United States
Department of
Agriculture

Forest Service

Pacific Northwest
Research Station

General Technical
Report
PNW-GTR-275
November 1991

Sampling Methods for Amphibians in Streams in the Pacific Northwest

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Wildlife-Habitat Relationships: Sampling Procedures for Pacific Northwest Vertebrates

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Portland, Oregon
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Preface

Concern about the value of old-growth Douglas-fir forests to wildlife in the Pacific Northwest began escalating in the late 1970s. The available information on wildlife-habitat relationships suggested that as many as 75 species including amphibians, birds, and mammals, could be dependent on old-growth forests. The USDA Forest Service chartered the Old-Growth Forest Wildlife Habitat Program to investigate the role old growth plays in maintaining viable populations of wildlife. It was apparent that broad surveys of vertebrate communities would be necessary to determine which species were truly closely associated with old-growth forests. Insufficient guidance on techniques, procedures, and sample sizes was available in the existing literature. We assembled a team of researchers from universities and Federal agencies to conduct pilot studies to develop sampling protocols and to test the basic experimental design for contrasting the wildlife values of young, mature, and old-growth forests. The sampling protocols resulting from the pilot studies were implemented in 1984-86 across broad areas of the Cascade Range in southwestern Washington and in Oregon, the Oregon Coast Ranges, and the Klamath Mountains of southwestern Oregon and northern California. Naturally, improvements were made to the protocols as time passed. A tremendous amount of experience in sampling was gained.

Our goal in this series is to compile the extensive experience of our collaborators into a collection of methodology papers providing biologists with pilot study-type information for planning research or monitoring populations. The series will include papers on sampling bats, aquatic amphibians, terrestrial amphibians, forest-floor mammals, small forest birds, and arboreal rodents, as well as papers on using telemetry for spotted owl studies and a guide to bird calls.

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Abstract

Bury, R. Bruce; Corn, Paul Stephen. 1991. Sampling methods for amphibians in streams in the Paciific Northwest. Gen. Tech. Rep. PNW-GTR-275. Portland, OR: U.S. Department of'Agriculture, Forest Service, Pacific Northwest Research Station. 29 p.

Methods describing how to sample aquatic and semiaquatic amphibians in small streams and headwater habitats in the Pacific Northwest are presented. We developed a technique that samples IO-meter stretches of selected streams, which was adequate to detect presence or absence of amphibian species and provided sample sizes statistically sufficient to compare abundance of individual species among streams. Physical and biological parameters of streams are described as well as ways to collect amphibians effectively. The system can be modified for use in a variety of waterways and for different study objectives. We provide recommendations for improvements on future studies.

Keywords: Amphibians, Pacific Northwest, streams, sampling techniques.

Contents

Introduction

Permanent creeks and small streams with rocky substrates are a prominant feature of old-growth forests in the Pacific Northwest. These small waters provide essential cover, breeding sites, and feeding habitat for many species of amphibians. These aquatic amphibians are an important part of the forest ecosystem in their numbers and their ecological roles (Bury 1988, Nussbaum and others 1983). For example, we have found 200 amphibian larvae in one IO-meter length of a small stream in old-growth forest, and we estimated that density was about 9 amphibians per square meter of habitat. Although individual animals are relatively small-sized vertebrates, their high abundance composes a major part of the food chain in biomass. For example, Hairston (1987) estimated that in deciduous forests of the Appalachian Mountains, aquatic and semiaquatic salamanders (a different group of species than those in the Northwest) contributed 2.3 kilograms of predator biomass per hectare of forest, which rivals the combined biomass of birds and small mammals in the same region.

Some of the species of vertebrates most sensitive to environmental perturbations resulting from timber harvest are aquatic and semiaquatic amphibians, particularly three widespread species: tailed frogs, *Ascaphus truei* Stejneger,' Olympic salamanders, *Rhyacotriton olympicus* (Gaige), and giant salamanders, *Dicamptodon* spp. Recent studies suggest few or no individuals of tailed frogs and Olympic salamanders in streams in logged areas compared to streams in mature or old-growth forests (Bury and Corn 1988, Corn and Bury 1989, Welsh 1990). Giant salamanders occur in almost all flowing waters, but they may reach higher densities in forested habitats than in streams in logged or young managed stands, depending on geographic location.

Surveys of headwaters and small streams can serve to document the density and diversity of aquatic amphibians in different stream conditions (steep versus slow-moving waters), substrates (silty versus rocky), or stand development (young forest versus old growth). These streamside (riparian) and aquatic habitats are also the most productive sites for wildlife in forests (Bury 1988).

Most published research to date is based on paired sites, and there are marked differences in amphibian abundance in streams flowing through recently logged areas compared to streams in uncut forests. The bulk of these studies compare only responses of giant salamanders (Conner and others 1988, Hawkins and others 1983, Murphy and Hall 1981, Murphy and others 1981). These biologists used electroshocking, which may not be adequate to sample the entire assemblage of aquatic amphibians (Corn and Bury 1989).

This paper describes techniques suitable for determining presence and abundance of all aquatic amphibians in small headwater (first-, second-, or third-order) streams. These are usually less than 3 meters wide. We hope this framework will assist field biologists and managers to study forest wildlife more effectively.

[1] Common and scientific names follow Banks and others (1987) and Collins (1990).

Stream-Dwelling Amphibians

The Tailed Frog

The tailed frog is endemic to the Pacific Northwest, occurring from British Columbia to northern California and in the northern Rocky Mountains (northeast Oregon, southeast Washington, northern Idaho, and western Montana). The tailed frog is the only living species in the family Ascaphidae. It is one of the most primitive frogs in the world, and its closest relatives live in New Zealand. Tailed frogs frequent segments of drainages where temperatures are generally cool year-round, which are conditions that usually occur only in closed-canopy forests.

Male tailed frogs possess a short external extension of the cloaca that resembles a tail but is not, giving this frog its name. It is used in mating to deliver sperm directly into the cloaca of the female, an important evolutionary adaptation for a species that breeds in rapidly flowing water. In contrast, pond-breeding frogs fertilize eggs externally. Adult tailed frogs range from 35 to 50 millimeters total length, with females usually larger than males. Ground color differs from olive green to black, with small darker blotches often present. The skin may be smooth or have fine-grained warts. The outer hind toe is conspicuously wider than the other hind toes.

Tadpoles (larvae) of tailed frogs may reach 60 millimeters total length. Tadpole color varies from brown with darker mottling to black. Usually there is a white spot at the tip of the tail. The skin around the mouth (the oral disk) of tadpoles is modified as a large sucker, an adaptation for clinging to rocks in fast-flowing waters. Tadpoles feed on diatoms and algae which they scrape off of rocks by using rows of keratinized "teeth" located inside the oral disk.

The length of time required for tailed frog tadpoles to complete development and metamorphose into juvenile frogs may be the longest of any North American frog. The larval period is generally 2 years in northern California (Bury 1968) and in western Oregon and Washington, but tadpoles in the Rocky Mountain populations or at high elevations may require 3 years between hatching and metamorphosing into juvenile frogs (Metter 1964, 1967). Recently, Brown (1990) argued that tailed frog tadpoles in the northern Cascade Range, where streams are ice-covered in winter, metamorphose after 4 years.

Our field research (Bury and others 1990, Corn and Bury 1989) in the Oregon Coast Range suggests a shorter larval period, perhaps because winters are milder than in the Cascade Range, and streams do not have ice cover. We have collected tadpoles from two streams in different seasons over 5 years. By August in these streams, all tadpoles are metamorphosing or have metamorphosed, and in the fall, we have found only small tadpoles (hatchlings). These data indicate that tadpoles in these streams metamorphose after only 1 year. The apparent variability in length of the larval period suggests that temperature and food availability during the growing season are probably the most important environmental variables influencing growth of tailed frog tadpoles (Brown 1990).

Daugherty and Sheldon (1982) found that adults may not breed until 7 to 8 years old in Montana. It is likely that life history characteristics of adults are also influenced by environmental constraints.

In both the southern and eastern portions of the range of tailed frogs, populations are separated by dry forests or ridges and open areas (grassland, oak woodland, chaparral). There is little migration between populations inhabiting adjacent drainages (Daugherty and Sheldon 1982, Metter 1964). Local environmental conditions may be reflected in phenotypic variation among these isolated populations. Larvae in the same geographic area may differ in body colors (black or brown; with or without a prominent white tail tip) and tail height, which can be related to substrate color and water velocity, respectively (Metter 1967).

The Olympic Salamander

This primitive amphibian is restricted to the Olympic Mountains of Washington and southward in the Coast Range and western flanks of the Cascade Range to north coastal California. Olympic salamanders have been considered to belong to a single variable species, but recently, Good and others (1987) suggested that there may be at least three genetically distinct geographic units within the genus *Rhyacotriton,* perhaps representing different species. Olympic salamanders are small, less than 100 millimeters in total length. Dorsal color is usually a mottled brown, and the ventral surface is yellow with small black flecks.

Like the tailed frog, Olympic salamanders require cool waters; however, Olympic salamanders usually are only found in shallow water or in the splash zones of small creeks or in seeps. They can reach densities of more than 30 per square meter (Nussbaum and Tait 1977), but these populations are rare.

Giant Salamanders

Giant salamanders frequent cool, cascading creeks as well as larger, slower streams and standing water. Giant salamanders can comprise over 95 percent of the predator biomass in small streams (Murphy and Hall 1981), exceeding trout and salmon in importance as the top carnivore. Adult giant salamanders occur on land in wet weather, where they are a major predator on large-sized invertebrates and, occasionally, on small mammals or other salamanders (Bury 1972). Adults grow to 340 millimeters long, which places them among the largest terrestrial salamanders in the world (Nussbaum and others 1983). Total length of larvae ranges from 40 to 140 millimeters. Some larvae are neotenic, meaning that sexual maturity is attained without transformation into the terrestrial form. Larval characteristics, such as external gills, the tail fin, and aquatic habitat are retained. Neotenic larvae may reach 350 millimeters. Recently transformed juveniles will be about 100 millimeters total length.

The taxonomy of giant salamanders has been revised recently by Good (1989) who recognized four species based on genetic variation of enzymes. The- Pacific giant salamander, *D. tenebrosus* (Baird and Girard), occurs from the Cascade Range to the coast from southern British Columbia to northern California, except on the Olympic Peninsula. These populations were formerly included in *D. ensatus* (Eschscholtz) (Daugherty and others 1983, Nussbaum and others 1983), but this name is now restricted to genetically distinct populations of giant salamanders in coastal California from about Mendocino County southward to Santa Cruz County (Good 1989). The changes in scientific names are necessary because the name *ensatus* was used in 1833 to describe salamanders collected near San Francisco Bay. The name *tenebrosus* was the first name used to describe giant salamanders from northern Oregon (Baird and Girard 1852). The common name for *D. ensatus* is the California giant salamander (Collins 1990).

Cope's giant salamander, *D. copei* (Nussbaum): is a smaller form that is almost always neotenic. Cope's giant salamander is restricted to extreme northern Oregon, western Washington, and the Olympic Peninsula (Good 1989; Nussbaum 1970, 1976).

The Idaho giant salamander, *D. atterimus* (Cope), occurs in northern Idaho and extreme western Montana (Daugherty and others 1983, Good 1989). This species is isolated from other giant salamander species by the northern Great Basin and the Columbia Basin.

All four species of giant salamanders are similar in appearance. Adults have an olive-green to dark brown ground color and darker colored marbling, which may be restricted to the head or may be absent in some animals. Larvae possess a low tail fin and short external gills. Larvae are usually dark brown or black on the dorsal surface, except for some mottling on the tail fin and a light stripe behind the eye. Larval Pacific giant salamanders from northern California and southern Oregon may have marbling like that of adults.

There are only a few areas in southern Washington and northern Oregon where the ranges of the Pacific giant and Cope's giant salamander overlap. Usually, there will only be one species present in a stream, and for most forestry studies, the identification of giant salamanders at the genus level is sufficient. Voucher specimens, however, can be saved for later identification by experts.

Other Species

Several other species of amphibians occur in or near small streams. Dunn's salamander, *Plethodon dunni* Bishop, and Van Dyke's salamander, *plethodon vandykei* Van Denburgh, are often found in shallow waters or in rock rubble along creeks or in seeps. Although these species do not require flowing water for breeding, they seem to be closely associated with small streams in many areas. Investigations of aquatic amphibians should also include Dunn's and Van Dyke's salamanders because they can be common along stream banks. in inland parts of northern California, the black salamander, *Aneides flavipunctatus* (Strauch), is associated with stream banks and seeps (Lynch 1981).

Other species of amphibians may breed and lay eggs in the slower portions of creeks and streams, including the roughskin newt, *Taricha granulosa* (Skilton), the red-legged frog, *Rana aurora* Baird and Girard, and the foothills yellow-legged frog, R. boylei Baird. Identification of these species is provided in Nussbaum and others (1983) and Stebbins (1985).

Experimental Design

Sampling Plan

Aquatic amphibians are abundant in forested streams in the Pacific Northwest and provide adequate sample sizes to indicate the effects of forest management practices. Our recent research in the Coast Range of Oregon (Corn and Bury 1989) involved a survey of small headwater streams (1 to 2 meters wide) over a wide geographic area, and we found that hand collecting of one lo-meter long segment of stream was sufficient to determine both occurrence and relative abundance of aquatic amphibians. A single lo-meter-long survey, however, would be inadequate if the study was focused on a single stream or involved an intensive examination of one drainage basin. Further, the hand-collecting techniques described below are less useful on streams much wider than 2 meters (larger third-order and fourth- or fifth-order streams). Electroshocking has been used to sample amphibians (Hawkins and others 1983, Murphy and Hall 1981, Murphy and others 1981) but this technique seems to be biased towards capturing large-sized giant salamanders and may miss Olympic salamanders and other species (Corn and Bury 1989). Studies of streams wider than 2 meters may need to employ both electroshocking and hand collecting to provide a more complete picture of the amphibians present.

Sampling intensity-Hand collection is labor intensive, requiring about 10 staff-hours of effort for each 10 meters of stream surveyed. Therefore, it is necessary to determine the amount of each stream reach that needs to be sampled. First, one can question whether one lo-meter survey is sufficient to sample the amphibian community. In the Coast Range of Oregon, we sampled one creek three times (sample areas were 50 meters apart) to determine variation among nearby areas in the same creek (table 1). All sites had similar numbers of larval giant salamanders and tadpoles of tailed frogs. The coefficient of variation (CV = standard deviation + mean x 100) of density was 31.7 percent for Pacific giant salamanders and 35.2 percent for tailed frogs (Corn and Bury 1989). By comparison, the CV of density among 23 streams (single lo-meter surveys) flowing in uncut forests was 75.7 percent for Pacific giant salamanders and 50.5 percent for tailed frogs. The variability in estimated density of these two species was less within the one stream sampled three times than among a group of streams, thereby suggesting that one sample per stream was adequate to provide basic information on the amphibian community.

In lo-meter-long sections of streams sampled in 1984 and 1985, we caught a mean of 42.6 amphibians (range 19 to 92) in 23 streams in uncut forests, and a mean of only 9.9 (0 to 43) in 20 streams in stands that had been logged 14 to 40 years before. These sample sizes were adequate to apply statistical tests for differences in abundance, and there was a low probability of failing to detect the presence of any of the aquatic amphibians (Corn and Bury 1989).

Shorter surveys, for example, one 5-meter-long section, would provide only about half the number of captures as lo-meter surveys, but, more importantly, surveys 5 meters long would be inadequate even for determining presence of common species. Presence of tailed frogs or Olympic salamanders are important indicators of stream-health, and field efforts must be sufficient to reveal these species, even when abundance is low or where they occur in a clumped distribution.

Table l-Comparison of amphibians captured in three lo-meter samples 50 meters apart in a tributary of the south fork of the Smith River, Douglas County, Oregon

Species	Stream section		
	1	2	3
Tailed frog	30	27	19
Pacific giant salamander	19	24	15
Dunn's salamander	0	1	0
Roughskin newt	0	1	0
Total	49	53	34

We can predict the ability of stream surveys of different lengths to detect the presence of amphibian species by dividing our data from the Coast Range into 1 -meter long segments and using the proportion of these segments where each species was present and absent to calculate the probability of failing to detect a species in a stream where it is actually present. In the 23 streams in uncut forests in the Coast Range (Corn and Bury 1989), we found Pacific giant salamanders in all streams and 192 of the l-meter-long segments (83.5 percent). Tailed frogs were in 22 streams and 97 of the l-meter segments (44.1 percent). Olympic salamanders were present in 14 streams and 39 of the l-meter segments (27.9 percent). The binomial probability (P) of failing to detect a species where it is actually present (table 2) is as follows:

$$P = q^n ,$$

where q = the proportion of 1 -meter segments where the species was absent, and n = the length (m) of the survey. Pacific giant salamanders are ubiquitous, and either 5-meter or lo-meter surveys will detect this species. A lo-meter survey has less than a l-percent chance of failing to detect tailed frogs, but the probability of missing this species increases to a marginally acceptable 5.5 percent with a 5-meter survey. Also, there is a high probability (one in five) of missing Olympic salamanders that are actually present with a 5-meter survey, but only a 4-percent probability with a lo-meter survey. Ten meters, then, is the minimum acceptable length for a single survey of a headwater stream.

General surveys-A single 1 O-meter stream survey is appropriate when the study involves a general description of aquatic amphibians over a wide geographic area (for example, Bury and others 1991, Corn and Bury 1989). In this case, there is less interest in describing the variation within individual streams than in describing variation among broad categories of streams; for example, streams in uncut forests versus streams in logged stands, or streams in young, mature, and old-growth forests. Given limited resources, it is probably better to sample as many different streams as possible. Discretion should be used in selecting streams so that the inferences drawn from the data are valid statistically.

Table 2-Binomial probabilities of failing to detect aquatic amphibians present in a stream by using 5-meter and 10-meter-long surveys

Species	Number of streams	Proportion of 1 -meter segments[a] Present (P)	Absent (q)	Probability of failing to detect in survey of 5 meters	10 meters
Pacific giant salamander	23	0.835	0.165	0.0001	1.5 x 10-e
Tailed frog	22	.441	.559	.055	.003
Olympic salamander	14	.279	.721	.195	.038

[a] The proportion of l-meter segments where each species was present or absent are from streams where each species was recorded in the Oregon Coast Range (Corn and Bury 1989).

Ideally, the streams selected for sampling should be a random sample of all streams in a given area. Basic criteria applied in selecting streams include the presence of flowing water (many first-order streams may be intermittent in the summer) and accessibility by foot (within 1 kilometer of a road or major trail). Study sites should be upstream from road crossings to avoid possible effects of road construction on the stream.

Several decisions in selecting streams should be made before field work begins. Topographic maps (7.5 minute) and forest-type maps (1 :1,000 scale) produced by the Forest Service and Bureau of Land Management will show most first- and second-order stream channels. Select a map section (1 square mile) at random and then identify all streams that seem to meet the selection criteria, including stage of forest development around the stream and degree of logging upstream from the potential sample reach (fig. 1). The presence of logged areas upstream from uncut forests has little apparent effect on amphibian presence or abundance (Corn and Bury 1989), but further work is needed on this situation. If one is studying streams in uncut forests, it is best to try to minimize potential confounding influences. Streams where logging has occurred across the channel upstream from the study reach should be rejected, but some amount of logging on slopes upstream from the sample reach can be tolerated (fig. 2).

Select at random two or three of the streams in each section that meet the criteria as potential study sites. The initial list of study sites will be longer than the number of streams actually sampled. When streams are inspected in the field, some will not be suitable and will be rejected for the following reasons: some streams that meet all the map criteria will be intermittent; others might be wider and deeper than they appear on maps, making hand-collecting difficult; and certain sites may prove impractical to reach because of topographic barriers, private ownership, or active logging operations.

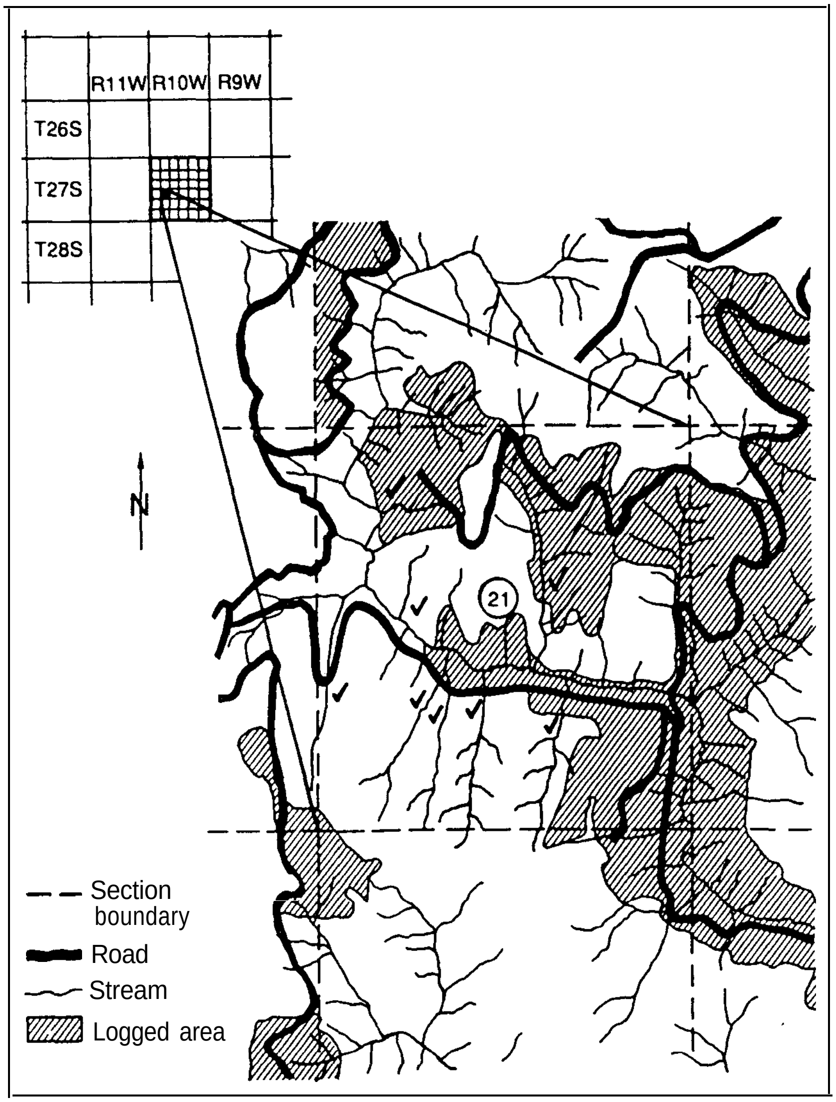

Figure I-An example of preselecting streams for surveys of aquatic amphibians. A map section is chosen at random, and all streams that meet the selection criteria are identified (✓).

The approximate number of streams (n) needed to determine abundance of amphibians accurately can be estimated by the formula:

$$n = s^2 \times \frac{4}{L^2} ,$$

where s^2 = the sample variance of total density and L = the amount of error to be tolerated in estimating total density (Snedecor and Cochran 1967). In 23 streams in uncut forests in the Oregon Coast Range (Corn and Bury 1989), mean amphibian

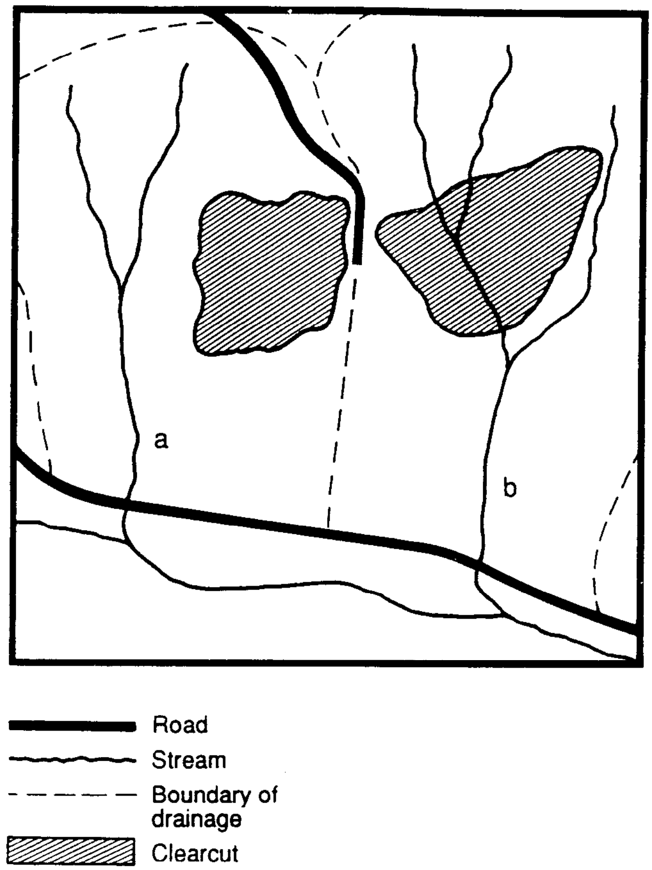

Figure 2—A hypothetical example of two streams in uncut forests. Stream "a" could be sampled because logging in the drainage basin has not occurred directly in the stream channel. Stream "b" would not be sampled because logging has extended across the stream channel.

density was 3.8 per square meter (s^2 = 5.60). Thus, 22 streams would need to be sampled if one is willing to tolerate an error of 1 per square meter, but about 90 streams would need to be sampled if an error of 0.5 per square meter is desired.

Watershed studies and paired sites—There have been several recent surveys of amphibians in the Pacific Northwest (Bury and others 1991, Corn and Bury 1989, Hawkins and others 1983, Welsh 1990, Welsh and Lind 1991), but there are few studies devoted to single drainage basins. Studies of single watersheds are needed to determine the distributions of amphibian populations from headwaters to higher order streams. Watersheds can usually be located where several management activities have affected small streams. An intensive study of such a watershed may not be all that useful, however, for determining the effects of management activities, because extrapolating the results to a broader geographic area requires assumptions that may not be valid (Hall and others 1978).

Hall and others (1978) promote sampling of several paired streams as the most desirable technique for evaluating the effects of management activities. Such an approach may be used to cover broad spatial and temporal scales, but it requires the assumption that conditions were similar in both streams before the treatment was applied to one of them. Paired comparisons require fewer sites than do general surveys, and they facilitate the use of nonparametric statistics (Hail and others 1978). Because of the inherent variability among streams and the need for a large sample size to achieve precise estimates of abundance (see above), a paired design using nonparametric statistics "should be more powerful in detecting effects of watershed practices than conventional designs based on parametric analyses" (Hail and others 1978, p. 1364).

For paired comparisons and watershed studies especially, we now suggest sampling more than one 10-meter length of individual streams. Three 5-meter surveys, for example, would increase the catch of amphibians by 50 percent and provide a more complete picture of the variability within a stream. Stream surveys employing three 5-meter stretches (each 50 meters from the other) were developed in northern California by Welsh (1990) and Welsh and Lind (1991). Also, three are the minimum number of multiple samples per stream necessary to characterize variation within individual streams. If the resources are available, we recommend that three lo-meter segments or more than three 5-meter segments be done on each stream.

Selection of streams proceeds much the same as that described for general surveys. Locate potential pairs of streams on maps and then select a random sample of these for sampling. Paired tests should be performed as close to one another as possible to reduce outside variables (geography, soils, water chemistry) that increase with distance between sites. Because of the fragmented logging history in the Pacific Northwest, it is occasionally possible to locate a tributary with mature or old-growth forest adjacent to a tributary that has been logged. Aspect must also be considered when selecting streams. North-facing slopes are much cooler in summer than south-facing slopes, which may be a limiting factor to species like Olympic salamanders and tailed frogs in drier, hotter climates (for example, interior northern California and southern Oregon). If streams are paired comparisons, they should be on the same aspect and elevation, be of the same size, and have the same gradient (slope).

Variables

Habitat Variables-Relating the occurrence and abundance of amphibians to stream characteristics should include accurate measurement of habitat variables. We recorded 12 physical and biological variables of the stream and adjacent areas (appendix 1; "Stream data," items 6 to 17). For each amphibian capture, we denoted five characters of the individual and seven microhabitat features (appendix 1; "Specimen data," items 2 to 13). These measures and categories are important to define the stream being sampled and for comparisons among streams.

We were particularly interested in niche separation among aquatic amphibians; thus, we collected microhabitat data. For cursory surveys and applied questions, microhabitat data could be optional. The study will lack scientific rigor, however, and important ecological data will be overlooked.

The list of variables we selected (appendix 1) is not exhaustive. Categories should be deleted, added, or substituted to fulfill specific needs. For example, we recorded substrate at 1-meter intervals simply by estimating by sight the dominant size category on a transect across the stream. Another study might wish to concentrate on the effects of siltation, and greater detail should be added here by recording embeddedness (the amount of siltation in a stream). Important variables and the techniques used to measure these stream features are described in detail by Platts and others (1983) and Hamilton and Bergersen (1984).

Specimen data—The data recorded from individual animals also depend on the study objectives. For most surveys, it is important to identify size classes and to determine the sex of animals. Except for investigations requiring series of animals (for example, studies of food habits), most animals can be released unharmed after basic measurements are recorded. It is possible to measure length of amphibians fairly accurately in the field. Additional data should include the developmental stage of tailed frog larvae (see Metter 1967). Knowing the distribution of developmental stages allows the age structure of the tadpoles to be determined. We have developed a simplified scheme for recording the development stages of tadpoles (fig. 3). Salamander larvae show little morphological differentiation from hatching to transformation, but the age structure of a population can be inferred from an analysis of the size distribution.

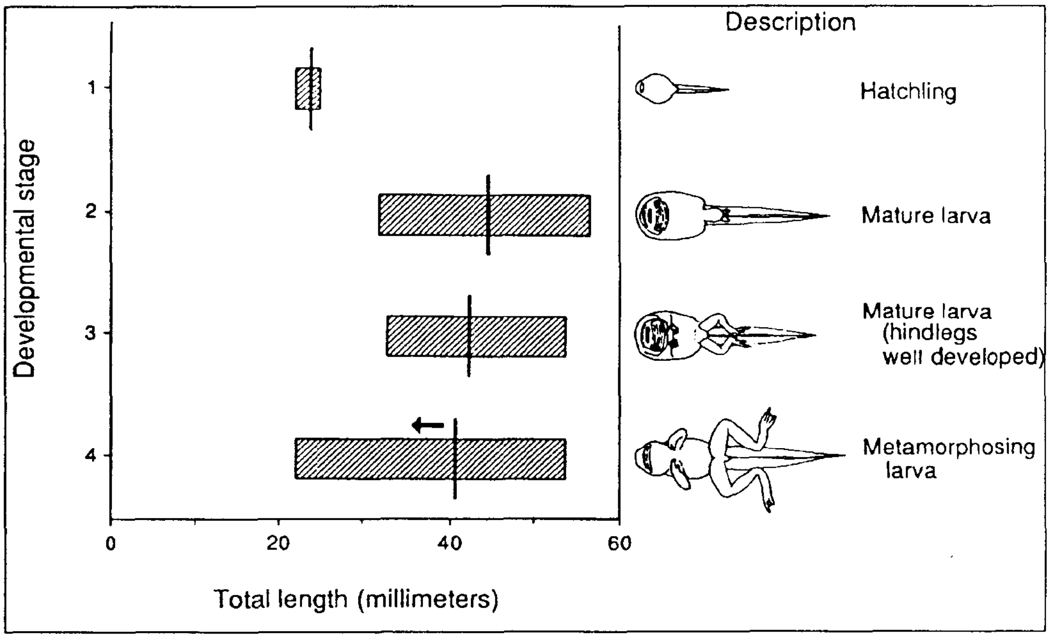

Figure 3—A simplified scheme for recording development of tadpoles of the tailed frog. Size ranges of specimens we collected in the Oregon Coast Range in 1984-85 are given in millimeters. Note that the size of metamorphosing tadpoles decreases as the tail is resorbed.

Field Methods

A scientific collecting permit from a state wildlife management agency is required for the collecting and preservation of amphibians. A permit should be secured before field work begins. There are currently no amphibian species in the Pacific Northwest on the Federal list of threatened or endangered species. Several species, however, have been proposed for review as candidates for listing. State and Federal wildlife agencies will have current information on protected species.

Site Selection

To avoid observer bias, the segment of a stream that is to be sampled should be randomly selected; however, avoid placement of the segment in unusual or unique conditions, such as a waterfall or large debris dam. It may be necessary to avoid thickets of vegetation, where they block access to the water. For example, dense patches of devil's club, *Oplopanax horridum* (J.E. Smith) Miq., can pose a risk of injury. If most of the stream channel is densely vegetated, however, the stream should probably not be sampled because a limited or biased sample would be the likely result. Similarly, log jams or areas with large fallen trees in or across the channel usually render the stream inaccessible. In some streams and especially in logged areas, the study stretch may need to be split into two or more lengths to search between logs and slash in the creek. Because most streams will have *some* segments impossible to sample, a stream should be inspected before choosing a segment to sample. Reconnoiter the stream for 100 to 200 meters upstream from the access point (usually a road crossing), and draw a rough map of the channel, noting inaccessible segments. Divide the accessible sections into 1 O-meter long segments, and choose one of these (at random) to sample. It is up to the investigator's judgement to determine whether stream segments are accessible. If criteria are too strict, however, streams that should be sampled may be rejected.

If multiple segments of one stream are to be sampled, then a systematic scheme is usually employed. The first segment is chosen at random, and then successive segments are a fixed distance (for example, 50 meters) upstream from each other.

Time of Survey

Streams are usually sampled in the summer months to be sure that intermittent waters are not sampled. High precipitation from late fall to spring in the Pacific Northwest can swell small streams, thereby making them difficult to search. Surveys conducted during the rainy season (high water) may not be comparable to summer surveys (low water).

Surveys during the wrong season may also underestimate the abundance of some species. Tailed frog larvae metamorphose in late summer and may disperse out of creeks, depending on geographic location. Transforming frogs appear in early August in the Oregon Coast Range and later occur farther north or at higher elevations. Adult tailed frogs concentrate in creeks during dry weather, but during periods of rain they may forage in nearby woods; thus, adults may be absent in creeks during periods of prolonged rainfall, even in the summer. The optimum time for stream surveys is June and July in the Oregon Coast Range and California and June through August in the Cascade Range of Oregon and Washington.

Transect Layout

The lo-meter-long section of the stream is flagged at l-meter intervals (11 flags comprising 10 sections) along the course of the creek; flags are placed on sides of the stream, where they are left undisturbed during the entire survey. While one team member records vegetation and major physical parameters adjacent to the creek, the other team member (or members) describe stream habitat variables along the lo-meter stretch (pool-riffle ratios; substrate codes; mean width and depths at 0-, 5, and 10-meter points). All habitat features are recorded before collecting. Appendix 1 illustrates the data sheets and describes the measurements to be taken.

Crew Size and Technique

We found that one recorder (whose time is excluded from search effort) and two collectors were optimal for stream surveys in our field efforts in 1983-85. Three collectors tend to crowd each other in a creek (except for larger sized waters), whereas one collector generally cannot turn objects while also tending downstream nets. A two-person crew collecting together is best. The first person turns larger objects and removes them from the creek and then rakes through gravel and cobble with a potato rake, grabbing any animals encountered. The second person holds a heavy-duty dip net (D-shape) or hardware cloth screen immediately downstream of disturbed cover and keeps alert to any amphibians washed into or seen escaping from the net(s). Many animals are washed into the nets by the current and nets need to be checked about once a minute if they are being silted or filled with rocks or leaves; the nets can be set longer if the flow is not murky.

Collecting Methods and Teamwork

Moist streambanks should be searched before the water gets worked, because rocks from the streambed will be deposited on top of the bank. Banks are worked in l-meter lengths, and then this section is searched in the water. A standard distance from the edge of the stream (25 to 50 centimeters) should be sampled on all streams. Streambanks composed largely of soil should usually be left undisturbed, but one should be aware of larger rocks and downed wood embedded in such banks. The crevices under these rocks and logs may often harbor amphibians.

The stream survey begins at the downstream end and proceeds in l-meter increments. All moveable rocks, small boulders, and downed woody material are removed from the stream bed and placed on an adjacent bank. Considerable care should be used when moving larger objects, particularly large rocks in a cascade or small waterfall. Rocks should be moved in a way that prevents other rocks from falling onto the collector. The collector must tell team members that a moderate or large object is to be moved, and the direction of effort. Nets need to be set so they intercept the greatest flow of water, which varies along sides of large objects. For large objects, set the nets so the downstream collector can assist with leverage. Teamwork is essential for efficient collecting effort in flowing water.

No moveable object is left unturned, and hundreds of rocks may be displaced in a 1O-meter stretch. It requires two collectors about 10 staff -hours (5 hours elapsed time) to search an average lo-meter length of water in a forested environment; the duration of a search is about half that in many logged areas where silt or sand fills in spaces between rocks.

Each l-meter segment is searched by sight before any cover is removed, General viewing can reveal animals in riffles, especially tailed frog larvae. In pools, visual search is particularly important to spot amphibians that may be resting on the bottom of the stream but not under rocks. Pools longer than the l-meter segment should be searched carefully for their entire length, and any animal not under cover should be caught to -record the initial position of these animals accurately. Usually these are giant salamander larvae, and they can be caught by hand or in a dip net. Crevices under unmovable logs or boulders are searched by probing with the hands and then by sweeping the area with a sturdy net. After the pool has been searched by sight, it is worked from the downstream end in the same manner as is the rest of the stream. The water level in a pool will drop as rocks aye removed from the channel downstream, which makes it easier to capture animals under cover at the bottom of the pool.

It is important to recognize which object is being moved and where it was located (precisely in what part of the riffle or pool). Mentally note microhabitats before disturbance because you may need to recall which rock, now in your hand or on the bank, yielded a frog or salamander washed into the net. Once capture is secured, measure the rock, water depth, and other parameters (appendix 1). It is often necessary to try to describe a site after it has been disturbed, so it is critical to measure water depth before turning over a large rock or boulder (objects that frequently yield many individuals) or draining a pool. The undersides of rocks should be inspected before the rocks are deposited on the bank, because tadpoles of tailed frogs can cling to these surfaces with their suctorial mouths. The person moving objects has to place the object out of the water and out of the collector's way. Objects should be moved safely to adjacent stream banks and not tossed downstream where the second person usually is holding the net.

To avoid possible recapture of animals already counted, captured amphibians are kept alive in a plastic bucket partly filled with water or in large plastic bags kept in the shade. Separate large-sized giant salamander larvae, because they will eat smaller amphibians, even in a bucket. Place ail rocks and cover objects that were moved back into the stream channel, and return animals to the stream after the survey is finished.

We strongly recommend laboratory identification of species, field trial runs, and cross-checking of abilities before collecting data on streams. Ornithologists repeat and cross-check field identifications of birds and their songs to increase observer accuracy. Similarly, amphibians require special attention and acquired skill for effective capture under field conditions. For example, tailed frog larvae often can be seen attached to rocks in the most torrential part of riffles. In this case, place a piece of hardware cloth downsteam from the larvae and work up to the animal; sometimes, they will "pop" off the rock and be swept into the net. Otherwise, one could disturb the larvae and have them swept downstream and not be counted in the survey.

Collecting of stream amphibians is difficult because of the many cover sites, flowing water, and dark conditions under forest canopies. These surveys require a high degree of motivation and interest by the field crew. We suggest a rigorous training period before sampling for quantified data. Most of our teams were led by herpetologists with one to three decades of field experience, but most field crew members quickly learned the techniques by observation and in-field training. We developed competitiveness in search and capture of animals and team spirit.

Data Recording

If only two people are available, both should collect and stop when each animal is found, denoting times out for data recording. Time of collecting provides an index of effort per site, which helps to plan team assignments. The recorder on a three-person crew takes captured animals from the collectors and writes down microhabitat data called out by the collector who measures microhabitat at the exact point of capture (or first observation) of the specimen. Each animal is placed in a plastic bag and held against the bottom of the bag until it is relaxed. Total length and snout-vent length can then be measured with a straight metric ruler (small white vinyl is best) to the nearest millimeter. The distal end of the tail is sometimes missing from giant salamander larvae; this condition should be recorded. More detailed measuring can be done in the laboratory if the study objectives dictate such precision. We prefer field measures to relate the approximate size of an animal to the place of capture, and field measurements are adequate for assignment of individuals to size classes.

Two data sheets are used (appendix 1). The first data sheet records stream and habitat data. A space is provided for a rough-sketch map of the stream section. The second sheet is used for recording information on individual specimens. Data sheets are best if photocopied onto waterproof blank sheets. Pens with waterproof ink or pencils are required for recording data under field conditions.

Deposition of Specimens

Two or three voucher specimens of each species from each stream should be preserved to ensure positive identification of species and to verify locality records. Identification of aquatic species is generally easy, but there are many areas in the Pacific Northwest where careful measurements are necessary to identify giant salamanders (four species) or woodland salamanders of the genus *Plethodon* (two or three species may occur near streams depending on geographic location). Voucher specimens are presented in the laboratory. Amphibians are killed in chlorotone; precise body measurements are recorded; a permanent label is affixed to the specimen; and the specimen ispreserved by using a lo-percent solution of formalin in a shallow pan lined with paper towels and having a tight-fitting lid. An incision should be made in the ventral body wall of large giant salamanders, thereby allowing thorough preservation of the internal organs. Detailed methods for euthanasia and preservation are provided by Corn and Buty (1990) or Pisani (1973). Voucher specimens should be deposited at a regional or national museum, whose curator should be contacted for permission to deposit specimens before field work is begun.

Analysis and Interpretation

The survey techniques described here should provide reliable data on the presence and abundance of amphibians inhabiting headwater streams. Analysis of species richness (number of species) can be used for a gross appraisal of differences in amphibian populations among habitat types. For example, in the Oregon Coast Range, we usually collected three or four species of amphibians in streams in uncut forests, but streams in logged stands seldom had more than two species present (fig. 4).

Each survey constitutes a census of the stream section, and the area searched is known, so that density (relative abundance) can be calculated (because some animals possibly may escape capture, density values should be considered minimum estimates). Comparisons of amphibian abundance among streams should use density instead of raw numbers of animals captured, because stream widths differ. Thus, surveys of a standard length do not always sample the same amount of habitat. Density (relative abundance) allows a better understanding of differences among habitats than does species richness. Pacific giant salamanders were present in all 23 streams in uncut forests in the Oregon Coast Range, but they were also present in 14 of 20 (70 percent) streams in logged stands (Corn and Bury 1989). Density of Pacific giant salamanders, however, was 4.5 times higher in streams in uncut forests compared to streams in logged stands (fig. 5).

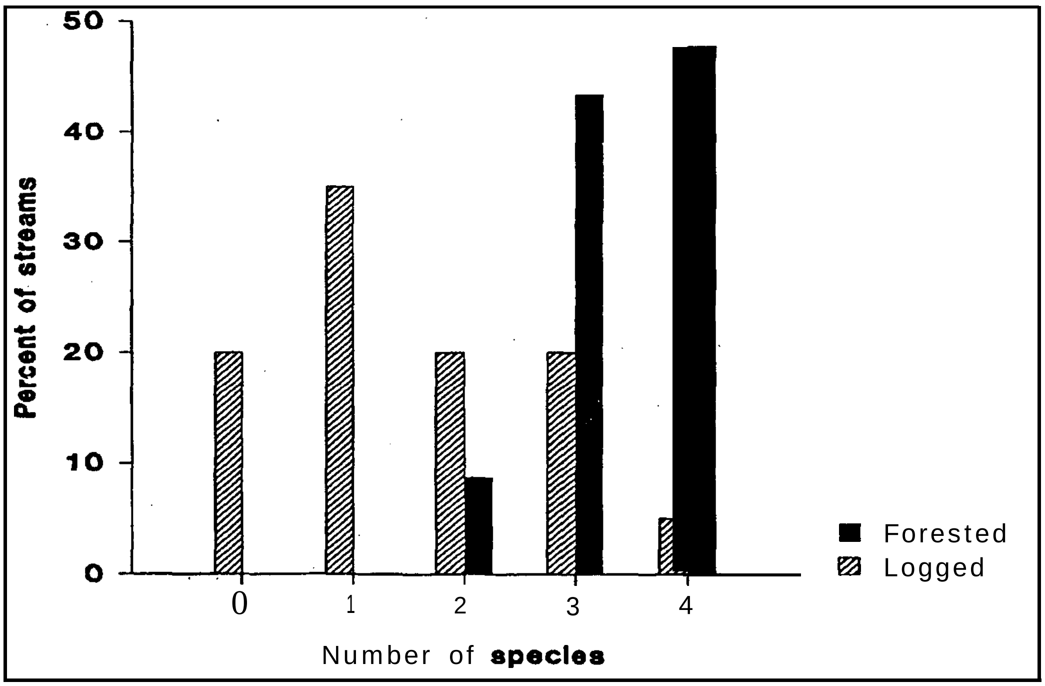

Figure 4-Number of amphibian species recorded from streams in uncut forests and streams in 14- to 40-year-old logged stands (from Corn and Bury 1989).

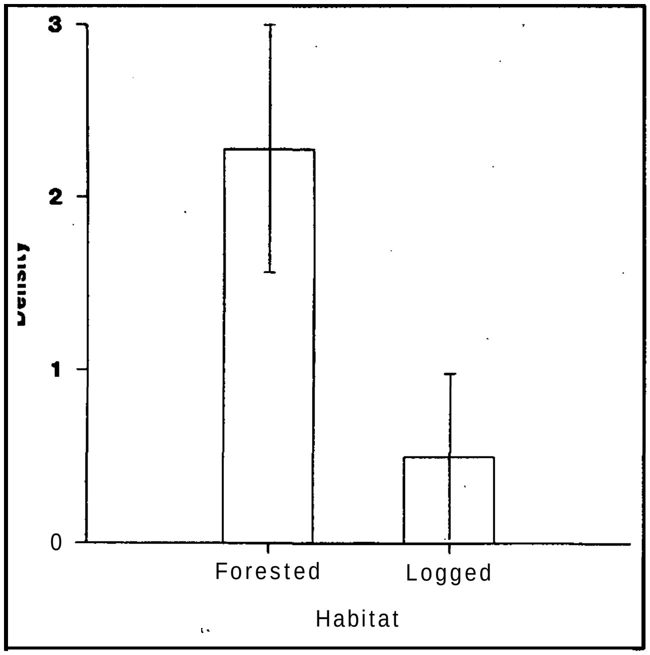

Figure 5-Density of Pacific giant salamanders in streams in uncut forests and streams in 14- to 40-year-old logged stands (Corn and Bury 1989). Error bars indicate a 95-percent confidence interval around the means.

Biomass of each amphibian species can also be obtained. All animals captured can be weighed in the field before they are released, but this extra step may add considerable time to the survey. Sufficient accuracy can be obtained by estimating the mass of each animal with a regression equation developed separately. Accurate measurements (including mass) should be taken from specimens retained for preservation, and these data are used to generate regression coefficients from the relation:

$$mass = a \times L^b,$$

where L = length (total or snout-vent length). The coefficients a and b are most easily obtained from a linear regression of log-transformed mass versus length:

$$\ln(mass) = b \times \ln(L) + \ln(a) .$$

Mass can then be estimated for all animals that have had length measured in the field. Separate regression equations should be developed for larvae and adults of each species.

Biomass is usually a better indicator of the ecological importance of species in an ecosystem than is density. For example, density of Pacific giant salamanders and density of tailed frogs were similar in streams flowing through logged stands in the Oregon Coast Range (Corn and Bury 1989), but biomass of Pacific giant salamanders was eight times greater than biomass of tailed frogs in these streams (fig. 6).

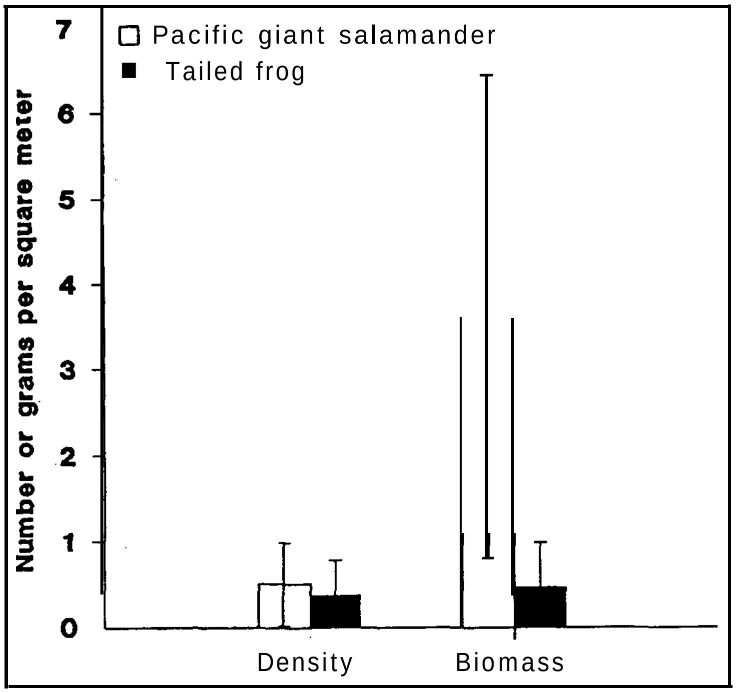

Figure 6-Density and biomass of Pacific giant salamanders and tailed frogs in streams in 14- to 40-year-old logged stands in the Oregon Coast Range (Corn and Bury 1989). Error bars indicate a 95-percent confidence interval around the means.

Data on size of animals can be used to estimate the number and distribution of size classes present in a population. These data can be used to investigate the effects of management activities on demography of a species. Size classes can be roughly estimated by visual inspection of a histogram of body lengths, or size classes can be determined more precisely by using the statistical program MIX[2] (Macdonald and Green 1988). This method uses a maximum-likelihood method to fit frequency distributions to mixtures of populations (Macdonald and Pitcher 1979). The goodness-of-fit of the mixture of distributions to the histogram of sizes is tested with a chi-square approximation of the likelihood ratio statistic (Macdonald and Green 1988).

We applied the maximum-likelihood method to sizes of Pacific giant salamander larvae from streams in uncut forests (fig. 7), with the constraints that sizes of larvae were normally distributed and that the coefficients of variation of all size classes were equal. Three size classes fit the data (x^2 = 19.7, P = 0.18). This analysis suggests that there are three age classes of giant salamander larvae in the Oregon Coast

[2] The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of ***any*** product or service to the exclusion of others that may be suitable.

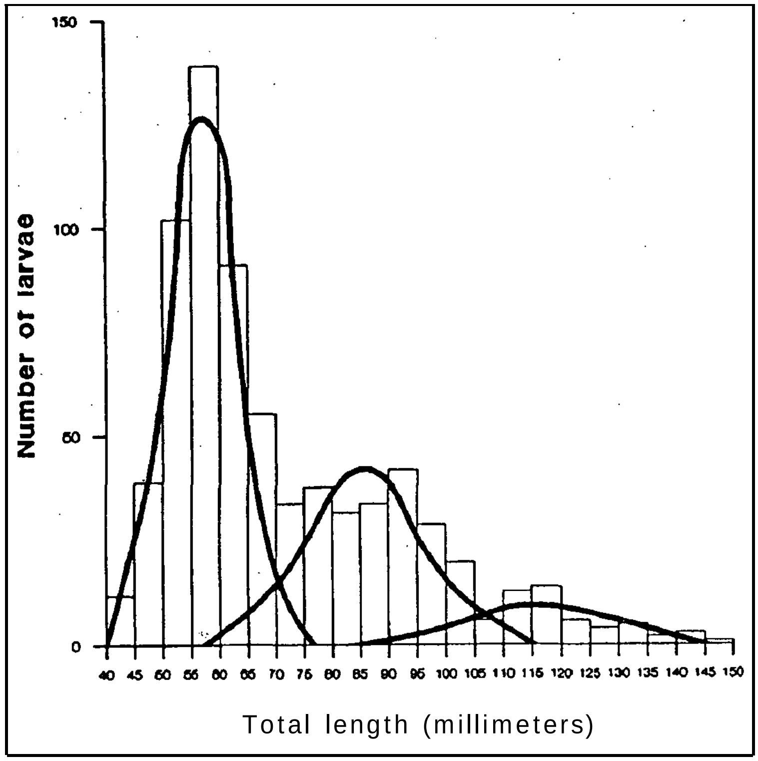

Figure 7-Size-frequency distribution of Pacific giant salamander larvae from streams in uncut forests in the Oregon Coast Range. Distributions for three size classes were fit by maximum-likelihood estimation (Macdonald and Pitcher 1979).

Range: 1 -year-old larvae (61.6 percent of larvae) with a mean total length of 57 millimeters, 2-year-old larvae (29.6 percent of larvae) with a mean total length of 86 millimeters, and 3-year-old larvae (8.8 percent of larvae) with a mean total length of 116 millimeters. The largest size class is probably incomplete because transformation into adult salamanders begins at about 100 millimeters total length.

Knowledge of local landscapes and the environmental setting of streams is essential to interpreting the population data of amphibians. For example, stream substrate is an important influence on abundance of amphibians and can be a result of local geology (Duncan and Ward 1985) or a result of management activities (including road building as well as logging) that caused erosion and sedimentation (Beschta 1978, Burns 1972, Reid and Dunne 1984, Rice and others 1979).

Knowledge of conditions upstream from a sample reach is also necessary. Corn-and Bury (1989) found that tailed frogs were more likely to be present in a stream flowing through a logged area if there was uncut forest upstream. We suspect that tailed frogs and Olympic salamanders are often extirpated in streams in clearcuts, because timber harvest results in a rise of water temperatures and drying of the terrestrial habitat (Bury and Corn 1988). If the stream flows out of an uncut forest, however, water temperature is usually moderated. If the stream is sampled in a clearcut close to the forest, Olympic salamanders and tailed frogs may be present, but we do not know whether these animals represent surviving residents in the opened habitat or if they are dispersing individuals lost to the breeding population occurring upstream in the cooler, forested habitat.

Conclusions and Recommendations

Collecting short reaches of headwater streams has been applied in 120 small streams in Douglas-fir forests in California; Oregon, and Washington (Bury and others 1991, Corn and Bury 1989, Welsh and Lind 1991) and has proven to be a useful technique for determining presence and abundance of aquatic amphibians. Intensive studies of single watersheds have been used to study the effects of forest management on stream habitats and fish populations, for example, Carnation Creek on Vancouver Island (Hartman and others 1987). But, intensive studies have not been applied to amphibian populations. Such studies will be valuable in answering many of the questions we still have about the biology of stream amphibians and their responses to forest management. Intensive studies require a long-term commitment because streams will need to be monitored both before and after a management activity.

We also suggest additional extensive studies to compare management activities across a wide geographic area. We recommend paired streams (Hall and others 1978) with adequate replication to include natural variation. Preferably, 10 pairs of streams should be sampled for each treatment to be investigated, and we recommend sampling three 5-meter-long segments of each stream. A three-person crew should be able to sample 10 pairs of streams in 4 to 6 weeks. This time is in addition to the time required for selection of study sites (review of maps and ground truthing).

There has been a major initiative to study aquatic amphibians in the Pacific Northwest, but many questions remain unanswered. First, we stress the importance of knowing how stream communities respond to timber harvest and how long any negative effects persist. Second, we need to know the life history characteristics of amphibians in both natural and disturbed habitats, especially their dispersal limitsand their abilities to reinvade disturbed habitats. Lastly, there is much to be learned about other habitat types (such as Sitka spruce or redwood forests), other geographic areas (for example, the Rocky Mountains in Idaho and Montana or the east slope of the Cascade Range), and energetic relations in other sizes of streams. We hope this paper provides a springboard for these needed studies.

Acknowledgments

We thank Lawrence Jones for his considerable contribution to the development of these sampling techniques and for reviewing this manuscript. Andrew B. Carey and Leonard F. Ruggiero also read and commented on the manuscript. This is contribution number 88 of the Wildlife Habitat Relationships in Western Oregon and Washington Project.

Equivalents

When you know:	Multiply by:	To find:
Millimeters (mm)	-0.0394	Inches
Centimeters (cm)	0.394	Inches
Meters (m)	3.281	Feet
Square meters (m^2)	10.764	Square feet
Hectares (ha)	2.471	Acres
Square kilometers (km^2)	*0.386*	Square miles
Cubic meters (m^3)	*35.315*	Cubic feet
Grams (g)	*0.035*	Ounces
Mitliliters (ml)	*0.035*	Fluid ounces

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Appendix 1

Stream Survey Data Form

Two separate forms are used to record stream data. Categories of data are described below for each.

Stream data-These are data recorded at each stream before the survey begins. One form is used for each stream (fig. 8).

1. Standard header. The stream number is a four-digit code. The first two digits are the year, and the last two digits are the stream number given sequentially to each stream sampled.

2. Crew Record the names (initials) of participants.

3. Record air temperature 2 meters above the stream and the water temperature.

4. Begin time and end time. Use 24-hour notation for when the actual search for amphibians begins and ends. Do not record time used to determine stream parameters.

5. Breaks time. Record the total number of minutes for all breaks, whether for rest breaks or for pauses for data recording. Space is provided for keeping track of individual breaks.

6. Site location. Several blanks are provided for describing the location of the stream.

7. Weather. Note cloud cover (clear, partly cloudy, overcast), wind (none, moderate, high), and precipitation (fog, mist, light or heavy rain, snow).

8. Elevation (meters). Use U.S. Geological Survey topographic maps.

9. Aspect (degrees). Record the direction of flow of the lo-meter stream segment. Often this may be different from the general direction of the stream.

10. Drainage direction. This is the orientation of the drainage basin as a whole. Record descriptive direction (for example, N, NNE, NE).

11. Gradient. Using the clinometer, determine the slope (percent drop) from the lo-meter flag to the O-meter flag.

12. Side slope. Determine the slope of the channel on each side of the stream (facing downstream). Use the clinometer and measure slope (percent) from the. center of the stream at the S-meter mark to points 10 meters uphill.

13. Vegetation cover. Use a spherical densiometer to estimate percent cover (amount of shading) at 0, 5, and 10 meters. The names of the dominant species in each vegetation layer (canopy, midstory, ground) are listed separately below. Use standard four-letter abbreviations (PSME = Douglas-fir).

14. Stream width (to nearest 0.1 meter). Record at 0, 5, and 10 meters.

STREAM SURVEY DATA SHEET: STREAM DATA

Technique			Province		Habitat			Stream Number				Day		Month		Year		Crew				
A	Q	T																				

Air °C		Water °C		Begin Time				End Time				Break Time			Breaks

State ____________ County ______________________________ Township ________ Range ________ Section ________

District/Forest ______________________________ Weather ______________________________

Elevation				Aspect			Drainage Direction			Gradient		Side Slope				Vegetation Cover (%)					
												Right		Left		0 m		5 m		10 m	

Stream Width (cm)									Stream Depth (cm)								
0 m			5 m			10 m			0 m			5 m			10 m		

Stream Section	1		2		3		4		5		6		7		8		9		10	
Pool Ratio																				
Substrate																				

Dominant Vegetation Species:

Canopy (>15m) ________ ________ ________

Midstory (2-15m) ________ ________ ________

Ground (<2m) ________ ________ ________

Associated Species					
Salmonids		Sculpins		Crayfish	

Amphibian Species									
Ascaphus truei			Dicamptodon (all)			Rhyacotriton olympicus		Plethodon dunni	

Plethodon vehiculum		Taricha granulosa		Rana aurora							

Notes

Stream Map:
(stream section number)

10 m
(10)
9 m
(9)
8 m
(8)
7 m
(7)
6 m
(6)
5 m
(5)
4 m
(4)
3 m
(3)
2 m
(2)
1 m
(1)
0 m

Figure 8—Sheet for recording data from each stream survey.

15. Stream depth (centimeters). At the same three flags as above, measure the water depth at three positions: l/4, l/2, and ***3/4*** of the distance across the stream. Sum these values and divide by ***4*** (the fourth value is the stream edge, which has depth = 0).

16. Pool ratio. Determine the length (decimeters) of each l-meter section of the stream that is in a pool. If the segment is all pool, the value = 10; if all riffle, the value = 0.

17. Substrate. Establish a visual transect across the stream at each flag (l-10 meters). Determine the predominant substrate intercepting the transect (see the substrate descriptions and codes at the bottom of the specimen data sheet). Do not average. For example, if 60 percent of the substrate is between 65 and 256 millimeters in size (cobble, substrate code 9), record a value of 9 for that section.

18. Associated species. After the survey, record the numbers of fish (salmonids-and sculpins) and crayfish encountered.

19. Amphibian species. After the survey, record the total numbers of each species of amphibian collected.

20. Survey map. Draw a rough map of the lo-meter segment showing major habitat features, such as pools, riffles, boulders, and downed wood.

Specimen data-These data are recorded for each amphibian encountered. Several sheets may be needed for each stream (fig. 9).

1. Standard header. Same as above.

2. Stream section. Record the l-meter section (see survey map) where the animal was first observed.

3. Species. Use a four-letter code incorporating the first two letters of the genus and species; for example, ASTR = ***Ascaphus*** *truei,* the tailed frog).

4. Age. A = adult, J = juvenile, L = larva (tadpole). Juveniles are transformed individuals that are not sexually mature.

5. Sex/Stage. M = male, F = female; leave blank if unknown (-1 and 0 may be used for males and females, respectively). For tailed frog tadpoles, record the developmental stage (fig. 3): 1 = hatchling tadpoles, 2 = tadpoles without well-developed hindlegs, 3 = tadpoles with well-developed hindlegs, 4 = metamorphosing tadpoles (at least one front leg emerged).

6. Total length (millimeters). This is most easily measured after placing the specimen in a plastic bag. Note individuals that do not have complete tails.

7. Environment. Record the general location of the specimen. Use the codes listed at the bottom of the data sheet.

STREAM SURVEY DATA SHEET: SPECIMEN DATA

Sheet # ______ of ______

Technique	Province	Habitat	Stream Number	Day	Month	Year
A Q T						

Stream Section	Species	Age	Sex/ Stage	Length (mm)	Envi- ron- ment	Water Depth or Distance from Water (cm)	Stream Width (cm)	Posi- tion	Substrate		Cover Size (cm)	
									I-Cover	II-Envir.	Length	Width

Environment:

R - Riffle
P - Pool
Z - Splash Zone
S - Seep
B - Bank/Soil

Position:

N - On
U - Under
I - In
S - Suspended

Substrate

1 - Silt/Clay
2 - Fine Sand (1mm)
3 - Coarse Sand (1-2mm)
4 - Gravel (3-4mm)
5 - Gravel (5-8mm)
6 - Gravel (9-16mm)
7 - Gravel (17-32mm)
8 - Pebble (33-64mm)
9 - Cobble (65-256mm)
10 - Boulder (>256mm)
11 - Wood
12 - Bark
13 - Soil
14 - Vegetation

Figure 9—Sheet for recording data from individual amphibians captured during stream surveys.

8. Depth or distance (centimeters). Record either the depth of the water where the specimen was encountered, or the distance from the water if found on the bank.

9. Width (centimeters). Record the stream width where the specimen was encountered.

10. Position. Record the specimen position relative to the substrate. Use the codes at the bottom of the data sheet.

11. Substrate I (cover). Use the substrate codes to list the cover item the specimen was found on, under, or in.

12. Substrate II (environment). Determine the substrate under the major cover object. Often large rocks or logs will have smaller rocks or silt underneath.

13. Cover size (centimeters). Record the length and width of the primary cover object.

Appendix 2

Equipment Needed for Stream Surveys

Quantity	Description
1	Dip net. Long-handled, D-shape net with fine mesh aquatic bag.
1	Dip net. Fine mesh aquarium net.
2-3	Hand-held nets. 8- by 12-inch size, constructed from l/8-inch mesh hardware cloth.
1	Potato rake (high quality).
1	Turkey baster (to suck up hatchling amphibians).
Several	Plastic bags (heavy gauge).
1	Plastic pail (l-2 gallon).
2	Polarized glasses (for looking in pools when sun is on water).
1	Thermometer, armored case.
1	Clinometer.
1	Spherical densiometer.
3	Metric rulers (one 300 millimeters, two 150 millimeters).
1	1O-meter measuring tape.
1	3-meter measuring tape.
Several	Data sheets.
Several	Pencils and small sharpener.

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