Inventory Methods for Plethodontid Salamanders

Standards for Components of British Columbia's Biodiversity No.36

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Ministry of Environment, Lands and Parks
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Preface

This manual, version 2.0, is a revised and improved presentation of standard methods for inventory of plethodontid salamanders in British Columbia at three levels of inventory intensity: presence/not detected, relative abundance, and absolute abundance. The manual was compiled by the Elements Working Group of the Terrestrial Ecosystems Task Force, under the auspices of the Resources Inventory Committee (RIC). The objectives of the working group are to develop inventory methods that will lead to the collection of comparable, defensible, and useful inventory and monitoring data for the species component of biodiversity.

This manual is one of the Standards for Components of British Columbia's Biodiversity (CBCB) series which present standard protocols designed specifically for groups of species with similar inventory requirements. The series includes an introductory manual (*Species Inventory Fundamentals No. 1*) which describes the history and objectives of RIC, and outlines the general process of conducting a species inventory according to RIC standards, including selection of inventory intensity, sampling design, sampling techniques, and statistical analysis. The *Species Inventory Fundamentals* manual provides important background information and should be thoroughly reviewed before commencing with a RIC wildlife inventory. RIC standards are also available for vertebrate taxonomy (No. 2), animal capture and handling (No. 3), and radio-telemetry (No. 5). Field personnel should be thoroughly familiar with these standards before engaging in field inventories which involve any of these activities.

Standard data forms are required for all RIC species inventory. Survey-specific data forms accompany most manuals while general wildlife inventory forms are available in *Species Inventory Fundamentals No. 1 [Forms]* (previously referred to as the Dataform Appendix). This is important to ensure compatibility with provincial data systems, as all information must eventually be included in the Species Inventory Datasystem (SPI). For more information about SPI and data forms, visit the Species Inventory Homepage at: http://www.env.gov.bc.ca/wld/spi/

It is recognized that development of standard methods is necessarily an ongoing process. The CBCB manuals are expected to evolve and improve very quickly over their initial years of use. Field testing is a vital component of this process and feedback is essential. Comments and suggestions can be forwarded to the Elements Working Group by contacting:

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The Resources Inventory Committee consists of representatives from various ministries and agencies of the Canadian and the British Columbia governments as well as from First Nations peoples. RIC objectives are to develop a common set of standards and procedures for the provincial resources inventories, as recommended by the Forest Resources Commission in its report "The Future of our Forests".

For further information about the Resources Inventory Committee and its various Task Forces, please access the Resources Inventory Committee Website at: http://www.for.gov.bc.ca/ric.

Terrestrial Ecosystems Task Force

All decisions regarding protocols and standards are the responsibility of the Resources Inventory Committee. Background information and protocols presented in this version are based on substantial contributions from Dr. Ted Davis in an earlier unpublished draft, *Standardized Methodology for the Inventory of Biodiversity: Terrestrial Salamanders*, with comments from Drs. Patrick Gregory and Kristina Ovaska and editorial assistance from Trudy Chatwin and Ann Eriksson. John Boulanger provided statistical review to version 2.0 of this manual.

This manual and its associated dataforms were edited to their final forms by Leah Westereng and James Quayle.

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1. INTRODUCTION

Terrestrial salamanders are generally small, secretive and inconspicuous, but their numbers and importance can far exceed what casual observation might suggest. They can be major contributors to biological complexity in terms of species diversity, trophic dynamics, and interactions within communities (Hairston 1987). For example, in the Hubbard Brook watershed in New Hampshire, the biomass of terrestrial salamanders is estimated to be about equal to the biomass of small mammals in the same area (Burton and Likens 1975). Similarly, in Goldstream Provincial Park on Vancouver Island, the seasonal peak surface abundance of Western Redback salamanders (*Plethodon vehiculum*) can be as high as 1.8 salamanders/m^2 (Davis 1996, 1998). Locally, other species of salamanders can be very abundant as well.

In British Columbia, many species of amphibians are at the northern extent of their range and must contend with conditions that are very different from what populations of the same species experience farther south. Thus, populations in British Columbia may be ecologically and genetically very different from populations elsewhere, and their study here can clarify patterns and processes that are important in the dynamics of amphibian populations at the limits of their distribution. In addition, with increasing human demands on the environment in the United States, some populations of amphibian species also present in British Columbia have declined (Corn and Fogleman 1984; Hayes and Jennings 1986; Bradford 1989, 1991; Kagarise Sherman and Morton 1993; Barry and Shaffer 1994; Blaustein 1994). Therefore, relatively undisturbed areas here may represent important refugia, now or in the future, even for species with broad geographic ranges that extend farther south. Thus, amphibian populations in British Columbia can have considerable scientific and conservation significance beyond the simple protection of our native species.

In recent decades, habitat fragmentation and alteration, introduction of exotic predators, acid precipitation, and chemical pollution have led to declines and losses of many amphibian populations (Pechmann and Wilbur 1994, Blaustein and Wake 1995). Declines and losses of amphibian populations have also occurred in the absence of obvious human involvement, but the causes are largely obscure (Pechmann and Wilbur 1994). Although there are no reports of declines of terrestrial salamanders in undisturbed environments, it is unlikely we would detect such declines without systematic monitoring, were they to occur. There is concern that the fragmentation or loss of temperate old-growth forests in western North America might reduce amphibian diversity and abundance, of which terrestrial salamanders make up a considerable fraction (Herrington and Larsen 1985; Aubry *et al.* 1988; Bury and Corn 1988; Gibbons 1988; Raphael 1988; Welsh and Lind 1988; Hansen *et al.* 1991; Dupuis *et al.* 1995; Dupuis 1997). Thus, it is very important to provide standards and encourage inventory and monitoring of amphibians, so that population trends may be assessed and managed. This manual is a guide to conducting presence/not detected (possible) surveys, estimating the relative and absolute abundance, and monitoring the population dynamics of terrestrial salamanders in British Columbia.

2. INVENTORY GROUP

Nine species of salamanders occur in British Columbia, four of which are members of Family Plethodontidae (Table 1). Plethodontid salamanders lack lungs and the exchange of respiratory gases occurs across the highly vascularized skin and buccal cavity. As a result of transcutaneous gas exchange, the skin is very permeable to water, making these salamanders especially susceptible to desiccation (Shoemaker *et al.* 1992). This restricts them to moist microhabitats. Nevertheless, like many plethodontids, the species that occur in British Columbia are completely terrestrial: they lay their eggs on land, their young hatch as miniature replicas of the adults, and they do not require standing or running water during any part of their life cycle. Like all amphibians, their body temperature varies with the ambient temperature (poikilothermy) and heat is obtained mainly from the external environment (ectothermy). Thus, their surface activity is constrained by moisture and temperature.

Plethodon idahoensis (Coeur d'Alene Salamander), differs from the other terrestrial salamanders in British Columbia in that it has a very restricted distribution and is associated with seepages and the splash zone of creeks or waterfalls (Leonard *et al.* 1993). Therefore, somewhat different methods are needed for it than are needed for the other plethodontid species. However, *Plethodon vandykei* (Van Dyke's Salamander), which is very similar to *P. idahoensis*, has been found far from water, so *P. idahoensis* may also occur in microhabitats away from creeks. In that case, the methods described here will be appropriate for *P. idahoensis* in areas away from seepages and splash zones.

The remaining five species of salamanders (*Taricha granulosa, Ambystoma gracile, Ambystoma macrodactylum, Ambystoma tigrinum,* and *Dicamptodon tenebrosus* (=*ensatus*); Table 1) have terrestrial adult stages, but they must return to water to reproduce where they lay eggs which develop into aquatic larvae. During the adult terrestrial stages, these species can be found considerable distances from water, and some of the methods described in this manual may be applicable to them. However, they are usually easier to find in their aquatic environments so initial inventories should include ponds and streams.

Three species, *Aneides ferreus* (Clouded Salamander), *Plethodon vehiculum* (Western Redback Salamander), and *Ensatina eschscholtzii* (Ensatina), have wide distributions in similar terrestrial coniferous forest habitats and are the focus of this manual. These species have similar natural history characteristics but differ in the details of their microhabitat requirements (see below; Davis 1996, 1998). Locally, they can be very abundant, but populations tend to be patchy across apparently homogeneous habitat. Resources such as mates and prey are obtained primarily at the surface and little or no feeding is thought to take place underground (Fraser 1976a,b; Maiorana 1976). Thus, their ability to grow and reproduce is directly related to the length of time that they spend near the surface (Houck 1977; Jaeger 1980, Semlitsch and West 1983). They can be found at the surface fairly easily throughout most of the year, but disappear during the coldest part of the winter when below-freezing temperatures force them underground or deep inside logs. Dry conditions late in the summer and in early autumn can have a similar effect.

Table 1. Salamanders of British Columbia.

Data from Green and Campbell (1984), Stebbins (1985), and Leonard *et al.* (1993).
SVL = snout-vent length; TL = total length.

Family	Species Name & Code	Size (mm)	Reproductive Mode/Habitat	Typical Terrestrial Habitat
Salamandridae	Roughskin Newt, *Taricha granulosa* A-TAGR	60-90 SVL 120-180 TL	Eggs and larvae aquatic/ lakes, ponds, swamps, and slow moving streams.	Under or within logs or leaf litter; nocturnally and diurnally active on surface.
Ambystomatidae	Northwestern Salamander, *Ambystoma gracile* A-AMGR	75-100 SVL 150-200 TL	Eggs and larvae aquatic/ lakes, ponds, and slow moving streams.	Terrestrial habitat poorly known. Underground burrows, occasionally under or within logs; some populations may be neotenic.
Ambystomatidae	Long-toed Salamander, *Ambystoma macrodactylum* A-AMMA	40-60 SVL 80-120 TL	Eggs and larvae aquatic/ temporary pools, small lakes, ponds, and slow moving streams.	Terrestrial habitat poorly known. Underground burrows, under rocks, bark and logs on soil or within leaf litter.
Ambystomatidae	Tiger Salamander, *Ambystoma tigrinum* A-AMTI	70-90 SVL 140-180 TL	Eggs and larvae aquatic/ lakes and ponds.	Terrestrial habitat poorly known, but are usually found near lakes and ponds; some populations are neotenic.
Dicamptodontidae	Pacific Giant Salamander, *Dicamptodon tenebrosus (=ensatus)* A-DITE	90-150 SVL 150-250 TL	Eggs and larvae aquatic/ clear fast moving streams or mountain lakes.	Terrestrial habitat poorly known. Underground burrows, within or under logs; may be neotenic.
Plethodontidae	Clouded Salamander, *Aneides ferreus* A-ANFE	48-66 SVL 80-110 TL	Eggs terrestrial; direct development/ cavities within logs.	Under bark on logs or within logs; especially decay class 3.

Family	Species Name & Code	Size (mm)	Reproductive Mode/Habitat	Typical Terrestrial Habitat
Plethodontidae	Western Redback Salamander, *Plethodon vehiculum* A-PLVE	40-55 SVL 80-110 TL	Eggs terrestrial; direct development/ in cavities below surface.	Talus, under rocks, bark and logs on soil or within leaf litter and Sword Fern bases.
Plethodontidae	Ensatina, *Ensatina eschscholtzii* A-ENES	40-60 SVL 80-120 TL	Eggs terrestrial; direct development/ cavities below surface or under or within logs.	Talus, under rocks, bark and logs on soil or within leaf litter.
Plethodontidae	Coeur d'Alene Salamander, *Plethodon idahoensis* A-PLID	40-55 SVL 80-110 TL	Eggs terrestrial; direct development/ under rocks or within logs.	Near seepages or streams; splash zone of creeks or waterfalls under rocks or woody debris, or under logs, bark and bark on logs near water.

Peak abundance at the surface is usually in the spring or early summer (Ovaska and Gregory 1989; Davis 1991, 1996, 1997, 1998), but surface abundance can increase dramatically at any time of the year if conditions are favourable. Females lay and brood small clutches of eggs in the early summer. The larval stage is passed in the egg, and young hatch in the autumn as miniature replicas of the adults (McKenzie 1970; Davis 1991). All three species are opportunistic predators, feeding on small terrestrial invertebrates.

2.1 Clouded Salamander (*Aneides ferreus*)

The geographical distribution of this species is strikingly disjunct: Vancouver Island, British Columbia, and south of the Columbia River in Western Oregon and northwestern California (Wake 1965). In British Columbia, *A. ferreus* are found on Vancouver Island at altitudes less than about 600 m, and are well established on many of the smaller islands nearby (Davis and Gregory 1993). They can be found in moist terrestrial habitats such as under exfoliating bark and in cracks and cavities of decomposing logs, stumps, and snags, in talus, and occasionally in trees (Nussbaum *et al.* 1983; Stebbins 1985; Davis and Gregory 1993; Leonard *et al.* 1993; Davis 1996, 1998). Davis (1996, 1998) usually found *A. ferreus* in decay class 3 logs, and much less commonly in logs of the other decay classes. They are very rarely found under coarse woody debris (CWD) on the soil surface. These animals are very site-specific and most movements of individuals are < 2 m between captures that may be many months apart (Davis 1991). Peak abundance at the surface occurs in June (Davis 1991, 1996, 1997, 1998). Courtship and mating take place in the spring, and females lay small clutches of eggs in cavities within decomposing logs in the early summer (McKenzie 1970; Davis and Gregory

1993). Prey consists of small terrestrial arthropods, especially insects (Stelmock and Harestad 1979).

There is no evidence that *A. ferreus* are endangered at the present time or that they require special protection. However, since they are often associated with decaying logs and their distribution is patchy, logging and silvicultural practices could affect their abundance, and local source populations might need protection or habitat enhancement.

For a detailed summary of the status and natural history of *A. ferreus*, see Davis and Gregory (1993). Additional information can be found in Davis (1991, 1996, 1997, 1998). For field identification, descriptions can be found in Nussbaum *et al.* (1983), Green and Campbell (1984), Stebbins (1985), Leonard *et al.* (1993), and Corkran and Thoms (1996).

2.2 Western Redback Salamander (*Plethodon vehiculum*)

This species is found from southern Oregon to southern British Columbia, west of the Cascade and Coast mountains (Stebbins 1985; Leonard *et al.* 1993). In British Columbia, they are found throughout Vancouver Island and on the mainland in the Fraser Valley as far as Hope (Green and Campbell 1984). Curiously, they have not been recorded from any of the Gulf Islands and are absent from most of the other islands surrounding Vancouver Island. This contrasts dramatically with *A. ferreus* (see section 2.1).

Plethodon vehiculum are found within leaf litter and Sword Fern (*Polystichum munitum*) bases, under moss, rocks or CWD on the forest floor, and under or among rocks on talus and rock outcrops (Leonard *et al.* 1993). They favour damp, but not wet, shady areas of the forest and can be very abundant (Davis 1996, 1998). Ovaska (1988b) reported a high degree of site-specificity and small home ranges. Most movements of individuals between captures over a two-year period were < 3 m. On Vancouver Island, salamanders move from underground retreats during warm wet weather, so peak surface abundance occurs in the spring and autumn, depending on recent weather conditions (Ovaska and Gregory 1989). Courtship and mating occur mainly in October and November (Ovaska and Gregory 1989), but eggs are laid the following summer. Eggs and nests are not well documented, probably because eggs are laid beneath the surface (Leonard *et al.* 1993). Hatchlings appear in the autumn and take two to three years to reach sexual maturity (Ovaska and Gregory 1989). Prey consists of terrestrial invertebrates.

There is no evidence that *P. vehiculum* are endangered at the present time or that they require special protection. However, numbers are reduced in clearcuts (Dupuis *et al.* 1995; Dupuis 1997; Davis 1996, 1997, 1998) and in second-growth stands (Dupuis *et al.* 1995; Dupuis 1997). Abundance varies greatly across apparently homogeneous habitat, but at least some populations appear to be very stable (Davis 1996, 1998). Very dense local populations may act as source populations for adjacent less favourable habitat.

For natural history notes see Peacock and Nussbaum (1973), Ovaska (1987, 1988a,b), Ovaska and Gregory (1989), and Davis (1996, 1998). For field identification, descriptions can be found in Nussbaum *et al.* (1983), Green and Campbell (1984), Stebbins (1985), Leonard *et al.* (1993), and Corkran and Thoms (1996).

2.3 Ensatina (*Ensatina eschscholtzii*)

This species is found from extreme northwestern Baja California to southern British Columbia, west of the Sierra Nevada mountains in California (but absent from the Great Valley of California), west of the Cascade crest in Oregon and Washington, and on eastern Vancouver Island, the adjacent mainland, and up the Fraser valley to Boston Bar in British Columbia (Green and Campbell 1984; Leonard *et al.* 1993). These salamanders can be found in damp microhabitats under rocks or CWD on the forest floor, at the entrance of rodent burrows, and under or among rocks on talus, and particularly within and under bark piles at the base of snags and stumps, but are almost never found in perpetually wet areas (Leonard *et al.* 1993). They may be difficult to find during the day, but may be abundant on the surface at night during warm wet weather and are sometimes observed on paved roads when conditions are favourable. This species has not been studied in British Columbia, but its ecology and genetics has been intensively studied in California (Stebbins 1954; Wake and Yanev 1986).

If disturbed, individuals may show a defensive display and produce a milky poison on the dorsal side of the tail. Also, the tail is easily autotomized, usually at the basal constriction, leaving a predator with a writhing noxious tail while the salamander escapes (Green and Campbell 1984; Leonard *et al.* 1993). For natural history notes see Stebbins (1954) and Davis (1996, 1998), and for field identification see Nussbaum *et al.* (1983), Green and Campbell (1984), Stebbins (1985), Leonard *et al.* (1993), and Corkran and Thoms (1996).

3. PROTOCOLS

For the inventory, conservation and management of amphibians, it is important to consider the natural history of each species. For example, the abundance of terrestrial salamanders can be extremely variable across or within what appear to be homogeneous sites (Davis 1996, 1998). This may occur because the sites may actually consist of a patchwork of microhabitats of varying quality. Thus, the overall population, known as a metapopulation, might contain a number of subpopulations that are linked by occasional dispersal (Hanski and Gilpin 1991). Some subpopulations might be reproductive sinks and persist only as a result of immigration from reproductive source populations. The state of the population (source or sink) may change through time because of changes in the environment, or random fluctuations in reproductive success.

The rationale for using standard techniques in inventory and monitoring work is that the results of different studies are much more likely to be comparable (Heyer *et al.* 1994:17). However, simply using the same methods will not guarantee that the results are comparable. For example, apparent terrestrial salamander surface abundance, determined by searches of natural cover, can vary with the time of day, recent weather conditions, season, or year, independent of the actual abundance (Davis 1996, 1998). Also, searches of natural cover among sites that differ in the amount and type of cover may not be comparable because some types of cover may be difficult to search efficiently, and this could result in unequal search effort among sites. Finally, search effort, the microhabitat searched, and the ability to detect salamanders varies among individual field workers or through time with the same individual (Davis 1996, 1998). Thus, it is important that the details of the methods be reported, and the assumptions be clearly understood. Also, when possible, a variety of techniques should be used (Heyer *et al.* 1994:17). Caution should be exercised when attempting to compare results among studies, sites, or through time.

The methods recommended for sampling terrestrial salamanders in British Columbia are summarized in Table 2. When considering sampling schemes and methods, the different types of information, levels of effort, cost, specific site characteristics and limitations must be considered in light of the objectives of the study and the urgency of the management decisions to be made. Often, several different methods may be needed to address different aspects of a study. As new information is obtained, new questions and hypotheses may be formed, the objectives redefined and the methods modified. Typically, there will be a tradeoff between the amount of time and money an investigator can devote to a particular plot or site and the number of replicate plots or sites that it is possible to establish (Hairston 1989).

Since the inventory methods recommended involve the handling and/or capture of salamander(s), consult the manual, *Live Animal Capture and Handling Guidelines for Wild Mammals, Birds, Amphibians, and Reptiles* (CBCB manual no.3) for more information.

Table 2. Summary of sampling methods.

PN = presence/not detected; RA = relative abundance; AA = absolute abundance

Sampling Method	Description	Intensity	Recommended Use	Limitations
Time-Constrained Search (TCS)	Search under natural cover	PN	Most direct approach for PN	Disturbs habitat
Transect Search	Search under natural cover	PN	Systematic approach for PN	Disturbs habitat
Night Driving	Drive or bicycle along paved roads	PN	For *E. eschscholtzii* only	Efficiency unknown
Quadrat Sampling: Point Sampling	Stratified random sampling using small (e.g., 1 x 1 m) quadrats; random walk or along transects	PN RA	Use when density > 0.5 individuals/m^2	Disturbs habitat
Quadrat Sampling: Broad Sampling	Stratified random sampling using large quadrats (e.g., 8 x 8 m)	PN RA	Use when density < 0.5 individuals/m^2	Disturbs habitat
Transect Sampling	Random or systematic sampling along transects	RA	Use where elevational or habitat gradients exist	Disturbs habitat
Pitfall Trapping	Pitfall traps set out in grids, arrays or transects	RA	Relatively non-destructive and recommended for intensive monitoring; eliminates observer bias	Labour intensive when used with drift fences; may miss some species; not recommended for *A. ferreus*.
Artificial Cover Objects (ACOs)	ACOs set out in grids, arrays or transects	RA	Relatively non-destructive; recommended for intensive monitoring; attracts all species; reduces observer bias	Labour intensive to set up; ACO may change through time.

3.1 Sampling Standards

3.1.1 Habitat Data Standards

A minimum amount of habitat data must be collected for each survey type. The type and amount of data collected will depend on the scale of the survey, the nature of the focal species, and the objectives of the inventory. As most, provincially-funded wildlife inventory projects deal with terrestrially-based wildlife, standard attributes from the terrestrial Ecosystem Field Form developed jointly by MOF and MELP (1995) will be used. The manual, *Species Inventory Fundamentals (No. 1),* contains a generic discussion of habitat data collection as well as a list of the specific requirements for plethodontid salamander surveys (Appendix E).

3.1.2 Marking and Identification

The recognition of individuals or previously captured animals is essential for estimating relative abundance when repeated sampling results in recaptures, and for obtaining information on the movements of individual animals, growth rates, age at sexual maturity, frequency of reproduction and probability of survival. There are four marking techniques that have been used with terrestrial salamanders: pattern mapping, radioactive tagging, fluorescent marking, and toe-clipping. The recommended marking scheme is toe-clipping, but fluorescent marking is being investigated (T. Davis and K. Ovaska, pers. comm.). Marks can be group-specific (e.g., date or site), or individual-specific. Many studies require group marks only, which are much simpler to use than individual marks, and so are recommended unless individual marks are needed for other purposes. Individual marks will be needed if individual growth rates, space-use patterns, and other life history characteristics are required.

Toe-clipping

Toe-clipping is generally the most practical method for marking more than a few individuals. Because it is relatively easy to do and inexpensive, it is by far the most common method of marking small salamanders and other amphibians. Toe-clipping has been used in almost every study of terrestrial salamanders in which individual-specific marks were required. However, salamanders should not be routinely marked unless there is a clear reason for doing so. For much inventory work, marking of individual animals is neither necessary nor desirable. Before undertaking a marking program, the reasons for doing so must be clearly stated. Although toe-clipping is faster and easier to do than other methods of marking, it is time-consuming and sometimes difficult. Also, toe-clipping might have negative effects on survivorship. Little work has been done on the effects of toe-clipping on the survival, behaviour and recapture rates of salamanders. However, Clarke (1972) has shown that toe-clipping can reduce survivorship in Fowler's Toad (*Bufo woodhousei fowleri*), and Golay and Durrer (1994) reported that toe-clipping of natterjack toads can lead to infection and necrosis, sometimes involving the entire limb. A discussion of ethical issues relative to toe-clipping appears in the March 1995 issue of FROGLOG.

To mark salamanders individually, two to four toes are removed with small, good quality scissors. Generally, no more than three toes are removed, but never more than one toe from each foot. Removing two toes from the salamander is optimal, because a single toe can be lost occasionally by accident or attempted predation, and a minimum number of toes cut should minimize any adverse effects caused by the procedure. An inexpensive head mounted magnifier (e.g., Magni-focuser®, Edroy Products Co., Inc., Nyack, New York) will make clipping and reading the marks easier, and a pen light is useful under the reduced light conditions that can exist beneath dense forest canopies on cloudy days. After the toes are clipped, the code should be read back to the data collector to ensure that the mark corresponds to what is recorded on the data sheet, because while clipping the toes, it is easy to become confused as to orientation of the salamander and the order in which the mark is read. After finishing with each salamander, the scissors should be dipped in 95% ethanol to reduce the chance of transmitting infections between salamanders. The antiseptic Bactine® could be applied to clipped digits to prevent infection (Donnelly *et al*. 1994).

The choice of a coding system is largely a matter of personal taste and experience, but it is desirable to use a system that is simple and easily recorded. Several coding schemes are presented by Donnelly *et al.* (1994). Presented here is a simple symbolic coding scheme that does not require mental addition and uses a single numeric character per foot (Figure 1). For these reasons, this is the standard method of coding for toe-clipping that will be used. Each mark is of the form 0000 where each character place corresponds to a particular foot. Numbers correspond to particular toes. No more than one toe from each foot should be excised. The code is read from the left front foot to the left back foot, to the right front foot and finally to the right back foot. Toes are counted from proximal to distal, except that the most proximal toe on each foot is not counted because it is too small to use. A dorsal view is used because if the ventral side is turned upwards, these salamanders will struggle. Thus, 0320 represents toes number three on the left hind foot and number 2 on the right forefoot. For most studies, only two and three-toe marks will be needed. To avoid using the same code twice, a sheet containing all the codes should be prepared, and codes checked off as they are used. Additional numbers may be used to indicate unusual marks (e.g., 5 = foot missing; 6 = leg missing; 7 = 2 or more toes missing; 8 = toes fused; 9 = see comments).

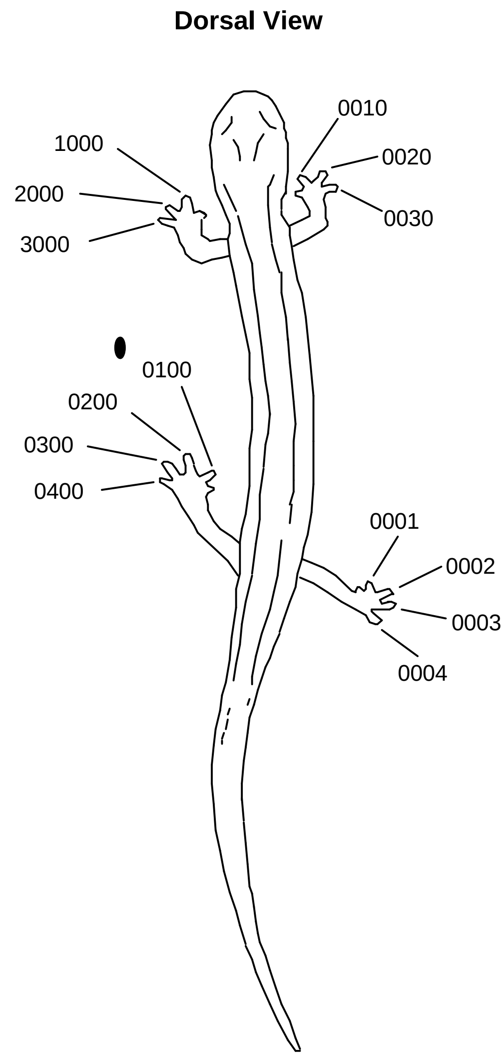

Figure 1. A symbolic coding scheme for toe-clipping terrestrial salamanders.

The code is read from the left front foot to left back foot to right front foot to right back foot. At lower left, an (M) marks toes that have been clipped; this mark reads 2403. Note that the most proximal digit which is small, is not used.

3.1.3 Measurements

Weight

- Salamanders may be weighed in a plastic bag with a 10 g spring scale (e.g., Pesola® spring scale) to the nearest 0.1 g. The scale may be adjusted to zero with the plastic bag empty, but this should be checked frequently. These scales are very accurate in still air, but a wind screen is needed when the air is moving. A 2-litre plastic water bottle with the top cut off is a convenient wind screen, but the plastic bag should not touch the sides of the bottle. When raining, water clings to the bag thereby increasing its weight, so under these conditions weighing is time-consuming and it is difficult to get an accurate reading.

Length

- Snout-vent length (SVL) is generally preferred over total length because tails can be partially missing and are difficult to measure on live animals. Typically, SVL is measured to the nearest 0.1 mm with a vernier caliper. The salamander can be held against the first two fingers of the left hand by the thumb and the caliper can be operated with the right hand. It is important to hold the salamander so that the vertebral column is straight. Too firm a grip will cause the salamander to struggle, and some practice is needed to develop the technique. The salamander will also struggle if turned ventral side up, so the anterior end of the vent is estimated relative to the hind limb. Alternatively, the salamander can be restrained inside a plastic bag or a Plexiglas® and sponge device described by Wise and Buchanan (1992). Some inaccuracies are inevitable as the salamander will attempt to contort its body, and efforts should be made to ensure that the vertebral column is straight. To assess precision, repeated measurements should be made on a series of live specimens, and to assess accuracy these should be checked against measurements taken when the same animals are anesthetized or dead.
- SVL can be measured from the tip of the snout to either the anterior or posterior end of the vent. Some researchers prefer the posterior end, as it separates body length from tail length, the entire vent region being part of the body (Leonard *et al.* 1993:163). However, the measurement is frequently interpreted as snout-*to*-vent length, so the measurement is taken to the anterior end of the vent. This can be considered standard (Stebbins 1985:3; Heyer *et al*. 1994:276), and is the standard for RIC inventories. Still, care must be taken when comparing SVL measurements from different studies.
- Routine anesthesia is not recommend in the field, but can be accomplished with a few drops of Metofane® (methoxyflurane) applied to a piece of gauze attached to the inside of the lid of a 500 ml jar. The salamander is placed in the jar and will become limp and immobile in about one minute. Recovery time is about 10 minutes.

Sex/Age

- Determining the sex of adult *P. vehiculum* can be accomplished by sliding a moistened finger anteriorly on the underside of the snout (Ovaska 1987). The protruding premaxillary teeth can be felt in males, but not in females.
- Davis (1991) distinguished juvenile from adult *A. ferreus* on the basis of colouration, but if an animal was ambiguously coloured, it was considered an adult if the SVL was 50 mm.

3.1.4 Voucher Specimens

Monitoring studies and inventories should include voucher specimens, preserved and deposited in the collection of a museum or university. The institution should be contacted before the specimens are collected. Collecting voucher specimens allows the identification to be verified, and the study to be re-evaluated later. Appropriate field data, including location, date, identification number, species name, and the collector's name should accompany the specimen. A discussion of the importance of voucher specimens and how they should be prepared can be found in Heyer *et al.* (1994:66). All voucher collections and preparation must follow the manual no. 4, *Inventory Methods for Voucher Specimen Collection, Preparation, Identification and Storage Protocol: Standards for Components of British Columbia's Biodiversity* (RIC 1999).

3.1.5 Permits

All native amphibian species in British Columbia are under the protection of the Wildlife Act (1982) and can not be collected or disturbed without a permit from the Wildlife Branch, Ministry of Environment, Lands and Parks. For more information on how to obtain a permit see manual no. 4, *Voucher Specimen Collection, Preparation, Identification and Storage Protocol* (RIC 1999).

3.1.6 Survey Design Hierarchy

Plethodontid salamander surveys follow a survey design hierarchy which is structured similarly to all RIC standards for species inventory. Figure 2 clarifies certain terminology used within this manual (also found in the glossary), and illustrates the appropriate conceptual framework for a pitfall trapping survey. A survey set up following this design will lend itself well to standard methods and RIC data forms.

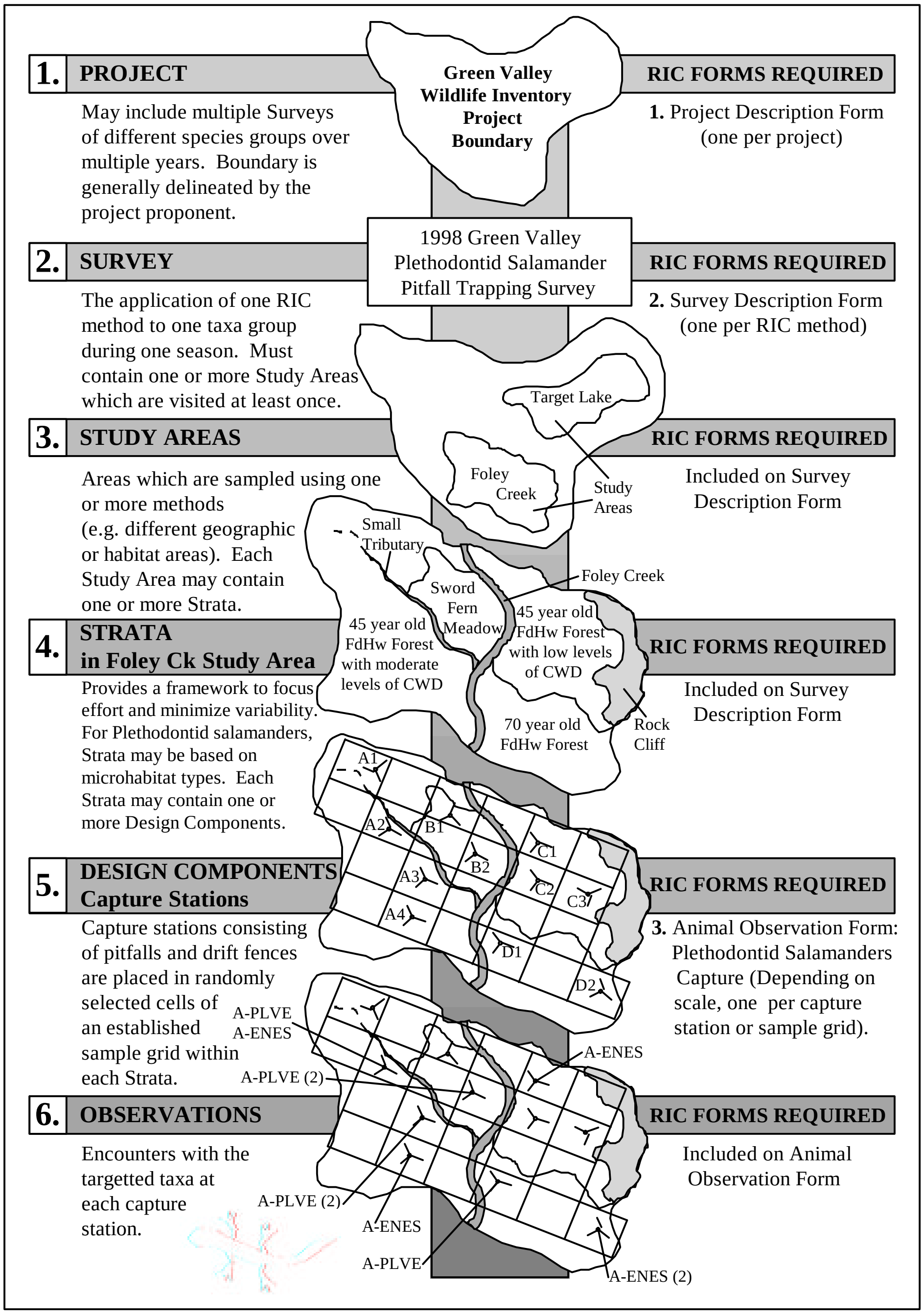

Figure 2. RIC species inventory survey hierarchy with examples.

3.2 Inventory Surveys

The table below outlines the type of surveys that are used for inventorying plethodontid salamanders for the various survey intensities. These survey methods have been recommended by wildlife biologists and approved by the Resources Inventory Committee.

Table 3. Types of inventory surveys, the data forms needed, and the level of intensity of the survey.

Survey Type	Forms Needed	*Intensity
Time Constrained Search	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form - General • Animal Observation Form- Plethodontid Salamander Time Constrained Searches/Quadrat Sampling	• PN
Night Driving	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form - General • Animal Observation Form- Plethodontid Salamander Transect Sampling	• PN
Quadrat Sampling: Point or Broad	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form - General • Animal Observation Form- Plethodontid Salamander Time Constrained Searches/Quadrat Sampling	• PN • RA
Fixed-width Transect Sampling	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form - General • Animal Observation Form- Plethodontid Salamander Transect Sampling	• PN • RA
Artificial Cover Objects (ACO's)	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form - General • Capture Form - Plethodontid Salamander • Animal Observation Form- Plethodontid Salamander Capture	• PN • RA
Pitfall Trapping	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form - General • Capture Form - Plethodontid Salamander • Animal Observation Form- Plethodontid Salamander Capture	• PN • RA

* PN = presence/not detected (possible); RA = relative abundance; AA = absolute abundance

3.3 Presence/Not detected

Recommended methods: Time-constrained searches (TCSs); transect searches; night driving (*for E. eschscholtzii* only).

If the goal of the study is to determine the number of species of terrestrial salamanders present in a specific area (species richness), the most direct approach is to systematically search the natural habitat by turning over natural cover and searching specific microhabitats when weather conditions are warm and wet. This is more complicated than it might first appear, because terrestrial salamanders can be very secretive and virtually impossible to find when conditions of temperature or moisture are unfavourable. Therefore, not finding a particular species at a site, even after extensive searching, does not necessarily mean that the species is absent from that site. However, if the appropriate microhabitats are searched when weather conditions are favourable, and searches are done several times in a season, as the cumulative number of unproductive searches increases, it becomes increasing unlikely that the species is present.

The most direct approach to establishing presence is to search under natural cover, concentrating on species-specific microhabitats, especially when weather conditions are wet and mild. *Plethodon vehiculum* and *E. eschscholtzii*, are most easily found on the soil under logs and rocks. Large and moderate size CWD (10 cm or more in diameter) should be checked, but in general, searching through leaf litter or turning over very small objects is not very efficient. If conditions are wet, *P. vehiculum* can often be found in and around the bases of Sword Fern (*Polystichum munitum*). Piles of bark or wood should be searched thoroughly. Talus may contain dense populations of *P. vehiculum* or *E. eschscholtzii*. For *A. ferreus*, bark on logs should be removed and the decayed wood separated layer by layer. This species can be found under bark that is securely attached to the log, so any bark that can be reasonably peeled with a wrecking bar or light axe should be removed. If logs are cracked, they can be pried or split open. *A. ferreus* may also be found within or under moss on logs and trees. Simply searching under cover objects on the soil will yield few if any individuals, even where these salamanders are very abundant.

Some habitat modification is unavoidable, and if searches are thorough they can be very destructive. Habitat disturbance can be minimized by returning cover objects to their original positions. Also, removing bark and splitting logs often creates new spaces that are subsequently used by salamanders, especially if the bark or logs are put back in place. If disturbance of the natural habitat is unacceptable or prohibited, pitfall trapping, the use of artificial cover objects, or night driving may be useful.

Data analysis for presence/not detected surveys

The analysis of presence/not detected data depends on the objectives of the inventory effort. Table 1 highlights suggested analysis methods for given objectives.

Quantifying probability of detection: The main purpose of these methods is to document species geographic ranges. From a statistical point of view, it is important to attempt to quantify the detection probability (as a function of population density, population spatial distribution, detection probability, sampling effort, and other covariates) for a species to allow a general estimate of the optimal amount of effort needed for surveys. Also, if an attempt is made to quantify probabilities of detection, a more statistically conclusive statement can be made about possible reasons for not detecting a species as opposed to a simple “none were found” conclusion. A simple way to estimate probability of detection (at an assumed density and spatial distribution) is through the use of the negative binomial distribution with data from relative abundance surveys. This procedure is detailed in manual no.1,*Species Inventory Fundamentals*, section 5.0 (sections 5.2.4 and 5.3.1).

Table 4. RIC objectives and analysis methods for presence/not detected data

RIC Objective	Analysis Methods	Program
• Document species range	• Analysis to ensure adequate effort. Negative binomial estimate[1]	• See manual no.1, section 5.2
• Determine habitat associations	• Logistic regression	• Generic statistical analysis software
• Detect change in distribution over time	• Use relative abundance methods and regression techniques.	• Generic statistical analysis software

[1] See manual no. 1, *Species Inventory Fundamentals*, section 5.2 for more details on negative binomial methods.

Documenting species distribution changes: If the objective is to detect changes in distribution over time, a more intensive survey regime is recommended using relative abundance methods. This will allow an actual probability level to be associated with changes in distribution or apparent local extinction. A conclusion that species have become extinct in an area using presence/not detected methods will be inconclusive if no estimate of survey precision is possible.

Documenting habitat associations: If habitat association is an objective it will be important to document habitat types at the scale of salamander home ranges.

3.3.1 Time-Constrained Searches (TCSs)

As a general preliminary approach, informal opportunistic searches may reveal the presence of the target species, especially if the appropriate microhabitats are searched.These may be done as time-constrained searches (TCSs) which are equal-effort searches as measured by the number of person-hours spent searching (Corn and Bury 1990). In areas where these species are common, a 1-person-hour search will yield many salamanders. Searches should be done on wet, mild days during daylight hours. TCSs should be cover as much habitat as possible, so no more than a few minutes should be spent searching any one object. This method does not work well for habitat associations, since the selection of sampling units would be arbitrarily based on the search area that could be covered in a unit amount of time.

TCSs should be used as quick surveys of sites and are not a substitute for more systematic transect searches (see Section 3.3.3). If the target species are not found after 1-person-hour of searching, transect searches should be done.

Office procedures

- Review the introductory manual No. 1 *Species Inventory Fundamentals.*
- Obtain maps for Project and Study Area(s) (*e.g.*, 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps). Any map which is used to record data should be referenced to NAD83.
- Outline the Project Area on a small to large scale map (1:250,000 – 1:20,000).
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the Project Area from maps.
- Delineate one to many Study Areas within this Project Area. Study areas should be representative of the Project Area if conclusions are to be made about the Project Area. For example, this means if a system of stratification is used in the Sampling Design then strata within the Study Areas should represent relevant strata in the larger Project Area.
- Based on the maps and other knowledge of the Study Area (previous reports, local resource specialists) identify sites which are of most interest. Delineate sites of relatively uniform habitats.

Sampling design

- There is no formal sampling design other than a limitation on the time spent searching.
- Concentrate on species-specific microhabitats. The approximate amount of area searched should be noted on survey data forms.
- [The Design Components for this survey are search units.]

Sample effort

- Search appropriate microhabitats when weather conditions are favourable for 1-person-hour. If the target species are not located, transect searches are indicated (Section 3.3.3).

Equipment

- Garden forks, wrecking bar, hatchet or light axe
- Field guides to amphibians (Nussbaum *et al.* 1983; Leonard *et al.* 1993)

- Maps
- Data forms (waterproofed) and pencil
- Calipers
- Thermometer
- 10 g spring scale
- Plastic bags

Field procedures

- Record appropriate environmental conditions and habitat information.
- When weather conditions are wet and mild, search species-specific microhabitats for 1-person-hour. Record the amount of area that was covered in the search. If the target species are not located, transect searches are required (Section 3.3.3).
- Search species-specific microhabitats:
  - *P. vehiculum* and *E. eschscholtzii* - search on the soil under logs and rocks >10 cm in diameter and in piles of bark and wood. Avoid leaf litter or very small objects. In talus, search through rocks of all sizes.
  - *P. vehiculum* - search in and around the bases of Sword Ferns when conditions are wet.
  - *A. ferreus* - bark on logs in decay states 2-4 (Appendix A) should be removed and the decayed wood separated layer by layer. Logs should be split along natural cracks and split open.
- Record appropriate measurements for individual animals (see Section 3.1.3).
- Obtain voucher specimens where appropriate (see Section 3.1.4).

Data Entry

The Design Components for this survey are search units. When digitally entering your survey data, choose ‘Block/Search Area’ from the ‘Design Component Type’ picklist.

3.3.2 Transect Searches

If no salamanders are found during a 1-hour TCS, a more systematic approach is needed to establish their presence or absence. These species are occasionally difficult to locate, populations are patchy, and areas where they occur might be overlooked. Transect searches address these problems.

The recommended approach is to search the appropriate species-specific microhabitats (Table 1) along 2 m wide transects that are set out systematically across the study area. This method assumes that all salamanders will be detected within the 2 m strip searched. These transects should be parallel to each other and approximately 20 m apart. Each transect is generally 100 m long, but may longer or shorter depending on the size of the study area. Ideally, the transects should extend across the entire area. Where this is not possible, the area should be stratified and transects set out so that all habitats and sections of the area are well represented.

It should be noted that a fixed-width (strip) transect will only be valid if the strip line of two meters is followed. This means ignoring ideal microhabitats which are just past the two meter mark. The perpendicular distance (from the strip center) of any sightings which are past the two meter mark should be noted in the data set so that these observations are not included in indices.

Because this protocol is for presence/not detected only, it is not necessary to measure the precise length of the transect or that all transects be of the same length. Rather, the idea is to get good coverage of the area. Thus, transects can follow a compass line beginning at a convenient road or trail and end at some natural feature such as a creek or ridge top. Nevertheless, the approximate length of the transects and their locations should be recorded, as well as the number of person-hours spent searching. Note that the surface density of these species can vary hugely over short distances in what superficially appears to be a homogeneous area. Davis (1996, 1998) found that the surface density of *P. vehiculum* in Goldstream Provincial Park varied by a factor of 72 over a distance of 200 m, and that the number of salamanders caught over an extended period in an old-growth site differed by a factor of more than 12 between plots 50 m apart.

Office procedures

- Review the introductory manual No. 1 *Species Inventory Fundamentals.*
- Obtain maps for Project and Study Area(s) (*e.g.,* 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps). Typically 1:50 000 are used, but a larger scale such as 1:20 000 is ideal for identifying and then overlaying transects on to the map sheets. Any map which is used to record data should be referenced to NAD83.
- Outline the Project Area on a small to large scale map (1:250,000 – 1:20,000).
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the Project Area from maps.
- Delineate one to many Study Areas within this Project Area. Study areas should be representative of the Project Area if conclusions are to be made about the Project Area. For example, this means if a system of stratification is used in the Sampling Design then strata within the Study Areas should represent relevant strata in the larger Project Area.

- Based on the maps and other knowledge of the Study Area (previous reports, local resource specialists) identify strata which are of most interest. Delineate areas of relatively uniform habitats.
- Select the details of transect placement. Ideally, transects should cover the entire area of interest, be parallel to each other, and be 20 m apart.

Sampling design

- The sampling design is systematic.
- Transects should either sample the entire area of interest or the area be stratified and transects set out so that all habitats and sections of the area are well represented. Concentrate on species-specific microhabitats (Table 1).
- [The Design Components for this survey are transects.]
- Survey Timing:
  - Searches should be conducted when the habitat is moist and temperatures mild.
  - Peak surface abundance for all these species is from mid-April until mid-June, although surface abundance can also be high in October after the first autumn rains.

Sample effort

- Search appropriate microhabitats when weather conditions are favourable at least three times in a season (at least one week apart). Different transects should be established upon each occasion. If the target species are not found after this amount of effort, they are probably absent or populations are at a very low density.
- As the cumulative number of unproductive searches increases, it becomes increasingly unlikely that the species is present. A method using the negative binomial distribution can be used to guide sampling effort if pre-existing relative abundance data are available. This procedure is detailed in manual no.1, section 5.0 (sections 5.2.4 and 5.3.1).

Equipment

- Garden forks, wrecking bar, hatchet or light axe
- Field guides to amphibians (Nussbaum *et al.* 1983; Leonard *et al.* 1993)
- Maps
- Data forms (waterproofed) and pencil
- Calipers
- Thermometer
- 10 g spring scale
- Plastic bags
- Compass
- Hip chain and/or 100 m measuring tape
- Flagging tape and marking pen

Field procedures

- Select a starting line (e.g., road, stream, elevation) from which the transects will extent.
- Mark the starting end of each transect with flagging tape.
- Record appropriate environmental conditions and habitat information.

- When weather conditions are wet and mild, search species-specific microhabitats along 2 m wide transects.
- Transects may be followed with a compass, but do not need to be marked except at the starting end.
- Search species-specific microhabitats:
  - *P. vehiculum* and *E. eschscholtzii* - search on the soil under logs and rocks >10 cm in diameter and in piles of bark and wood. Avoid leaf litter or very small objects. In talus, search through rocks of all sizes.
  - *P. vehiculum* - search in and around the bases of Sword Ferns when conditions are wet.
  - *A. ferreus* - any log in decay classes 2-4 (see Appendix A) that is intersected by the transect should be searched by removing the bark along its entire length, even portions outside the transect. All the bark should be removed and the decayed wood separated layer by layer. Logs should be split along natural cracks and split open. Davis (1996, 1998) found that this species is rarely found outside of this microhabitat, so if this species is to be located, many such logs need to be searched.
- Record the number of transects, their distance apart, the approximate length of each transect, and the number of person-hours spent searching.
- Record appropriate measurements for individual animals (see Section 3.1.3).
- Obtain voucher specimens where appropriate (see Section 3.1.4).

Data Entry

The Design Components for this survey are transects. When digitally entering your survey data, choose ‘Transect’ from the ‘Design Component Type’ picklist.

3.3.3 Night Driving (for *E. eschscholtzii* only)

Night driving may be thought of as a kind of encounter transect in which the transect is a road (Shaffer and Juterbock 1994). Usually, a motor vehicle is used, but amphibians may be more easily seen from a bicycle. Night driving is useful for detecting the presence of *E. eschscholtzii*, but other species may be found as well. Paved roads with little vehicle use are best. The best time to start searching is usually just after dark on wet, warm, dark and windless nights. *E. eschscholtzii* are sometimes difficult to find in the forest, but can be found regularly on particular sections of road. However, if they are not found on the road, this does not mean they are not in the forest. Why *E. eschscholtzii* can sometimes be located in this way and the other species usually can not is unknown, but it suggests that *E. eschscholtzii* may have larger home range sizes than the other species. This method is untested with respect to estimating relative or absolute abundance, and should be used for presence/not detected inventory only. The efficiency of this method is unstudied for terrestrial salamanders, thus more testing needs to be done in areas where presence is known to evaluate how effective night driving is for detecting salamanders.

Office procedures

- Review the introductory manual No. 1 *Species Inventory Fundamentals.*
- Obtain maps for Project and Study Area(s) (*e.g.,* 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps). Any map which is used to record data should be referenced to NAD83.
- Outline the Project Area on a small to large scale map (1:250,000 – 1:20,000).
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the Project Area from maps.
- Delineate one to many Study Areas within this Project Area. Study areas should be representative of the Project Area if conclusions are to be made about the Project Area. For example, this means if a system of stratification is used in the Sampling Design then strata within the Study Areas should represent relevant strata in the larger Project Area.
- Based on the maps and other knowledge of the Study Area (previous reports, local resource specialists) identify strata which are of most interest. Delineate areas of relatively uniform habitats.

Sampling design

- Select areas that are convenient to check and might contain the target species. There is no formal sampling design.
- [The Design Components for this survey are transects.]

Sampling effort

- Search when weather conditions are favourable (just after dark on wet, warm, dark and windless nights) several times in a season. Since the efficiency of this method has not yet been studied, conclusions can not be made as to the likelihood of a species being absent, even as the cumulative number of unproductive searches increases.

Equipment

- Car or bicycle with headlight

- Spotlight
- Field guide to amphibians (Nussbaum *et al.* 1983; Leonard *et al.* 1993)
- Data forms (waterproofed) and pencil
- Calipers
- Thermometer
- 10 g spring scale
- Plastic bags

Field procedures

- Start searching just after dark on wet, warm, dark, and windless nights.
- Drive slowly and scan the road surface for salamanders. Paved roads with little vehicle use are best.
- Record location, distances and weather conditions.
- Record appropriate measurements for individual animals observed (see Section 3.1.3).
- Obtain voucher specimens where appropriate (see Section 3.1.4).

Data Entry

The Design Components for this survey are transects. When digitally entering your survey data, choose ‘Transect’ from the ‘Design Component Type’ picklist.

3.4 Relative Abundance

Recommended methods: Quadrat sampling, transect sampling (for elevational or habitat gradients only), pitfall traps, or artificial cover objects (ACOs) (see Table 2 for specific recommendations).

Estimates of relative abundance of terrestrial salamanders usually involve searches of natural cover objects and microhabitats. Recommended methods include quadrat and transect sampling. However, because the habitat is disturbed, these methods may be unsuitable where repeated searches of the same area are needed, or where disturbance of the natural habitat is unacceptable or prohibited. For example, *A. ferreus* is typically found under bark on logs or within logs (Davis 1991, 1996, 1998), and one thorough search of this microhabitat can be very destructive. Such destructive sampling is unacceptable where sampling through time is needed and may be prohibited in parks and reserves. Also, searches of natural cover among areas that differ in the amount and type of CWD may not be comparable because some types of cover may be difficult or impossible to search. To overcome some of these difficulties, unit-effort pitfall trapping and artificial cover objects (ACOs) may be used to estimate relative abundance.

If the goal of the study is to estimate relative abundance among study areas, the study areas should be sampled several times within a season to account for variation in surface abundance as the result of local variation in environmental conditions. Sample size should be determined by ongoing analysis of survey precision, accompanied by power analysis of statistical tests to be used with survey data using programs such as MONITOR. This raises the possibility that individuals might be counted on more than one occasion, which would inflate the estimate of relative population size. To control this problem, individuals need to be marked. The recommended method of marking is toe-clipping. For simple estimates of relative abundance, a group mark (the same mark for all individuals) can be used, but individual marks can also be employed if the study requires tracking of individuals through time or space.

If the goal of the study is to monitor and explain population dynamics, an individual marking and identification system and a method of determining the ages of individuals is needed. Again, toe-clipping is the recommended marking technique. For these salamanders, age classes can be determined for the first two or three years of life by using body size as an indication of age, but after that, tracking individuals is the only dependable method available for determining age. The sampling design may be stratified to account for environmental heterogeneity, but sampling should be randomized whenever possible (Green 1979; Krebs 1989; Hayek 1994). Stratification is essential to maintain similar levels of precision between surveys, and randomization within strata will help reduce bias.

Data analysis for Relative Abundance

A variety of methods are introduced in this section to estimate relative abundance. The quantification of sampling intensity, and effort is fundamental to the use of indices and relative abundance measures. This way the assumption of equal bias of surveys between areas and over time can be met. In addition, the usefulness of indices is very dependent on the precision of estimates. It is recommend that power analysis procedures be integrated into the study design of all these techniques. As described in manual no. 1, *Species Inventory Fundamentals*

(Section 5.0), programs such as MONITOR, POWER AND PRECISION, and NQUERY are user friendly, and can be easily used in an adaptive fashion to calculate sample sizes needed for the ultimate analysis questions. Statistically speaking, sample size should be determined by ongoing analysis of survey precision, accompanied by power analysis of statistical tests to be used with survey data using programs such as MONITOR.

If studies are designed appropriately the following general analysis methods can be used.

Table 5. RIC objectives and analysis methods for relative abundance data.

Objective	Analysis method[1]	Programs[2]
• Trends in abundance over time	• Sample methods • Regression techniques • Power analysis	• QUADRAT, TRANSECT • Generic statistical packages • MONITOR
• Comparison in abundance between areas	• ANOVA, negative binomial tests • Power analysis	• QUADRAT, TRANSECT • Generic statistical packages • Power analysis software
• Determine whether habitat modifications have altered population size	• Parametric, or data based methods • Power analysis	• QUADRAT, TRANSECT • Generic statistical packages • Power analysis software

[1] See manual no. 1, Species Inventory Fundamentals, section 5.3 for more details on analysis methods.
[2] See manual no. 1, Species Inventory Fundamentals, Appendix G for more details on software packages.

Difficulties with count data: One inherent problem with count data is that they are rarely normally distributed, which makes the application of parametric statistical methods risky, especially if sample sizes are low. For a detailed discussion of analysis of count data see manual no. 1, *Species Inventory Fundamentals* (Section 5.0).

Trend analysis: The basic method for determination of trends is linear regression. There are a variety of refinements to linear regression that can be used with data depending on sampling assumptions and other characteristics of the data. Manual no. 1, *Species Inventory Fundamentals* (Section 5), provides a detailed discussion of these techniques.

Comparison between areas: Parametric tests and other methods can possibly be used to compare areas if surveys are conducted concurrently. If surveys are conducted non-concurrently (such as in different years), then the results might be biased by population fluctuations. See manual no. 1, *Species Inventory Fundamentals* (Section 5.0), for a thorough discussion of analysis of count data.

Habitat based inference: Logistic regression or similar methods can be used for habitat association but this approach requires that habitat units be the primary sample unit as opposed to population units.

3.4.1 Quadrat Sampling

Quadrat sampling consists of thoroughly searching for salamanders within randomly selected *quadrat* sampling units (Jaeger and Inger 1994). If the goal of the study is to compare either relative abundance or surface densities among study areas, seasons, or years, quadrat sampling is especially useful and lends itself to powerful statistical analysis. However, the technique is not without its problems. Large logs, which often represent important terrestrial salamander habitat, may have to be excluded from the quadrats because they can not be overturned. If study areas differ in the number, size, or decay class of such large logs, comparison among study areas will not be possible. This method will not give good estimates of relative abundance among *A. ferreus*, *P. vehiculum* and *E. eschscholtzii*, because the species-specific microhabitats are not equally accessible. Because they are found under cover on the soil, *P. vehiculum* are relatively more accessible than *A. ferreus*, which favour cracks and cavities within logs and under bark on logs, or *E. eschscholtzii*, which may be underground in burrows during the day. Searching at night when the salamanders are foraging on the surface may improve the situation, but even very similar species of *Plethodon* may appear on the surface at different times during the night (K. Ovaska, unpubl. data).

Two types of quadrat sampling are possible: *point sampling* (e.g., 1 x 1 m quadrats) and *broad sampling* (e.g., 8 x 8 m quadrats). Point sampling is appropriate when salamander densities are high (>0.5 individuals/m^2), and broad sampling is appropriate when salamander densities are low (<0.5 individuals/m^2). In both cases, relatively large areas of interest are identified, stratified, and the quadrats are randomly placed within the strata. Small quadrats measuring 1 x 1 m have been used successfully to sample terrestrial salamanders. A quadrat-frame is strongly recommended. These can be randomly located within the area of interest, or randomly located along parallel, evenly spaced transects. Large quadrats can be approximately 10 x 10 m or smaller. Jaeger and Inger (1994) recommend 8 x 8 m quadrats because these approximate the 25 x 25 foot quadrats used in most previous studies. However, based on a preliminary sample, an optimal quadrat size (that gives the maximum precision for the least cost) can be calculated, and this should be done whenever possible (Krebs 1989). It is important that biologists make sure that enough samples of different salamander species are used to determine optimal quadrat size. Many times one quadrat might be ideal for one species but not ideal for another. Obviously optimal quadrat size is probably specific to a particular species at a particular sight. Dupuis *et al.* (1995) and Dupuis (1997) found that the optimum size quadrat was 1 x 2 m for *P. vehiculum* at sites on Vancouver Island, but the optimum size might be different at other sites. Krebs (1989) has program QUADRAT which will estimate optimal sizes for quadrats.

If statistical tests are to be used, the location of quadrats within a study area or along a transect must be randomized (e.g., by reference to a table of random numbers). If estimates of relative abundance across study areas or through time is the goal of the study, either simple or stratified random sampling must be employed to establish the location of quadrats and transects within the sampling area (Green 1979; Krebs 1989; Heyer *et al.* 1994). Use stratified random sampling in heterogeneous habitats.

Davis (1996, 1998) estimated surface abundance of *P. vehiculum* in five areas in Goldstream Provincial Park using randomly placed quadrats along parallel transects. In each area, he used four parallel 100 m transects, 20 m apart. Ten 1 x 1 m quadrats were established along each transect by dividing the transect into 1 m sections, each section representing a quadrat, and randomly selecting ten sections along each transect with the stipulation that quadrats must be at least 2 m apart.

Office procedures

- Obtain maps for Project and Study Area(s) (*e.g.*, 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps). Typically 1:50 000 are used, but a larger scale such as 1:20 000 is ideal for identifying and then overlaying transects on to the map sheets. Any map which is used to record data should be referenced to NAD83.
- Outline the Project Area on a small to large scale map (1:250,000 – 1:20,000).
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the Project Area from maps.
- Delineate one to many Study Areas within this Project Area. Study areas should be representative of the Project Area if conclusions are to be made about the Project Area. For example, this means if a system of stratification is used in the Sampling Design then strata within the Study Areas should represent relevant strata in the larger Project Area.
- Based on the maps and other knowledge of the Project Area (previous reports, local resource specialists) identify study areas which are of most interest.
- Stratify sampling where appropriate.
- Determine the precise areas to be sampled and the location of quadrats and transects. If random directions and/or distances are required, these should be determined before going into the field.

Sampling design

- The location of quadrats within a study area or along a transect must be randomized.
- Use stratified random sampling in heterogeneous habitats.
- Point sampling:
  - Use the random walk method or
  - Place quadrats along regularly spaced parallel transects (this method often preferred). This results in systematic sampling of the area of interest. The locations of the quadrats along transects and the order of searching among transects should be randomized. At least ten quadrats should be placed along each transect. Transects can start at a road or trail and extend across the area to be sampled. The number and length of transects depends on the size of the area to be sampled and the amount of time available.
- [The Design Components for this survey are quadrats.]

Sampling effort

- To compare relative abundance among sites within a study area, sampling should be done within the shortest time possible, preferably on the same day.
- Because variation in surface abundance depends on recent weather conditions, study areas must be sampled several times during a season.

Personnel

- For point sampling, a crew of two is adequate. One person should do all the searching while the other records the data.
- For broad sampling, a crew of four to six is required. The same crew should search all quadrats.

Equipment

- Maps
- Data form (waterproofed) and pencil
- Field guide to amphibians (Nussbaum *et al*. 1983; Leonard *et al.* 1993).
- Plastic bags
- Calipers
- Thermometer
- 10 g spring scales
- Garden forks, wrecking bar, hatchet or light axe
- Metal 1 x 1 m quadrat-frame (point sampling); Stakes and twine (broad sampling)
- Compass
- Hip chain
- 50 m measuring tape
- Knee pads

Field Procedures

- A preliminary search (e.g. TCS, see Section 3.3.1) to select study areas is recommended, but disturbance should be kept to a minimum.
    - If the preliminary search suggests that densities are high (>0.5 individuals/m^2), use *point sampling*, with or without parallel transects.
    - If densities are low (<0.5 individuals/m^2), use *broad sampling*. Broad sampling is also preferred when groups of individuals are widely spaced, for multi-species sampling, and is superior to point sampling for sampling *A. ferreus*.
- Whenever possible, determine the optimal quadrat size (that gives the maximum precision for the least cost) based on a preliminary sample (Krebs 1989). Ensure that enough samples of different salamander species are used to determine optimal quadrat size. Obviously optimal quadrat size is probably specific to a particular species at a particular sight.

Field Procedures: Point Sampling

Protocol for comparison of large areas using the random walk method

- In each Study Area to be compared, divide the Study Area into 25 to 30 equal area strata (e.g., 100 x 100 m).
- From within each strata the “random walk” method is used.
    - Produce a random sequence of sampling among these strata.
    - For each strata area, produce sequential random compass directions and distances (e.g., to a maximum of 20% of the length of one side of the strata area).

- Go to the center of the first strata area and begin the randomized walk by following the predetermined compass directions and distances.
- Follow the first compass direction for the distance listed. This will be the first sample point where a quadrat will be placed.
- Take care not to disturb the natural cover (avoid stepping on logs) when walking between sampling points. Each sampling point is the starting point for the next random direction and distance.
- The number of quadrat samples searched in each strata should be adaptively determined using the power analysis methods described in section 5.0 of manual no.1, *Species Inventory Fundamentals*. Define any *a priori* rules that might be necessary to deal with overlapping quadrats, unsearchable habitat, and what procedure should be followed if the edge of the unit is encountered. For example:

1. If part of the current quadrat is within 2 m of a previously searched quadrat, the sampling point is moved along the same compass direction 2 m beyond the previously searched quadrat. Obviously, one does not want to search the same quadrat twice. Also, the area around the quadrat will be disturbed, so moving 2 m beyond the previously searched quadrat should place the quadrat in undisturbed habitat.

2. If part of the quadrat lands on habitat that can not be searched (e.g., a large log or rock, or a standing tree) then the quadrat is moved to the next possible spot along the compass direction. However, this rule should not be used to avoid brush or other difficult and inconvenient locations.

3. If the compass direction and distance leads to the edge of the large unit before the distance is completed, a new randomly selected compass direction from the edge of the plot will be used to complete the distance.

- See searching quadrats at each sample point for remaining procedures

Protocol for comparison of small areas using quadrats along parallel transects

- Stratify the Project Area. Within the different strata select Study Areas to be sampled (e.g., 100 x 100 m).
- Produce a random sequence of sampling among these Study Areas to be sampled.
- Place transects in each area.
  - Decide on the number, spacing, and length of transects. Ideally, each area should contain the same number of transects and each transect should be the same length.
  - Minimally, there should be four transects per area and they should be no more than 40 m apart. Davis (1996, 1998) used 100 m long transects, 20 m apart for *P. vehiculum*.
- Randomly place quadrats along each transect.
  - Determine the number of quadrats for each transect. There should be at least 10 randomly placed quadrats along each 100 m transect. Longer transects should have more quadrats. Each area should contain the same number of quadrats.
  - From a table of random numbers, determine the position of each quadrat along each transect. This should be done before going into the field.
  - From the start of the transect, walk the first distance listed. This will be the first sample point where a quadrat will be placed.

- Take care not to disturb the natural cover (avoid stepping on logs) when walking between sampling points. Each sampling point is the starting point for the next random distance.
- Define any *a priori* rules that might be necessary to deal with overlapping quadrats, unsearchable habitat, and what procedure should be followed if the edge of the unit is encountered. For example:

  1. Quadrats must be at least 2 m apart.

  2. If part of the quadrat lands on habitat that can not be searched (e.g., a large log or rock, or a standing tree) then the quadrat is moved to the next possible spot along the transect. However, this rule should not be used to avoid brush or other difficult and inconvenient locations.

- See searching quadrats at each sample point for remaining procedures.

Searching quadrats at each sample point

- At each sample point a small quadrat-frame of optimal size (e.g. 1 x 1 m) is dropped on the ground and the salamanders within the quadrat are collected.
  - Crews of two are recommended. One person should do all the searching while the other person records the data. If more than one crew is needed, they should be randomly assigned to transects.
  - Search the entire perimeter first and work in toward the center. This avoids having salamanders escape from the quadrat before they are discovered.
  - Each salamander should be placed in its own zip-lock plastic bag as it is found.
  - All debris (rocks, pieces of bark or wood, and leaves) should be removed from the quadrat, but returned when the search is done.
  - Measurements and/or marking should be done only after the entire quadrat has been searched and all the salamanders located. Record appropriate measurements for individual animals (see Section 3.1.3)
- This procedure is repeated until all areas have been sampled, preferably on the same day.
- The density of salamanders within each area can be estimated by averaging the number of salamanders found per quadrat. Statistical comparisons can be made among areas or through time.

Field Procedures: Broad sampling

- Imagine a 1000 x 1000 m grid is placed over the Study Area. Divide the 1000 x 1000 m grid into X number of transects. Sample 50 to 100 quadrats in the area of interest randomly along the transects.
- Randomly sample along transects using quadrats
  - Produce a random sequence of sampling among these transects to avoid short-term variation in surface abundance that may correspond to variation in environmental conditions during the search.
  - From a table of random numbers, determine the position of each quadrat along each transect. This should be done before going into the field.
  - From the start of the transect, walk the first distance listed. This will be the first sample point where a quadrat will be placed.

  - Take care not to disturb the natural cover (avoid stepping on logs) when walking between sampling points. Each sampling point is the starting point for the next random distance.
- It is important to avoid conscious or unconscious selection or avoidance of particular habitat patches. Conscious or unconscious selection or avoidance of particular habitats will bias the sample and undermine the purpose of the study.
- Searching at each broad sampling quadrat:
  - Locate the quadrats in the field and mark the 8 x 8 m perimeter with stakes and twine.
  - A crew of four to six is recommended and the same crew should search all quadrats. If more than one crew is needed, they should be randomly assigned to transects.
  - Searching should be done from the perimeter toward the center to reduce the likelihood of animals escaping from the quadrat before they are counted.
  - Search at a very fine scale whether or not the habitat appears suitable. This is best accomplished on hands and knees.
  - Each salamander should be placed in its own zip-lock plastic bag as it is found.
  - Measurements and/or marking should be done only after the entire quadrat has been searched and all the salamanders located. Record appropriate measurements for individual animals (see Section 3.1.3).
- This procedure is repeated until all areas have been sampled. More than one sampling period may be required.

Data Entry

The Design Components for this survey are quadrats. When digitally entering your survey data, choose ‘Quadrat’ from the ‘Design Component Type’ picklist.

Data Analysis

- <u>Comparison of large areas using the random walk method</u>:The density of salamanders within each strata area can be estimated by averaging the point samples. Statistical comparisons can be made among Study Areas (each containing 25 to 30 strata areas) or within the same Study Area through time.
- <u>Comparison of small areas using quadrats along parallel transects:</u> The density of salamanders within each area can be estimated by averaging the number of salamanders found per quadrat. Statistical comparisons can be made among areas or through time.
- <u>Broad sampling:</u> The density of salamanders within each area can be estimated by averaging the number of salamanders found per quadrat. Statistical comparisons can be made among areas or through time.

3.4.2 Transect Sampling (for elevational or habitat gradients)

Transects are essentially long, narrow (e.g., 2 m wide) quadrats that extend across study areas. It is the best technique for studying elevational gradients, or habitat gradients (e.g., streamside to upland), and where such gradients exist it is preferable to quadrat sampling for an overall assessment. If the transects are randomly located, they will be independent samples and can be used to monitor changes through time or detect differences among study areas. They are not recommended in the absence of a gradient (Jaeger 1994), except when *A. ferreus* only is the target species (see section 3.4.3).

The actual search of the transect involves turning over potential cover objects, searching through forest litter, and tearing bark off logs, just as in quadrat searches. A compass line can be followed, but it is best to mark the center of the transect with string so that the transect is straight and does not deviate into "better" habitat. The ends of the transects should be marked with stakes, flagging tape and metal tags for future reference. (Note: flagging tape deteriorates over time, but is easy to see. Metal tags are relatively permanent, but are difficult to see.) Care should be taken not to count animals serendipitously found outside the transect. This method assumes that all salamanders will be detected within the transect strip searched.

Details of transect placement, orientation, length, and number depend on the purpose of the study and the size of the study area. If the purpose of the study is to measure changes through time, multiple randomly placed parallel transects can be sampled at each time period, but previously sampled transects should not be resampled. Transects are typically 2 m wide, but the length of the transects will depend on the size of the area to be traversed. If the transect is very long, subsections of the transect can be sampled randomly or systematically, and stratified or not depending on the objectives and the nature of the study areas. If the transect is subsampled then it is important that equal effort or sampling intensity is maintained between transects over time. If the purpose of the study is to investigate relative abundance or species turnover continuously along a gradient, then transects should run parallel to the gradient, and begin at randomly selected points along a *starting line*, which may be a road, stream, etc. If one is interested in the effect of the gradient on abundance or other parameters at specific places along the gradient, then parallel transects are set out systematically (the same distance between neighbouring transects) and perpendicular to the gradient. In this case, each transect samples a different level along the gradient, and randomly selected subsections of such transects can be treated as independent data points for each level. These issues are discussed by Jaeger (1994).

Office procedures

- Review the introductory manual No. 1 *Species Inventory Fundamentals.*
- Obtain maps for Project and Study Area(s) (*e.g.*, 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps). Typically 1:50 000 are used, but a larger scale such as 1:20 000 is ideal for identifying and then overlaying transects on to the map sheets. Any map which is used to record data should be referenced to NAD83.
- Outline the Project Area on a small to large scale map (1:250,000 – 1:20,000).
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the Project Area from maps.

- Delineate one to many Study Areas within this Project Area. Study areas should be representative of the Project Area if conclusions are to be made about the Project Area. For example, this means if a system of stratification is used in the Sampling Design then strata within the Study Areas should represent relevant strata in the larger Project Area.
- Based on the maps and other knowledge of the Project Area (previous reports, local resource specialists), select the area and the gradient to be sampled.
- Choose the details of transect placement, orientation, stratification, length, and number (usually 25-30). These details will depend on the purpose of the study and the size of the area.

Sampling design

- To define optimal transect length, it recommended that biologists use the techniques of Krebs (1989, p192).
- Long transects may be divided into subsections and randomly or systematically searched. If the transect is subsampled then it is important that equal effort or sampling intensity is maintained between transects over time.
- Transects can be stratified or not depending on the objectives and the nature of the study areas. If relative abundance along a gradient is being investigated, then transects randomly located along a starting line should run parallel to the gradient.
- If one is interested in the effect of the gradient on abundance or other parameters at specific points along the gradient, then parallel transects are set out systematically and perpendicular to the gradient.
- [The Design Components for this survey are transects and point count stations.]

Sampling effort

- If population monitoring is an objective of surveys, it is recommended that power analysis packages are used to determine the number of transects rather than blindly relying on 25-30 transects to give statistically valid results.

Equipment

- Maps (1:50 000, 1:20 000)
- Calipers
- Thermometer
- 10 g spring scale
- Field guides to amphibians (Nussbaum *et al.* 1983; Leonard *et al*. 1993)
- Data forms
- Compass
- Hip chain and/or 100 m measuring tape
- Garden forks, wrecking bar, hatchet or light axe
- Pocket altimeter
- Plastic bags
- Flagging tape
- Metal tags

Field procedures

- Select a starting line (e.g., road, stream, elevation) from which the transects will extent.
- Mark the ends of the transects with flagging tape and metal tags.
- Follow a compass line and mark the center of the transect with string.
- Search all habitats and turn over all potential cover objects in a 2 m strip along the transect.
- For transects parallel to gradients, record the location of each salamander caught. For elevational gradients, a pocket altimeter may be used. For other gradients, the distance from the starting line, measured with a hip chain or tape, should be recorded.
- Record appropriate measurements for individual animals (see Section 3.1.3).

Data Entry

The Design Components for this survey are transects. When digitally entering your survey data, choose ‘Transect’ from the ‘Design Component Type’ picklist.

3.4.3 Transect Sampling (for *A. ferreus*)

Because *A. ferreus* is restricted to particular microhabitats (bark on logs and within logs of decay classes 2-4), quadrat searches or conventional transect searches may yield few individuals, even where this species is relatively abundant. Therefore, a modified transect search is recommended for this species only.

Transects should be parallel, 6 m wide, with the origins randomly located along a starting line (road, stream, contour, etc.). This method assumes that all salamanders will be detected within the 6 m strip which is searched. Each transect is generally 100 m long, but may longer or shorter depending on the size of the study area. Ideally, the transects should extend across the entire study area. Where this is not possible, transects may be randomly subdivided.

The species-specific microhabitats for *A. ferreus* are searched along the transect and all other microhabitats ignored. Any log in decay classes 2-4 (see Appendix A) that is within the 6 m wide transect should be searched by removing the bark and splitting it open along any cracks. Davis (1996, 1998) found that this species is rarely found outside of this microhabitat, so if this species is to be located, many such logs need to be searched.

Office procedures

- Review the introductory manual No. 1 *Species Inventory Fundamentals.*
- Obtain maps for Project and Study Area(s) (*e.g.,* 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps). Typically 1:50 000 are used, but a larger scale such as 1:20 000 is ideal for identifying and then overlaying transects on to the map sheets. Any map which is used to record data should be referenced to NAD83.
- Outline the Project Area on a small to large scale map (1:250,000 – 1:20,000).
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the Project Area from maps.
- Delineate one to many Study Areas within this Project Area. Study areas should be representative of the Project Area if conclusions are to be made about the Project Area. For example, this means if a system of stratification is used in the Sampling Design then strata within the Study Areas should represent relevant strata in the larger Project Area.
- Based on the maps and other knowledge of the Project Area (previous reports, local resource specialists), select the area and the gradient to be sampled.
- Choose the details of transect placement, orientation, stratification, length, and number (usually 20-30). These details will depend on the purpose of the study and the size of the area.
- If the transects are very long, subsections should be randomly selected for sampling.

Sampling design

- Long transects may be divided into subsections and randomly or systematically searched. Transects can be stratified or not depending on the objectives and the nature of the study areas. It is important that transects are randomly located and that subsequent transects do not overlap.
- [The Design Components for this survey are transects.]

- Sample Timing:
  - Searches should be conducted when the habitat is moist and temperatures mild.
  - Surface abundance for this species is dependent on recent weather conditions, but because logs tend to retain moisture, individuals can be found in most months. Peak surface abundance is from April until July, and in October after the first autumn rains.

Sampling effort

- Generally, 25 to 30 transects are needed for statistical significance.

Equipment

- Maps (1:50 000, 1:20 000)
- Calipers
- Thermometer
- 10 g spring scale
- Field guides to amphibians (Nussbaum *et al.* 1983; Leonard *et al*. 1993)
- Data forms
- Compass
- Hip chain
- Measuring tape
- Wrecking bar, hatchet or light axe
- Pocket altimeter
- Plastic bags
- Flagging tape
- Metal tags

Field procedures

- Select a starting line (e.g., road, stream, elevation) from which the transects will extent.
- Mark the ends of the transects with flagging tape and metal tags.
- Follow a compass line and mark the center of the transect with string.
- Search all logs in decay classes 2-4 in a 6 m strip along the transect. The dimensions of the transect can be determined by measuring 3 m either side of the center line.
- Record the length of each transect.
- Record the size and decay class of the logs searched.
- Record appropriate measurements for individual animals (see Section 3.1.3).

Data Entry

The Design Components for this survey are transects. When digitally entering your survey data, choose ‘Transect’ from the ‘Design Component Type’ picklist.

3.4.4 Pitfall Trapping

As well as being relatively non-destructive, pitfall trapping has the advantages of being relatively easy to do once the traps are in place, it can be done repeatedly over long periods of time without disturbing the natural habitat, and the amount and type of CWD and individual effort are independent of the trapping effort. Also, in conjunction with mark-recapture methods (Section 3.1.2), pitfall trapping can be used to estimate life-history characteristics. Unfortunately, the capture rate varies widely among species (Bury and Corn 1987; Buhlmann *et al.* 1988; Welsh and Lind 1988; Corn and Bury 1990; Welsh 1990; Dodd 1991; Corn 1994; Greenberg *et al.* 1994), and many species, because they are site-tenacious or have specific microhabitat requirements, are not readily trapped (Welsh and Lind 1988; Corn 1994). Thus, pitfall trapping will not give a reliable estimate of relative abundance among species. For example, *A. ferreus* are rarely caught with this technique, but *P. vehiculum* and *E. eschscholtzii* can be captured in large numbers (Bury and Corn 1987; Corn and Bury 1990). However, it is not known if the latter two species are captured with the same efficiency. If one assumes that capture rates of individual species do not vary among habitat types, pitfall trapping will give estimates of relative abundance among species between study areas or over time, but if animals are released, they must be marked to identify recaptures (for marking, see Section 3.1.2). Estimates of relative abundance should not include recaptures.

Pitfall traps may be set out individually along the base of logs or in grids (Corn 1994), but they are usually used in combination with drift fences (Campbell and Christman 1982; Vogt and Hine 1982; Semlitsch and Gibbons 1985; Semlitsch 1985,1987; Bury and Corn 1987; Greenberg *et al.* 1994). In theory, drift fences should greatly increase capture rates, but experiments to demonstrate this have not been done for the terrestrial salamanders found in British Columbia. Drift fences and pitfall traps are arranged in various configurations called *arrays* (Vogt and Hine 1982; Jones 1986, Bury and Corn 1987; Corn 1994).

If pitfall traps are arranged in grids it might be possible to use some mark-recapture methods to compare capture rates among habitats or even between species. This possibility is discussed further in the section, "Absolute Abundance".

Office procedures

- Review the introductory manual No. 1 *Species Inventory Fundamentals.*
- Obtain maps for Project and Study Area(s) (*e.g.,* 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps). Typically 1:50 000 are used, but a larger scale such as 1:20 000 is ideal for identifying and then overlaying transects on to the map sheets. Any map which is used to record data should be referenced to NAD83.
- Outline the Project Area on a small to large scale map (1:250,000 – 1:20,000).
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the Project Area from maps.
- Delineate one to many Study Areas within this Project Area. Study areas should be representative of the Project Area if conclusions are to be made about the Project Area. For example, this means if a system of stratification is used in the Sampling Design then strata within the Study Areas should represent relevant strata in the larger Project Area.

Sampling design

- Single pitfall traps can be considered independent sampling units if randomly located within the study area. However, to increase the number of salamanders per sample, grids or arrays are recommended.
- Each grid or array should be considered a single sampling unit, and for comparison among habitats, replication of the sampling units is required.
    - The location of grids or arrays should follow a stratified random design if monitoring is an objective. Otherwise, a simple random design may be used.
    - The grid or array design will depend on the goals of the study and the questions being asked. Figure 3 shows a 3-fence array that will intercept animals moving in any direction and uses less material than other configurations (Corn 1994).
- [The Design Components for this survey will either be a Grid or Array of traps, or a single trap.]

Sampling effort

- Generally, 25 to 30 sampling points are needed for statistical significance. The general degree of sampling effort should be adaptively determined using power analysis packages discussed in manual no. 1, *Species Inventory Fundamentals*.
- Traps should be checked within 24 hours of being opened.
- The time that the traps are open should be equal between areas and over time to ensure that samples are true replicates. The sequential order of checking should be determined. Check pitfalls in the same order that they were opened so that the trapping effort is equal among traps.

Equipment

- Maps
- Data forms
- Field guides to amphibians (Nussbaum *et al.* 1983; Leonard *et al.* 1993)
- Calipers
- Thermometer
- 10 g spring scale
- 4 litre ice cream bucket
- 500 g yogurt tub
- Moss or sponge
- Hardware cloth
- 50 cm wide aluminium flashing
- 6 or 10 ml plastic sheeting
- Stakes

Construction of pitfall traps and drift fences

Pitfall trap construction

A tested design suitable for terrestrial salamanders is shown in Figure 3. The trap consists of a 4-liter ice cream bucket and a funnel made from a 500 g yogurt tub. Hatchling, juvenile and adult *A. ferreus* (which are better climbers than either *P. vehiculum* or *E. eschscholtzii*) are unable to escape from this trap (T. Davis, unpubl. data), but can easily climb out if there is no funnel in place, in spite of the horizontal surface formed by the lid of the 4-liter bucket. When not in use, traps can be covered with the lid from the yogurt tub funnel. A piece of wood or foam may be placed in the bottom of the trap to act as a raft in the event that the trap collects rain water. To reduce desiccation and provide cover, a small amount of wet moss (or a small sponge) can be placed in the trap, but not so much as to afford a bridge to the funnel or a refuge from the collector. If predation (e.g., by shrews) is a problem, a separate compartment at the bottom of the trap can be created with a piece of hardware cloth. The size of the holes in the hardware cloth should allow salamanders, which can squeeze through surprisingly small holes, to pass into the bottom compartment, but should exclude predators such as shrews.

A wood or bark cover raised above the trap should improve capture rates and may help protect the trapped animals from desiccation and predation by birds. When the traps are checked, the funnel should be removed and the undersurface of the lid and sides of the 4-liter bucket checked for salamanders.

Drift fence construction

Drift fences can be made from a variety of materials including plastic, tar paper and window screen, but the preferred material is 50 cm wide aluminium flashing (Corn 1994). The advantages of aluminium flashing are that it is relatively self-supporting and requires few stakes, is very durable, and has a smooth surface which may discourage climbing. The flashing is placed in a 20 cm-deep trench and soil is used as backfill. The trench can be dug with a shovel or mattock, but large roots can make digging very difficult and an axe may be needed to cut through them. Where roots are a serious problem, 6 or 10 mil plastic sheeting can be used instead of flashing and the lower edge stapled to the roots where necessary. Plastic sheeting requires a stake about every two meters. Drift fences are labour-intensive to install and it requires one day for four to six people to install three to six arrays (Corn 1994).

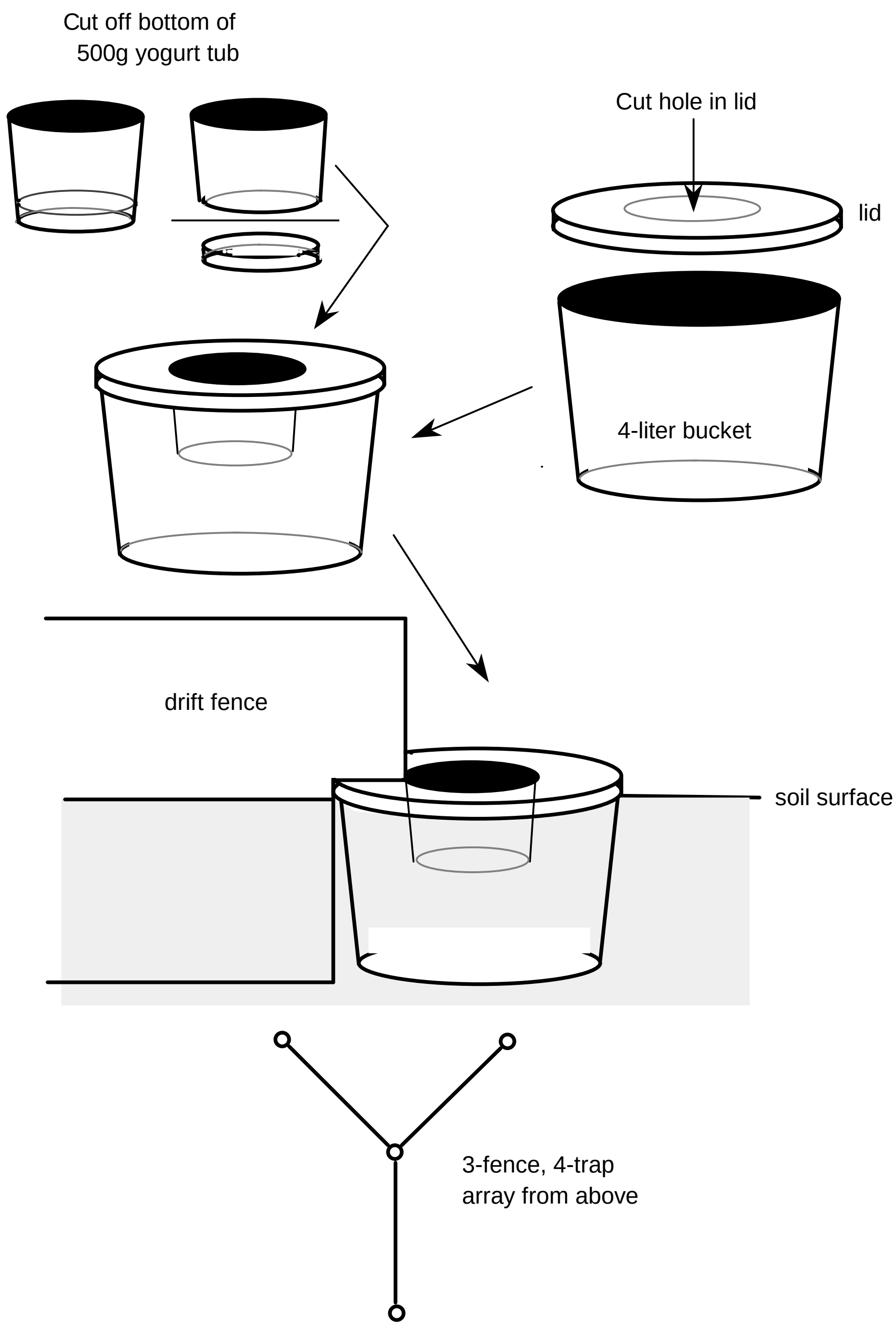

Figure 3. Construction of a pitfall trap and drift fence array for terrestrial salamanders.

Field procedures

- Set out individual pitfall traps or pitfall traps and drift fence arrays along the base of logs or in grids
- Pitfall traps should be tested under controlled conditions to be sure that the target species can not escape.
- Pitfall traps should be operated when weather conditions are favourable.
- Checking traps:
  - The sequential order of checking should be determined. Pitfalls should be checked in the same order that they were opened so that the trapping effort is equal among traps.
  - Traps must be checked frequently to prevent accidental mortality of the various vertebrates (e.g., shrews) that may be caught (Grant *et al.* 1992).
  - If relative abundance among study areas is the objective, then traps can be checked when conditions are mild and wet. This will increase the number of salamanders per sample.
  - If one is interested in variation in numbers through time, traps can be checked daily or weekly. In some studies, traps have been operated continuously for months to years (Bury and Corn 1987; Raphael 1988; Corn and Bury 1991; for a summary see Corn 1994).
  - Because salamanders are excellent climbers, all interior surfaces of the trap should be thoroughly checked.
- Record appropriate measurements for individual animals caught (see Section 3.1.3).

Data Entry

The Design Components for this survey are (a) Grids with traps; (b) Arrays with traps; or (c) Station with traps. When digitally entering your survey data, choose ‘Grids/Arrays or Station’ from the ‘Design Component Type’ picklist before entering observations. Record trap information by choosing ‘Traps’ from the ‘Design Component Type’ picklist.

3.4.5 Artificial Cover Objects (ACOs)

Artificial cover objects (ACOs) are generally easier and less disruptive to install than arrays of pitfall traps. They are especially well suited to studies that require repeated sampling, are relatively easy to sample once in place, result in little or no damage to the natural habitat, and can attract species that are difficult to trap in pitfall traps. Unlike pitfall traps, sampling can be opportunistic with no risk of mortality from failure to check frequently (Grant *et al.*, 1992) and movements of individuals are not limited. Because ACOs can be checked repeatedly over long periods, certain rare species can eventually be detected without the damage to the habitat that would result from repeated searches of natural cover. In conjunction with mark-recapture methods, they can be used to monitor individual movements and to estimate life-history characteristics. Also, they can be used to investigate the relationship between habitat characteristics and abundance, and differential microhabitat use among species. ACOs can be of a standard size and number, independent of the amount and type of CWD. Thus, variability in search effort is essentially eliminated and they should give dependable estimates of relative abundance across study areas that differ in structure. It is important to stress that this is only true if ACO's are monitored in equal time periods, and designed in a way that efforts are replicated.

Because the suitability of ACOs as cover objects varies among species, they can only provide measures of relative abundance among similar study areas and not among species within study areas. Also, through processes of decay and invasion by fungi and arthropods, the nature of the ACOs may change through time, although this should be consistent across similar study areas and subject to the same conditions that natural CWD experiences. Finally, it is not known to what extent the availability of natural cover objects may influence capture rates.

If the target organisms are to be successfully sampled, the ACOs must be made with species-specific microhabitats. Any simple cover board placed on the soil will attract *P. vehiculum* and *E. eschscholtzii*, but *A. ferreus* require a more complex design. An ACO that is suitable for all three species consists of a baseboard and two cover boards (Davis 1996, 1997, 1998).

ACOs are very efficient at attracting the Roughskin Newt (*Taricha granulosa*). Other species of amphibians and reptiles, including the Northwestern Salamander (*Ambystoma gracile*), the Long-toed Salamander (*Ambystoma macrodactylum*), the Pacific Treefrog (*Hyla regilla*), the Red-legged Frog (*Rana aurora*), the Northwestern Garter Snake (*Thamnophis ordinoides*), and the Common Garter Snake (*Thamnophis sirtalis*), have been occasionally found under these ACOs. They may be suitable for other species of amphibians and reptiles as well.

Fellers and Drost (1994) have successfully used 30 x 30 x 5 cm pieces of untreated pine or fir for monitoring the Pacific Slender Salamander (*Batrachoseps pacificus*) in California. These may be suitable for *P. vehiculum* and *E. eschscholtzii* as well, but larger boards have a better ability to retain moisture.

Office procedures

- Review the introductory manual No. 1 *Species Inventory Fundamentals.*
- Obtain maps for Project and Study Area(s) (*e.g.*, 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps). Typically 1:50 000 are used, but a larger scale such as 1:20 000 is ideal for identifying and then overlaying

transects on to the map sheets. Any map which is used to record data should be referenced to NAD83.

- Outline the Project Area on a small to large scale map (1:250,000 – 1:20,000).
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the Project Area from maps.
- Delineate one to many Study Areas within this Project Area. Study areas should be representative of the Project Area if conclusions are to be made about the Project Area. For example, this means if a system of stratification is used in the Sampling Design then strata within the Study Areas should represent relevant strata in the larger Project Area.

Sampling design

- Before setting out ACOs, the presence of the target species should be established (Section 3.1).
- The number, size, and spatial distribution of ACOs will depend on the objectives of the study.
- Systematically set out ACOs or ACO arrays in grids within the area of interest or randomly place them within strata after the area of interest has been stratified.
- If set out individually, each ACO can be considered a separate sampling unit. If set out in arrays, each array is considered a separate sampling unit.
- [The Design Components for this survey will either be a Grid or Array of traps, or a single trap.]

Sample effort

- ACOs are generally checked every two weeks. In this way, patterns of seasonal abundance can be tracked.
- It is important that there is equal time between checks of ACO's to ensure that samples are true replicates.

Personnel

- A crew of two is optimum for checking ACOs.

Equipment

- Maps
- Data forms (waterproofed) and pencil
- Field guides to amphibians (Nussbaum *et al.* 1983; Leonard *et al.* 1993)
- Plastic bags or container
- Calipers
- Thermometer
- 10 g spring scale
- One 1.8 m long untreated rough cut 2 x 12 base board (maximum length)*
- Two 1.8 m long untreated rough cut 1 x 6 cover boards
- Cedar lath
- Nails
- Shovel, axe, and mattock

*A large and massive cover object will resist moisture loss and temperature changes, and a 1.8 m long 2 x 12 (5 cm x 30.5 cm) board is about the largest baseboard that can be carried by one person into the forest. Commercial lumber is often treated with fungicides that may harm amphibians, so untreated, rough-cut, full dimensional lumber is desirable. Douglas-fir (*Pseudotsuga menziesii*) ACOs have been used successfully (Davis 1996, 1997, 1998), but the suitability of wood from other species of trees is unknown.

Field procedures

- Individually label ACO's (e.g., with a metal tag) so that variation among ACOs can be assessed.
- Carry the ACOs to the predetermined locations.
- With shovel, axe, and mattock, clear the space beneath the baseboard of vegetation and place it flat on the soil surface. Put the two top cover boards in place. Strips of cedar lath, nailed to the top surface of the baseboard with galvanized nails, separate the top cover boards from the baseboard in such a way as to create a wedge-shaped space between the cover boards and the baseboard (Figure 4). Rain water can drip through the crack between the two top cover boards into this space. This creates a complex microhabitat so that a salamander could be found on the soil under the baseboard, or between the baseboard and the top boards. Top boards are required for *A. ferreus* only.
- To allow the salamanders time to discover the ACOs, leave them undisturbed for two to three months.
- Determine the timing of trap checks. There should be equal time between checking ACO's to ensure that samples are true replicates.
- A crew of two is optimum for checking ACOs. Each person can be mainly responsible for one-half of the ACO, but both people should scan all the surfaces. Frequently, a salamander will be spotted by one person that was overlooked by another.
- When checking the boards, the top boards are removed to one side, and the upper surface of the baseboard checked. Salamanders are easy to see on the exposed surface of the baseboard, but may suddenly and rapidly escape into the forest litter, so the boards should be removed decisively, and the surface of the baseboard checked immediately. Once the salamanders from the top of the baseboard are secured, the baseboard may be pivoted upwards leaving one edge on the soil. Again, salamanders may suddenly bolt toward the forest litter. This makes them easy to see, but if they reach the litter they will be very difficult to locate, so these individuals should be picked up immediately. If they do not move, they can be difficult to see because of cryptic colouration and low light conditions, so the soil surface should be scanned systematically at the scale of juvenile salamanders. Again, the technique is to lift the baseboard, immediately scan and secure any moving salamanders, then scan the surface systematically.
- Salamanders should be held in containers or plastic bags while setting the boards back in place. If the salamanders are simply counted in place and not removed from the ACO, they can very easily be crushed when the baseboard or top boards are returned to their original positions.
- After the salamanders are caught, one person should take the measurements and mark salamanders while the other records the data (Sections 3.1.2, 3.1.3).

- Encourage released salamanders to crawl back under the ACO. This is essential because salamanders left on the surface may be subject to desiccation and predation, or they may simply walk away from the ACO to another location.

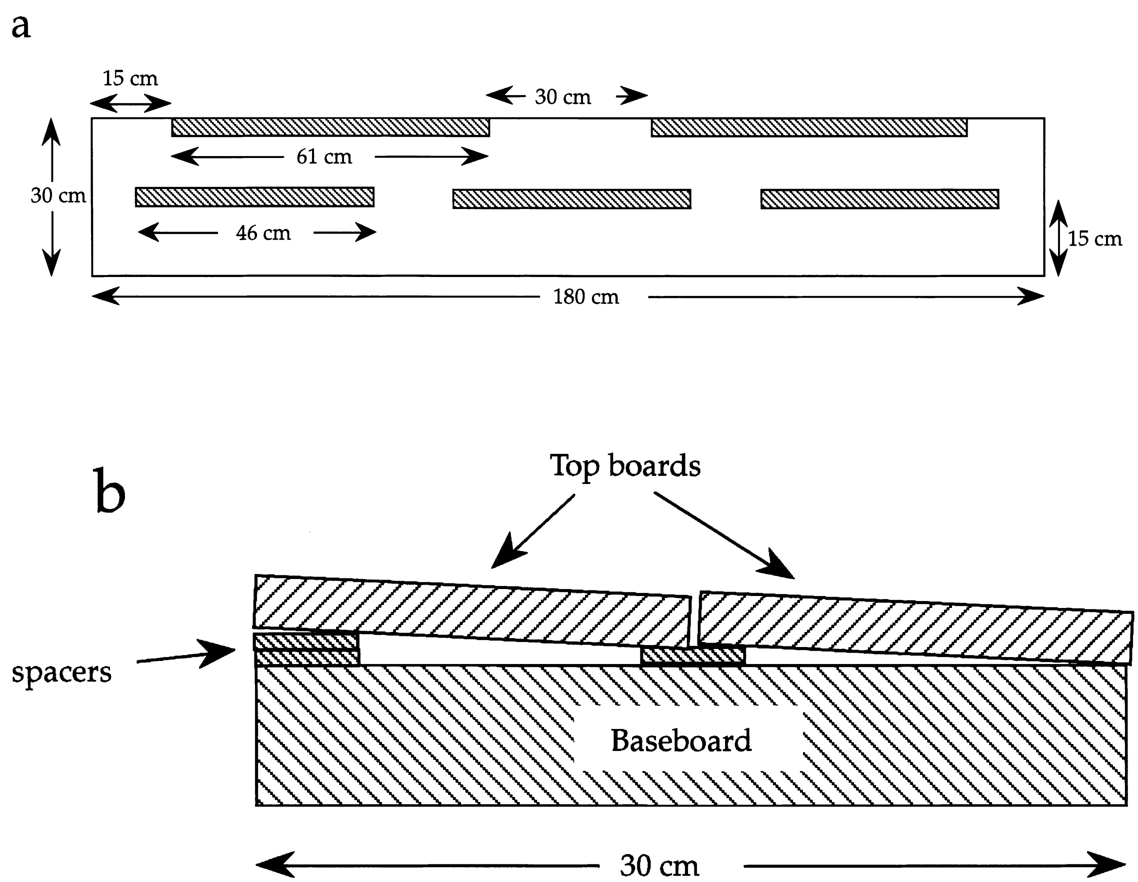

Figure 4. Diagram of an artificial cover object (ACO).

(a) The baseboard portion (viewed from above) of an ACO (previously published in Heyer *et al*. 1994:148, and Davis 1996, 1998). Strips of cedar lath (7 x 38 mm, or 0.27" x 1.5") in lengths of 46 cm (18") and 61 cm (24") are attached with galvanized nails along the middle and one edge of the base board, respectively. The strips along the edge are doubled, so that the lath raises above the baseboard about 14 mm (0.55"). The baseboard is placed on the ground with the lath strips facing up. Top boards (2.5 x 15 x 180 cm, or 1" x 6" x 72") are placed on top of the lath strips, creating wedge-shaped spaces. **(b)** Cross-section of the ACO showing spaces created between the top boards and the baseboard (previously published in Davis 1996, 1998).

Data Entry

The Design Components for this survey are (a) Grids with traps; (b) Arrays with traps; or (c) Station with traps. When digitally entering your survey data, choose 'Grids/Arrays or Station' from the ‘Design Component Type’ picklist before entering observations. Record trap information by choosing ‘Traps’ from the ‘Design Component Type’ picklist.

3.5 Absolute Abundance

Recommended method: Not recommended.

Determining the absolute density of terrestrial salamanders is problematic and should not be attempted if relative abundance is all that is actually needed. At any particular time, an unknown proportion of the population is underground or otherwise inaccessible. Usually, investigators are content with reporting maximum surface density as an index of absolute abundance based on quadrat searches (Ovaska and Gregory 1989; Jaeger 1979; Bury 1983; Corn and Bury 1990; Davis 1996, 1998). Maximum counts can not give a statistical estimate of absolute abundance for there is no measure of whether all the salamanders were counted. Even still some attempts have been made to estimate the total population using either corrections based on the number assumed to be underground or with mark-recapture methods.

There is a large literature on mark-recapture methods (Begon 1979; Seber 1982; Krebs 1989). If salamanders are marked so that individuals can be identified then it may be possible to mark-recapture estimators to allow absolute estimates. However, low to non-existent recapture rates make application of this technique difficult (Linda Dupuis, UBC, per. comm.). Mark-recapture methods have been used to estimate absolute abundance of terrestrial salamanders, but assumptions of the methods are often violated (Merchant 1972, revised by Hairston 1987). Site-tenacity is a particularly difficult problem. Thus, mark-recapture methods may give biased estimates of the density of terrestrial salamanders, and are not to be depended upon for this purpose.

Some studies have removed salamanders from the trapping area (using pitfall traps or ACO's) after capture and used removal estimators with some success (Linda Dupuis, UBC, per. comm.). Given low recapture rates, long term removal based estimates may be the only technique to gain statistical estimates of density. Program CAPTURE (Otis *et al.* 1978) has a removal based estimator (model M_b) that would work with this type of data.

Based on censuses in fenced plots, Davis (1996, 1998) estimated that <24% of the *P. vehiculum* population was on the surface during times of maximum surface abundance. Average searches in the spring probably represent about 10% of the total population.

GLOSSARY

ABSOLUTE ABUNDANCE: The total number of organisms in an area. Usually reported as absolute density: the number of organisms per unit area or volume.

ACCURACY: A measure of how close a measurement is to the true value.

ACO: Abbreviation for artificial cover object.

AMPHIBIAN: Any member of Class Amphibia (salamanders, newts, frogs, toads, and caecilians). Quadrupedal, ectothermal, vertebrates without scales, feathers or fur.

ARTIFICIAL COVER OBJECT (ACO): Any cover object placed in an area by the investigator; usually a board, but could be made of any material.

BIODIVERSITY: Jargon for biological diversity: "the variety of life forms, the ecological roles they perform, and the genetic diversity they contain" (Wilcox, B.A. 1984 cited in Murphy, D.D. 1988. Challenges to biological diversity in urban areas. Pages 71-76 *in* Wilson, E.O. and F.M. Peter, eds. 1988. Biodiversity. National Academy Press, Washington, DC. 519 pp.).

BIOMASS: The weight (expressed as mass) of living organisms.

BLUE LIST: Taxa listed as BLUE are sensitive or vulnerable; indigenous (native) species that are not immediately threatened but are particularly at risk for reasons including low or declining numbers, a restricted distribution, or occurrence at the fringe of their global range. Population viability is a concern as shown by significant current or predicted downward trends in abundance or habitat suitability.

CBCB (Components of B.C.'s Biodiversity) Manuals: Wildlife species inventory manuals that have been/are under development for approximately 36 different taxonomic groups in British Columbia; in addition, six supporting manuals.

COARSE WOODY DEBRIS (CWD): Logs, or pieces of wood or bark with the smallest dimension $\geq$10 cm.

CREPUSCULAR: Active at twilight

CWD: Abbreviation for coarse woody debris (q.v.).

DECAY CLASS: A classification of the serial decay states of logs.

DESIGN COMPONENTS: Georeferenced units which are used as the basis for sampling, and may include geometric units, such as transects, quadrats or points, as well as ecological units, such as caves or colonies.

DISPERSAL: The movement of individuals away from the immediate environment of their parents and neighbours.

DIURNAL: Active during the daytime

ECTOTHERMY: The condition in which heat is obtained mainly from the external environment.

EWG (Elements Working Group): A group of individuals that are part of the Terrestrial Ecosystems Task Force (one of 7 under the auspices of RIC) which is specifically concerned with inventory of the province's wildlife species. The EWG is mandated to provide standard inventory methods to deliver reliable, comparable data on the living "elements" of BC's ecosystems. To meet this objective, the EWG is developing the CBCB series, a suite of manuals containing standard methods for wildlife inventory that will lead to the collection of comparable, defensible, and useful inventory and monitoring data for the species populations.

FECUNDITY: In salamanders, the number of eggs laid/female.

HAPHAZARD SAMPLE: A sample that has been selected by chance and without planning. Not the same as a random sample (q.v.).

HOME RANGE: The area in which an animal normally lives.

INVENTORY: The process of gathering field data on wildlife distribution, numbers and/or composition. This includes traditional wildlife range determination and habitat association inventories. It also encompasses population monitoring which is the process of detecting a demographic (e.g. growth rate, recruitment and mortality rates) or distribution changes in a population from repeated inventories and relating these changes to either natural processes (e.g. winter severity, predation) or human-related activities (e.g. animal harvesting, mining, forestry, hydro-development, urban development, etc.). Population monitoring may include the development and use of population models that integrate existing demographic information (including harvest) on a species. Within the species manuals, inventory also includes, species statusing which is the process of compiling general (overview) information on the historical and current abundance and distribution of a species, its habitat requirements, rate of population change, and limiting factors. Species statusing enables prioritization of animal inventories and population monitoring. All of these activities are included under the term inventory.

LIFE HISTORY: An organism's life-time pattern of growth and reproduction. Includes, among other things, fecundity, survivorship, mode of reproduction, age at reproduction, parental care, body size, and life span.

MARK-RECAPTURE METHODS: Methods used for estimating abundance that involve capturing, marking, releasing, and then recapturing again one or more times.

METAPOPULATION: A population of subpopulations that are linked by dispersal.

MICROHABITAT: At a fine scale, the portion of a habitat defined with respect to particular elements (e.g., under bark on logs).

MONITOR: To follow a population (usually numbers of individuals) through time.

NEOTENY: Attaining reproductive maturity while in the larval state by delayed somatic development.

NOCTURNAL: Active at night

OBSERVATION: The detection of a species or sign of a species during an inventory survey. Observations are collected on visits to a design component on a specific date at a specific time. Each observation must be georeferenced, either in itself or simply by association with a specific, georeferenced design component. Each observation will also include numerous types of information, such as species, sex, age class, activity, and morphometric information.

PITFALL TRAP: A can or bucket buried flush with the substrate so that an animal will fall into it.

PLETHODONTID SALAMANDERS: Salamanders of the Order Caudata: Family Plethodontidae (q.v.).

PLETHODONTIDAE: The largest Family of salamanders with about 220 species. Many are terrestrial, and all are lungless. Typically, they have slender bodies, long tails, excellent vision, and a well-developed tongue.

POIKILOTHERMY: The condition in which body temperature varies with the ambient temperature.

POPULATION: A group of organisms of the same species occupying a particular space at a particular time.

PRECISION: A measurement of how close repeated measures are to one another.

PREMAXILLARY TEETH: Teeth associated with the premaxillae, the most anterior bones of the upper jaw.

PRESENCE/NOT DETECTED (POSSIBLE): A survey intensity that verifies that a species is present in an area or states that it was not detected (thus not likely to be in the area, but still a possibility).

PROJECT AREA: An area, usually politically or economically determined, for which an inventory project is initiated. A project boundary may be shared by multiple types of resource and/or species inventory. Sampling for species generally takes place within smaller, representative study areas so that results can be extrapolated to the entire project area.

PROJECT: A species inventory project is the inventory of one or more species over one or more years. It has a georeferenced boundary location, to which other data, such as a project team, funding source, and start/end date are linked. Each project may also be composed of a number of surveys.

QUADRAT: A sampling unit used to assess the density of organisms. Etymologically, it means a four-sided figure, but in practice refers to any sampling unit, whether circular, regular or irregular polygon, or any other shape.

QUADRAT-FRAME: A square frame of wood or metal, usually with inside dimensions of 1 m x 1 m.

RANDOM SAMPLE: A sample that has been selected by a random process, generally by reference to a table of random numbers.

RED LIST: Taxa listed as RED are candidates for designation as Endangered or Threatened. Endangered species are any indigenous (native) species threatened with imminent extinction or extirpation throughout all or a significant portion of their range in British Columbia. Threatened species are any indigenous taxa that are likely to become endangered in British Columbia, if factors affecting their vulnerability are not reversed.

RELATIVE ABUNDANCE: The number of organisms at one location or time relative to the number of organisms at another location or time. Generally reported as an index of abundance.

REPRODUCTIVE SINK: A subpopulation that, without immigration from other subpopulations, produces too few offspring for long-term persistence.

REPRODUCTIVE SOURCE: A subpopulation that produces a net surplus of individuals that disperse to other subpopulations.

RIC (Resources Inventory Committee): RIC was established in 1991, with the primary task of establishing data collection standards for effective land management. This process involves evaluating data collection methods at different levels of detail and making recommendations for standardized protocols based on cost-effectiveness, co-operative data collection, broad application of results and long term relevance. RIC is comprised of seven task forces: Terrestrial, Aquatic, Coastal/Marine, Land Use, Atmospheric, Earth Sciences, and Cultural. Each task force consists of representatives from various ministries and agencies of the Federal and BC governments and First Nations. The objective of RIC is to develop a common set of standards and procedures for the provincial resources inventories. [See http://www.for.gov.bc.ca/ric/]

SALAMANDER: Any member of Class Amphibia: Order Caudata (tailed amphibians including salamanders and newts).

SITE-SPECIFICITY: The tendency to remain at one location.

SNOUT-VENT LENGTH (SVL): In salamanders, the length of an animal measured from the tip of the snout to the anterior end of the cloacal vent.

SPATIAL DISTRIBUTION: The dispersion of individuals in space.

SPECIES RICHNESS: The number of species in a particular area.

SPI: Abbreviation for ‘Species Inventory’; generally used in reference to the Species Inventory Datasystem and its components.

STABLE POPULATION: A population in which the numbers of individuals remain constant through time.

STARTING LINE: A line from which a series of parallel transects begins, which is perpendicular, or nearly perpendicular, to them.

STATISTICAL POWER: The probability of correctly rejecting a null hypothesis. Thus, a powerful test is one that has a high probability of detecting a difference when such a difference actually exists.

STATISTICAL SIGNIFICANCE: Rejection of the null hypothesis at some significance level (usually 0.05). Statistical significance may or may not be relevant to biological significance (see Krebs 1989, p.8).

STOCHASTIC: Chance (i.e., random) events.

STRATIFICATION: The separation of a sample population into non-overlapping groups based on a habitat or population characteristic that can be divided into multiple levels. Groups are homogeneous within, but distinct from, other strata.

STUDY AREA: A discrete area within a project boundary in which sampling actually takes place. Study areas should be delineated to logically group samples together, generally based on habitat or population stratification and/or logistical concerns.

SURVEY: The application of one RIC method to one taxonomic group for one season.

SURVIVORSHIP: The probability of a new-born individual surviving to a specified age.

SYSTEMATIC SAMPLE: A sample obtained by randomly selecting a point to start, and then repeating sampling at a set distance or time thereafter.

TALUS: a sloping mass of rocky fragments.

TERRESTRIAL ECOSYSTEMS TASK FORCE: One of the 7 tasks forces under the auspices of the Resources Inventory Committee (RIC). Their goal is to develop a set of standards for inventory for the entire range of terrestrial species and ecosystems in British Columbia.

TIME-CONSTRAINED SEARCH (TCS): An equal-effort search as measured by the number of person-hours spent searching.

YELLOW-LIST: Includes any native species which is not red- or blue-listed.

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APPENDIX

Appendix A. Decay classes for bark and logs.

General site descriptions should follow the recommendations in Ministry of Environment, Lands and Parks, and Ministry of Forests (1998). For specific microhabitats of terrestrial salamanders, use the classification below.

Microhabitat Classification

The Microhabitat Classification uses two features in an alpha-numeric code. The first part of the code describes the location that the salamander is found, for example, under bark on Ground (BarkG) within moss (MossW). The numeric part of the code is used where applicable and describes the decay stage or class. These decay classes are broken down into tow categories: ‘log’ and ‘bark’. For decay classes, snags and stumps are treated as logs. These categories are useful for general inventory purposes of plethodontid salamanders.

Table A 1. Microhabitat Classification.

Code	Description
BarkG#	Bark - under the Bark on the Ground (plus Bark decay class)
BarkL#	Bark - under the Bark on Log (plus Bark decay class)
LogG#	Log - under Log on Ground (plus Log decay class)
LogW#	Log - Within Log (plus Log decay class)
SnagsB#	Snags and Stumps - under Bark (plus Log decay class)
SnagsW#	Snags and Stumps - within Wood (plus Log decay class)
SurfaceL#	Surface - on Log (plus Log decay class)
Surface B#	Surface - on Bark (plus Bark decay class)
Surface F	Surface - on or within forest Floor litter
RocksU	Under Rock on ground
MossU	Under Moss
MossW	Within Moss
Fern	Within Sword Fern bases
Talus	In rock pile or Talus
Unspec.	Unspecified

# indicates the decay class of the log or bark

Table A 2. Decay classes for bark.

Class #	Description
1	Intact, new bark
2	Bark breaks into large, slid pieces
3	Bark easily breaks into small blocky pieces

Table A 3. Decay classes for logs (Modified from Sollins (1982)).

Class	General	Bark	Invading roots	Structural integrity
1	Intact, recently downed trees	Intact and not loose	Absent	Sound
2	Some loose bark, but most is difficult to pull off log; stem mostly sound	Mostly intact, but some loose	Absent	Sapwood somewhat decayed; heartwood mostly sound
3	Bark easily pulled off log; stem partly rotted	Loose, or absent	Sapwood only	Sapwood decayed, but heartwood mostly sound
4	Deeply decomposed logs with invasion by roots	Detached or absent	Throughout	Heartwood rotten, branch stubs pull out
5	Hummocks of wood chunks and organic material	Detached or absent	Throughout	None