rapid assessment, and nearly so for

Table 2.207 – Spearman Rank correlations between amphibian species richness and number of 10-m intervals sampled or the number of 10-m intervals sampled with significant water using 4 survey methods in Stillman watershed streams, Washington, 2000-2001

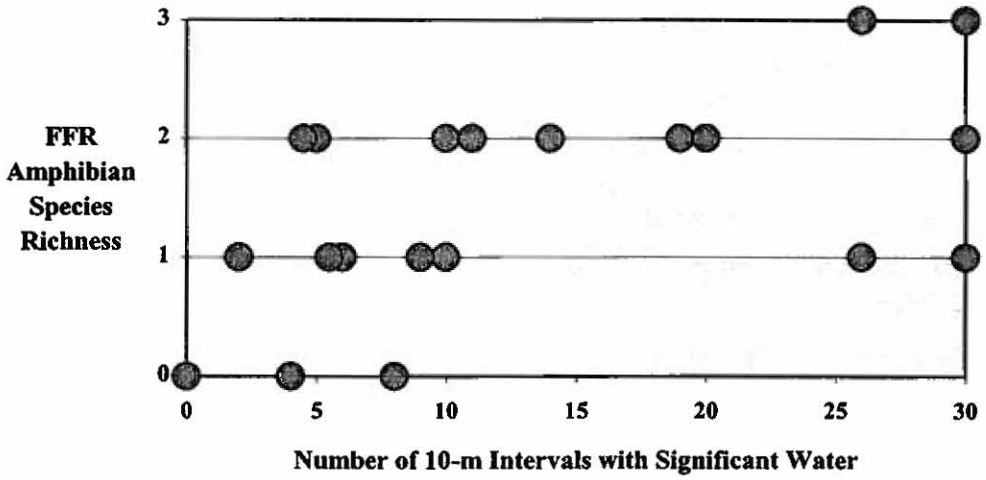
Survey Method	Interval Categorization									
	10-m Intervals Sampled					10-m Intervals with Significant Water[1]				
	n	r_s (ρ)[2]		*p*[3]		n	r_s (ρ)		*P*	
		FFR[4]	All	FFR	All		FFR	All	FFR	All
Spotlight Survey Day	15	***0.531***	***0.529***	***0.0398***	***0.0404***	15	***0.455***	***0.563***	***0.0777***	***0.0293***
Spotlight Survey Night	14	0.347	***0.655***	0.1947	***0.0143***	14	0.118	***0.526***	0.6585	***0.0489***
Rapid Assessment	26	**0.695**	**0.703**	**0.0005**	**0.0004**	26	**0.750**	**0.746**	**0.0002**	**0.0002**
Rubble Rousing	18	***0.550***	**0.663**	***0.0232***	**0.0063**	18	**0.656**	**0.882**	**0.0069**	**0.0003**

[1] See Analysis subsection of Section 2.1.
[2] Spearman rank correlation coefficient (see Zar 1996).
[3] Probability associated with respective values of the Spearman rank correlation coefficient; significant probabilities are emboldened, those approaching significant are emboldened and italicized; the rejection criterion (α) was conservatively adjusted to 0.0127 for the four tests conducted in each of the FFR and Overall categories (see footnote 4).
[4] Analysis based on FFR or Overall (All) amphibian species.

rubble rousing. Spotlight surveys were more poorly correlated to these measures of sampled area, and night spotlighting was generally the least well correlated of the two spotlighting methods.

For FFR amphibian species, we recorded the maximum possible species richness using rapid assessment when the number of 10-m intervals with significant water reached 26 (Figure 2.201).

Figure 2.201 - Relationship between FFR amphibian species richness and 10-m intervals with significant water for headwater streams in the Stillman watershed, Washington, 2000-2001



Species richness tended to be positively correlated among methods (Table 2.208), but the

Table 2.208 – Spearman Rank correlations among 4 survey methods for FFR and overall amphibian species richness from Stillman watershed streams, Washington, 2000-2001

	FFR Amphibians[1]				All Amphibians			
Survey Method	**Spotlight Survey Day**	**Spotlight Survey Night**	**Rapid Assessment**	**Rubble Rousing**	**Spotlight Survey Day**	**Spotlight Survey Night**	**Rapid Assessment**	**Rubble Rousing**
Spotlight Survey Day		***0.0616*** n = 14	***0.0236*** n = 15	***0.0496*** n = 8		***0.0150*** n = 14	***0.0619*** n = 15	***0.0683*** n = 8
Spotlight Survey Night	***0.500***		0.9847 n = 14	***0.0599*** n = 7	***0.650***		0.5813 n = 14	0.3325 n = 7
Rapid Assessment	***0.585***	0.005		**0.0061** n = 18	***0.482***	0.147		**0.0039** n = 18
Rubble Rousing	***0.742***	***0.768***	**0.666**		***0.689***	0.396	**0.700**	

[1] For each comparison, the Spearman rank correlation coefficient (r_s or ρ) is above the diagonal and the sample size for each test is below the diagonal. Experiment-wise error-adjusted α for 6 tests in each group was 0.0085; but significant values are emboldened, values that approach significance are emboldened and italicized.

only significant correlation was between rapid assessment and rubble rousing, for both FFR amphibian species and all amphibian species. Night spotlight surveys were the only method that was poorly correlated with rapid assessment for both richness groupings.

Species Composition: FFR species: Detection of the 3 FFR species known to occur in Stillman (Pacific tailed frog, *Ascaphus truei*; Dunn's salamander, *Plethodon dunni*; and Columbia torrent salamander, *Rhyacotriton kezeri*) varied substantially among the 4 survey methods (Table 2.209). In general, rapid assessment detected all FFR species more consistently than other methods. In particular, in 7 of 9 comparisons of FFR species richness between rapid assessment and another method, richness from rapid assessment was either significantly higher (n = 1) or tended to be higher (n = 6; Tables 2.210, 2.211, and 2.212), whereas only one other comparison (i.e., between day spotlight surveys and rubble rousing) approached significance (Table 2.210).

Rapid assessment detected Pacific tailed frog in the greatest number of streams (n = 6, including one stream that was sampled in both years; Table 2.210). By comparison, rubble rousing detected tailed frog in only 1 of 3 streams in which it had been detected with rapid assessment. Night spotlight sampling detected tailed frog in only 2 streams, but failed to detect it in 5 streams (including the one sampled in both years) that were rapid assessed. Tailed frog was detected by night spotlighting but not by rapid assessment in one stream. Day spotlight sampling detected tailed frog in 5 streams, but did not detect them in 3 of the 6 streams in which they were detected with rapid assessment. Daytime spotlight sampling also did not detect tailed frog in one of two years for the stream sampled in both years. Tailed frogs were detected by day spotlighting but not by rapid assessment in 2 streams. In all 3 cases in which a spotlight method detected Pacific tailed frog, but rapid assessment failed to detect it, only one post-metamorph (either a juvenile or an adult) was found with the spotlight survey.

Rapid assessment also detected Dunn's salamander in the greatest number of streams (n = 6, including in the same stream sampled in both years). Dunn's salamander was not found in any streams outside of those in which it was detected using rapid assessment. Rubble rousing came closest to the rapid assessment total, detecting Dunn's salamander in 3 of 5 streams. Day and night spotlight surveys found Dunn's salamander in only 2 streams and 1 stream, respectively.

Rapid assessment also detected Columbia torrent salamander in the greatest number of streams (n = 18, including a single stream sampled in both years). Similar to the results for Dunn's salamander, Columbia torrent salamander was not detected in any streams outside of those in which it was found with rapid assessment. Daytime spotlight surveys found Columbia torrent salamanders in 9 of 14 streams in which they were encountered using rapid assessment, whereas night spotlight surveys detected torrent salamanders in 6 of 13 streams in which they were found with rapid assessment. Rubble rousing detected torrent salamanders in 7 of 12 streams in which they were found with rapid assessment.

Other amphibians: Rapid assessment also generally detected non-FFR amphibians more frequently than other methods (Table 2.213). For the two taxa, giant salamanders and western red-backed salamander, for which enough data existed, 4 of 6 comparisons showed that rapid assessment tended to results in higher species richness that other sampling methods (Tables 2.214 and 2.215), although none of these comparisons was significant. In contrast, only one other comparison, that between day spotlight surveys

Table 2.209 – Occurrence of FFR amphibian species using 4 survey methods in Stillman watershed streams, Washington, 2000-2001

Stream	Year	Pacific tailed frog (ASTR)				Dunn's salamander (PLDU)				Columbia torrent salamander (RHKE)			
		Spotlight		RA[1]	RR	Spotlight		RA	RR	Spotlight		RA	RR
		Day	Night			Day	Night			Day	Night		
STL11040313	'00	ND[2]	ND	P	-	ND	ND	ND	-	P	ND	P	-
STL11041011	'00	ND	ND	ND	-	ND	ND	ND	-	P	P	P	-
STL12042120	'00	ND	ND	ND	-	ND	ND	ND	-	ND	ND	P	-
STL12043108	'00	P	P	P	-	ND	ND	ND	-	P	P	P	-
STL12043226	'00	ND	ND	P	-	ND	ND	P	-	P	P	P	-
STL12043226	'01	P	ND	P	P	P	ND	P	P	P	P	P	P
STL12043322	'00	ND	ND	ND	-	ND	ND	ND	-	ND	ND	P	-
STL12043407	'00	ND	ND	P	-	ND	ND	P	-	P	ND	P	-
STL12043417	'00	ND	ND	ND	-	ND	ND	ND	-	ND	ND	ND	-
STL11040512	'01	P	ND	P	ND	ND	ND	P	P	P	ND	P	P
STL11041713A	'01	ND	ND	P	ND	ND	ND	ND	ND	P	P	P	ND
STL11041713B	'01	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	P	ND
STL12042121	'01	P	P	ND	ND	ND	P	P	P	P	P	P	P
STL12042213	'01	ND	ND	ND	ND	ND	ND	P	ND	ND	ND	P	ND
STL12042214	'01	ND	ND	ND	ND	ND	ND	ND	ND	ND	P	P	P
STL12043225	'01	P	-	ND	ND	P	-	P	ND	P	-	P	P
STL11040218	'01	-	-	ND	ND	-	-	ND	ND	-	-	ND	ND
STL11040513	'01	-	-	ND	ND	-	-	ND	ND	-	-	P	P
STL11040519	'01	-	-	ND	ND	-	-	ND	ND	-	-	P	P
STL11040602	'01	-	-	ND	ND	-	-	ND	ND	-	-	ND	ND
STL11040607	'01	-	-	ND	ND	-	-	ND	ND	-	-	ND	ND
STL11040703	'01	-	-	ND	ND	-	-	ND	ND	-	-	ND	ND
STL11040709	'01	-	-	ND	ND	-	-	ND	ND	-	-	P	ND
STL11041716	'01	-	-	ND	ND	-	-	ND	ND	-	-	ND	ND
STL12041741	'01	-	-	ND	ND	-	-	ND	ND	-	-	ND	ND
STL12043501	'01	-	-	ND	ND	-	-	ND	ND	-	-	P	ND
Sample Size	Year 2000	8	7	8	0	8	7	8	0	8	7	8	0
	Year 2001	8	8	18	18	8	8	18	18	8	8	18	18
	Overall[3]	15	14	25	18	15	14	25	18	15	14	25	18

[1] Rapid assessment (RA) and rubble rousing (RR).
[2] Not detected (ND), present (P), or not sampled (-) are the data indicated.
[3] Overall sample size does not equal the sum of the two years as 1 stream was repeated in 2001 (in blue).

and rubble rousing for giant salamanders, approached significance. In particular, giant salamanders were detected in 12 streams with rapid assessment. Of the 4 methods, only nighttime spotlight survey results were similar to those of rapid assessment. We found giant salamanders in 9 streams with both rapid assessment and rubble rousing. Giant salamanders were found in 2 rapid-assessed streams where they were not found with

Table 2.210 – Wilcoxon signed rank comparisons for Pacific tailed frog (*Ascaphus truei*) occurrence using 4 survey methods in Stillman watershed streams, Washington, 2000-2001

Survey Method	Spotlight Survey Day	Spotlight Survey Night	Rapid Assessment	Rubble Rousing
Spotlight Survey Day		0.1573	0.4142	***0.0833***
Spotlight Survey Night	SSD>SSN		***0.0588***	> 0.9999
Rapid Assessment	SSD<RA	***SSN<RA***		0.1573
Rubble Rousing	***SSD>RR***	SSN=RR	RA>RR	

Note: Numbers above the diagonal in the table are probabilities associated with the Wilcoxon signed rank test statistic for each comparison; directionality of the test result or lack of it is below the diagonal. Experiment-wise error-adjusted α for 6 tests in each group was 0.0085; values approaching significance are emboldened and italicized.

Table 2.211 – Wilcoxon signed rank comparisons for Dunn's salamander (*Plethodon dunni*) occurrence using 4 survey methods in Stillman watershed streams, Washington, 2000-2001

Survey Method	Spotlight Survey Day	Spotlight Survey Night	Rapid Assessment	Rubble Rousing
Spotlight Survey Day		>0.9999	***0.0253***	>0.9999
Spotlight Survey Night	SSD=SSN		***0.0253***	NC
Rapid Assessment	***SSD<RA***	***SSN<RA***		***0.0833***
Rubble Rousing	SSD=RR	---	***RA>RR***	

Note: Numbers above the diagonal in the table are probabilities associated with the Wilcoxon signed rank test statistic for each comparison; directionality of the result or lack of it is below the diagonal. Experiment-wise error-adjusted α for 6 tests in each group was 0.0085; values near significance are emboldened and italicized; NC indicates that too few observations existed to calculate the test statistic.

Table 2.212 – Wilcoxon signed rank comparisons for Columbia torrent salamander (*Rhyacotriton kezeri*) occurrence using four survey methods in Stillman watershed streams, Washington, 2000-2001

Survey Method	Spotlight Survey Day	Spotlight Survey Night	Rapid Assessment	Rubble Rousing
Spotlight Survey Day		0.3173	***0.0253***	>0.9999
Spotlight Survey Night	SSD>SSN		**0.0082**	>0.9999
Rapid Assessment	***SSD<RA***	***SSN<RA***		***0.0253***
Rubble Rousing	SSD=RR	SSN=RR	***RA>RR***	

Note: Numbers above the diagonal in the table are probabilities associated with the Wilcoxon signed rank test statistic for each comparison; directionality of the result or lack of it is below the diagonal. Experiment-wise error-adjusted α for 6 tests in each group was 0.0085; significant values are emboldened, values approaching significance are emboldened and italicized.

Table 2.213 – Occurrence of giant salamanders (*Dicamptodon* sp.), western red-backed salamander (*Plethodon vehiculum*), and other amphibians using 4 survey methods in Stillman watershed streams, Washington, 2000-2001

Stream	Year	Giant salamanders (DISP)				Western red-backed salamander (PLVE)				Other amphibians[1]			
		Spotlight		RA[2]	RR	Spotlight		RA	RR	Spotlight		RA	RR
		Day	Night			Day	Night			Day	Night		
STL11040313	'00	P[3]	P	P	-	ND	ND	P	-	ND	ND	ND	-
STL11041011	'00	P	P	P	-	ND	ND	ND	-	ND	ND	ND	-
STL12042120	'00	ND	ND	P	-	ND	ND	ND	-	ND	ND	ND	-
STL12043108	'00	ND	ND	P	-	ND	ND	ND	-	ND	ND	ND	-
STL12043226	'00	ND	P	P	-	ND	ND	ND	-	ND	ND	ND	-
STL12043226	'01	P	P	P	P	ND	ND	P	P	ND	ND	TAGR	ND
STL12043322	'00	ND	ND	ND	-	ND	ND	ND	-	ND	ND	ND	-
STL12043407	'00	P	P	P	-	ND	ND	ND	-	ND	ND	RAAU	-
STL12043417	'00	P	P	ND	-	ND	ND	ND	-	ND	ND	ND	-
STL11040512	'01	ND	P	P	ND	ND	ND	P	ND	ND	ND	ND	ND
STL11041713A	'01	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
STL11041713B	'01	ND	P	P	ND	ND	ND	ND	ND	AMGR	AMGR	ND	ND
STL12042121	'01	P	P	P	P	ND	P	ND	ND	ND	AMGR	ND	ND
STL12042213	'01	P	P	P	P	ND	ND	P	ND	ND	ND	ND	ND
STL12042214	'01	ND	ND	ND	ND	ND	ND	P	ND	ND	ND	ND	ND
STL12043225	'01	ND	-	ND	ND	ND	-	P	ND	ND	-	ND	ND
STL11040218	'01	-	-	ND	ND	-	-	ND	ND	-	-	ND	ENES
STL11040513	'01	-	-	ND	ND	-	-	ND	ND	-	-	ND	ND
STL11040519	'01	-	-	ND	ND	-	-	ND	ND	-	-	ND	ND
STL11040602	'01	-	-	ND	ND	-	-	ND	ND	-	-	ND	ND
STL11040607	'01	-	-	ND	ND	-	-	ND	ND	-	-	ND	ND
STL11040703	'01	-	-	ND	ND	-	-	ND	ND	-	-	ND	ENES
STL11040709	'01	-	-	ND	ND	-	-	P	ND	-	-	AMGR	ND
STL11041716	'01	-	-	ND	ND	-	-	ND	ND	-	-	ND	ND
STL12041741	'01	-	-	ND	ND	-	-	ND	ND	-	-	ND	ND
STL12043501	'01	-	-	P	P	-	-	P	ND	-	-	ND	ND
Sample Size	Year 2000	8	7	8	0	8	7	8	0	8	7	8	0
	Year 2001	8	8	18	18	8	8	18	18	8	8	18	18
	Overall[4]	15	14	25	18	15	14	25	18	15	14	25	18

[1] Four-letter codes for other amphibians detected are in Appendix III.
[2] Rapid assessment (RA) and rubble rousing (RR).
[3] Not detected (ND), present (P), or not sampled (-) are the data indicated.
[4] Overall sample size does not equal the sum of the two years as 1 stream was repeated in 2001 (in blue).

rubble rousing, whereas giant salamanders were detected in 1 rubble-roused stream where they were not found with rapid assessment. In contrast, day spotlight surveys did not detect giant salamanders in 5 streams where they were found with rapid assessment, but day spotlight surveys found them in 1 stream where they were not found with rapid assessment. Day spotlight surveys and rapid assessment both detected giant salamanders in the same 6 other streams. Similarly, rubble rousing did not detect giant salamanders in 3 streams where they were found with rapid assessment; but no stream in which rapid

Table 2.214 – Wilcoxon signed rank comparisons for giant salamander (*Dicamptodon* sp.) occurrence using 4 survey methods in Stillman watershed streams, Washington, 2000-2001

Survey Method	Spotlight Survey Day	Spotlight Survey Night	Rapid Assessment	Rubble Rousing
Spotlight Survey Day		***0.0833***	0.2568	NC
Spotlight Survey Night	***SSD<SSN***		> 0.9999	0.1573
Rapid Assessment	SSD>RA	SSN>RA		0.1573
Rubble Rousing	---	SSN>RR	RA>RR	

Note: Numbers above the diagonal in the table are probabilities associated with the Wilcoxon signed rank test statistic for each comparison; directionality of the result or lack of it is below the diagonal. Experiment-wise error-adjusted α for 6 tests in each group was 0.0085; values approaching significance are emboldened and italicized; NC indicates that too few observations existed to calculate the test statistic.

Table 2.215 – Wilcoxon signed rank comparisons for western red-backed salamander (*Plethodon vehiculum*) occurrence using 4 survey methods in Stillman watershed streams, Washington, 2000-2001

Survey Method	Spotlight Survey Day	Spotlight Survey Night	Rapid Assessment	Rubble Rousing
Spotlight Survey Day		NC	***0.0143***	NC
Spotlight Survey Night	---		0.1025	> 0.9999
Rapid Assessment	***SSD<RA***	SSN<RA		***0.0143***
Rubble Rousing	---	SSN=RR	***RA>RR***	

Note: Numbers above the diagonal in the table are probabilities associated with the Wilcoxon signed rank test statistic for each comparison; directionality of the result or lack it is below the diagonal. Experiment-wise error-adjusted α for 6 tests in each group was 0.0085; values approaching significance are emboldened and italicized; NC indicates that too few observations existed to calculate the test statistic.

assessment did not detect giant salamanders were they detected with rubble rousing. Rubble rousing and rapid assessment both detected giant salamanders in the same 4 other streams.

The rapid assessment method detected almost all the western red-backed salamanders found in the study. No western red-backed salamanders were found using day spotlight surveys, and western red-backed salamanders were detected only once each by night spotlight surveys and rubble rousing. In but one case, using night spotlight surveys, was a western red-backed salamander found on a stream where the species was not detected with rapid assessment.

Relative Density: FFR SPECIES: *Pacific tailed frog*: Estimates of relative density for Pacific tailed frog were uniformly low in the Stillman watershed headwater landscape regardless of sampling method used (Table 2.216). Rubble rousing returned the highest estimate of relative density (0.600 individuals/m^2), but it was the only stream in which non-zero densities were recorded. In contrast, we recorded lower non-zero densities for rapid assessment in 7 streams (range: 0.003-0.027 individuals/m^2). Relative densities with rapid assessment were generally higher than those obtained with spotlight surveys,

and density differences between each spotlight method and rapid assessment were the only comparisons approaching significance (Table 2.217). Coefficient of variations (CV: standard deviation/mean) across contrasting methods were high (> 1), but those involving either day spotlight surveys or rapid assessment had the lowest CVs among contrasts (Table 2.218). Notably, rubble rousing had the highest CVs among methods. Rapid assessment revealed higher densities of the in-stream life stages (larvae and metamorphs) than spotlighting. Data were generally correlated between methods (Table 2.219), although no correlations were significant. Night spotlight surveys was poorly correlated with all methods except day spotlighting.

Dunn's salamander: Estimates of relative density for Dunn's salamander were also low in the Stillman watershed headwaters using any method (Table 2.220), ranging from zero to 0.3 individuals/m^2. Rubble rousing returned the highest relative density estimates. Rapid assessment was the only method for which differences in density between it and the other methods approached significance (Table 2.221). Rapid assessment was also the only method for which the coefficients of variation, albeit high (> 1) all around, were lower than each contrasting method (Table 2.222). Data were variably correlated between methods (Table 2.223). As with Pacific tailed frog data, the only significant correlation was between rapid assessment and rubble rousing, and night spotlight surveys was the most poorly correlated with other methods.

Columbia torrent salamander: Estimates of relative density for the Columbia torrent salamander were highly variable (Table 2.220). However, as consistently the most often detected amphibian in the headwater landscape of the Stillman watershed, it returned the highest relative density estimates, up to 9.0 individuals/m^2. The highest relative densities were recorded with the rubble rousing method. Differences between rapid assessment and each of the 2 spotlight methods as well as differences between spotlight methods approached significance (Table 2.224). The difference between rapid assessment and rubble rousing was an ambiguous result as rubble rousing returned larger relative abundance estimates in 4 cases. Similar to tailed frog, CVs were lowest between contrasts generally involving day spotlight surveys and rapid assessment (Table 2.225). Likewise, the highest CVs involved rubble rousing. Torrent salamander data were generally positively correlated between methods (Table 2.226). Similar to the data for Pacific tailed frog and Dunn's salamander, the strongest correlations involved rapid assessment and daytime spotlight surveys, and between the two spotlight methods. Also similar to the other species, the poorest correlations involved both spotlight methods and rubble rousing.

Van Dyke's salamander: We mention Van Dyke's salamander here for completeness as it is the 4th and only other FFR species known to occur in the Willapa physiographic region of southwest Washington. A salamander recorded as Van Dyke's was found during the survey of stream STL12042121 in 2001. The surveyor who found the animal did not submit it for independent verification and no photograph was taken, so the record could not be verified. Subsequent search of the area failed to reveal this species.

OTHER AMPHIBIAN SPECIES: *Giant salamanders*: Giant salamanders were detected at low to moderately high densities in the headwater landscape of the Stillman watershed (Table 2.227). Rubble rousing recorded the highest relative densities of giant salamanders, up to 1.250 individuals/m^2. We found no significant differences in relative density between methods (Table 2.228), and only the difference approaching significance was between rapid assessment and daytime spotlight surveys. Unlike for the analyses on other species,

Table 2.216 – Relative density (measured as individuals/m^2) of Pacific tailed frog (*Ascaphus truei*) using 4 survey methods in Stillman watershed streams, Washington, 2000-2001

Stream	Year	Spotlight Surveys								Rapid Assessment				Rubble Rousing			
		Day				Night											
		L[1]	M	P	T	L[1]	M	P	T	L[1]	M	P	T	L[1]	M	P	T
STL11040313	'00	ND	ND	ND	0.000	ND	ND	ND	0.000	ND	ND	0.003	0.003	-	-	-	-
STL11041011	'00	ND	ND	ND	0.000	ND	ND	ND	0.000	ND	ND	ND	0.000	-	-	-	-
STL12042120	'00	ND	ND	ND	0.000	ND	ND	ND	0.000	ND	ND	ND	0.000	-	-	-	-
STL12043108	'00	0.003	ND	ND	0.003	0.007	0.000	0.000	0.007	0.020	0.000	0.000	0.020	-	-	-	-
STL12043226	'00	ND	ND	ND	0.000	ND	ND	ND	0.000	ND	0.007	ND	0.007	-	-	-	-
STL12043226	'01	0.007	ND	ND	0.007	ND	ND	ND	0.000	0.007	0.017	0.003	0.027	0.004	ND	0.002	0.600
STL12043322	'00	ND	ND	ND	0.000	ND	ND	ND	0.000	ND	ND	ND	0.000	-	-	-	-
STL12043407	'00	ND	ND	ND	0.000	ND	ND	ND	0.000	0.003	ND	ND	0.003	-	-	-	-
STL12043417	'00	ND	ND	ND	0.000	ND	ND	ND	0.000	ND	ND	ND	0.000	-	-	-	-
STL11040512	'01	ND	ND	0.003	0.003	ND	ND	ND	0.000	ND	ND	0.007	0.007	ND	ND	ND	0.000
STL11041713A	'01	ND	ND	ND	0.000	ND	ND	ND	0.000	ND	ND	0.008	0.008	ND	ND	ND	0.000
STL11041713B	'01	ND	ND	ND	0.000	ND	ND	ND	0.000	ND	ND	ND	0.000	ND	ND	ND	0.000
STL12042121	'01	ND	ND	0.003	0.003	ND	ND	0.003	0.003	ND	ND	ND	0.000	ND	ND	ND	0.000
STL12042213	'01	ND	ND	ND	0.000	ND	ND	ND	0.000	ND	ND	ND	0.000	ND	ND	ND	0.000
STL12042214	'01	ND	ND	ND	0.000	ND	ND	ND	0.000	ND	ND	ND	0.000	ND	ND	ND	0.000
STL12043225	'01	ND	ND	0.004	0.004	-	-	-	-	ND	ND	ND	0.000	ND	ND	ND	0.000
STL11040218	'01	-	-	-	-	-	-	-	-	ND	ND	ND	0.000	ND	ND	ND	0.000
STL11040513	'01	-	-	-	-	-	-	-	-	ND	ND	ND	0.000	ND	ND	ND	0.000
STL11040519	'01	-	-	-	-	-	-	-	-	ND	ND	ND	0.000	ND	ND	ND	0.000
STL11040602	'01	-	-	-	-	-	-	-	-	ND	ND	ND	0.000	ND	ND	ND	0.000
STL11040607	'01	-	-	-	-	-	-	-	-	ND	ND	ND	0.000	ND	ND	ND	0.000
STL11040703	'01	-	-	-	-	-	-	-	-	ND	ND	ND	0.000	ND	ND	ND	0.000
STL11040707	'01	-	-	-	-	-	-	-	-	ND	ND	ND	0.000	ND	ND	ND	0.000
STL11040709	'01	-	-	-	-	-	-	-	-	ND	ND	ND	0.000	ND	ND	ND	0.000
STL11041716	'01	-	-	-	-	-	-	-	-	ND	ND	ND	0.000	ND	ND	ND	0.000
STL12041741	'01	-	-	-	-	-	-	-	-	ND	ND	ND	0.000	ND	ND	ND	0.000
STL12042013	'01	-	-	-	-	-	-	-	-	ND	ND	ND	0.000	ND	ND	ND	0.000
STL12042331	'01	-	-	-	-	-	-	-	-	ND	ND	ND	0.000	ND	ND	ND	0.000
STL12043501	'01	-	-	-	-	-	-	-	-	ND	ND	ND	0.000	ND	ND	ND	0.000
STL12043504	'01	-	-	-	-	-	-	-	-	ND	ND	ND	0.000	ND	ND	ND	0.000
STL12043508	'01	-	-	-	-	-	-	-	-	ND	ND	ND	0.000	ND	ND	ND	0.000
Sample Size	Year 2000	8	7	8	0	8	7	8	0	8	7	8	0	8	7	8	0
	Year 2001	8	8	23	23	8	8	23	23	8	8	23	23	8	8	23	23
	Overall[2]	15	14	31	23	15	14	31	23	15	14	31	23	15	14	31	23

[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] Overall sample size for each of the spotlight surveys and rapid assessment do not equal the sum of the two years because one stream sampled in 2000 was repeated in 2001 (in blue).

Table 2.217 – Paired t-test comparisons for Pacific tailed frog (*Ascaphus truei*) density data using 4 survey methods in Stillman watershed streams, Washington, 2000-2001

Survey Method	Spotlight Survey Day	Spotlight Survey Night	Rapid Assessment	Rubble Rousing
Spotlight Survey Day		0.4332	***0.0622***	0.3603
Spotlight Survey Night	SSD>SSN		***0.0433***	0.3588
Rapid Assessment	***SSD<RA***	***SSN<RA***		0.3446
Rubble Rousing	SSD<RR	SSN<RR	RA>RR	

Note: In each half of the table, probabilities for each two-tailed test are above the diagonal; directionality of the result or lack of it is below the diagonal. Experiment-wise error-adjusted α for 6 tests in each group was 0.0085; values approaching significance are bold-italicized.

Table 2.218 – Comparison of coefficients of variation for Pacific tailed frog (*Ascaphus truei*) density data using 4 survey methods in Stillman watershed streams, Washington, 2000-2001

Method 1	CV 1[1]	Method 2	CV 2	Sample Size
Spotlight Survey Day	**1.852**	**Spotlight Survey Night**	2.803	15
Spotlight Survey Day	**1.634**	**Rapid Assessment**	1.689	16
Spotlight Survey Day	**1.166**	**Rubble Rousing**	2.828	8
Spotlight Survey Night	2.803	**Rapid Assessment**	**1.618**	15
Spotlight Survey Night	2.646	**Rubble Rousing**	2.646	7
Rapid Assessment	**2.828**	**Rubble Rousing**	4.243	18

[1] Coefficients of variation (CV) are listed for each method; the lower CV in each contrast is emboldened.

Table 2.219 – Spearman Rank correlation between survey methods for Pacific tailed frog (*Ascaphus truei*) density data from Stillman watershed streams, Washington, 2000-2001

Survey Method	Spotlight Survey Day	Spotlight Survey Night	Rapid Assessment	Rubble Rousing
Spotlight Survey Day		***0.0287*** n = 14	0.1555 n = 15	0.1013 n = 8
Spotlight Survey Night	0.585		0.5640 n = 14	0.6831 n = 7
Rapid Assessment	0.367	0.154		***0.0117*** n = 23
Rubble Rousing	0.619	-0.167	0.612	

Note: In each half of the table, probabilities and Spearman rank correlation coefficients (sample size is also given below each coefficient) for each test are located, respectively, above and below the diagonal. Experiment-wise error-adjusted α for 6 tests in each group was 0.0085; values approaching significance are emboldened and italicized.

night spotlight surveys had the lowest CVs in all contrasts, although rapid assessment had a lower CV in the two contrasts where the comparison was not with night spotlighting (Table 2.229). Similar to the pattern in other species, rubble rousing has the highest CVs. Giant salamander data was positively correlated among all methods; the correlation between rapid assessment and rubble rousing was significant and all other combinations approached significance (Table 2.230).

Western red-backed salamander: Western red-backed salamander were also recorded at fairly low densities (0.100 individuals/m^2) in the headwater landscape of the Stillman watershed (Table 2.224). Too few data were obtained with spotlighting and rubble rousing surveys for this species to do a comparative statistical analysis; only 2 of 17 western red-backed salamanders found were encountered with a method other than rapid assessment.

Other species: Four additional species (northwestern salamander [*Ambystoma gracile*], ensatina [*Ensatina eschscholtzii*], northern red-legged frog [*Rana aurora aurora*], and roughskin newt [*Taricha granulosa*]) were encountered during our comparative method surveys in Stillman watershed headwater streams (Table 2.224). Data were too sparse to conduct analyses on any of these species; we recorded no more than 6 individuals of any of these species and ≤ 2 on any one stream.

Effort differences among methods: As expected, substantial differences in effort existed among methods (Table 2.231). Except for the comparison between the spotlight survey types, all other comparisons were significant or approaching significance (Table 2.232). As expected, rubble rousing required the greatest effort, and spotlight surveys required the least effort; rapid assessment was intermediate. A 300-m reach requiring 1-3 hr to spotlight required 6-18 hr to survey it with rapid assessment, a ca. 6-fold difference in effort. To do 10 1-m belts with rubble rousing over this same 300-m reach required 1-4 times the rapid assessment effort; however, the area comprising 10 1-m rubble-roused intervals represents only 3% of the area of a 300-m reach. Range of variation in survey time was greatly altered by the number of amphibians found, which affects processing time in rapid assessment and rubble rousing. Spotlight surveys lack processing time.

Effort was not significantly correlated between all methods. Day and night spotlighting were significantly correlated with one another, and correlations between rubble rousing and each of rapid assessment and daylight spotlight surveys approached significance (Table 2.233). Yet, other than rubble rousing, effort for neither of the spotlight survey types was correlated with effort for the other methods.

Survey limitations: In 2000, our spotlight surveying was limited to 8 reaches by habitat structure. The 8 reaches that we were able to effectively spotlight survey were the only ones available among the 38 reaches that were rapid-assessed in which we found amphibians. The remaining 30 streams could not be effectively spotlighted because dense vegetation and woody debris accumulations (> 20% of the reach) precluded using that method. In 2001, we were time-limited rather than habitat-limited. Twelve of 30 reaches had habitat that would have permitted spotlighting, but we spotlighted the same number of reaches as in 2000, including the one repeat. Nonetheless, based on parallel habitat criteria, we would have been unable to effectively sample 73% of the reaches with spotlighting in 2001 that we were able to sample with rapid assessment.

Table 2.220 – Relative density of Dunn's salamander (*Plethodon dunni*) and Columbia torrent salamander (*Rhyacotriton kezeri*) using 4 survey methods in Stillman watershed streams, Washington, 2000-2001

Stream	Year	Dunn's salamander (PLDU)				Columbia torrent salamander (RHKE)			
		Spotlight		RA	RR	Spotlight		RA	RR
		Day	Night			Day	Night		
STL11040313	'00	0.000	0.000	0.000	-	0.013	0.000	0.137	-
STL11041011	'00	0.000	0.000	0.000	-	0.063	0.033	0.350	-
STL12042120	'00	0.000	0.000	0.000	-	0.000	0.000	0.030	-
STL12043108	'00	0.000	0.000	0.000	-	0.013	0.010	0.120	-
STL12043226	'00	0.000	0.000	0.017	-	0.120	0.053	0.753	-
STL12043226	'01	0.003	0.000	0.020	0.300	0.123	0.007	0.347	9.000
STL12043322	'00	0.000	0.000	0.000	-	0.000	0.000	0.007	-
STL12043407	'00	0.000	0.000	0.003	-	0.010	0.000	0.007	-
STL12043417	'00	0.000	0.000	0.000	-	0.000	0.000	0.000	-
STL11040512	'01	0.000	0.000	0.003	0.000	0.003	0.000	0.027	1.000
STL11041713A	'01	0.000	0.000	0.000	0.000	0.125	0.117	0.275	0.000
STL11041713B	'01	0.000	0.000	0.000	0.000	0.000	0.000	0.026	0.000
STL12042121	'01	0.000	0.003	0.013	0.100	0.103	0.097	0.093	2.900
STL12042213	'01	0.000	0.000	0.008	0.000	0.000	0.000	0.017	0.000
STL12042214	'01	0.000	0.000	0.000	0.000	0.000	0.004	0.015	0.462
STL12043225	'01	0.004	-	0.004	0.000	0.039	-	0.096	1.565
STL11040218	'01	-	-	0.000	0.000	-	-	0.000	0.000
STL11040513	'01	-	-	0.000	0.000	-	-	0.050	4.200
STL11040519	'01	-	-	0.000	0.000	-	-	0.007	0.400
STL11040602	'01	-	-	0.000	0.000	-	-	0.000	0.000
STL11040607	'01	-	-	0.000	0.000	-	-	0.000	0.000
STL11040703	'01	-	-	0.000	0.000	-	-	0.000	0.000
STL11040709	'01	-	-	0.000	0.000	-	-	0.061	0.000
STL11041716	'01	-	-	0.000	0.000	-	-	0.000	0.000
STL12041741	'01	-	-	0.000	0.000	-	-	0.000	0.000
STL12043501	'01	-	-	0.000	0.000	-	-	0.007	0.000
Sample Size	Year 2000	8	7	8	0	8	7	8	0
	Year 2001	8	8	23	23	8	8	23	23
	Overall[2]	15	14	31	23	15	14	31	23

[1] Not detected (ND), present (P), or not sampled (-) are the data indicated.
[2] Overall sample size for each of the spotlight surveys and rapid assessment do not equal the sum of the two years because one stream sampled in 2000 was repeated in 2001 (in blue).

Table 2.221 – Paired t-test comparisons for Dunn's salamander (*Plethodon dunni*) density data using 4 survey methods in Stillman watershed streams, Washington, 2000-2001

Survey Method	Spotlight Survey Day	Spotlight Survey Night	Rapid Assessment	Rubble Rousing
Spotlight Survey Day		NV	***0.0358***	0.4512
Spotlight Survey Night	SSD=SSN		***0.0418***	0.3559
Rapid Assessment	***SSD<RA***	***SSN<RA***		***0.0460***
Rubble Rousing	SSD<RR	SSN<RR	***RA>RR***	

Note: In each half of the table, probabilities for each two-tailed test are above the diagonal; directionality of the result or lack of it is below the diagonal. Experiment-wise error-adjusted value of α for 6 tests in each group was 0.0085; values approaching significance are emboldened and italicized; NV indicates no value was obtained as the difference between samples was zero with no variance.

Table 2.222 – Comparison of coefficients of variation for Dunn's salamander (*Plethodon dunni*) density data using 4 survey methods in Stillman watershed streams, Washington, 2000-2001

Method 1	CV 1[1]	Method 2	CV 2	Sample Size
Spotlight Survey Day	3.873	**Spotlight Survey Night**	3.873	15
Spotlight Survey Day	2.760	**Rapid Assessment**	**1.537**	16
Spotlight Survey Day	**1.873**	**Rubble Rousing**	2.138	8
Spotlight Survey Night	3.873	**Rapid Assessment**	**1.591**	15
Spotlight Survey Night	2.646	**Rubble Rousing**	**1.984**	7
Rapid Assessment	**2.059**	**Rubble Rousing**	3.294	18

[1] Coefficients of variation (CV) are listed for each method; the lower CV in each contrast is emboldened.

Table 2.223 – Spearman Rank correlation between survey methods for Dunn's salamander (*Plethodon dunni*) density data from Stillman watershed streams, Washington, 2000-2001

Survey Method	Spotlight Survey Day	Spotlight Survey Night	Rapid Assessment	Rubble Rousing
Spotlight Survey Day		0.7893 n = 14	***0.0603*** n = 15	0.4026 n = 8
Spotlight Survey Night	-0.071		0.1912 n = 14	0.2123 n = 7
Rapid Assessment	0.485	0.349		**0.0044** n = 23
Rubble Rousing	0.316	0.509	0.691	

Note: In each half of the table, probabilities and Spearman rank correlation coefficients for each test are located, respectively, above and below the diagonal. Experiment-wise error-adjusted α for 6 tests in each group was 0.0085; significant values are emboldened, those approaching significance are bold-italicized.

Table 2.224 – Paired t-test comparisons for Columbia torrent salamander (*Rhyacotriton kezeri*) density data using 4 survey methods in Stillman watershed streams, Washington, 2000-2001

Survey Method	Spotlight Survey Day	Spotlight Survey Night	Rapid Assessment	Rubble Rousing
Spotlight Survey Day		***0.0649***	***0.0224***	0.1325
Spotlight Survey Night	***SSD>SSN***		***0.0253***	0.1830
Rapid Assessment	***SSD<RA***	***SSN<RA***		***0.0670***
Rubble Rousing	SSD<RR	SSN<RR	***RA>RR***	

Note: In each half of the table, probabilities for each two-tailed test are above the diagonal; directionality of the result or lack of it is below the diagonal. Experiment-wise error-adjusted α for 6 tests in each group was 0.0085; values approaching significance are emboldened and italicized.

Table 2.225 – Comparison of coefficients of variation for Columbia torrent salamander (*Rhyacotriton kezeri*) density data using 4 survey methods in Stillman watershed streams, Washington, 2000-2001

Method 1	CV 1[1]	Method 2	CV 2	Sample Size
Spotlight Survey Day	**1.365**	**Spotlight Survey Night**	1.779	15
Spotlight Survey Day	**1.317**	**Rapid Assessment**	1.403	16
Spotlight Survey Day	**1.180**	**Rubble Rousing**	1.636	8
Spotlight Survey Night	1.779	**Rapid Assessment**	**1.417**	15
Spotlight Survey Night	**1.608**	**Rubble Rousing**	1.726	7
Rapid Assessment	**1.734**	**Rubble Rousing**	2.117	18

[1] Coefficients of variation (CV) are listed for each method; the lower CV in each contrast is emboldened.

Table 2.226 – Spearman Rank correlation between survey methods for Columbia torrent salamander (*Rhyacotriton kezeri*) density data from Stillman watershed streams, Washington, 2000-2001

Survey Method	Spotlight Survey Day	Spotlight Survey Night	Rapid Assessment	Rubble Rousing
Spotlight Survey Day		**0.0029** n = 14	**0.0014** n = 15	0.2338 n = 8
Spotlight Survey Night	0.797		***0.0096*** n = 14	0.5096 n = 7
Rapid Assessment	0.826	0.692		***0.0108*** n = 23
Rubble Rousing	0.450	0.269	0.618	

Note: In each half of the table, probabilities and Spearman rank correlation coefficients for each test are located, respectively, above and below the diagonal. Experiment-wise error-adjusted α for 6 tests in each group was 0.0085; significant values are emboldened, values approaching significance are emboldened and italicized.

Table 2.227 – Relative density of giant salamanders (*Dicamptodon* sp.), western red-backed salamander (*Plethodon vehiculum*), and other amphibians using four survey methods in Stillman watershed streams, Washington, 2000-2001

Stream	Year	Giant salamanders (DISP)				Western red-backed salamander (PLVE)				Other amphibians[1]			
		Spotlight		RA[2]	RR	Spotlight		RA	RR	Spotlight		RA	RR
		Day	Night			Day	Night			Day	Night		
STL11040313	'00	0.003	0.017	0.010	-[3]	0.000	0.000	0.017	-	0.000	0.000	0.000	-
STL11041011	'00	0.017	0.037	0.097	-	0.000	0.000	0.003	-	0.000	0.000	0.000	-
STL12042120	'00	0.000	0.000	0.010	-	0.000	0.000	0.000	-	0.000	0.000	0.000	-
STL12043108	'00	0.000	0.000	0.003	-	0.000	0.000	0.000	-	0.000	0.000	0.000	-
STL12043226	'00	0.000	0.023	0.030	-	0.000	0.000	0.000	-	0.000	0.000	0.000	-
STL12043226	'01	0.043	0.007	0.070	0.400	0.000	0.000	0.007	0.100	0.000	0.000	TAGR	0.000
STL12043322	'00	0.000	0.000	0.000	-	0.000	0.000	0.000	-	0.000	0.000	0.000	-
STL12043407	'00	0.003	0.013	0.007	-	0.000	0.000	0.000	-	0.000	0.000	RAAU	-
STL12043417	'00	0.005	0.020	0.000	-	0.000	0.000	0.000	-	0.000	0.000	0.000	-
STL11040512	'01	0.000	0.003	0.007	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000
STL11041713A	'01	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
STL11041713B	'01	0.000	0.005	0.005	0.000	0.000	0.000	0.000	0.000	AMGR	AMGR	0.000	0.000
STL12042121	'01	0.010	0.017	0.007	0.100	0.000	0.003	0.000	0.000	0.000	AMGR	0.000	0.000
STL12042213	'01	0.008	0.008	0.025	1.250	0.000	0.000	0.017	0.000	0.000	0.000	0.000	0.000
STL12042214	'01	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.000	0.000	0.000	0.000	0.000
STL12043225	'01	0.000	-	0.000	0.000	0.000	-	0.004	0.000	0.000	-	0.000	0.000
STL11040218	'01	-	-	0.000	0.000	-	-	0.000	0.000	-	-	0.000	ENES
STL11040513	'01	-	-	0.000	0.000	-	-	0.000	0.000	-	-	0.000	0.000
STL11040519	'01	-	-	0.000	0.000	-	-	0.000	0.000	-	-	0.000	0.000
STL11040602	'01	-	-	0.000	0.000	-	-	0.000	0.000	-	-	0.000	0.000
STL11040607	'01	-	-	0.000	0.000	-	-	0.000	0.000	-	-	0.000	0.000
STL11040703	'01	-	-	0.000	0.000	-	-	0.000	0.000	-	-	0.000	ENES
STL11040709	'01	-	-	0.000	0.000	-	-	0.004	0.000	-	-	AMGR	0.000
STL11041716	'01	-	-	0.000	0.000	-	-	0.000	0.000	-	-	0.000	0.000
STL12041741	'01	-	-	0.003	0.100	-	-	0.000	0.000	-	-	0.000	0.000
STL12043501	'01	-	-	0.000	0.000	-	-	0.003	0.000	-	-	0.000	0.000
Sample Size	Year 2000	8	7	8	0	8	7	8	0	8	7	8	0
	Year 2001	8	8	23	23	8	8	23	23	8	8	23	23
	Overall[4]	15	14	31	23	15	14	31	23	15	14	31	23

[1] Four-letter codes for other amphibians detected are in Appendix II; one individual was recorded for all species indicated except those underlined, for which two individuals were found. Densities of all taxa were ≤ 0.050 individuals/m^2.

[2] Rapid assessment (RA) and rubble rousing (RR).

[3] No data, not sampled (-).

[4] Overall sample size does not equal the sum of the two years as 1 stream was repeated in 2001 (in blue).

Table 2.228 – Paired t-test comparisons for giant salamanders (*Dicamptodon* sp.) density data using 4 survey methods in Stillman watershed streams, Washington, 2000-2001

Survey Method	Spotlight Survey Day	Spotlight Survey Night	Rapid Assessment	Rubble Rousing
Spotlight Survey Day		0.2756	***0.0474***	0.2118
Spotlight Survey Night	SSD<SSN		0.2072	0.2122
Rapid Assessment	SSD<RA	SSN<RA		0.1814
Rubble Rousing	SSD>RR	SSN>RR	RA>RR	

Note: In each half of the table, probabilities for each two-tailed test are above the diagonal; directionality of the result or lack of it is below the diagonal. Experiment-wise error-adjusted α for 6 tests in each group was 0.0085; values approaching significance are emboldened and italicized.

Table 2.229 – Comparison of coefficients of variation for giant salamander (*Dicamptodon* sp.) density data using 4 survey methods in Stillman watershed streams, Washington, 2000-2001

Method 1	CV 1[1]	Method 2	CV 2	Sample Size
Spotlight Survey Day	1.907	**Spotlight Survey Night**	**1.090**	15
Spotlight Survey Day	1.983	**Rapid Assessment**	**1.645**	16
Spotlight Survey Day	**1.944**	**Rubble Rousing**	2.007	8
Spotlight Survey Night	**1.090**	**Rapid Assessment**	1.575	15
Spotlight Survey Night	**1.001**	**Rubble Rousing**	1.858	7
Rapid Assessment	**2.612**	**Rubble Rousing**	2.940	18

[1] Coefficients of variation (CV) are listed for each method; the lower CV in each contrast is emboldened.

Table 2.230 – Spearman Rank correlation between survey methods for giant salamanders (*Dicamptodon* sp.) density data from Stillman watershed streams, Washington, 2000-2001

Survey Method	Spotlight Survey Day	Spotlight Survey Night	Rapid Assessment	Rubble Rousing
Spotlight Survey Day		***0.0154*** n = 14	***0.0318*** n = 15	***0.0165*** n = 8
Spotlight Survey Night	0.647		***0.0368*** n = 14	***0.0514*** n = 7
Rapid Assessment	0.554	0.558		**0.0010** n = 23
Rubble Rousing	0.906	0.795	0.796	

Note: In each half of the table, probabilities and Spearman rank correlation coefficients for each test are located, respectively, above and below the diagonal. Experiment-wise error-adjusted α for 6 tests in each group was 0.0085; significant values are emboldened, values approaching significance are emboldened and italicized.

Table 2.231 – Comparisons of effort (measured as surveyor hours) for 4 survey methods in Stillman watershed headwater streams, Washington, 2000-2001

Stream	Year	Spotlight Surveys						Rapid Assessment			Rubble Rousing		
		Day[1]			Night								
		area (m^2)	sr-hr	m^2/ sr-hr	area (m^2)	sr-hr	m^2/ sr-hr	area (m^2)	sr-hr	m^2/ sr-hr	area (m^2)	sr-hr	m^2/ sr-hr
STL11040313	'00	300	2.4	125.0	300	2.6	115.4	300	20.4	14.7	-	-	-
STL11041011	'00	300	5.0	60.0	300	4.6	65.2	300	22.2	13.5	-	-	-
STL12042120	'00	300	1.2	250.0	300	1.4	214.3	300	9.6	31.3	-	-	-
STL12043108	'00	300	2.4	125.0	300	2.0	150.0	300	19.8	15.2	-	-	-
STL12043226	'00	300	2.4	125.0	300	2.2	136.4	300	37.6	8.0	-	-	-
STL12043226	'01	300	8.2	36.6	300	5.4	55.6	300	32.4	9.3	10.0	30.0	0.3
STL12043322	'00	300	3.0	100.0	300	2.0	150.0	300	18.6	16.1	-	-	-
STL12043407	'00	300	1.6	187.5	300	2.6	115.4	300	20.4	14.7	-	-	-
STL12043417	'00	200	3.4	58.8	200	3.4	58.8	200	8.4	23.8	-	-	-
STL11040512	'01	300	5.8	51.7	300	6.6	45.5	300	11.0	27.3	10.0	16.0	0.6
STL11041713A	'01	120	3.0	40.0	120	2.6	46.2	120	6.0	20.0	10.0	8.6	1.2
STL11041713B	'01	190	1.0	190.0	190	1.0	190.0	190	4.0	47.5	10.0	5.6	1.8
STL12042121	'01	300	5.8	51.7	300	6.4	46.9	300	13.8	21.7	10.0	17.2	0.6
STL12042213	'01	120	2.4	50.0	120	2.6	46.2	120	5.4	22.2	10.0	23.6	0.4
STL12042214	'01	260	2.4	108.3	260	2.0	130.0	260	11.0	23.6	10.0	11.2	0.9
STL12043225	'01	230	4.4	52.3	-	-	-	230	4.2	54.8	10.0	20.0	0.5
STL11040218	'01	-	-	-	-	-	-	40	2.2	18.2	10.0	4.8	2.1
STL11040513	'01	-	-	-	-	-	-	100	6.2	16.1	10.0	10.4	1.0
STL11040519	'01	-	-	-	-	-	-	150	4.0	37.5	10.0	4.6	2.2
STL11040602	'01	-	-	-	-	-	-	90	1.4	64.3	10.0	5.1	2.0
STL11040607	'01	-	-	-	-	-	-	90	0.6	150.0	10.0	2.1	4.8
STL11040703	'01	-	-	-	-	-	-	70	1.6	43.8	10.0	5.2	1.9
STL11040709	'01	-	-	-	-	-	-	230	7.0	32.9	10.0	5.4	1.9
STL11041716	'01	-	-	-	-	-	-	50	1.6	31.3	10.0	2.4	4.2
STL12041741	'01	-	-	-	-	-	-	170	2.8	60.7	10.0	6.4	1.6
STL12043501	'01	-	-	-	-	-	-	300	9.0	33.3	10.0	9.8	1.0

[1] Units: area (m^2), surveyor-hours (sr-hr), and area covered per surveyor-hour (m^2/sr-hr). Surveyor-hours are hours multiplied by the number of surveyors.

2.3 Discussion

We were unable to use the spotlight methods in a high proportion of streams (nearly three-fourths in Stillman) to which rapid assessment was applied because brushy undergrowth associated with stream channels effectively limited visibility, and spotlight methods, as Jones and Raphael (2001) describe and implemented in this study, do not allow stream alteration (either of substrate or vegetation) to enhance detection. The other two methods are 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 Coast Range physiographic province and we expect that this condition will limit opportunities to apply spotlighting in other physiographic provinces as well.

Table 2.232 – Paired test comparisons of effort (measured as surveyor-hours) between survey methods in Stillman watershed streams, Washington, 2000-2001

Survey Method	Spotlight Survey Day	Spotlight Survey Night	Rapid Assessment	Rubble Rousing
Spotlight Survey Day		0.9566	**0.0002**	**0.0059**
Spotlight Survey Night	SSD>SSN		**< 0.0001**	***0.0104***
Rapid Assessment	SSD<RA	SSN<RA		**< 0.0001**
Rubble Rousing	SSD<RR	SSN<RR	RA<RR	

Note: For each two-tailed test, probabilities are above the diagonal and directionality of the test result or lack of it are below the diagonal. Experiment-wise error-adjusted α for 6 tests in each group was 0.0085; significant values are emboldened, values approaching significance are emboldened and italicized.

Table 2.233 – Spearman Rank correlation between pairs of survey methods for effort data (measured as surveyor-hours) in Stillman watershed streams, Washington, 2000-2001

Survey Method	Spotlight Survey Day	Spotlight Survey Night	Rapid Assessment	Rubble Rousing
Spotlight Survey Day		**0.0013** n = 14	0.8368 n = 15	***0.0459*** n = 8
Spotlight Survey Night	0.858		0.8197 n = 14	0.2165 n = 7
Rapid Assessment	0.053	0.061		***0.0141*** n = 23
Rubble Rousing	0.755	0.505	0.595	

Note: In each half of the table, probabilities and Spearman rank correlation coefficients for each test are located, respectively, above and below the diagonal. Experiment-wise error-adjusted value of α for 6 tests in each group was 0.0085; significant values are emboldened, values approaching significance are emboldened and italicized.

The data from 2001 not only reconfirm the notion from 2000 data that rapid assessment is better than spotlighting methods in the Stillman Watershed, they suggest that rapid assessment performs better than rubble rousing for species detection of all taxa and may even be superior for assessing relative abundance of most species. One area of ambiguity between rapid assessment and spotlighting methods involves detecting giant salamanders. We expect that part of this confusion arises from the fact that 2 species were collapsed into one for analysis. If the 2 giant salamander taxa respond even slightly differently, a likely condition, the collapsed analysis would not be interpretable. Only genetic information, currently being collected on the two taxa, will allow distinguishing the degree of asymmetry in habitat use and landscape occupancy patterns between these two species. Other data have shown that the coastal giant salamander is better detected by nocturnal surveys (L. Jones, *unpubl. data*); that pattern alone could explain some of the ambiguity between night spotlighting and rapid assessment. Nonetheless, for FFR amphibian species, rapid assessment appears to consistently perform better than spotlighting surveys, although a somewhat larger sample size is needed to make this

analysis robust. Yet, as applied here, spotlighting surveys will always be limited to a subset of streams to which the other methods are applied unless the habitat alteration restriction is removed.

The more interesting result from this analysis is that rapid assessment performed better than rubble rousing. Rubble rousing has long been regarded as the "standard" of in-stream survey methods, so understanding this result in a sampling context is of some importance. The key difference between rapid assessment and rubble rousing in the way we used them relates to their mode of application. Rapid assessment involved searching the entire longitudinal distance of the reach with limited search in the vertical (depth of substrate) dimension, but rubble rousing involved searching a randomly selected subset of a fraction of the longitudinal axis, and searching that subset intensively in the vertical axis (i.e., in our case to a depth of 30 cm). Since stream habitats are patchy, as reflected by amphibians occupying different habitat patches (Welsh *et al.* 1997), sampling randomly selected 1-m patches (i.e., belts) over a relatively small fraction of the longitudinal axis has a high probability of missing patches that different species occupy when compared to searching the full length of the longitudinal axis (as in rapid assessment). The particularly interesting result is that rapid assessment also appears to perform better for assessing relative abundance. A similar argument may explain this difference; randomly sampled 1-m belts have a high probability of missing patches that have high amphibian densities.

Data from all methods were generally positively correlated. However, the strongest relationships (i.e., the significant ones) were between the two spotlighting methods and between rapid assessment and rubble rousing for all taxa with enough data except giant salamanders (see previous discussion regarding the potential species confounds). In contrast, we found no significant correlations between data obtained with either of the two non-manipulative spotlighting methods and that obtained with either of the two manipulative methods. This may indicate that data collected with these two method types is fundamentally different, and thus, not comparable. Tight correlations between rapid assessment and the old standard method, rubble rousing, provides some confidence that these methods return similar measures. Clearly, rapid assessment has a lesser error of omission than spotlight surveys or rubble rousing (at the level at which we applied the latter). Assessment of how much error of omission (not detecting a species when it is *in fact* present) is intrinsic to rapid assessment the way we applied it will require greater effort (e.g., repeated surveys over a short time interval). We have the advantage of knowing all possible FFR species that may be present at the watershed scale, so with satisfactory habitat relationship data, we expect to know the absolute level of error of omission for species detection in most cases at the NP basin scale. Errors in relative abundance data represent a more difficult problem (i.e., not detecting all the individuals actually present), but we expect that greater effort may provide insight into this error. Regardless of what level of error is ultimately identified, effort limitations will impose some known level of Type II error (hopefully small) that will have to be viewed as acceptable using the best method (presumably rapid assessment). However, these data indicate that the error level for spotlight survey methods is too great for FFR use.

As expected, methods fell into their expected rankings of survey effort, with spotlighting being the least costly and rubble rousing being the most costly. However, the difference between application of rubble rousing using 10 1-m belts and rapid assessment was not large. However, we anticipate that increasing the number of belts with rubble rousing to

approach the error of omission levels found with rapid assessment would make the rubble rousing effort even more costly.

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 (see Section 1.2). One important assumption underlies this method:

The distance of stream searched is long enough to ensure a high probability of detecting the species when present.

We consider this assumption to be critical to the use of rapid assessment. Underestimates of the length of stream required to locate a particular species will result in errors of omission (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 error of omission will unnecessarily increase the cost of surveys. As interpretation of an acceptable level of error of omission would almost certainly vary among FFR stakeholders, we selected a mode of evaluation that would show how error of omission varied with effort, providing stakeholders with the potential 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 Pacific tailed frog in northern California. There, search distances required were 500 m for the salamander (Diller and Wallace 1996) and 1000 m for the frog (Diller and Wallace 1999). We needed to determine the appropriate search distances for the Pacific 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 error could be minimized, and (2) determine whether SAA species responses to habitat variation are 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 water for 2001, and the Stillman and Washougal watersheds in 2000 (see Section 2.1). The Stillman watershed streams used in this analysis were part of a larger set that encompassed all the streams used in Research Question A except one, and an additional group of streams randomly selected in the manner described previously.

Rapid Assessment: We sampled streams using a modified rapid assessment method. We included light touch sampling as described in Section 2.1, recording the 1st detection of all target species (for our purposes, all amphibians present), and recording the second and subsequent detections of all amphibian taxa to the end of surface water (including spatially intermittent reaches). Our method differed from the way the original method was applied 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 section-based choice (Diller and Wallace 1996, 1999), and we sampled each stream beyond the

next 30 m after the 1st detection for any particular species. Our intent was that sampling the entire stream would help gauge for errors of omission for those species not detected over the entire stream length. For Stillman watershed Type N reaches, we continued recording the target amphibians until 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 large size of Type N systems in this watershed.

Analyses: We provide descriptive data on numbers of reaches in which each species of amphibian was either found or undetected. As with Research Question A, we pooled giant salamanders because we could not distinguish species for all individuals. Where applicable, results of all non-parametric tests were corrected for tied ranks. Data were analyzed using Statview 5.0 (SAS Institute, Inc.) software.

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 2 x 2 contingency analyses for aspect and stand age; a Chi-square test was used for the 2 x 3 contingency analysis. For streams sampled both years in which a species was detected in only one of the two years, we scored that species as present for analyses involving those streams. We also used contingency analyses to compare FFR amphibian species richness and overall amphibian species richness to the presence of each taxon, using streams as the sample unit. We made the latter analyses orthogonal by reducing the species richness in each comparison by the taxon to which it was being compared.

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 1st-detection distance in 10-m increments on the x-axis. The cumulative percentage of streams sampled in which the species was detected per 10-m distance increments was arrayed on the y-axis. We created distributions only for those species found in ≥ 6 streams in each of the Stillman and Washougal River watersheds. We compared cumulative frequency distributions between strata using Kolmogorov-Smirnov tests (Zar 1996).

We compared cumulative frequency distributions for 1st-detection data among strata. In the few streams for which we had 1st-detection distances in each of 2000 and 2001, we used the longest of the two distances for that stream's stratum representation in different curves. This guaranteed that the minimum distance determined to achieve detection in any stratum for a particular species would be the most conservative (i.e., longest) using this method. We provided a descriptive comparison of the variation in 1st-detection distance for those species in repeatedly sampled streams as too few streams were repeated to enable robust statistical comparison.

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 in 2000 and 2001 for survey distance by dividing number of individuals found by length of stream sampled. For 2001 data, we also were able to calculate densities as stream width was measured on all 10-m segments. We performed these analyses using Stillman data for all species detected in ≥ 10 streams.

Significant indicates statistical significance based on $\alpha = 0.05$, which was conservatively adjusted to address experiment-wise error rates where >1 test was performed. Still, we believe it useful to look at probabilities as a guide to the likely importance of results.

3.2 Results

General Detection Patterns in the Stillman Watershed: *Year 2000*: We conducted rapid assessment on 63 streams (Table 3.201). We detected amphibians and FFR amphibian species, respectively, in 60% (n = 38) and 52% (n = 33) of those streams.

We found 3 FFR amphibians: Columbia torrent salamander, Dunn's salamander, and Pacific tailed frog. Of FFR taxa, Columbia torrent salamanders were most frequently recorded; we found them in nearly half (n = 31) the streams. The other 2 FFR species were each found in < 12% of sampled streams (Table 3.201).

Seven non-FFR amphibian species (Cope's giant salamander, northern red-legged frog, northwestern salamander, coastal giant salamander, Pacific treefrog, rough-skinned newt, and western red-backed salamander)[3] were detected in 46% (n = 29) of sampled streams (Table 3.201). Collective giant salamanders were the most frequently detected non-FFR taxon; giant salamanders were found in exactly 25% (n = 16) of streams (Table 3.201). Western red-backed salamander was the only other species recorded at moderate frequencies; it occurred in 16% (n = 11) of streams. All other non-FFR amphibians were found in < 10% of streams.

Species richness was significantly correlated with the number of 10-m intervals sampled and the numbers of watered 10-m intervals, whether richness of FFR species or all taxa was considered (Table 3.202). Correlations with the watered intervals were equal to or stronger than those addressing all intervals.

Year 2001: We completed rapid assessment in 48 streams (Table 3.201). We detected amphibians and FFR amphibians, respectively, in 65% (n = 31) and 60% (n = 29) of those streams.

As in 2000, we found 3 FFR amphibians: Columbia torrent salamander, Dunn's salamander, and Pacific tailed frog. A 4th FFR species, Van Dyke's salamander, was recorded in 1 stream, but this record could not be verified (see Relative Abundance: FFR species subsection of Section 2.2). As in 2000, the Columbia torrent salamander was the most often recorded species; we found them in 58% (n = 28) of streams. The 2 other FFR amphibians were each found in 23% (n = 11) of sampled streams (Table 3.201).

The same 7 non-FFR target amphibian species found in 2000 were detected in 2001; these 7 species were recorded in 56% (27 of 48) of streams (Table 3.201). As in 2000, giant salamanders was the most frequently detected non-FFR taxon. In 2001, western red-backed salamanders were detected equally frequently; both giant salamanders and red-backed salamanders were found in 40% (n = 19) of streams (Table 3.201). All other non-FFR target amphibians were found in < 8% of streams.

[3] Although we collapsed giant salamanders into one taxon for analysis, a number of individuals of giant salamanders could be confidently identified to species, thus the listing of both species here.

Table 3.201 – Amphibian species detected during rapid assessment of streams in the Stillman watershed, 2000-2001

Stream[1]		Year	10-m Intervals[2]		FFR Species[3]				Other Species[3]							Total Spp
			Total	Watered	ASTR	PLDU	RHKE	TOTAL	AMGR	Disp	PLVE	PSRE	RAAU	TAGR	TOTAL	
1	STL11040205	'00	13	4	ND[4]	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
2	STL11040217	'00	15	0	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
3	STL11040221	'00	38	25	ND	ND	+	1	ND	ND	ND	ND	ND	ND	0	1
4	STL11040303	'00	17	13	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
5	STL11040308	'00	18	3	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
6	STL11040313	'00	120	120	+	ND	+	2	ND	+	+	ND	ND	ND	2	4
7	STL11040405	'00	5	5	ND	+	ND	1	ND	ND	+	ND	ND	ND	1	2
8	STL11040411	'00	2	0	ND	ND	ND	0	ND	ND	ND	+	ND	ND	1	1
9	STL11040517	'00	18	16	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
10	STL11040522	'00	4	4	ND	ND	ND	0	ND	ND	ND	+	ND	ND	1	1
11	STL11040524	'00	6	2	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
12	STL11040803	'00	7	0	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
13	STL11040804	'00	5	0	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
14	STL11040812	'00	3	0	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
15	STL11040814	'00	10	10	ND	ND	+	1	ND	ND	ND	ND	ND	ND	0	1
16	STL11040825	'00	53	3	+	ND	+	2	ND	ND	ND	ND	ND	ND	0	2
17	STL11040901	'00	15	11	+	ND	+	2	ND	+	+	ND	ND	ND	2	4
18	STL11040907	'00	11	0	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
19	STL11040916	'00	33	11	ND	ND	+	1	ND	+	ND	ND	ND	ND	1	2
20	STL11041008	'00	38	18	ND	ND	+	1	ND	+	ND	ND	ND	ND	1	2
21	STL11041010	'00	2	0	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
22	STL11041502	'00	2	0	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
23	STL11041606	'00	5	0	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
24	STL11041712	'00	26	0	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
25	STL11041715	'00	13	0	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
26	STL11041719	'00	95	95	ND	ND	+	1	+	+	ND	ND	ND	+	3	4
27	STL12040708	'00	23	23	ND	ND	+	1	ND	+	ND	ND	ND	ND	1	2
28	STL12040808	'00	3	1	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
29	STL12041708	'00	49	49	ND	+	+	2	ND	+	+	ND	ND	ND	2	4
30	STL12041720	'00	42	42	ND	ND	+	1	ND	+	ND	ND	ND	ND	1	2
31	STL12041731	'00	20	20	ND	ND	+	1	ND	ND	+	ND	ND	ND	1	2
32	STL12041737	'00	10	0	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
33	STL12041738	'00	10	10	ND	ND	ND	0	ND	ND	+	ND	ND	ND	1	1
34	STL12041741	'00	20	20	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
35	STL12041906	'00	14	11	ND	ND	+	1	ND	+	ND	ND	ND	ND	1	2
36	STL12042005	'00	20	13	+	ND	ND	1	ND	+	ND	ND	+	ND	2	3
37	STL12042107	'00	1	1	ND	ND	+	1	ND	ND	ND	ND	ND	ND	0	1
38	STL12042120	'00	49	26	ND	ND	+	1	ND	+	ND	ND	ND	ND	1	2
39	STL12042323	'00	15	7	ND	ND	+	1	ND	ND	+	ND	+	ND	2	3
40	STL12042330	'00	17	4	ND	ND	+	1	ND	ND	+	ND	+	ND	2	3
41	STL12042332	'00	16	14	ND	ND	+	1	ND	ND	ND	ND	ND	ND	0	1
42	STL12042604	'00	26	4	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0

[1] Streams in red were sampled in both years.
[2] Total = all 10-m intervals sampled; Watered = 10-m intervals with significant water.
[3] Species codes correspond to the list in Appendix III.
[4] Data are present (+) or not detected (ND).

Table 3.201 – Amphibian species detected during rapid assessment of streams in the Stillman watershed, 2000-2001 (continued)

Stream[1]		Year	10-m Intervals[2]		FFR SPECIES[3]				OTHER SPECIES[3]							Total Spp
			Total	Watered	ASTR	PLDU	RHKE	TOTAL	AMGR	Disp	PLVE	PSRE	RAAU	TAGR	TOTAL	
43	STL12042712a	'00	5	5	ND	ND	+	1	ND	ND	ND	ND	ND	ND	0	1
44	STL12042712b	'00	5	5	ND	ND	+	1	ND	ND	ND	ND	ND	ND	0	1
45	STL12042903	'00	9	5	ND	ND	+	1	ND	ND	ND	ND	ND	ND	0	1
46	STL12042918	'00	14	13	ND	ND	+	1	+	ND	ND	ND	ND	ND	1	2
47	STL12043006	'00	1	1	ND	ND	ND	0	+	ND	ND	ND	ND	ND	1	1
48	STL12043108	'00	14	14	+	ND	+	2	ND	+	ND	ND	ND	ND	1	3
49	STL12043114	'00	32	7	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
50	STL12043206	'00	6	4	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
51	STL12043223	'00	7	7	ND	ND	+	1	ND	+	ND	ND	ND	ND	1	2
52	STL12043226	'00	45	44	+	+	+	3	ND	+	ND	ND	ND	ND	1	3
53	STL12043308	'00	9	8	ND	ND	+	1	ND	ND	ND	ND	ND	ND	0	1
54	STL12043316	'00	33	6	ND	ND	+	1	+	ND	ND	ND	ND	ND	1	1
55	STL12043322	'00	46	46	ND	ND	+	1	+	ND	ND	+	ND	ND	2	3
56	STL12043403	'00	9	6	ND	ND	ND	0	ND	ND	+	ND	ND	ND	1	1
57	STL12043406	'00	7	0	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
58	STL12043407	'00	68	57	+	+	+	3	ND	+	ND	ND	+	ND	2	5
59	STL12043410	'00	24	10	ND	ND	+	1	ND	ND	+	ND	ND	ND	1	2
60	STL12043417	'00	20	3	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
61	STL12043421	'00	4	4	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
62	STL12043503	'00	72	72	ND	+	+	2	ND	+	ND	+	ND	ND	2	2
63	STL12051203	'00	16	0	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
2000 Totals	Detections (n)[4]				**7**	**5**	**31**		**5**	**16**	**10**	**4**	**4**	**1**		
	% ($^{n}/_{63}$*100)				**11**	**8**	**49**		**8**	**25**	**16**	**6**	**6**	**2**		
1	STL11040218	'01	4	0	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
2	STL11040301	'01	77	77	+	ND	+	2	ND	+	ND	ND	ND	ND	1	3
3	STL11040302	'01	4	2	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
4	STL11040304	'01	56	56	ND	+	+	2	ND	+	ND	ND	ND	ND	1	3
5	STL11040305	'01	4	4	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
6	STL11040306	'01	5	4	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
7	STL11040313	'01	122	122	+	+	+	3	ND	+	+	ND	ND	+	3	6
8	STL11040322	'01	6	6	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
9	STL11040325	'01	31	29	+	ND	+	2	ND	+	+	ND	ND	ND	2	4
10	STL11040501	'01	131	109	+	+	+	3	ND	+	+	ND	ND	ND	2	5
11	STL11040512	'01	26	24	+	+	+	3	ND	+	+	ND	ND	ND	2	5
12	STL11040513	'01	9	8	ND	ND	+	1	ND	ND	ND	ND	ND	ND	0	1
13	STL11040519	'01	15	5	ND	ND	+	1	ND	ND	ND	ND	ND	ND	0	1
14	STL11040602	'01	8	0	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
15	STL11040607	'01	8	0	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
16	STL11040703	'01	6	3	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
17	STL11040707A	'01	4	0	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
18	STL11040707B	'01	1	0	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
19	STL11040709	'01	23	4	+	ND	+	2	+	ND	+	ND	ND	ND	2	4
20	STL11041024	'01	32	18	ND	ND	+	1	ND	+	+	ND	ND	ND	2	3

[1] Streams in red were sampled in both years.
[2] Total = all 10-m intervals sampled; Watered = 10-m intervals with significant water.
[3] Species codes correspond to the list in Appendix III. Data are present (+) or not detected (ND).
[4] Sampled streams (lines in this table) in which species was detected.

Table 3.201 – Amphibian species detected during rapid assessment of streams in the Stillman watershed, 2000-2001 (continued)

Stream[1]		Year	10-m Intervals[2]		FFR Species[3]				Other Species[3]							Total Spp
			Total	Watered	ASTR	PLDU	RHKE	TOTAL	AMGR	Disp	PLVE	PSRE	RAAU	TAGR	TOTAL	
21	STL11041703	'01	35	27	+	ND	+	2	ND	+	ND	ND	ND	ND	1	3
22	STL11041713A	'01	15	15	+	ND	+	2	ND	ND	ND	ND	ND	ND	0	2
23	STL11041713B	'01	20	2	ND	ND	+	1	ND	+	ND	ND	ND	ND	1	2
24	STL11041716	'01	4	0	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
25	STL12040710	'01	31	26	ND	+	+	2	ND	+	ND	ND	+	ND	2	4
26	STL12041707	'01	20	12	ND	ND	+	1	ND	ND	+	ND	ND	ND	1	2
27	STL12041708	'01	49	49	ND	ND	+	1	ND	ND	+	ND	ND	ND	1	2
28	STL12041721	'01	23	14	ND	+	ND	1	ND	ND	+	ND	ND	ND	1	2
29	STL12041741	'01	17	3	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
30	STL12041816	'01	13	11	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
31	STL12041904	'01	22	4	ND	ND	ND	0	ND	ND	+	ND	ND	ND	1	1
32	STL12041905	'01	18	10	+	ND	+	2	ND	+	+	ND	ND	ND	2	4
33	STL12041906	'01	12	9	ND	ND	+	1	ND	+	+	ND	ND	ND	2	3
34	STL12041909	'01	11	11	ND	ND	+	1	ND	+	ND	ND	ND	ND	1	2
35	STL12041912	'01	12	4	ND	ND	+	1	ND	ND	ND	ND	ND	ND	0	1
36	STL12042013	'01	2	0	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
37	STL12042109	'01	74	24	ND	+	+	2	ND	+	+	ND	+	+	4	6
38	STL12042120	'01	31	25	+	ND	+	2	ND	+	+	ND	ND	ND	2	4
39	STL12042121	'01	52	20	ND	+	+	2	+	+	ND	ND	ND	ND	2	4
40	STL12042213	'01	12	11	ND	+	+	2	ND	+	+	+	ND	ND	3	5
41	STL12042214	'01	26	22	ND	ND	+	1	ND	ND	+	ND	ND	ND	1	2
42	STL12042331	'01	4	3	ND	ND	ND	0	ND	ND	ND	+	+	ND	2	2
43	STL12043225	'01	26	21	ND	+	+	2	ND	ND	+	ND	ND	ND	1	3
44	STL12043226	'01	50	50	+	+	+	3	ND	+	+	ND	ND	+	3	6
45	STL12043403	'01	11	6	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
46	STL12043501	'01	62	62	ND	ND	+	1	ND	+	+	ND	ND	ND	2	3
47	STL12043504	'01	2	0	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
48	STL12043508	'01	3	0	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
2001 Totals	Detections (n)[4]				**11**	**11**	**28**		**2**	**19**	**19**	**2**	**3**	**3**		
	% ($^{n}/_{48}$*100)				**23**	**23**	**58**		**4**	**40**	**40**	**4**	**6**	**6**		

[1] Streams in red were sampled in both years.
[2] Total = all 10-m intervals sampled; Watered = 10-m intervals with significant water.
[3] Species codes correspond to the list in Appendix III. Data are present (+) or not detected (ND).
[4] Sampled streams (lines in this table) in which species was detected.

As for the year 2000, species richness was significantly correlated with numbers of 10-m intervals sampled and watered 10-m intervals, whether richness of FFR species or all taxa was considered (Table 3.202). Correlations involving the watered 10-m intervals were generally stronger than those with all 10-m intervals, except when considering 2001 alone.

We found no statistically significant associations between aspect categories (north and south) and the presence of any amphibian species (Table 3.203). All species except for the Pacific treefrog (*Pseudacris regilla*) and northern red-legged frog (*Rana aurora aurora*), two stillwater-breeding taxa infrequently detected, had slightly greater numbers of detections in north-facing streams.

Table 3.202 – Spearman Rank correlations between FFR and total amphibian species richness in Stillman watershed streams, Washington, 2000-2001

Species Richness	Time Interval	10-m Interval Categories					
		All 10-m Intervals			Watered 10-m Intervals		
		rho (ρ)	z-value	p[1]	rho (ρ)	z-value	p
FFR Species	2000	0.523	4.119	**< 0.0001**	0.707	5.570	**< 0.0001**
	2001	0.814	5.583	**< 0.0001**	0.820	5.620	**< 0.0001**
	2000-2001	0.674	7.070	**< 0.0001**	0.767	8.049	**< 0.0001**
All Species	2000	0.491	3.862	**0.0001**	0.724	5.700	**< 0.0001**
	2001	0.818	5.608	**< 0.0001**	0.799	5.479	**< 0.0001**
	2000-2001	0.660	6.927	**< 0.0001**	0.772	8.094	**< 0.0001**

[1] Significant probabilities are emboldened; the rejection criterion α was conservatively adjusted for 12 comparisons to 0.0043.

Table 3.203 – Relationship between north and south aspects and amphibian species presence in the Stillman watershed, Washington, 2000-2001

Group	Species[1]	Aspect	Sample Characteristics				Fisher's Exact Test Probability
			n	Present	Not Present	% Present	
FFR	ASTR	North	54	10	44	19	0.4222
		South	50	6	44	12	
	PLDU	North	54	10	44	19	0.2701
		South	50	5	45	10	
	RHKE	North	54	31	23	57	0.3262
		South	50	23	27	46	
Non-FFR	AMGR	North	54	5	49	9	0.4393
		South	50	2	48	4	
	DISP	North	54	18	36	33	0.5206
		South	50	13	37	26	
	PLVE	North	54	16	38	30	0.5024
		South	50	11	39	22	
	PSRE	North	54	2	52	4	0.4243
		South	50	4	46	8	
	RAAU	North	54	3	51	6	0.7082
		South	50	4	46	8	
	TAGR	North	54	2	52	4	> 0.9999
		South	50	2	48	4	

[1] Species codes are listed in Appendix III.

No statistically significant associations between the 300-m elevation categories and the presence of any amphibian species were found (Table 3.204), but 3 species approached significance: Dunn's salamander, western red-backed salamander, and northern red-legged frog. Dunn's salamander and northern red-legged frog were not recorded in the highest (601-900 m) elevation stratum, and western red-backed salamander was recorded

there but once.

We found one significant association between managed stand age (scored as younger [16-38 years] versus older [39-60 years] stands) and the occurrence of any amphibian species (Table 3.205). Giant salamanders were observed significantly more often in streams

Table 3.204 – Relationship between 300-m elevation categories and amphibian species presence in the Stillman watershed, Washington, 2000-2001

Group	Species[1]	Elevation (m)	Sample Characteristics				Chi-square	
			n	Present	Not Present	% Present	χ^2	p[1]
FFR	ASTR	0-300	31	2	29	6	2.78	0.2488
		301-600	49	9	40	18		
		601-900	24	5	19	21		
	PLDU	0-300	31	7	24	23	5.86	***0.0534***
		301-600	49	8	41	16		
		601-900	24	0	24	0		
	RHKE	0-300	31	16	15	52	3.04	0.2192
		301-600	49	29	20	59		
		601-900	24	9	15	38		
Non-FFR	AMGR	0-300	31	0	31	0	3.67	0.1596
		301-600	49	4	45	8		
		601-900	24	3	21	13		
	DISP	0-300	31	10	21	32	1.20	0.5481
		301-600	49	16	33	33		
		601-900	24	5	19	21		
	PLVE	0-300	31	10	21	32	7.71	***0.0212***
		301-600	49	16	33	33		
		601-900	24	1	23	4		
	PSRE	0-300	31	2	29	6	2.01	0.3656
		301-600	49	4	45	8		
		601-900	24	0	24	0		
	RAAU	0-300	31	5	26	16	6.64	***0.0361***
		301-600	49	2	47	4		
		601-900	24	0	24	0		
	TAGR	0-300	31	2	29	6	1.01	0.6042
		301-600	49	1	48	2		
		601-900	24	1	23	4		

[1] Species codes are listed in Appendix III.
[2] Probabilities approaching significance are emboldened and italicized; the rejection criterion α was conservatively adjusted to 0.0057 for 9 tests.

associated with younger stands than in streams associated with older stands. Further, the greater frequency with which Dunn's, Columbia torrent, and western red-backed salamanders appeared in younger stands approached significance (Table 3.205), and all taxa except for northwestern salamanders and northern red-legged frogs (both of which we found in very low numbers) were found with greater frequency in streams associated with younger stands.

We found a significant relationship between giant salamander and western red-backed salamander and FFR amphibian species richness (Table 3.206). Giant salamanders and western red-backed salamander presence was disproportionately associated with streams containing 2-3 FFR amphibian species. The relationship between FFR amphibian species richness and each of the Pacific tailed frog, Dunn's salamander, and Columbia torrent salamander presence approached significance (Table 3.206). Rough-skinned newt also showed the latter pattern, but its sample size was only 4. For these same 6 taxa, we found a significant relationship between overall amphibian species richness and the presence of each taxon (Table 3.206).

Table 3.205 – Relationship between younger and older stands and amphibian species presence in the Stillman watershed, Washington, 2000-2001

Group	Species[1]	Stand Age[2]	Sample Characteristics				Fisher's Exact Test Probability
			n	Present	Not Present	% Present	
FFR	ASTR	Younger	19	4	15	21	0.4854[3]
		Older	85	12	73	14	
	PLDU	Younger	19	6	13	32	***0.0294***
		Older	85	9	76	11	
	RHKE	Younger	19	14	5	57	***0.0438***
		Older	85	40	45	46	
Non-FFR	AMGR	Younger	19	1	18	5	> 0.9999
		Older	85	6	79	7	
	DISP	Younger	19	12	7	63	**0.0014**
		Older	85	19	66	22	
	PLVE	Younger	19	8	11	42	***0.0884***
		Older	85	19	66	22	
	PSRE	Younger	19	2	17	11	0.3010
		Older	85	4	81	5	
	RAAU	Younger	19	1	18	5	> 0.9999
		Older	85	6	79	7	
	TAGR	Younger	19	2	17	12	0.1515
		Older	85	2	83	2	

[1] Species codes are listed in Appendix III.
[2] Younger stands (16-38 years old); older stands (39-60 years old).
[3] Significant probabilities are emboldened, those approaching significance are emboldened and italicized; the rejection criterion α was conservatively adjusted to 0.0057 for 9 tests.

General Detection Patterns in the Washougal River Watershed: In 2000, we sampled 11 streams in the Washougal River watershed (Table 3.207). We detected amphibians in 73% (n = 8) of sampled streams. The only FFR amphibian species found was Cascades torrent salamander, which was detected in only 18% (n = 2) sampled streams. The only taxon observed with any frequency was giant salamanders, which was detected in 64% (n = 7) of the streams (Table 3.203). Species richness of the Washougal watershed was lower than in Stillman Basin. Pacific tailed frog was notably absent from this dataset.

Table 3.206 – Relationship between amphibian species richness and presence of various amphibian taxa in the Stillman watershed, Washington, 2000-2001

Species	Status	FFR Amphibian Species Richness			Fisher' Exact Test Result[1]	Overall Amphibian Species Detected			Fisher' Exact Test Result
		Low (0-1)	High (2)	% High		Low (0-2)	High (3-6)	% High	
Astr		n = 91	n = 13			n = 79	N = 25		
	Present	11	5	31	***0.0277***	6	10	63	**0.0004**
	Not Detected	80	8	9		73	15	17	
Pldu		n = 89	n = 15			n = 77	N = 27		
	Present	10	5	33	***0.0397***	4	11	73	**< 0.0001**
	Not Detected	79	10	11		73	16	18	
Rhke		n = 99	n = 5			n = 86	N = 18		
	Present	49	5	9	***0.0574***	37	17	31	**< 0.0001**
	Not Detected	50	0	0		49	1	2	
Amgr		n = 81	n = 23			n = 76	N = 28		
	Present	5	2	28	0.6486	4	3	43	0.3831
	Not Detected	76	21	22		72	25	26	
Disp		n = 81	n = 23			n = 83	N = 21		
	Present	12	19	61	**<0.0001**	15	16	52	**< 0.0001**
	Not Detected	69	4	5		68	5	7	
Plve		n = 81	n = 23			n = 81	N = 23		
	Present	14	13	48	**0.0004**	15	12	44	**0.0024**
	Not Detected	67	10	13		66	11	14	
Psre		n = 81	n = 23			n = 76	N = 28		
	Present	4	2	33	0.6116	4	2	33	0.6591
	Not Detected	77	21	21		72	26	27	
Raau		n = 81	n = 23			n = 78	N = 26		
	Present	4	3	43	0.1798	4	3	43	0.3627
	Not Detected	77	20	21		74	23	24	
Tagr		n = 81	n = 23			n = 78	N = 26		
	Present	1	3	75	***0.0331***	0	4	100	**0.0052**
	Not Detected	80	20	20		75	23	24	

[1] Significant probabilities are emboldened, those approaching significance are bold-italicized; the rejection criterion α was conservatively adjusted to 0.0057 for 9 tests.

Amphibian species richness was significantly correlated with the total number of 10-m intervals and the number of watered 10-m intervals (Spearman rank correlation: total intervals: $\rho = 0.819$, $z = 2.590$, $p = 0.0096$; watered intervals: $\rho = 0.819$, $z = 2.590$, $p = 0.0142$). Too few FFR species detections existed to address the FFR species richness relationship to sampled stratum categories.

Distance to 1st Detection Analyses: FFR SPECIES: *Columbia torrent salamander*: Cumulative 1st-detection curves for the Columbia torrent salamander in Stillman watershed streams were not significantly different between the years 2000 and 2001 (Figure 3.201; Kolmogorov-Smirnov test: df = 2, maximum difference = 0.241, $\chi^2 = 3.379$, $p = 0.3692$). The survey distance to achieve either the 90% or 100% detection levels differed by ≤ 10 m in each year (for the 90% level: 118 m in 2000, 120 m in 2001;

for the 100% level: 260 m in 2000, 270 m in 2001; Figure 3.201). However, the survey distance required to achieve 80% detection nearly doubled: 48 m in 2000, 92 m in 2001.

Pacific tailed frog: Unlike the Columbia torrent salamanders, cumulative 1st-detection curves for the Pacific tailed frog in Stillman watershed streams differed significantly between years 2000 and 2001 (Figure 3.202; Kolmogorov-Smirnov test: df = 2, maximum difference = 0.474, $\chi^2 = 25.579$, $p < 0.0001$). Like the Columbia torrent

Table 3.207 – Amphibian species detected by rapid assessment in streams in the Washougal watershed, Washington, 2000

Stream		10-m Intervals[1]		FFR SPECIES[2]				OTHER SPECIES[2]							Total Spp
		Total	Watered	ASTR	PLVA	RHCA	TOTAL	AMGR	DISP	PLVE	PSRE	RAAU	TAGR	TOTAL	
1	WAS02050127	18	18	ND	ND	ND	0	ND	+	ND	ND	ND	ND	1	1
2	WAS02050430	21	5	ND	ND	+	1	ND	0	ND	ND	ND	ND	0	1
3	WAS02050431	36	36	ND	ND	ND	0	ND	+	ND	ND	ND	ND	1	1
4	WAS02050506	15	14	ND	ND	ND	0	ND	+	ND	ND	ND	ND	1	1
5	WAS02050518	12	12	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
6	WAS02050525	78	76	ND	ND	+	1	ND	+	ND	ND	ND	ND	1	2
7	WAS02050529	44	38	ND	ND	ND	0	ND	+	ND	ND	+	ND	1	2
8	WAS02050617	2	2	ND	ND	ND	0	ND	ND	ND	ND	ND	ND	0	0
9	WAS02051040	51	51	ND	ND	ND	0	ND	+	ND	ND	ND	ND	1	1
10	WAS03052607	9	9	ND	ND	ND	0	ND	+	ND	ND	ND	ND	1	1
11	WAS02053229	3	2	ND	ND	ND	0	ND	0	ND	ND	ND	ND	0	0
Detection (n)				0	0	2	3	0	7	0	0	1	0	6	9
% ($^n/_{11}$*100)				0	0	18		0	64	0	0	9	0		

[1] Total = all 10-m intervals sampled; Watered = 10-m intervals with significant water.
[2] Species codes correspond to the list in Appendix III.

Figure 3.201 - Cumulative distribution of 1st-detection distances for the Columbia torrent salamander (*Rhyacotriton kezeri*) in Stillman watershed headwater streams, Washington, 2000-2001

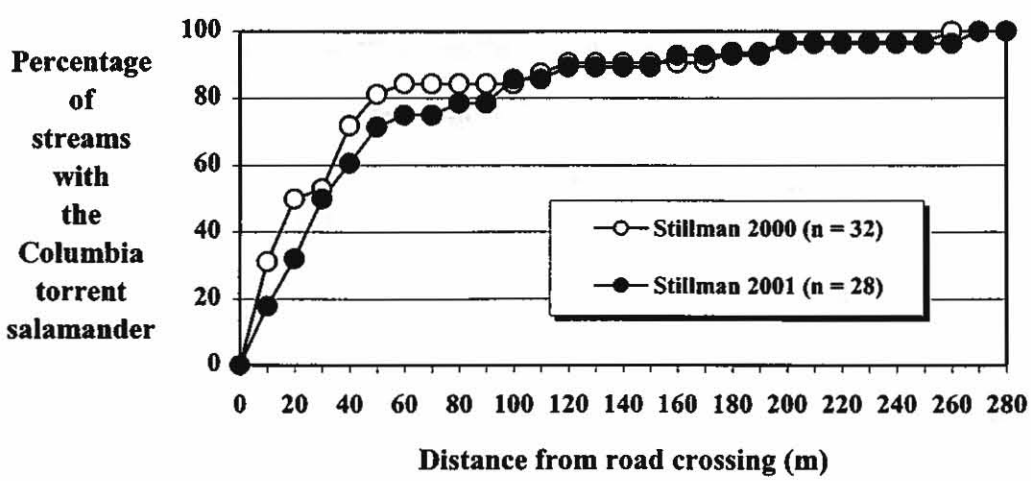
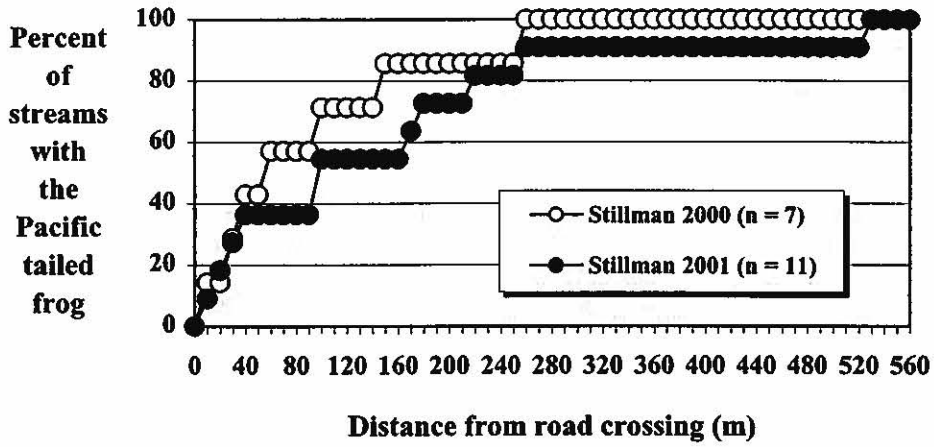


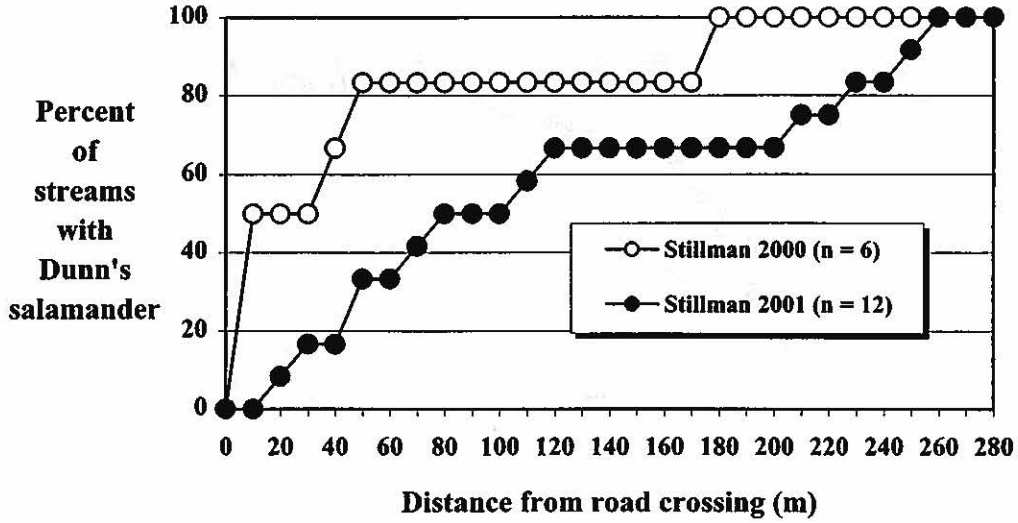
Figure 3.202 - Cumulative distribution of 1st-detection distances for the Pacific tailed frog (*Ascaphus truei*) in Stillman watershed headwater streams, Washington, 2000-2001



salamander, the distance needed to achieve 100% detection was 260 m in 2000, but the same distance more than doubled to 530 m in 2001. However, the distance required to achieve a 90% detection level saw a change of only 7 m between 2000 and 2001 (253 m in 2000; 260 m in 2001); yet, the distance needed to achieve 80% detection increased 71 m between 2000 and 2001 (147 m in 2000; 218 m in 2001; Figure 3.202).

Dunn's salamander: Cumulative 1st-detection curves for the Dunn's salamander in Stillman watershed streams were significantly different between years 2000 and 2001 (Figure 3.203; Kolmogorov-Smirnov test: df = 2, maximum difference = 0.621, $\chi^2 = 22.345, p < 0.0001$). The distance required to achieve the 80%, 90%, and 100%

Figure 3.203 - Cumulative distribution of 1st-detection distances for Dunn's salamander (*Plethodon dunni*) in Stillman watershed headwater streams, Washington, 2000-2001



detection levels all increased substantially between 2000 and 2001. In particular, distance needed to achieve a 100% detection level increased 80 m from 180 m in 2000 to 260 m in 2001; distance needed to achieve a 90% detection level in 2000 was 173 m, but 248 m in 2001; and the distance need to achieve an 80% detection level in 2000 was only 48 m, but 227 m in 2001 (Figure 3.203).

NON-FFR AMPHIBIANS: *Giant salamanders*: Cumulative 1st-detection curves for giant salamander were significantly different between watersheds, but not significantly different between 2000 and 2001 in the Stillman watershed (Figure 3.204; Table 3.205). The distance required to achieve the 100% detection level differed by only 10 m between 2000 and 2001 in the Stillman watershed (320 m in 2000; 310 in 2001), but differed by ≥ 230 m between either of the two years for the Stillman watershed and the Washougal watershed in 2000 (only 90 m in the Washougal watershed in 2000). However, distance needed to achieve 90% detection differed substantially among all categories: 84 m for

Figure 3.204 - Cumulative distribution of 1st-detection distances for giant salamanders (*Dicamptodon* sp.) in headwater streams of the Stillman and Washougal watersheds, Washington, 2000-2001

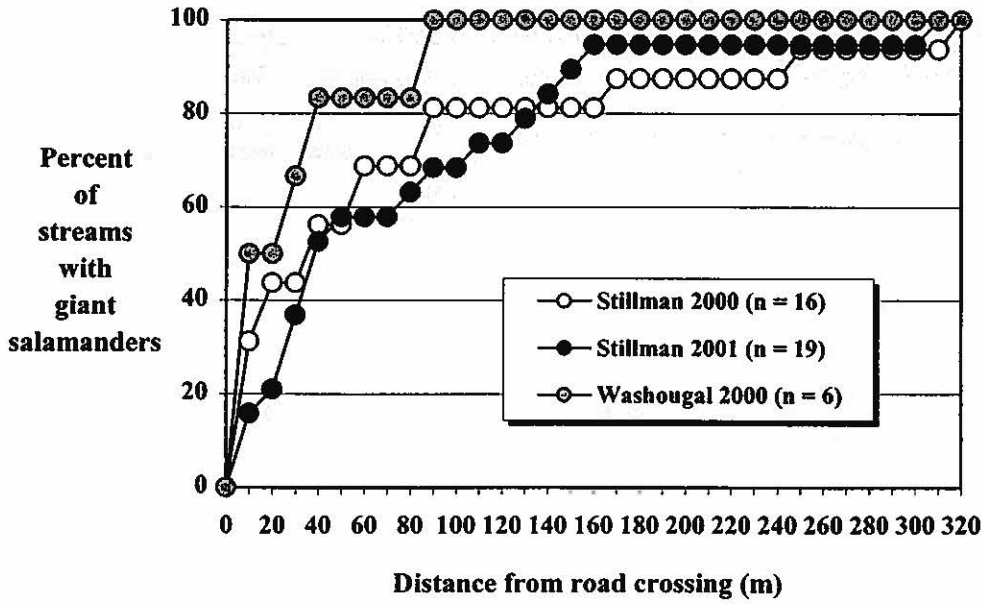


Table 3.205 – Comparison of cumulative 1st-detection distances as determined by rapid assessment for giant salamanders (*Dicamptodon* sp.) in the Stillman and Washougal watersheds, Washington, 2000-2001

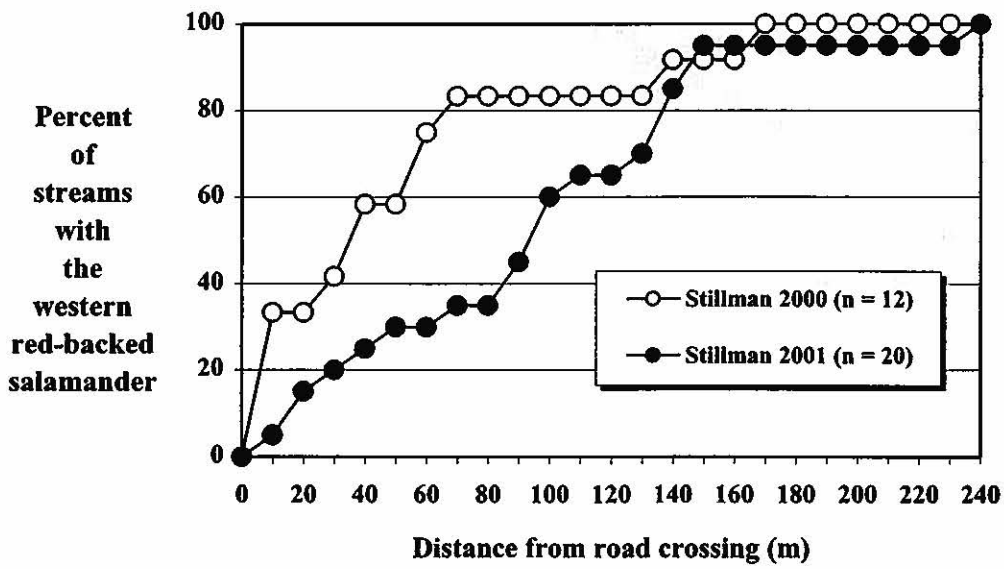
Contrasts		Kolmogorov-Smirnov Test Statistics		
		Maximum difference	χ^2	p[1]
Stillman 2000	Washougal 2000	0.697	32.061	**< 0.0001**
Stillman 2000	Stillman 2001	0.242	3.879	0.2876
Stillman 2001	Washougal 2000	0.697	32.061	**< 0.0001**

[1] Significant probabilities are emboldened; the rejection criterion α was conservatively adjusted to 0.0170 based on 3 contrast pairs.

Washougal in 2000; and 246 m for Stillman in 2000, but dropped to 150 m for Stillman in 2001 (Figure 3.204). Similarly, the distances to attain an 80% detection level differed substantially among categories: 38 m for Washougal in 2000, 89 m for Stillman in 2000, and an increase to 133 m for Stillman in 2001 (Figure 3.205). Overall, distance needed to achieve 100% detection in the Washougal watershed was about one-third that required to achieve 100% detection in the Stillman watershed.

Western red-backed salamander: Cumulative 1st-detection curves for western red-backed salamander were not significantly different between 2000 and 2001 in the Stillman watershed (Figure 3.206; Kolmogorov-Smirnov test: df = 2, maximum difference = 0.320, $\chi^2 = 5.120$, $p = 0.1546$), although we observed an increase in distance to achieve high detection levels between 2000 and 2001. The distance required to achieve the 100% detection level increased 70 m (170 m in 2000; 240 m in 2001). To reach 90% detection, the distance increased 6 m over the same period (138 m in 2000; 144 m in 2001), and to reach an 80% detection level, the distance increased 60 m (77 m in 2000; 137 m in 2001).

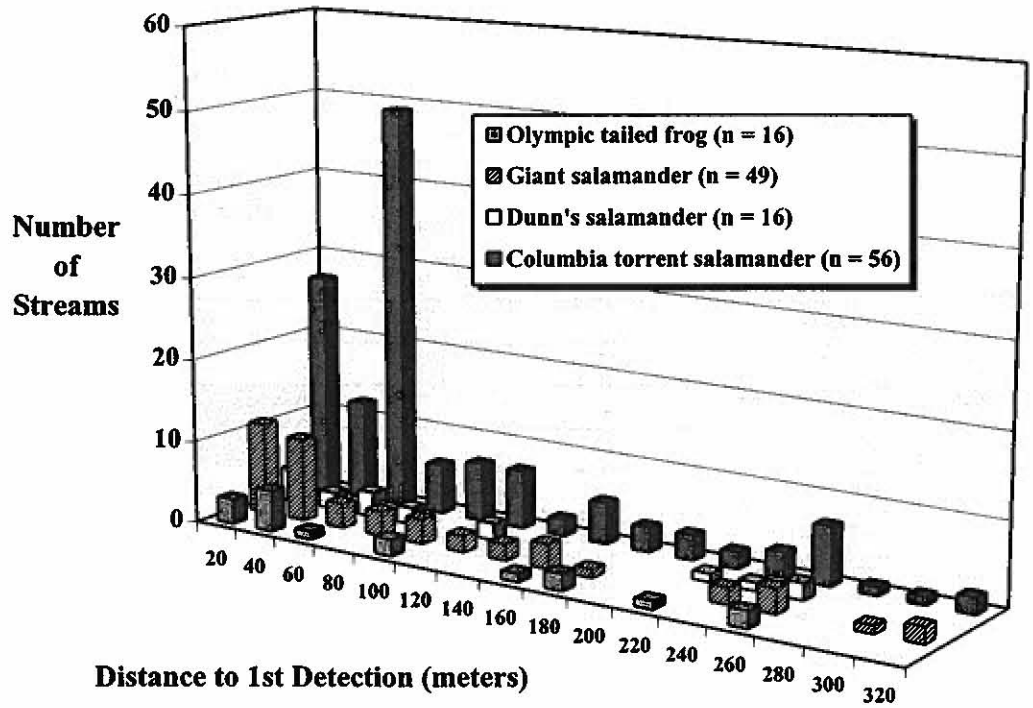
Figure 3.205 - Cumulative distribution of 1st-detection distances for the western red-backed salamander (*Plethodon vehiculum*) in Stillman watershed headwater streams, Washington, 2000-2001



In the Stillman watershed, 80% of 1st-detections of amphibians occurred at distances of ≤ 200 m (Figure 3.206).

No FFR amphibians were detected in large enough numbers in Washougal watershed streams to perform 1st-detection analyses. We found Cascades torrent salamander, the only FFR species detected, in just 2 streams. The 1st-detection distances for this species in these 2 streams were 2 m and 87 m (see Appendix IV). These 1st-detection distances fall within the range of distances we obtained for the Columbia torrent salamander in the Stillman watershed (Appendix IV; see also Figures 3.201 and 3.206), but data were too few to determine whether 1st-detection patterns between these congeners differ.

Figure 3.206 - Distribution of 1st-detection distances for amphibians in the Stillman watershed, Washington, 2000-2001



Resurveyed streams: Five Stillman watershed streams resampled with rapid assessment in 2001 provided data on detection distance changes for 6 amphibian species (Table 3.206). For 5 species where at least one comparison in 1st-detection distance could be made, 1st-detection distance varied between 0 and 171 m.

Columbia torrent salamander had the least variation in distance at 1st-detection (Table 3.206). We detected Columbia torrent salamander in all 5 streams repeated in 2001, and difference in 1st-detection distance averaged 2 m (standard deviation (s) = 12 m, standard error of the mean (se) = 5 m).

Next least variable in 1st-detection distance was the stream-restricted life stages of Pacific tailed frog. In 2001, we detected the stream-restricted life stages of Pacific tailed frog in both streams in which we found them in 2000 (Table 3.206). Difference in 1st-detection distance averaged 24 m (s = 37 m, se = 26 m).

With giant salamanders, we detected them in 4 of 5 streams in both years; in one stream, giant salamanders were detected in only one of the two years (Table 3.206). For the four streams where a difference could be calculated, it averaged -31 m (s = 95 m, se = 48 m). Excluding the 171 m outlier, the average was 15 m (s = 24 m, se = 9 m).

Both Dunn's and western red-backed salamanders were more variable. More than half of the streams (3 for Dunn's and 5 for western red-backed) for each species had detections in only one of the two years. For the one stream where Dunn's was detected in both years, the 1st-detection distance difference was 6 m. For the 2 streams where western red-backed salamanders were detected in both years, the 1st-detection distance difference averaged 6 m (s = 10 m, se = 7 m).

Most variable were the adult stages of Pacific tailed frog and rough-skinned newts, all the examples of which were only detected in one of the two years.

Ten comparisons for different species could not be made because the species was not found in both years on the sampled reach.

Table 3.206 – Comparison of 1st-detection distances for different amphibian species among 5 streams in the Stillman watershed, Washington, 2000-2001

Species		Streams	1st detection distance (m)		Between year difference[1]
			Year 2000	Year 2001	
Pacific tailed frog	adult	STL11040313	34	---	NC
		STL12042120	---	256	NC
	stream restricted[2]	STL11040313	479	529	50
		STL12043226	23	21	-2
Giant salamander		STL11040313	243	72	-171
		STL12041708	8	---	NC
		STL12041906	9	30	21
		STL12042120	34	34	36
		STL12043226	34	23	-11
Dunn's salamander		STL11040313	---	250	NC
		STL12041708	2	---	NC
		STL12043226	43	48	6
Western red-backed salamander		STL11040313	21	34	13
		STL12041708	1	0	-1
		STL12041906	---	11	NC
		STL12042120	---	84	NC
		STL12043226	---	138	NC
Columbia torrent salamander		STL11040313	5	23	18
		STL12041708	1	1	0
		STL12041906	36	36	0
		STL12042120	5	11	6
		STL12043226	25	10	-15
Rough-skinned newt		STL11040313	---	179	NC
		STL12043226	---	131	NC

[1] First detection distance for year 2001 minus that for year 2000; positive numbers in light gray mean the detection distance was greater in 2001; negative numbers in dark gray mean the detection distance was greater in 2000; NC means no comparison possible as the species was detected in only one year in that stream.

[2] Life stages that are stream-restricted: eggs, larvae, and metamorphs.

In stream life stages or species tied to water (e.g., Columbia torrent salamanders) were redetected more consistently. Nonetheless, excluding the outlier of 171 m, all other 1st-detection differences where a comparison was possible regardless of species were ≤ 50 m, and most were ≤ 25 m.

Comparison of 1st-Detection Data to Measures of Relative Abundance: In the Stillman watershed, 1st-detection distances were only poorly inversely correlated with relative abundance measures using density (Table 3.207), and no pattern was significant. Giant salamanders were the taxon that most closely approached significance in the most categories, and Pacific tailed frog approached significance in 2000, but its sample size was small (n = 7). The species with the largest sample sizes in both years, Columbia torrent salamander, showed no significant relationship in any category.

Table 3.207 – Spearman rank correlation comparison of 1st-detection distance with measures of relative abundance in the Stillman watershed, Washington, 2000-2001

Categories Compared		Amphibian Species[1]									
		Astr		Disp		Pldu		Plve		Rhke	
		ρ[2]	p[3]	ρ	p	ρ	p	ρ	p	ρ	p
1st Detection Distance 2000	Next 30 m Density	-0.777	***0.057***	-0.464	***0.072***	-0.103	0.837	-0.246	0.414	-0.087	0.640
	Next X Distance Density[4]	-0.674	***0.099***	-0.477	***0.065***	0.000	>0.999	-0.238	0.430	-0.002	0.991
1st Detection Distance 2001	Next 30 m Density	0.095	0.754	0.104	0.659	0.095	0.754	0.285	0.2149	-0.173	0.3694
	Next X Distance Density[4]	-0.032	0.917	-0.398	***0.092***	-0.011	0.972	0.116	0.6136	-0.189	0.3265

[1] Species codes in Appendix I. The two giant salamanders species are collectively included in Disp.
[2] Spearman rank correlation coefficient (rho).
[3] Probability. Emboldened probabilities are significant; those approaching significance are emboldened and italicized.
[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 measure of relative abundance (Spearman rank correlation: $\rho \leq 0.270$, $p \geq 0.5079$ for both).

Variation in 1st-Detection Distance with Habitat Conditions: FFR Species: *Columbia torrent salamander*: We found no significant difference in the curves for north- versus south-facing streams for the Columbia torrent salamander (Figure 3.207; Kolmogorov-Smirnov test: df = 2, maximum difference = 0.310, $\chi^2 = 5.586$, p = 0.1225). Curves for north and south-facing streams reached the 100% detection level 10 m from one another (north-facing: 260 m; south-facing: 270 m). Yet, differences to reach the 90% detection level were 105 m for south-facing streams, but 175 m on north facing streams. A similar pattern was observed at the 80% detection level; the south-facing curve reached the 80% level at 52 m, and the north-facing curve required twice the distance (100 m).

We found significant differences between Columbia torrent salamander 1st-detection curves among elevation categories (Figure 3.208; Table 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, but the difference between the low and mid elevation category was not significant. The 100% detection level was reached at 200 m in the mid elevation category, and 260 m and 270 m, respectively, in the high and low

elevation categories. The 90% detection level was attained at 100 m in the mid elevation category, 173 m in the low elevation category, and 252 m in the high elevation category. The 80% detection level was reached at 47 m in the mid-elevation category, at 92 m in the high elevation category, and 119 m in the low elevation category.

Figure 3.207 - Cumulative distribution of 1st-detection distances for the Columbia torrent salamander (*Rhyacotriton kezeri*) between aspect categories in Stillman watershed headwater streams, Washington, 2000-2001

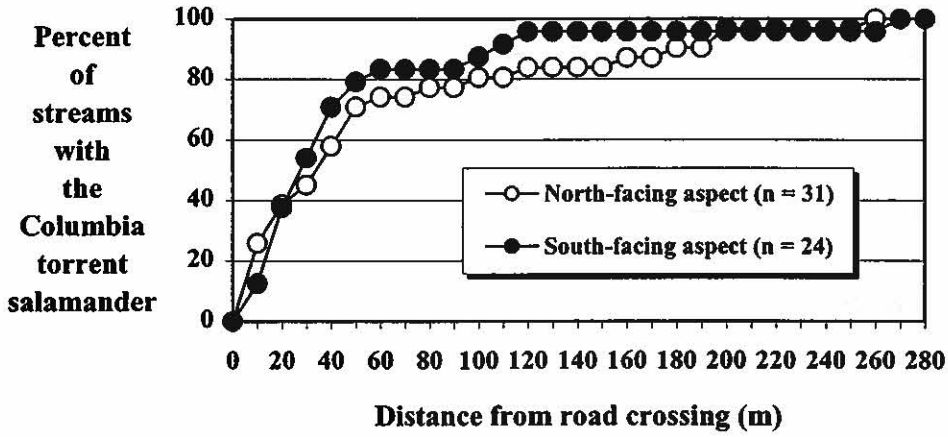
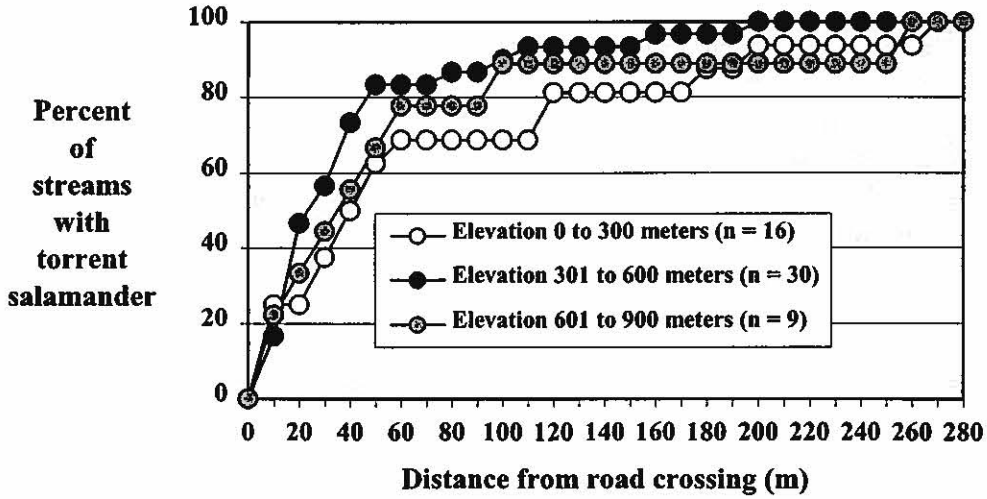


Figure 3.208 - Cumulative distribution of 1st-detection distances for the Columbia torrent salamander (*Rhyacotriton kezeri*) among elevation strata in Stillman watershed headwater streams, Washington, 2000-2001



We found no significant difference in Columbia torrent salamander 1st-detection curves between younger (16-38 years) and older (39-60 years) stands (Figure 3.209; Kolmogorov-Smirnov test: df = 2, maximum difference = 0.241, $\chi^2 = 3.379$, p = 0.3692).

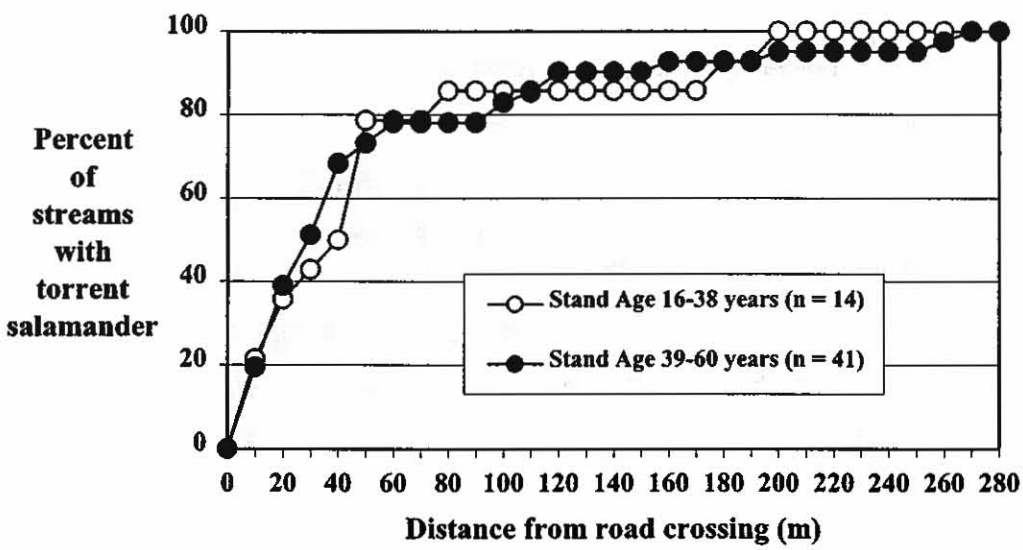
Pacific tailed frog: Too few Pacific tailed frog detections in several strata restricted its stratum analysis to aspect. For aspect, we found a significant difference in the curves for north- and south-facing streams (Figure 3.210; Kolmogorov-Smirnov test: df = 2, maximum difference = 0.614, $\chi^2 = 42.982$, $p < 0.0001$). On south-facing streams, the

Table 3.208 – Comparison of cumulative 1st-detection distances as determined by rapid assessment for the Columbia torrent salamander (*Rhyacotriton kezeri*) between elevation strata in the Stillman watersheds, Washington, 2000-2001

Contrasts		Kolmogorov-Smirnov Test Statistics		
		Maximum difference	χ^2	p[1]
0-300 m	301-600 m	0.448	11.655	**0.0059**
0-300 m	601-900 m	0.345	6.897	0.0636
301-600 m	601-900 m	0.552	17.655	**0.0003**

[1] Significant probabilities are emboldened; the rejection criterion α was conservatively adjusted to 0.0170 based on 3 contrast pairs.

Figure 3.209 - Cumulative distribution of 1st-detection distances for the Columbia torrent salamander (*Rhyacotriton kezeri*) in 2 stand age groups in Stillman watershed headwater streams, Washington, 2000-2001



100% detection level was reached in 180 m, whereas nearly 3 times that distance was required on north-facing streams (i.e., 530 m). The 90% detection level was attained at 174 m on south-facing streams, and 260 m on north-facing ones. The 80% detection level was reached at 148 m for south-facing streams, but 255 m on north-facing ones.

Dunn's salamander: For Dunn's salamander, we found a significant difference in the curves for north- and south-aspect streams (Figure 3.211; Kolmogorov-Smirnov test: df = 2, maximum difference = 0.586, $\chi^2 = 19.931$, $p < 0.0001$). The curve for south-

facing streams reached the 100% detection level in 180 m, whereas that for north- facing streams reached 100% at 260 m. The 90% level was reached at 173 m on south-facing streams and 250 m on north-facing ones. The 80% level was attained at 74 m on south-facing streams and 230 m on north-facing streams.

Dunn's salamander was not detected in the highest elevation category (i.e., 601-900 m; see Table 3.204), so only the low and mid elevation strata were compared. We found no significant difference in the curves for these two elevation strata (Figure 3.212; Kolmogorov-Smirnov test: df = 2, maximum difference = 0.207, $\chi^2 = 2.483$, $p = 0.5780$).

Figure 3.210 - Cumulative distribution of 1st-detection distances for Pacific tailed frog (*Ascaphus truei*) between aspect categories in Stillman watershed headwater streams, Washington, 2000-2001

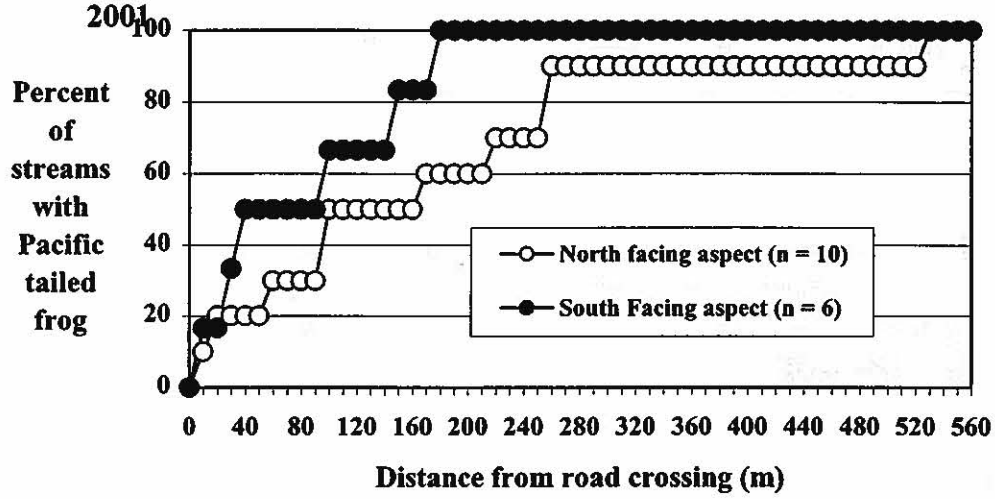
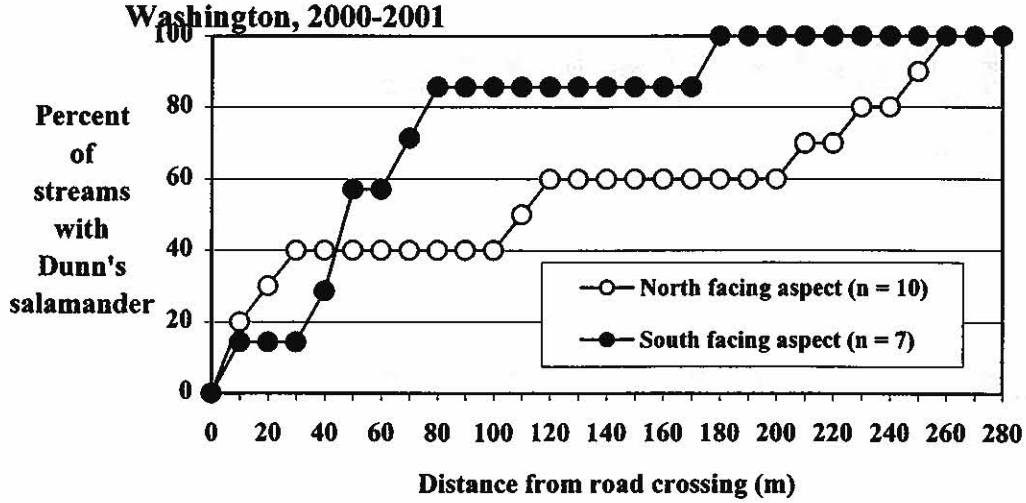


Figure 3.211 - Cumulative distribution of 1st-detection distances for Dunn's salamander (*Plethodon dunni*) between aspect categories in Stillman watershed headwater streams, Washington, 2000-2001



We found a significant difference in the curves for streams in younger versus older stands (Figure 3.213; Kolmogorov-Smirnov test: df = 2, maximum difference = 0.586, $\chi^2 =$

19.931, $p < 0.0001$).

NON-FFR SPECIES: *Giant salamanders*: We found a significant difference in the curves for north- and south-aspect streams (Figure 3.214; Kolmogorov-Smirnov test: df = 2, maximum difference = 0.242, $\chi^2 = 3.879$, $p < 0.0001$). The curve for north and south-facing streams reached the 100% detection level 10 m from each other, 310 m for south-facing streams and 320 m for north-facing streams.

Figure 3.212 - Cumulative distribution of 1st detection distances for Dunn's salamander (*Plethodon dunni*) between elevation strata in Stillman watershed headwater streams, Washington, 2000-2001

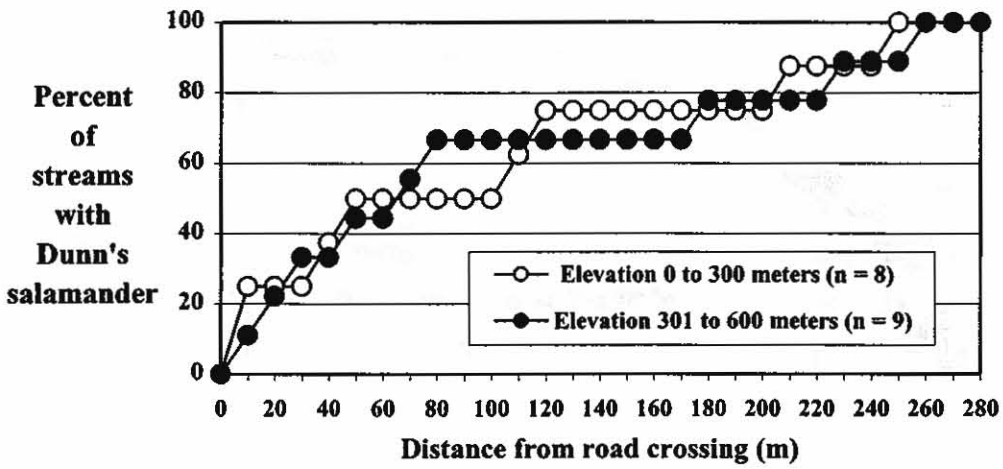
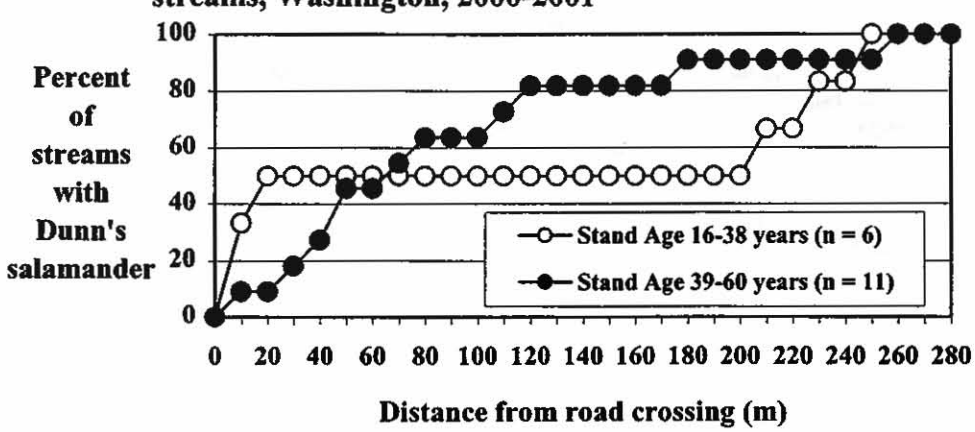


Figure 3.213 - Cumulative distribution of 1st-detection distances for Dunn's salamander (*Plethodon dunni*) in 2 stand age categories in Stillman watershed headwater streams, Washington, 2000-2001



Too few streams with giant salamanders were available for analysis in the uppermost elevation stratum (i.e., 601-900 m; see Table 3.204), so only the low and mid elevation

strata were compared. We found a significant difference in the curves for these two strata (Figure 3.215; Kolmogorov-Smirnov test: df = 2, maximum difference = 0.667, $\chi^2 = 29.333$, $p < 0.0001$).

We also found a significant difference in giant salamanders curves between younger and older managed stands (Figure 3.216; Kolmogorov-Smirnov test: df = 2, maximum difference = 0.485, $\chi^2 = 15.515$, p = 0.0009). Distance for the 100% detection level in older stands was roughly one-third that of younger stands.

Figure 3.214 - Cumulative distribution of 1st detection distances for giant salamander (*Dicamptodon* sp.) in 2 aspects in Stillman watershed headwater streams, Washington, 2000-2001

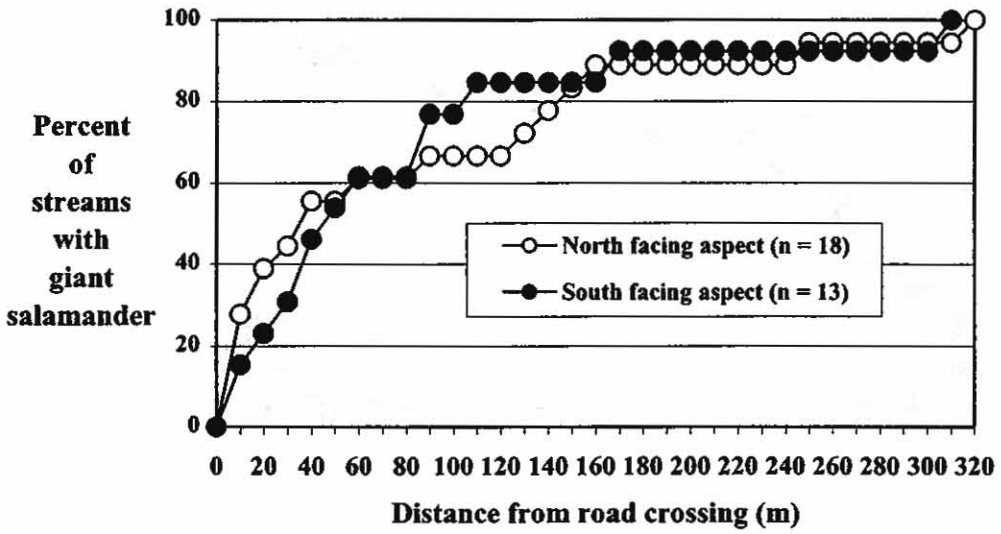
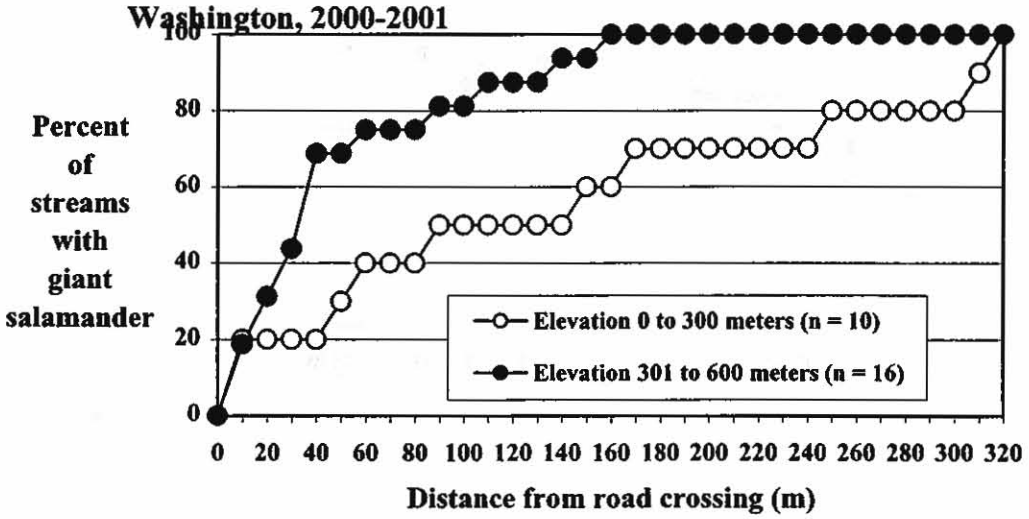


Figure 3.215 - Cumulative distribution of 1st-detection distances for giant salamanders (*Dicamptodon* sp.) in 2 elevation categories in Stillman watershed headwater streams, Washington, 2000-2001



Western red-backed salamander: We found no significant difference in the curves for north- and south-facing streams (Figure 3.217; Kolmogorov-Smirnov test: df = 2, maximum difference = 0.360, $\chi^2 = 6.480$, p = 0.0783).

Too few streams with western red-backed salamanders were available for analysis in the uppermost elevation stratum (i.e., 601-900 m; see Table 3.204), so only the low and mid elevation strata were compared. We found a significant difference in the curves for these two strata (Figure 3.218; Kolmogorov-Smirnov test: df = 2, maximum difference = 0.280, $\chi^2 = 3.920$, $p = 0.2817$).

Figure 3.216 - Cumulative distribution of 1st-detection distances for giant salamanders (*Dicamptodon* sp.) in 2 stand age groups in Stillman watershed headwater streams, Washington, 2000-2001

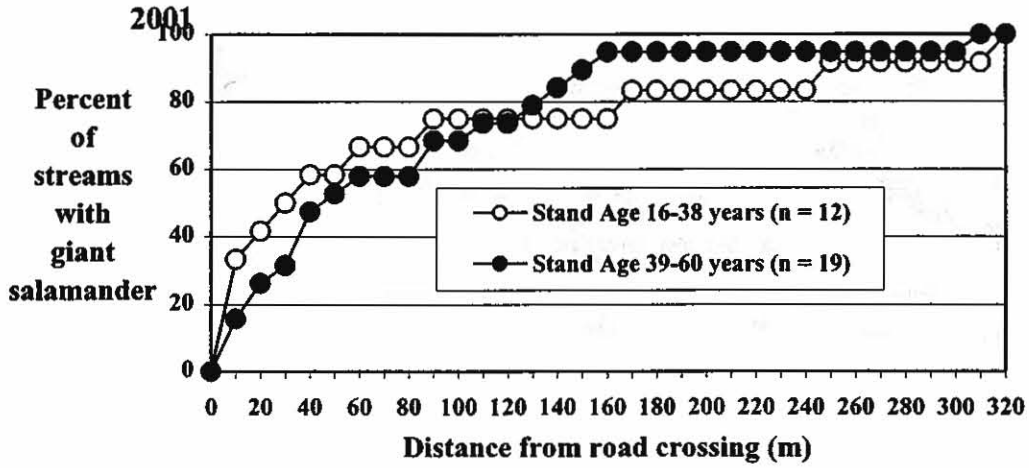
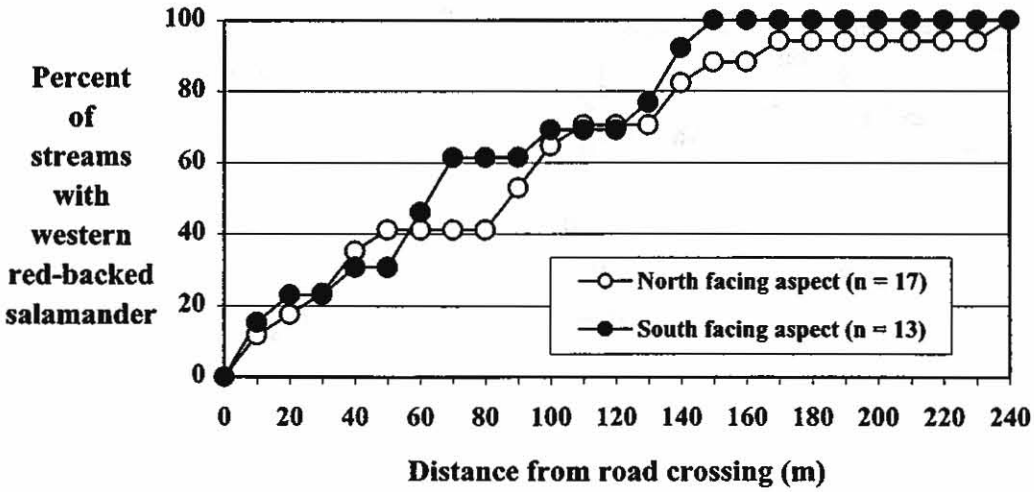


Figure 3.217 - Cumulative distribution of 1st-detection distances for western red-backed salamander (*Plethodon vehiculum*) between 2 aspect categories in Stillman watershed headwater streams, Washington, 2000-2001



We found no significant differences in the curves for the two stand ages for western red-backed salamander; Table 3.219; Kolmogorov-Smirnov test: df = 2, maximum difference = 0.280, $\chi^2 = 3.920$, $p = 0.2817$).

First detection data are provided in Appendix IV.

Figure 3.218 - Cumulative distribution of 1st-detection distances for western red-backed salamander (*Plethodon vehiculum*) in Stillman watershed headwater streams, Washington, 2000-2001

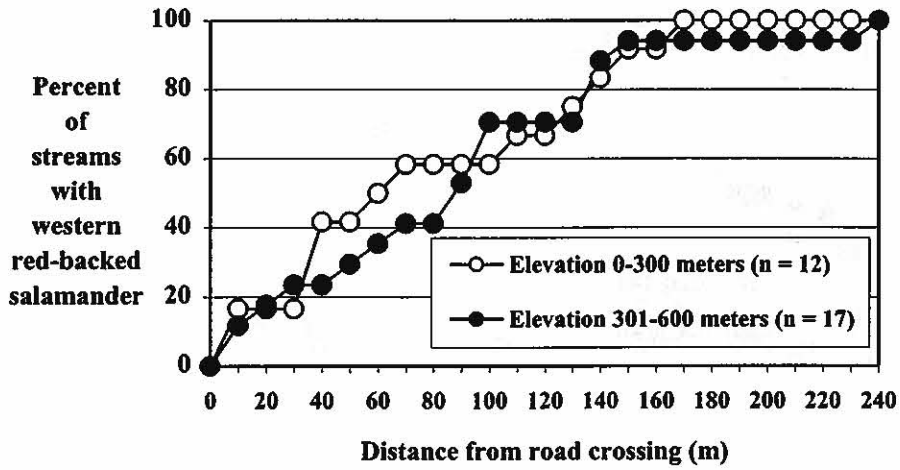
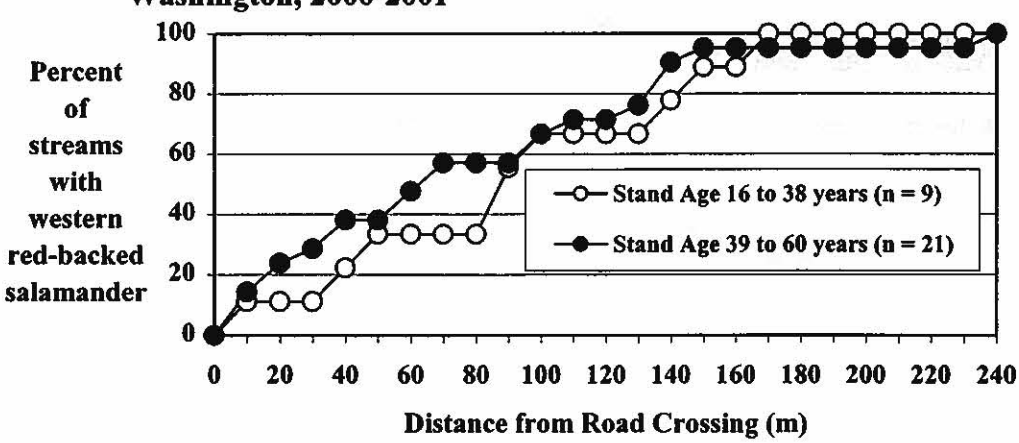


Figure 3.219 - Cumulative distribution of 1st-detection distances for western red-backed salamander (*Plethodon vehiculum*) in 2 stand age groupings Stillman watershed headwater streams, Washington, 2000-2001



3.3 Discussion

Results from 2001 data reinforce the notion from the preliminary study in 2000 that rapid assessment applied 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 that needed for the same or congeneric equivalent taxa in northern California. Notably, detection of all SAAs we observed, except for the in-stream life stages of Pacific tailed frog, reached a high detection level (≥ 80%) at distances ≤ 225 m, and reached a 100% detection level by 270 m. Considering all life stages of Pacific tailed frog, the 100% detection level was reached at 260 m, but that increased to 690 m when considering only instream life stages. Under some circumstances, such as identifying whether reproduction occurred recently, considering only instream life stages may be necessary. Nonetheless, curves for both Pacific tailed frog and Dunn's salamander are based on relatively few data, and additional data would improve confidence in these curves. Curves for Columbia torrent salamander, which are based on large sample sizes, imply that between-year variation in 1st-detection curves may not be significant unless a detection level other than 100% is selected (e.g., see Figure 3.201). Further data will be required to determine whether this holds for other species or in other, more dissimilar years (2000 and 2001 were on the dry side of average and droughty, respectively). Approaching a 100% detection level will be relatively costly for some species, distances needed to reach 100% detection in Washington may still range from < 33% (for Pacific tailed frog all life stages) to 90% (for Columbia torrent salamander) of the cost required to detect the same or congeneric taxa in California.

As conclusions from Research Question A suggest that rapid assessment, applied in the form used here, is more reliable for determining occupancy than other methods, one can choose a desired detection level and express results in a probabilistic fashion. However, the 100% detection level is based on the sample of streams in which a particular species was found. Potential errors of omission (not detecting the species when it is in fact present) for streams where the target species was not found are not addressed. As the data suggest that no known method is more reliable than rapid assessment. However, some kind of search protocol beyond rapid assessment is needed for streams where target taxa were undetected to evaluate errors of omission. Further, it is critical that this additional effort occur immediately after standard rapid assessment is applied in order to minimize temporal detection differences.

The 2001 data reinforce the notion that 1st-detection distance curves will be useful to help identify landscape-level variation among stratified habitat variables. Larger sample sizes and understanding sources of error are needed to have confidence in the stratum variation currently detected, especially for Pacific tailed frog.

The 2001 data also reinforce the pattern of greater amphibian species richness at sites with Pacific tailed frog. Larger sample size will be required to verify this pattern. If the pattern persists with further data, then the Pacific tailed frog might be useful as an indicator for SAA species richness. Whether it indicates a species richness situation for taxa beyond amphibians would need exploration.

The pattern of 1st detection distance being significantly inversely correlated with relative abundance largely disappeared with the addition of 2001 data. We expected an inverse relationship because as abundance declines, the distance required for detection to occur would be expected to increase. The added data generally do not disagree with this idea, but variation in the data prevent making this relationship generally useful as a relative abundance surrogate.

4. Key Findings

These findings remain preliminary.

- Year 2001 data reconfirm the idea that although visual systematic spotlight survey methods are low cost, their application (in the way Jones and Raphael (2001) applied it) is restricted by structure that interferes with visibility (e.g., dense, brushy vegetation). That application of spotlighting methods disallows structural alteration (including moving of surface objects to enhance detection), so that as the complexity of habitat structure increases, these spotlighting approaches will be progressively more ineffective. As a consequence, we expect that their application in the form used here will be limited in those physiographic provinces or forest seral and structural stages where the opportunity for structural complexity is greater (e.g., higher rainfall areas of Washington that promote denser understory growth, managed stands early (3-12 years) in the harvest rotation). At least one additional year of data will be required to make the analysis upon which this interpretation is based statistically robust. We expect that the removal of the restriction regarding structural alteration would reduce the differences observed between spotlighting methods as applied here and rapid assessment.
- Year 2001 data reconfirm the idea that rapid assessment methods perform better than either day or night spotlight surveys for determining presence/non-detection of FFR SAAs in the Coast Range physiographic province. Detection differences appear to be pronounced where target amphibians occur in low numbers. Also, rapid assessment methods perform better than the spotlight surveys for detecting other amphibians with the exception of giant salamanders. At least one more year of data will be needed to make these analyses statistically robust. Interpretation of giant salamander patterns will remain ambiguous until data for the two species can be partitioned.
- One unexpected finding of 2001 was that rapid assessment appears to perform better than rubble rousing surveys for determining presence/non-detection of all amphibians sampled in the Coast Range physiographic province, not just FFR SAAs. At least one more year of data will be required to enable conducting statistically robust analyses. The basis of better performance of rapid assessment is thought to be the lesser effort applied along a longitudinal axis by our mode of rubble rousing; this notion needs to be tested by increasing the rubble rousing effort along a longitudinal axis. This result also would replace rubble rousing with rapid assessment as the standard by which to compare other methods, posing the issue of how to test its error of omission level (not detecting a species when it is in fact present).
- Year 2001 data reconfirm the notion that rapid assessment performs better than spotlight surveys in assessing relative abundance of most amphibians except giant salamanders in the Coast Range physiographic province. At least one more year of data will be required to conduct statistically robust analyses. As with presence/non-presence detection analyses, interpretation of giant salamander relative abundance data will remain ambiguous until the two species can be partitioned.
- The further unexpected finding of 2001 was that rapid assessment seems to perform better than rubble rousing surveys to assess relative abundance of all amphibians in the Coast Range physiographic province. At least 1 more year of data will be needed to conduct statistically robust analyses. As with presence/non-presence data, the basis of better performance of rapid assessment is thought to be the lesser effort

applied along a longitudinal axis by our form of rubble rousing; this notion needs to be tested by increasing the rubble rousing effort along a longitudinal axis.

- Year 2001 analyses, revealing significant correlation between rapid assessment and rubble rousing, imply that these methods are analogous, and provides confidence in rapid assessment. Generally lack of correlation between either method and spotlight surveys suggest that these methods differ fundamentally in what is measured. Significant correlation between the types of spotlighting implies that they are similar measures. One more year of data will be needed to make these analyses statistically robust.
- Rapid assessment distances required to detect torrent salamanders and Pacific tailed frog at high levels (≥ 80%) in the Coast Range physiographic province are much less than distances used to detect these or congeneric taxa in northern California. Thus, application of rapid assessment may be done at a relatively lower cost compared to California. Year 2001 results revealed that rapid assessment can also be applied at a lower cost than rubble rousing.
- Year 2001 data reinforced the idea that streams surveyed using rapid assessment with Pacific tailed frogs have a higher amphibian species richness than streams in which the Pacific tailed frog was not detected. One more year of data will be needed for a robust statistical analysis of this finding.
- Year 2001 data support the notion that 1st-detection distance curves may be useful to detect responses of amphibians to differences in habitat. These data reinforce the notion implied by 2000 data 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. Interpretation of the giant salamander curves must be viewed as ambiguous until the 2 taxa can be partitioned.
- Year 2001 data revealed limited significant variation in 1st-detection distance curves between 2000 and 2001 for individual species, but significant variation in the curves for giant salamanders between physiographic provinces. Interpretation of the giant salamander curves must be viewed as ambiguous until the 2 taxa can be partitioned.
- Year 2001 data resulted in most of the significant relationships between 1st-detection distance and relative abundance of different amphibian species vanishing. One more year of data will be needed for a robust statistically analysis of this finding.

5. Suggested Priorities for Future Research

In order of descending importance:

- Sample sizes need to be increased for most of the analyses performed in this report in order to make them statistically robust. For most analyses addressed here, one more year of data should suffice, but a few will require 2 years. The latter is essential for some FFR species, such as Pacific tailed frog, which apparently occur at low levels over the Coast Range landscape. For Pacific tailed frog, we had to sample between 40 and 50 streams to guarantee detecting them at ≥ 5 streams. Fifty streams is the maximum one can reasonably expect to sample with 5 2-person crews during the low-flow summer season (roughly 2 months).
- A potentially significant portion of the error associated with the 1st-detection distances obtained with rapid assessment method is unknown. We suspect that a

major contribution to variation in 1st-detection distance is the relationship between the point where sampling started and the distance to the stream origin. A standardization of starting points relative to initiation points of water may help limit 1st-detection distance variation. This task is an in-house exercise that re-aligns the analysis based on initiation points of water that we did not address in this report, but should be completed with the larger dataset available following 2002 data collection.

- Estimating errors of omission for rapid assessment is crucial to understanding the validity of this method. Greater effort or repeated effort (over a short time interval to avoid seasonal confounds) on streams where target taxa were not found will be required to help assess this error. This represents a non-trivial task that will require substantially more effort than standard rapid assessment surveys, and will likely require more than one year to complete.
- We should continue to explore why the Pacific tailed frog appears to be correlated with SAA species richness. Its presence may be indicative of habitat quality that benefits various amphibians.

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Appendix I

Water Characterization and Channel Typing Used in Scoping in 2001

Basic water characterization of the stream was indicated per segment. Where this characterization changed, a new segment was begun. Flow beneath organic cover (i.e., logs, trees, stumps, and soil- or vegetation-covered root mats) did not represent a break in characterization class, except for circumstances defined as the "obscured" or "unknown" categories below. As a rule of thumb, the stream was imagined without its organic cover when characterizing its water condition. Nine water characterization classes were defined as:

1) **DRY**: No surface moisture or detectable water.
2) **MOIST**: No surface water visible, substrate moisture detectable, but not saturated.
3) **SATURATED**: No surface water visible, substrate saturated (soil clumps when compressed; water exudes when squeezed with forceful compression)
4) **STANDING POCKET WATER:** Pools of water in which no discernable flow exists separated by < 5 m of "dry" (see above). Any continuous surface water > 10 x 10 cm qualifies as a pocket. This characterization can be no shorter than 0.1 m.
5) **FLOWING POCKET WATER:** Pools of water in which flow is visible in at least some parts of the pool, separated by < 5 m of dry channel. Any unit of continuous surface water > 10 x 10 cm qualifies as a pocket. This characterization can be no shorter than 0.1 m.
6) **STANDING WATER:** Larger pools or areas of standing water (regardless of depth but not saturated ground) > 5 m in length. If dry dust or small pine needles placed anywhere on the surface of the pool move in a downstream direction without the aid of wind, it is flowing, not standing water.
7) **FLOWING WATER:** Any segment of channel upstream of the point of continuous flow that is > 5 m in length where water exposed at surface shows signs of flow.
8) **UNKNOWN:** Areas which could not be accessed (for example, the channel could physically not be walked). This could result from landowner restrictions, current operations (e.g., timber harvest or blasting), steep inaccessible terrain, or other alternatives.
9) **OBSCURED:** Segments > 5 m that could not be characterized because visibility was obscured by slash, debris, or dense vegetation. In cases where you can hear the stream flowing or can see it flowing through breaks in cover, record as a flowing water or flowing pocket water, not obscured. If the stream cannot be heard or seen, characterize as obscured. If the channel does not re-emerge at the end of the obscured segment, end the survey.

Basic channel types of the stream also were characterized per segment. Six water characterization classes were defined as:

1) **DEFINED CHANNEL:** A stream channel defined by sharp incision into the substrate where water and mineral sediment are (or have been) transported in concentrated flows and vegetation and organic detritus is generally absent. Channels form as a result of downslope hydraulic (water-powered) scour into mineral substrate. For purposes of this survey, low flow sections of the streambed must be mostly mineral substrate, comprised of sand, gravel, cobble, boulders, or bedrock. The boundary between the defined channel and surrounding riparian area is clear and usually abrupt. Woody debris or root mats suspended over the stream are not part of the streambed.
2) **INTERMITTENT CHANNEL:** This is a sub-category of **POORLY DEFINED CHANNEL** in which segments of **DEFINED CHANNEL** < 5 m long are interrupted by segments of **NO CHANNEL** or **FINE SEDIMENT CHANNEL** which are also < 5 m long.
3) **FINE SEDIMENT CHANNEL:** This is a sub-category of **POORLY DEFINED CHANNEL** in which a low-flow scour pattern indicates transport of fine sediments only (i.e., sand, soil, mud or silt).
4) **MODIFIED CHANNEL:** All channels in culverts and following road ditch lines are in this category. Other circumstances, such as recent forest practices or dirt-bike activity, that make it difficult to classify natural channel type should be classified as modified channel.
5) **PIPED CHANNEL:** Channels conveying flowing water in a tube(s) or pipe(s) in the soil, or well-defined channels that are covered by debris or canopy litter. Often, no expressed channel is defined at the surface.

Pipes can often be observed through "holes" or "windows" that partially expose the channel. Piping did not included places where water simply disappeared into the substrate. Generally associated with established vegetation (i.e. tree or other roots), small channels covered by canopy litter, macropores in the soil, or lava tubes.

6) **NO CHANNEL (NC):** An area or swale with no observable evidence of scour or erosion that defines its boundary with riparian or upslope areas.

Appendix II

Amphibian Species Known to Occur in the Stillman and Washougal Watersheds, Washington, 2000-2001.

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	Code	Common Name
Anura		**Frogs and Toads**
Ascaphus truei	ASTR	Pacific tailed frog
Bufo boreas	BUBO	Western toad
Pseudacris regilla	PSRE	Pacific treefrog
Rana aurora aurora	RAAU	Northern red-legged frog
Caudata		**Salamanders**
Ambystoma gracile	AMGR	Northwestern salamander
Ambystoma macrodactylum	AMMA	Long-toed salamander
Dicamptodon copei	DICO	Cope's giant salamander
Dicamptodon tenebrosus	DITE	Pacific giant salamander
Ensatina eschscholtzii	ENES	Ensatina
Plethodon dunni[1]	PLDU	Dunn's salamander
Plethodon larselli[2]	PLLA	Larch mountain salamander
Plethodon vandykei[3]	PLVA	Van Dyke's salamander
Plethodon vehiculum	PLVE	Western red-backed salamander
Rhyacotriton cascades[2]	RHCA	Cascades torrent salamander
Rhyacotriton kezeri[1]	RHKE	Columbia torrent salamander
Taricha granulosa	TAGR	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 III

Other Amphibians Recorded During Method Comparison Surveys in the Stillman Watersheds, 2000-2001

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	

Appendix IV

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 VI.

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 IVa
Characteristics of Reaches Sampled in the Stillman Watershed, Washington, 2000

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	
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 IVb

Characteristics of Reaches Sampled in the Washougal River Watershed, Washington, 2000

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 V

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 in 2000; and relative abundance data for Stillman Watershed streams sampled in 2000 and 2001, and Washougal Watershed streams sampled in 2000. The former data are in Appendix Tables Va, Vb, and Vc; and the latter data are in Appendix Tables Vd and Ve. Descriptions of column headings for the former three tables, left to right, are:

I. **Stream Number:** We identified streams with an 8-digit number. Each pair of the 1st 6 digits designated the **Township**, **Range**, and **Section**, respectively. In the Stillman Creek watershed, the other 2 digits indicated a unique road crossing number from the Type N crossing pool within the **Section** numbered from north to south. In the Washougal River Watershed, the remaining 2 digits indicated a unique road crossing within each **Township** block of Longview Fibre ownership. In the Cowlitz Watershed, the remaining 2 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.

Column headers for Appendix Tables Vd and Ve are self-explanatory.

Appendix Table Va

First Detection, Relative Abundance, and Survey Distance Data for the Stillman Watershed, 2000

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 Table Vb

First Detection, Relative Abundance, and Survey Distance Data for the upper Cowlitz Watershed, 2000

Stream Number	First Detection Distance (m)				Tally Next 30 meters				Tally Next X meters				Next X meters Survey Length (m)			
	ASTR	DISP	PLVA	RHCA	ASTR	DISP	PLVA	RHCA	ASTR	DISP	PLVA	RHCA	ASTR	DISP	PLVA	RHCA
09081701	217	51		51	0	2	2	0	0	2		0	100	100		100
10071701	65	45			13	6			37	7			100	100		
11090901	47	155			32	7			32	7			100	100		
12080401	1	140			9	4			23	4			100	100		
14090801	204	89			5	0			5	0			100	100		

Appendix Table Vc

First Detection, Relative Abundance, and Survey Distance Data for the Washougal Watershed, 2000

Stream Number	First Detection Distance (m)				Tally Next 30 meters				Tally Next X meters				Next X meters Survey Length (m)			
	ASTR	DISP	PLVA	RHCA	ASTR	DISP	PLVA	RHCA	ASTR	DISP	PLVA	RHCA	ASTR	DISP	PLVA	RHCA
02050127		5				3				9				100		
02050430				2				5				7				100
02050431		3				2				9				100		
02050506		4				0				0				100		
02050518																
02050525		83		87		9		0		33		6		100		100
02050529		7				3				13				100		
02050617																
02051040		37				1				2				100		
03052607		25				4				13				100		
03053229																

Appendix Table Vd – Individual counts of amphibian species detected during rapid assessment of streams in the Stillman watershed, 2000

Stream[1]		Year	10-m Intervals[2]		FFR SPECIES[3]				OTHER SPECIES[3]							Spp. Total
			Total	Watered	ASTR	PLDU	RHKE	TOTAL	AMGR	Disp	HYRE	PLVE	RAAU	TAGR	TOTAL	
1	STL11040205	'00	13	4	0	0	0	0	0	0	0	0	0	0	0	0
2	STL11040217	'00	15	0	0	0	0	0	0	0	0	0	0	0	0	0
3	STL11040221	'00	38	25	0	0	7	7	0	0	0	0	0	0	0	7
4	STL11040303	'00	17	13	0	0	0	0	0	0	0	0	0	0	0	0
5	STL11040308	'00	18	3	0	0	0	0	0	0	0	0	0	0	0	0
6	STL11040313	'00	120	120	76	0	63	139	0	18	0	5	0	0	23	162
7	STL11040405	'00	5	5	0	1	0	1	0	0	0	1	0	0	1	2
8	STL11040411	'00	2	0	0	0	0	0	0	0	1	0	0	0	1	1
9	STL11040517	'00	18	16	0	0	0	0	0	0	0	0	0	0	0	0
10	STL11040522	'00	4	4	0	0	0	0	0	0	20	0	0	0	20	20
11	STL11040524	'00	6	2	0	0	0	0	0	0	0	0	0	0	0	0
12	STL11040803	'00	7	0	0	0	0	0	0	0	0	0	0	0	0	0
13	STL11040804	'00	5	0	0	0	0	0	0	0	0	0	0	0	0	0
14	STL11040812	'00	3	0	0	0	0	0	0	0	0	0	0	0	0	0
15	STL11040814	'00	10	10	0	0	28	28	0	0	0	0	0	0	0	28
16	STL11040825	'00	53	3	1	0	68	69	0	0	0	0	0	0	0	69
17	STL11040901	'00	15	11	2	0	5	7	0	17	0	1	0	0	18	25
18	STL11040907	'00	11	0	0	0	0	0	0	0	0	0	0	0	0	0
19	STL11040916	'00	33	11	0	0	5	5	0	8	0	0	0	0	8	13
20	STL11041008	'00	38	18	0	0	36	36	0	18	0	0	0	0	18	54
21	STL11041010	'00	2	0	0	0	0	0	0	0	0	0	0	0	0	0
22	STL11041502	'00	2	0	0	0	0	0	0	0	0	0	0	0	0	0
23	STL11041606	'00	5	0	0	0	0	0	0	0	0	0	0	0	0	0
24	STL11041712	'00	26	0	0	0	0	0	0	0	0	0	0	0	0	0
25	STL11041715	'00	13	0	0	0	0	0	0	0	0	0	0	0	0	0
26	STL11041719	'00	95	95	0	0	19	19	76	27	0	0	0	74	177	196
27	STL12040708	'00	23	23	0	0	1	1	0	1	0	0	0	0	1	2
28	STL12040808	'00	3	1	0	0	0	0	0	0	0	0	0	0	0	0
29	STL12041708	'00	49	49	0	4	2	6	0	1	0	3	0	0	4	10
30	STL12041720	'00	42	42	0	0	3	3	0	1	0	0	0	0	1	4
31	STL12041731	'00	20	20	0	0	1	1	0	0	0	1	0	0	1	2
32	STL12041737	'00	10	0	0	0	0	0	0	0	0	0	0	0	0	0
33	STL12041738	'00	10	10	0	0	0	0	0	0	0	1	0	0	1	1
34	STL12041741	'00	20	20	0	0	0	0	0	0	0	0	0	0	0	0
35	STL12041906	'00	14	11	0	0	10	10	0	18	0	0	0	0	18	28
36	STL12042005	'00	20	13	1	0	0	1	0	1	0	0	2	0	3	4
37	STL12042107	'00	1	1	0	0	2	2	0	0	0	0	0	0	0	2
38	STL12042120	'00	49	26	0	0	10	10	0	3	0	0	0	0	3	13
39	STL12042323	'00	15	7	0	0	13	13	0	0	0	1	1	0	2	15
40	STL12042330	'00	17	4	0	0	4	4	0	0	0	2	1	0	3	7
41	STL12042332	'00	16	14	0	0	33	33	0	0	0	0	0	0	0	33
42	STL12042604	'00	26	4	0	0	0	0	0	0	0	0	0	0	0	0
43	STL12042712a	'00	5	5	0	0	19	19	0	0	0	0	0	0	0	19
44	STL12042712b	'00	5	5	0	0	19	19	0	0	0	0	0	0	0	19

[1] Streams in red were sampled in both years.
[2] Total = all 10-m intervals sampled; Watered = 10-m intervals with significant water.
[3] Species codes correspond to the list in Appendix II.

Appendix Table Vd – Individual counts of amphibian species detected during rapid assessment of streams in the Stillman watershed, 2000

Stream[1]		Year	10-m Intervals[2]		FFR SPECIES[3]				OTHER SPECIES[3]							Spp Total
			Total	Watered	ASTR	PLDU	RHKE	TOTAL	AMGR	Disp	HYRE	PLVE	RAAU	TAGR	TOTAL	
45	STL12042903	'00	9	5	0	0	2	2	0	0	0	0	0	0	0	2
46	STL12042918	'00	14	13	0	0	2	2	4	0	0	0	0	0	4	6
47	STL12043006	'00	1	1	0	0	0	0	4	0	0	0	0	0	4	4
48	STL12043108	'00	14	14	10	0	36	46	0	1	0	0	0	0	2	48
49	STL12043114	'00	32	7	0	0	0	0	0	0	0	0	0	0	0	0
50	STL12043206	'00	6	4	0	0	0	0	0	0	0	0	0	0	0	0
51	STL12043223	'00	7	7	0	0	6	6	0	1	0	0	0	0	1	7
52	STL12043226	'00	45	44	2	5	229	236	0	15	0	0	0	0	15	251
53	STL12043308	'00	9	8	0	0	5	5	0	0	0	0	0	0	0	5
54	STL12043316	'00	33	6	0	0	6	6	1	0	0	0	0	0	1	7
55	STL12043322	'00	46	46	0	0	2	2	55	0	29	0	0	0	84	86
56	STL12043403	'00	9	6	0	0	0	0	0	0	0	1	0	0	1	1
57	STL12043406	'00	7	0	0	0	0	0	0	0	0	0	0	0	0	0
58	STL12043407	'00	68	57	1	1	7	9	0	3	0	0	1	0	4	13
59	STL12043410	'00	24	10	0	0	7	7	0	0	0	1	0	0	1	8
60	STL12043417	'00	20	3	0	0	0	0	0	0	0	0	0	0	0	0
61	STL12043421	'00	4	4	0	0	0	0	0	0	0	0	0	0	0	0
62	STL12043503	'00	72	72	0	2	13	15	0	6	0	3	0	0	9	24
63	STL12051203	'00	16	0	0	0	0	0	0	0	0	0	0	0	0	0
64	STL11040205	'00	13	4	0	0	0	0	0	0	0	0	0	0	0	0
2000 Totals	2000 Count (n)[4]				93	13	663	769	140	139	50	20	5	74	428	1198
	% ($^{n}/_{1198}$*100)				7.8	1.1	55.3	64.2	11.7	11.6	4.2	1.7	0.4	6.2	35.8	

Appendix Table Ve – Individual counts of amphibian species detected during rapid assessment of streams in the Stillman watershed, 2001

Stream[1]		Year	10-m Intervals[2]		FFR Species[3]				Other Species[3]								
			Total	Watered	ASTR	PLDU	RHKE	TOTAL	AMGR	Disp	ENES	HYRE	PLVE	RAAU	TAGR	TOTAL	Spp Total
1	STL11040218	'01	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	STL11040301	'01	77	77	7	3	51	61	0	12	0	0	3	0	0	15	76
3	STL11040302	'01	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0
4	STL11040304	'01	49	41	0	2	27	29	0	5	0	0	0	0	0	5	34
5	STL11040305	'01	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0
6	STL11040306	'01	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0
7	STL11040313	'01	122	122	23	2	57	82	0	176	0	0	3	0	2	181	263
8	STL11040322	'01	6	6	0	0	0	0	0	0	0	0	0	0	0	0	0
9	STL11040325	'01	31	29	3	0	22	25	0	22	0	0	4	0	0	26	51
10	STL11040501	'01	131	99	17	3	226	246	0	166	0	0	3	0	0	169	415
11	STL11040512	'01	26	26	2	1	8	11	0	2	0	0	1	0	0	3	14
12	STL11040513	'01	9	8	0	0	5	5	0	0	0	0	0	0	0	0	5
13	STL11040519	'01	15	5	0	0	1	1	0	0	0	0	0	0	0	0	1
14	STL11040602	'01	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	STL11040607	'01	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	STL11040703	'01	7	2	0	0	0	0	0	0	0	0	0	0	0	0	0
17	STL11040707	'01	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	STL11040709	'01	23	3	1	0	14	15	2	0	0	0	1	0	0	3	18
19	STL11041024	'01	31	18	0	0	16	16	0	1	1	0	1	0	0	3	19
20	STL11041703	'01	32	27	3	0	9	12	0	39	0	0	0	0	0	39	51
21	STL11041713A	'01	14	13	1	0	33	34	0	0	0	0	0	0	0	0	34
22	STL11041713B	'01	20	2	0	0	5	5	0	1	0	0	0	0	0	1	6
23	STL11041716	'01	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	STL12040710	'01	31	31	0	3	12	15	0	3	0	0	0	2	0	5	20
25	STL12041707	'01	20	19	0	0	8	8	0	0	0	0	2	0	0	2	10
26	STL12041708	'01	31	31	0	0	5	5	0	0	0	0	3	0	0	3	8
27	STL12041721	'01	23	12	0	1	0	1	0	0	0	0	2	0	0	2	3
28	STL12041741	'01	17	5	0	0	0	0	0	0	0	0	0	0	0	0	0
29	STL12041816	'01	13	10	0	0	0	0	0	0	0	0	0	0	0	0	0
30	STL12041904	'01	22	6	0	0	0	0	0	0	0	0	1	0	0	1	1
31	STL12041905	'01	18	10	1	0	38	39	0	5	0	0	4	0	0	9	48
32	STL12041906	'01	11	8	0	0	19	19	0	30	0	0	1	0	0	31	50
33	STL12041909	'01	11	11	0	0	15	15	0	3	0	0	0	0	0	3	18
34	STL12041912	'01	12	3	0	0	19	19	0	0	0	0	0	0	0	0	19
35	STL12042013	'01	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	STL12042109	'01	73	24	0	6	53	59	0	10	0	0	6	2	1	19	78
37	STL12042120	'01	31	25	1	0	72	73	0	7	0	0	1	0	0	8	81
38	STL12042121	'01	52	52	0	4	34	38	1	2	0	0	1	0	0	4	42
39	STL12042213	'01	12	12	0	1	2	3	0	3	0	1	2	0	0	6	9
40	STL12042214	'01	20	20	0	0	4	4	0	0	0	0	2	0	0	2	6
41	STL12042331	'01	4	3	0	0	0	0	0	0	0	1	0	1	0	2	2
42	STL12043225	'01	26	20	0	1	21	22	0	0	0	0	1	0	0	1	23
43	STL12043226	'01	50	49	8	6	111	125	0	25	0	0	2	0	1	28	153

[1] Streams in red were sampled in both years.
[2] Total = all 10-m intervals sampled; Watered = 10-m intervals with significant water.
[3] Species codes correspond to the list in Appendix II.
[4] Sampled streams (lines in this table) in which species was detected.

Appendix Table Ve – Individual counts of amphibian species detected during rapid assessment of streams in the Stillman watershed, 2001 (continued)

Stream[1]		Year	10-m Intervals[2]		FFR SPECIES[3]				OTHER SPECIES[3]								
			Total	Watered	ASTR	PLDU	RHKE	TOTAL	AMGR	Disp	ENES	HYRE	PLVE	RAAU	TAGR	TOTAL	Spp ctr
44	STL12043403	'01	9	6	0	0	0	0	0	0	0	0	0	0	0	0	0
45	STL12043501	'01	62	61	0	0	19	19	0	4	0	0	2	0	0	6	25
46	STL12043504	'01	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	STL12043508	'01	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2000 Totals		2000 Count (n)[4]			67	33	906	1006	3	516	1	2	46	5	4	577	1583
		% ($^{n}/_{1584}$*100)			4.2	2.1	57.2	63.5	0.2	32.6	0.1	0.1	2.9	0.3	0.3	36.5	%

[1] Streams in red were sampled in both years.
[2] Total = all 10-m intervals sampled; Watered = 10-m intervals with significant water.
[3] Species codes correspond to the list in Appendix II.
[4] Sampled streams (lines in this table) in which species was detected.

Appendix Table Ve – Amphibian species detected by rapid assessment in streams in the Washougal watershed, Washington, 2000

Stream		10-m Intervals[1]		FFR SPECIES[2]				OTHER SPECIES[2]							Spp Total
		Total	Watered	ASTR	PLVA	RHCA	TOTAL	AMGR	Disp	PLVE	PSRE	RAAU	TAGR	TOTAL	
1	WAS02050127	18	18	0	0	0	0	0	51	0	0	0	0	51	51
2	WAS02050430	21	5	0	0	8	8	0	0	0	0	0	0	0	8
3	WAS02050431	36	36	0	0	0	0	0	15	0	0	0	0	15	15
4	WAS02050506	15	14	0	0	0	0	0	1	0	0	0	0	1	1
5	WAS02050518	12	12	0	0	0	0	0	0	0	0	0	0	0	0
6	WAS02050525	78	76	0	0	8	8	0	67	0	0	0	0	67	75
7	WAS02050529	44	38	0	0	0	0	0	13	0	0	1	0	14	14
8	WAS02050617	2	2	0	0	0	0	0	0	0	0	0	0	0	0
9	WAS02051040	51	51	0	0	0	0	0	23	0	0	0	0	23	23
10	WAS03052607	9	9	0	0	0	0	0	36	0	0	0	0	36	36
11	WAS02053229	3	2	0	0	0	0	0	0	0	0	0	0	0	0
Detection (n)				0	0	16	16	0	206	0	0	1	0	6	9
% ($^{n}/_{11}$*100)				0	0	18	18	0	64	0	0	9	0		

[1] Total = all 10-m intervals sampled; Watered = 10-m intervals with significant water.
[2] Species codes correspond to the list in Appendix II.

Appendix VI

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).

	Map Code	Description
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)	**Tgn_2**	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 VI (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)	**Tva_2**	BASALTIC-ANDESITE AND BASALT FLOWS (Upper Oligocene): Dark gray, basaltic-andesite and basalt, aphyric to augite-plagioclase phyric; 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)	**Tva_3**	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)	**Tvc_2**	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)	**Tvt_3**	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.