Inventory Methods for Tailed Frog and Pacific Giant Salamander

Standards for Components of British Columbia's Biodiversity No. 39

Prepared by
Ministry of Environment, Lands and Parks
Resources Inventory Branch
for the Terrestrial Ecosystems Task Force
Resources Inventory Committee

March 13, 2000

Version 2.0

Published by the
Resources Inventory Committee

Canadian Cataloguing in Publication Data

Main entry under title:

Inventory methods for tailed frog & Pacific giant salamander [computer file]

(Standards for components of British Columbia's biodiversity ; no. 39)

Available through the Internet.

Issued also in printed format on demand.

Includes bibliographical references.

ISBN 0-7726-3887-X

1. Ascaphus truei - British Columbia - Inventories - Handbooks, manuals, etc. 2. Dicamptodon tenebrosus - British Columbia - Inventories - Handbooks, manuals, etc. 3. Amphibian populations - British Columbia. 4. Ecological surveys - British Columbia - Handbooks, manuals, etc. I. British Columbia. Ministry of Environment, Lands and Parks. Resources Inventory Branch. II. Resources Inventory Committee (Canada). Terrestrial Ecosystems Task Force. III. Series.

QL654.I58 1999 333.95'78 C99-960167-9

Additional Copies of this publication can be purchased from:

Government Publications Centre
Phone: (250) 387-3309 or
Toll free: 1-800-663-6105
Fax: (250) 387-0388
www.publications.gov.bc.ca

Digital Copies are available on the Internet at:
http://www.for.gov.bc.ca/ric

Preface

This manual, version 2.0, is a revised and improved manual describing standard methods for inventory of Tailed Frogs and Pacific Giant Salamanders in British Columbia. This manual includes methods for inventory to evaluate presence and relative abundance. Version 2.0 attempts to incorporate new knowledge of the province's fast stream amphibians from surveys completed after the publication of version 1.1. This version also includes a more detailed section on sample design. Like its predecessor, this 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 that 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), voucher collection (No.4), 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]*. 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.elp.gov.bc.ca/rib/wis/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:

Species Inventory Unit
Wildlife Inventory Section, Resources Inventory Branch
Ministry of Environment, Lands & Parks
P.O. Box 9344, Station Prov Govt
Victoria, BC V8W 9M1
Tel: (250) 387 9765

Acknowledgements

Funding of the Resources Inventory Committee work, including the preparation of this document, is provided by the Corporate Resource Inventory Initiative (CRII) and by Forest Renewal BC (FRBC). Preliminary work of the Resources Inventory Committee was funded by the Canada-British Columbia Partnership Agreement of Forest Resource Development FRDA II.

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.

Version 2.0 of this manual is the result of the hard work of Linda Dupuis (Cascade Environmental). Version 2.0 incorporates comments by Karl Mallory (University of British Columbia), John Boulanger (Integrated Ecological Research) and Dr. John Richardson (University of British Columbia & Ministry of Environment, Lands and Parks). Contributors to earlier versions of this manual include Tom Ethier, Ann Eriksson, Trudy Chatwin, Laura Darling, Ted Davis, Laura Friis, Andrew Harcombe, Richard Wiacek, and Ian Hatter.

This manual was edited to its final form by James Quayle and Leah Westereng.

Table of Contents

List of Tables

List of Figures

1. INTRODUCTION

Small, fast flowing, permanent streams of first, second, or third order provide important habitat for certain stream-dwelling amphibians (Bury and Corn 1991). From a management perspective, these streams have historically been viewed as less important than salmonid streams, and have received little or no protection. Recent evidence of detrimental effects of logging on stream-dwelling amphibian communities in Oregon (Corn and Bury 1989), and within the context of the declining trend of amphibians world-wide (Blaustein and Wake 1990), indicate that more management and research is needed in these small streams.

In British Columbia there are two species of amphibians that inhabit fast, cascading streams; the Tailed Frog (*Ascaphus truei*) and the Pacific Giant Salamander (*Dicamptodon tenebrosus*). Since both these species are at the northern extent of their range, they are of special interest in terms of biogeography, occurring at the limits of their ecological and physiological adaptations. Declines in populations at the limit of their range may alert attention to factors that could threaten the species as a whole (Dupuis *et al.*, in press).

The purpose of this manual is to recommend methods and protocols for determining presence and abundance of both the Pacific Giant Salamander and the Tailed Frog. As the same inventory method is recommended for both species, it will be possible to conduct surveys for both amphibians simultaneously, where appropriate. As well, it is likely that the techniques described here will result in incidental captures of other species of amphibians. Specific techniques for proper sampling of pond-breeding and terrestrial species of amphibians are described in other manuals in this series.

2. INVENTORY GROUP

2.1 Tailed Frog A-ASTR
Ascaphus truei

2.1.1 Description

Adults range in size from 22 to 51 mm, and they have granular skin. They possess several unique traits for life in fast-flowing waters, including a large head and streamline body, broad, flattened outer toes, and vertical, diamond-shaped pupils. They also lack tympana (ear membranes), and the males possess a tail-like extension of the cloaca to achieve internal fertilization of a female's eggs (Green and Campbell 1984; Nussbaum *et al.* 1983).

Tadpoles are slate-grey, black or brown, and some populations can be quite mottled. They generally possess a characteristic white dot on the tip of the tail. Hatchlings are roughly 20 mm in length, and can be up to 65 mm long prior to metamorphosis (Leonard *et al.* 1993). In order to move around effectively in fast waters, the tadpoles have a ventrally flattened body and a laterally compressed tail bordered by a tapered tail fin. They also possess a flattened oral disc that serves as a sucker for clinging to rock surfaces.

2.1.2 Distribution in British Columbia

The Tailed Frog occurs primarily in the Coast and Mountains Ecoprovince, in cool mountain streams from sea level to 2140 metres in elevation. It ranges from the Lower Mainland to Portland Canal, north of Prince Rupert (Dupuis *et al.*, in press) and is strongly associated with the Coastal Western Hemlock (CWH) and Mountain Hemlock (MH) biogeoclimatic zones. More sporadic occurrences exist at higher elevation, in the Engelmann Spruce-Subalpine Fir (ESSF) and Alpine Tundra (AT) biogeoclimatic zones. The Tailed Frog is also found to a lesser extent in the extreme southern portion of the Border Ranges and Columbia Mountains of southeastern British Columbia, within the ESSF biogeoclimatic zone. These interior populations are separated from one other by the Rocky Mountain Trench, and from the Coast Range population by the dry biogeoclimatic zones of the Interior. In general, the presence of Tailed Frogs in British Columbia appears to be linked to climate and local geological characteristics (Sutherland *et al.*, in prep.).

2.1.3 Reproduction

Tailed Frogs do not reproduce until eight or nine years of age, roughly twice that of most other frogs (Brown 1990). Mating occurs in the autumn, with the male using its copulatory organ ("tail") to internally inseminate the female. The female can store the sperm for several months, and lay 35-70 eggs the following summer, under stream cobbles and boulders. Hatching occurs approximately six weeks later, in August or September.

2.1.4 Feeding

Adults consume pseudoscorpions, ticks, mites, spiders, centipedes, millipedes, a range of adult and larval insects and some freshwater crustaceans. Tadpoles use their vomerine teeth to scrape diatoms and algae from the surface of stones.

2.1.5 Tadpole habitat requirements

Tailed Frogs live in cool, cascading streams that flow year-round. In general, they have a clustered distribution in the landscape, apparently influenced by small and large-scale geomorphological and climatic characteristics (Sutherland *et al.*, in prep; Dupuis *et al.*, in press). More specifically the presence of Tailed Frogs coincides largely with humid, temperature climates (refer to Demarchi 1993). Also, they are found more frequently and at greater densities, in streams with a coarse, cobble substrate and anchored boulders.

Historical disturbances such as flooding, debris flow events, and timber harvests may also affect Tailed Frog distribution. Dupuis and Steventon (1999) found that despite large, natural variation in population size, Tailed Frog densities decreased with increasing levels of fine sediment (< 64 mm diameter), rubble, detritus and wood, and increased with bank width. These detrimental parameters were found at higher levels in clear-cut creeks than in undisturbed or buffered creeks. Finer sediments and detritus, which apparently clog interstitial spaces inhabited by larvae, tend to be prevalent in gullies with unstable banks or small creeks where flow does not adequately flush small particles. Interstitial spaces appear to be particularly important to larvae in the event of major bedload movements.

2.1.6 Adult habitat Requirements

Tailed Frog adults are terrestrial foragers, but little is known about individual home ranges. It is believed that individuals remain in or near their natal stream for their lifetime. Daugherty and Sheldon (1982) found that adults are extremely philopatric in Montana, which suggests that dispersal abilities may be poor, at least in drier areas of the range. In the Coastal Western Hemlock biogeoclimatic zone, adults have been encountered more than 200 m from a stream (Dupuis, pers. obs.; Bury, pers. obs.).

2.1.7 Status

The Kootenay population of Tailed Frogs is included on the provincial red-list and the Coast Range population is on the provincial blue-list (Min. Environ., Lands and Parks 2000). Both populations are expected to be vulnerable to resource exploitation and landscape alteration due to their use of specialized habitats, their long larval stages, small clutch sizes, and biennial reproduction. Logging and road building can increase both temperature and sediment load in streams, either of which may have a negative impact on *Ascaphus* populations. Some studies demonstrate that Tailed Frog populations decline or disappear following clearcut

logging (Dupuis and Steventon 1999; Bury and Corn 1991; Welsh and Lind 1991).

2.2 Pacific Giant Salamander A-DITE *Dicamptodon tenebrosus*

2.2.1 Description

Although Pacific Giant Salamanders are commonly about 150-250 mm in length, they can reach sizes in excess of 300 mm (as their name implies). Their heads and backs are coloured with light and dark brown markings surrounded by lighter halos, giving them a marbled appearance. *Dicamptodon tenebrosus* possesses a broad head with a short blunt snout. It lacks parotid glands, its feet have neither webs nor tubercles, and its legs will touch or overlap when adpressed.

Larval colouration is a uniform light brown with a light stripe running from the eye to the edge of the jaw (this may be difficult to see). Gills are located behind the head, and a small fin is present on the tail. Larvae generally metamorphose at 120-150 mm; however, neoteny is common and neotenes may reach sizes greater than 300 mm (Nussbaum *et al.* 1983). Adult forms are secretive and seldom encountered in British Columbia (Green and Campbell 1984).

2.2.2 Distribution in British Columbia

The only known location for this species in British Columbia is the coastal Douglas-fir biogeoclimatic zone (Coast and Mountains and Georgia Depression ecoprovinces) south of the Fraser River, specifically within the Cultus Lake and Chilliwack Lake drainage basins.

2.2.3 Reproduction

Pacific Giant Salamanders breed in the spring, with the male depositing many spermatophores on the stream bed. The female lays 85-200 eggs, each 15-20 mm in diameter (Nussbaum 1969). The eggs may occur singly or in clumps attached to the underside of rocks or logs by a short stalk. The female will stay with the eggs during their development, until they hatch in the fall. The larvae may become neotonic or take five to six years to develop into adults.

2.2.4 Feeding

The diet for both the adult and larvae is extremely varied. The adults have been known to eat land snails, sowbugs, centipedes, millipedes, larval and adult insects, salamanders, lizards, voles, mice, and shrews. Larval salamanders eat a wide range of terrestrial insects, sculpins, small salmonids, and the larvae of *Ascaphus*.

2.2.5 Larval habitat requirements

Pacific Giant Salamanders are inhabitants of closed canopy, mountain streams in Douglas-fir and Big-leaf Maple forests. Although permanent streams are required to accommodate the minimum two year larval period, there is some evidence that these can be intermittent.

Salamander larvae appear to persist in wet stream bed sediments or subterranean flows when surface water periodically dries up (K. Mallory, pers. comm.).

Pacific Giant Salamander larvae have a clustered distribution within a stream. It is possible to find dozens of larvae in a short reach and then none for tens of meters (J. Richardson, UBC, pers. comm.). This in-stream distribution pattern has allowed researchers to determine some of the species' key habitat requirements; these are substrate type, cover availability, cutbank presence, and water levels. Highest quality habitat is generally expected to include sections of stream with penetrable substrate (gravel, minimum of fine sediment), slower moving water (often as pools), numerous moveable cover objects (stones, large logs, boulders), and considerable undercutting of banks. Younger larvae occur in portions of the stream that are sheltered or away from turbulent flow. Older larvae can also be found in riffles.

At a landscape level, the distribution of Pacific Giant Salamanders appears to be random. Although occurrences are limited to the Chilliwack drainage and neighbouring sites, researchers have found absolutely no predictive power from discriminant functions or logistic regression based on a suite of environmental measures. Streams that look perfectly suitable may have no salamanders associated with them. In one British Columbia study, researchers attempted to "create" new populations in apparently suitable sites by transplanting 20-40 larvae into each of two streams. In both cases, a large portion of the population remained more than a year later. Biologists are currently looking for signs of successful metamorphosis in the transplanted animals.

2.2.6 Adult habitat Requirements

Records of terrestrial adults are rare in British Columbia, suggesting that individuals are extremely secretive, or that few individuals metamorphose. Nussbaum *et al.* (1983) proposed neoteny as "the rule" for streams that do not dry out but recent surveys have showed an increase in the proportion of neotenes and large-sized metamorphs at higher elevations (K. Mallory, pers. comm.).

In a study of 20 terrestrial adults that had been implanted with radio-transmitters, Johnston (1999) found that the vast majority of re-locations (80%) occurred within 20 m of a stream. Some salamanders never ventured away from the stream. Pacific Giant Salamanders often spent several days or weeks without changing location, and moved primarily on rainy nights. On occasions when adult salamanders made extended movements into the upslope forest, they appeared to utilize small mammal tunnels, root channels, and logs of an advanced decay class for refuge. Refuge sites were characterized by the availability of coarse woody debris, water, rocks, and leaf litter. Pacific Giant Salamanders avoid open habitats such as clearcuts (Johnston and Frid, in prep). During a relocation experiment, individuals introduced to clearcuts were significantly more sedentary than individuals released in a forested environment, and their movements were more strongly tied to rain events. There is no evidence of seasonal migration amongst terrestrial-bound Pacific Giant Salamanders.

2.2.7 Status

The Pacific Giant Salamander is on the provincial red-list list (Min. Environ., Lands and Parks 2000) due to the limited extent of its distribution, its low reproductive rate, and the current rate

of degradation of its habitat. Some researchers believe *D. tenebrosus* is probably declining in abundance due the effects of human development and industrial activities on its riparian habitat.

3. PROTOCOLS

3.1 Sampling Standards

Hand collection within streams is recommended. It involves turning over objects, raking gravels by hand (to avoid injuries), sweeping large boulders, and scanning the banks. Larvae and tadpoles are caught by means of dip nets held immediately downstream of searchers; larger Pacific Giant Salamander larvae can also be caught by hand. Hand collection can be used for reconnaissance (presence/not detected) surveys or relative abundance estimates, and can be used to census both species simultaneously.

Surveyors should be aware that hand collection can be disruptive and destructive to habitat. It is important that well-anchored cobbles and boulders be left in place because they are a primary source of stability in streams, which are otherwise subject to regular bedload movement. Maintaining these key habitat components will minimize disruption to the social patterns of the species, their vulnerability to predation, and the risk of mortality during debris flow and flooding events. Leaving anchored rock complexes untouched will also allow future monitoring of the same section of stream. Unembedded or loosely embedded cover objects should also be returned to their original location, to minimize temporary disruptions.

Surveyors should also be aware that hand collection within streams precludes the majority of the adults, which are predominantly terrestrial. Pacific Giant Salamanders occur near stream edges, and may be encountered some distance from streams on rainy nights. Similarly, Tailed Frogs are terrestrial foragers and have been found over 200 m from streams during moist conditions. Methods of terrestrial survey such as pitfall trapping or the use of coverboards target adults, but these are labour intensive and tend to yield little data. Nocturnal visual encounter surveys have been reasonably successful in some watersheds where adult Tailed Frogs have been abundant at the water's surface. Radio telemetry has provided some insight into the habitat requirements of the elusive adult Pacific Giant Salamander, but the technology does not permit long-term tracking and some individuals move very little in the period of a month, which is the current time limit of suitable telemetry batteries.

Electroshocking is not recommended, as it is potentially dangerous to the stream inhabitants. It may also be ineffective when used on amphibians because they lack swim bladders and will tend to remain submerged and concealed even when electrocuted. Incidental observations from fish electroshocking surveys, however, are a valuable source of information.

3.1.1 Time of year

Generally, streams should be sampled during the dry summer months, from June to September. Summer surveys increase the chance of adult encounters since both species tend to stay close to streams during dry conditions. Also, temperatures exceeding 8°C are more tolerable for surveyors and more conducive to finding both salamander larvae and frog tadpoles. Lastly, ephemeral streams are unlikely to be surveyed during this time period, and the low flows in permanent streams will improve the census of both species by facilitating the detection of individuals. As streams respond quickly to heavy rains, surveys should be

restricted to rainless periods. Both tadpoles and larvae may seek subterranean refuge during the rainy seasons, an adaptation to survival in a dynamic mountain stream environment.

3.1.2 Habitat data standards

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. Stream habitats are generally described using the Stream Site Card developed by Department of Fisheries and Oceans and Ministry of Environment (1989). Information on the Site Card can be found in *Reconnaissance (1:20,000) Fish and Fish Habitat Inventory: Data forms and User Notes*, available as hardcopy from Queens Printer or download at http://www.env.gov.bc.ca/fsh/IS/standards/standards.htm). Appendix E of 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 Tailed Frog and Pacific Giant Salamander surveys. A minimum amount of habitat data must be collected for each survey type, including stream location, average wet width, stream gradient, aspect, and substrate composition.

3.1.3 Survey design hierarchy

Figure 1 clarifies certain terminology used within this manual (also found in the glossary), and illustrates the appropriate conceptual framework for a hand collecting survey. A survey set up following this design will lend itself well to RIC standard methods and data forms.

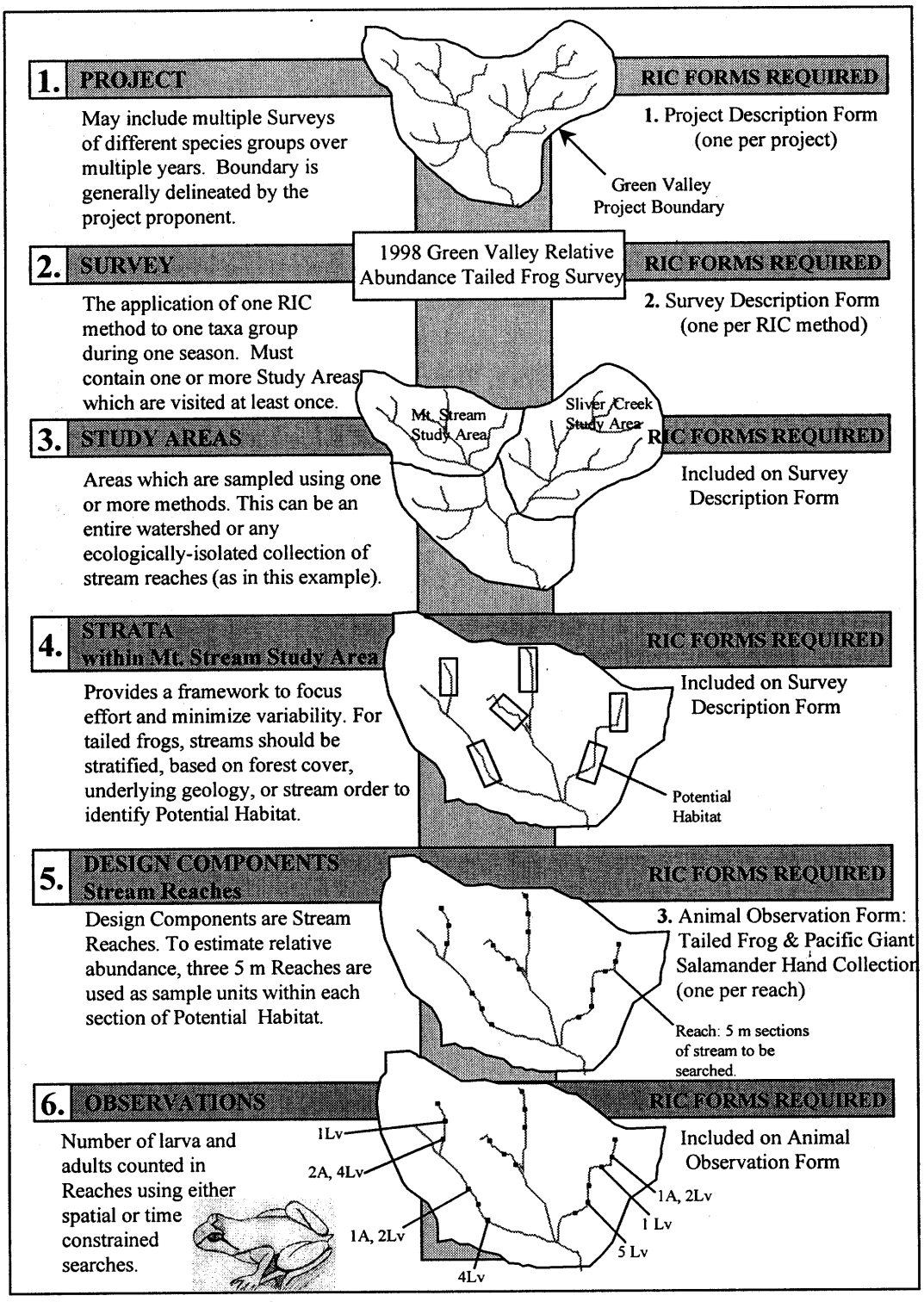

Figure 1. RIC species inventory survey design hierarchy with examples.

3.2 Inventory Surveys

The table below outlines the type of surveys that are used for Tailed Frog and Pacific Giant Salamander inventories of various levels of detail. These survey methods have been recommended by wildlife biologists and approved by the Resources Inventory Committee.

Table 1. Types of inventory surveys, the data forms needed, and the level of intensity of the survey.

Survey Type	Data Forms Needed	Intensity
Hand Collection (Time or Area-Constrained Searches)	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form • Animal Observation Form - Tailed Frog and Pacific Giant Salamander	• PN • RA

- PN = presence/not detected (possible); RA = relative abundance

3.3 Presence/not detected objectives

Time-constrained searches (TCS) are ideal for reconnaissance surveys. This non-intensive hand collection technique involves searching a creek for a specific time limit of 30 person-minutes (*e.g.*, two people searching for 15 minutes) for Tailed Frogs, and 120 person-minutes for Pacific Giant Salamanders. Timed searches are effective for determining the presence of amphibians because they (1) involve no set-up cost; (2) allow for larger sections of creek to be covered; and (3) maximize the total number of captures by focussing on the most suitable microhabitats. For Pacific Giant Salamanders and Tailed Frogs, these habitats include pools, areas of numerous, large cover objects, cutbanks, and riffles with large cobbles and boulders. Although a maximum search length can be established, it is important not to spatially confine a timed search because larvae and tadpole distributions are highly clustered, and they can easily be missed this way. A lack of encounters following a thorough TCS should be recorded as a lack of detection rather than an absence, since searches may occasionally result in missed tadpoles in more marginal habitats.

The survey design used for presence/not detected surveys should be determined based on densities expected in study areas.

See the Hand Collection Method section 3.5 for detailed protocol.

3.4 Relative abundance objectives

Area-constrained searches (ACS) are recommended for acquiring data on relative abundance (number of individuals/m^2). This intensive hand collection technique involves the thorough survey of three 5-m reaches (sampling units) for the Tailed Frog and one 120-m reach for the Pacific Giant Salamander. Work is initiated downstream, and carried out in one-metre increments. Relative abundance is calculated as the number of individuals encountered/area (wet width x survey length). The multiple reach approach used for the Tailed Frog lends itself to a "nested" study design, providing measures of within-stream variability as well as variability with the study area. This ACS approach is not suitable for animals of low density. The extensive ACS sampling unit recommended for Pacific Giant Salamanders takes into account the lower densities, potential territoriality of individuals, and conspecific predation by larger larvae. Should ACS surveys not be feasible due to financial or time restrictions, the TCS technique can provide a rough estimate of relative abundance, expressed as the number of individuals per unit of search effort.

By recording the developmental stage of Tailed Frog tadpoles and the length of Pacific Giant Salamander larvae, the age structure of the larval populations can be determined. The possibility then exists to augment the method described in this manual with certain mark-recapture techniques (not discussed here) that may provide insights into a population's ecology and life history.

See the Hand Collection Method section 3.5 for detailed protocol.

3.5 Hand Collection Method

3.5.1 Office procedures

- Review the introductory manual No. 1, *Species Inventory Fundamentals*.
- Obtain relevant maps for Project and Study Area(s) *e.g.*, 1:50 000 maps for areas within the range of the species, 1:20,000 TRIM maps.
- Delineate the Project Area on a map.
- Determine Biogeoclimatic zones and subzones for the Project Area from Meidinger and Pojar (1991), and Ecoregion, Ecosection, and Broad Ecosystem Units from Demarchi (1993).
- Delineate Study Area(s) on the maps, following the instructions below (under "Sampling Design"). These are the areas in which sampling will actually take place.

3.5.2 Sampling design

1. Clearly state your objectives (e.g., habitat requirements range information, watershed comparison, population trend).
2. Delineate Study Areas on a map. This will document the area in which you intend to sample, and to which your conclusions will apply. Include only that area of landscape that possesses the appropriate landscape-level habitat characteristics to sustain the focal species. For example, in the Coast and Mountains Ecoprovince, Tailed Frogs are found in swift-flowing streams in mountainous areas but not in gently flowing stream of the coastal lowlands. Pacific Giant Salamanders have not been found above elevations of 1100 m in the province.

   There are two recommended ways of delineating a Study Area for fast stream amphibians:

   - Use an entire watershed as the Study Area. The most meaningful information will be obtained by sampling discrete populations. As Tailed Frogs and Pacific Giant Salamanders both appear to spend much of their lives in close proximity to streams, watersheds can provide ecologically-based Study Areas. This is particularly true in areas where watershed boundaries act as barriers to amphibian dispersal, isolating all populations that are part of a larger metapopulation.
   - If resources do not permit a watershed-scale survey, use ecologically-isolated sections of a stream or several streams as the Study Area. Ideally, a Study Area should be large enough to include all populations that may interact ecologically. It is assumed that upstream larval populations drift/move to habitats downstream, and so, as a minimum, Study Areas should contain entire streams or portions of streams which are isolated by impassable barriers.
3. Stratify each of the streams within your Study Area by habitat. The number of strata you utilize will depend on your specific objectives although simpler is generally better. As a minimum, you are required to classify streams into one of two strata: Potential Habitat or Other (the latter in which you are not likely to conduct area-constrained searches). This will require you to use air photos, topographic maps, and field visits to identify suitable

streams. Surveyors should also consult the results of recent studies. Suitable areas should then be delineated on a map.

- For Tailed Frogs, stratify study streams on the basis of underlying geology (rock type; extent of large anchored rocks), forest cover type, and stream order. Recent research suggests that the distribution of Tailed Frogs may largely governed by geology (Dupuis and Steventon 1999; Dupuis *et al.*, in press; Sutherland *et al.*, in prep.).
- For the Pacific Giant Salamander, stratify streams on the basis of forest cover, elevation (under 100 m), and stream width. Other attributes may be included as well given that microhabitat needs differ at various stages of larval development.

4. Determine which technique is most feasible for your study. Time constraints (TCS) are ideal for general reconnaissance surveys and they distinguish good Tailed Frog and Pacific Giant Salamander streams, from fair streams and poor ones. For more comprehensive searches, and/or for identifying fine-scale associations between habitat and larval abundance, area constraints (ACS) may be best. ACS may also be used strategically to augment data from time constrained searches.
5. It is important to determine the sample size that is required to account for the enormous variability in ecological variables, and in amphibian distribution and abundance. Generally, the more clustered a species' distribution, the greater the sampling effort required. Tend towards more streams and less intensive effort per stream, for both Tailed Frogs and Pacific Giant Salamanders.
    - For ACS, you can use the literature to determine sample size requirements (e.g., Dupuis and Steventon (1999) successfully surveyed 15 creeks per watershed for Tailed Frogs). You can also calculate the probability of detection and the optimal sample size using specific equations in Krebs (1989). Given that amphibians are generally clustered in distribution rather than random, use equations designed for data with a negative binomial distribution. Alternatively, there are user-friendly software packages that help to determine optimum search effort, such as MONITOR, POWER AND PRECISION, and NQUERY. These techniques are described in more detail in manual No. 1, *Species Inventory Fundamentals*.
    - For TCS, sampling a maximum number of creeks is the best strategy. Ensure that sample size is equal in various strata, if you are intending to make comparisons.
6. For presence/not detected surveys, search "potential" and "questionable" creeks at random to avoid introducing experimenter bias. For relative abundance estimates, survey only "potential" creeks. Adopt a systematic random sampling design by randomly situating the first reach, and placing the remaining reaches upstream at 30-m intervals. If you have chosen to stratify the Study Area, you will need to select an equal number of reaches within each strata for proper statistical analyses. This design will prevent inexperienced field personnel from introducing biases. The larger the number of replicates, the greater the statistical power with which to interpret the results and draw conclusions.
7. For relative abundance (ACS) surveys, inspect and sketch a 100 to 200-m section of stream, taking note of accessibility and safety hazards. If the section is not suitable for sampling, continue on to the next 100 to 200-m section. Select sampling units (reaches) based on habitat attributes associated with the species of interest (refer to Section 2.0). Select extra stream sections in case the initial selection is not suitable for sampling (e.g., intermittent flow, private property, and restricted or difficult access).

3.5.3 Sampling effort

Hand searching spatially defined stream reaches (i.e., ACS) can be labour intensive. A crew of three can search one or two streams within a watershed per day, assuming that each stream contains three 5-m sampling units for Tailed Frogs and one 120-m sampling unit for Pacific Giant Salamanders.

When hand searching for the purpose of reconnaissance (i.e., TCS), the number of creeks surveyed in one day will vary greatly with road access and amphibian abundance within a given drainage. For Tailed Frogs, one can expect to survey up to 10 creeks; this estimate considers time for travel, describing the habitat, searching and handling tadpoles, and reassembling the search area. For Pacific Giant Salamanders, one would expect no more than 5 creeks to be done in a day.

Given the variability in Tailed Frog and Pacific Giant Salamander distribution and abundance, and the variability in creek types, the TCS and ACS results for one stream cannot be applied to other streams, including neighbouring ones. Similarly, the results from one drainage must not be applied to neighbouring drainages. It is best to present inventory results on a watershed-by-watershed basis.

If preliminary data are collected, the effectiveness of your study design can be evaluated midway through the field season. Krebs (1989; p. 83) and White and Bennetts (1996) provide a way of calculating the mean and dispersion of negative binomial data sets (see manual No. 1, *Species Inventory Fundamentals* for more detail). Relative abundance tests using mean and dispersion allow you to make comparisons of population size and distribution patterns. Alternatively, you can calculate relative abundance as the number of individuals/m^2 ± the standard error to determine the precision of your estimate. With this relative abundance estimate, it is important to document the search effort (time) involved to help standardize the data, particularly for future monitoring of the same creek.

3.5.4 Personnel

- The project leader should be a qualified biologist with experience in amphibian research and/or stream ecology.
- A crew size of three is optimal with the leader having a good working knowledge of the search image for the species, its natural history, and a basic understanding of where it is apt to hide.
- All personnel should thoroughly review manual No.3, *Live Animal Capture and Handling of Mammals, Birds, Amphibians, and Reptiles* before commencing.

3.5.5 Equipment

- Maps (1:50 000 or 1:20 000 if available)
- Field identification guides
- Flagging tape
- Data forms
- Dip nets (0.5 to 1-mm mesh, for Tailed Frogs)
- Plexiglas frame (for viewing creek substrate in turbulent or deep water)

- Bucket (for holding captured individuals)
- Tupperware containers (for holding large Pacific Giant Salamanders)
- Measuring tape or ruler
- Ziploc bags (for handling amphibians)
- Calipers and/or ruler
- Portable spring scales (10 and 50 g; for Pacific Giant Salamanders, and for Tailed Frog adults); a digital scale could be used for Tailed Frog tadpoles, but this can be labour intensive in streams with large densities.

3.5.6 Field procedures

Specimen and stream habitat data are to be recorded on data sheets.

Survey Preparation

- Sketch a map of the reach to be searched.
- Flag upstream and downstream end of the reach.
- Characterize site and stream habitat, using the Ministry of Fisheries *Stream Site Card* (see section 3.1.2 Habitat Data Standards).
- It is important that stream and site characteristics be recorded prior to censusing, without disturbing the original habitat.

Search Methods

- Stream search begins at the downstream end of the section of stream to be sampled and of each sample unit within it.
- Begin by inspecting the stream and stream bank (up to 1m from the water's edge) visually, to see if any amphibians are out in the open. Avoid stepping into the channel.
- Only unembedded cover objects such as rocks and coarse woody debris should be overturned, to minimize disturbance to the stream bank; cover objects must be returned to their original location and position.
- Begin aquatic search at the downstream end of a given reach. Each cover object should be carefully scanned for clinging Tailed Frog tadpoles before it is set aside.
- For comprehensive (ACS) surveys place all scanned, moveable cover objects on the stream bank.
- Sweep large, anchored rocks by hand, as their removal may be too damaging to the microhabitats of the stream.
- Return all cover objects to their original positions in the stream upon completion of the census.

Amphibian Collection and Handling

- If an amphibian is encountered, record its position (i.e., surface, under rock) and location on a data form; locational information includes depth (mm) and microhabitat (i.e., pool, riffle or run).
- To prevent recaptures, place all captured individuals in shaded buckets, immersed in the stream. This will minimize stress and overheating.

    - For Pacific Giant Salamanders, mark the capture location with a numbered piece of flagging tape, and then place a corresponding label on the animal before placing it into the bucket.
    - Tailed Frogs can be kept in one or two buckets but large-sized Pacific Giant Salamander larvae must be kept in separate containers because they will eat smaller amphibians.
- Captured individuals are passed on to the data recorder for physical measurements. This is accomplished by immobilizing an individual in a more or less straight position at the bottom of a Ziploc bag (this takes practice).
    - For Pacific Giant Salamander adults, record snout-vent length and tail-vent length, and weigh the animal in the plastic bag with a portable spring scale, to the nearest milligram.
    - For Tailed Frog adults, measure total length (tip of snout to coccyx) and weigh the individual with a spring scale.
    - For Pacific Giant Salamander larvae and Tailed Frog tadpoles measure total length (snout to tail tip) only.
    - The stage of development of tadpoles can also be recorded: (1) are forelimbs- and hindlimbs in the form of buds, or are they partially or fully developed; (2) does the mouth part constitute an adhesive disc or a biting mouth.
- For time constrained surveys processing time for amphibians is not included within the time limit.
- Upon completion of a survey, return captured individuals to the stream.
    - Pacific Giant Salamander larvae and Tailed frog adults return to their points of capture
    - Tadpoles are released at the upstream end of the altered reach to that they can drift to new desired locations. (Note that the channel bed repeatedly sorts itself out with each large rainfall.)

3.5.7 Data analysis

Data Entry

When entering your data into the provincial Species Inventory Data System (SPI), you will be required to specify a Design Component. For survey of stream amphibians, you will be entering data at the level of the individual stream sample units. When digitally entering your survey data, choose ‘Reach’ from the ‘Design Component Type’ picklist.

Mapping

Maps should depict Study Areas, identify areas stratified as Potential Habitat, and indicate the locations of sample units on maps of 1:20,000 (or larger) scale. Differentiate between sample units where frogs or salamanders were found, and those where they were not. If possible, also show any known barriers to movements that were present. Ensure that mapped objects are labeled properly in a way that allows them to be linked back to data sets and references in reports.

Statistical Tests

Tailed Frog count data generally have a negative binomial distribution. Likely causes of this non-normal distribution are the presence of many zero counts, and unequal variances between samples. Given that the normal distribution is a required assumption for most parametric tests, non-parametric tests should be used for analysis of the data, as described in White and Bennets (1996). These techniques are discussed further in *Species Inventory Fundamentals*. Multivariate statistics can also be suitable (see Dupuis and Steventon 1999).

Depending on the number of samples collected, it may be useful to:

- test for significant differences in habitat parameters between sample units where amphibians were present and those where they were not;
- examine the relationship between amphibian size (or stage of development) and habitat parameters;
- test for significant differences in amphibian population structure or abundance between reaches or creeks

Calculate a measure of abundance and variability in terms of the mean number of animals observed per unit effort. This can be estimated for each reach, stream, strata or study area.

It is not a good idea to extrapolate presence/no detection data or abundance estimates for Tailed Frogs or Pacific Giant Salamanders from one stream or watershed to others.

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.

ADPRESSED: The relative length of salamander limbs can be evaluated by pressing them against the side of the body and checking the distance separating them or the amount they overlap.

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.).

BIOGEOCLIMATIC ZONE: A large geographic region with a homogenous macroclimate resulting in similar nutrient cycling and patterns of vegetation and soil.

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.

CLOACA: The reproductive and excretive caudal opening in amphibians, reptiles and birds.

COARSE WOODY DEBRIS: Dead woody material occurring on the stream bank or in the channel.

COBBLE: A rock greater than 64 mm but less than 256 mm in diameter.

COCCYX: Fused tail vertebrae.

COMPREHENSIVE SEARCH: A search technique in which all 5 m of a sample unit are search as thoroughly and non-destructively as possible.

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.

ECOREGION: Regions of broad geographic relationships based on macroclimatic processes and physiography.

ELECTROSHOCKING: An application of an electrical current in a stream or lake in order to capture or control amphibians and fish.

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.

INTERMITTENT STREAM: Streams which receive their water from surface runoff. Streamflow occurs during the wet seasons and in areas with considerable rainfall, streams may be considered "permanent".

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.

LARVA: An immature form that differs from the adult.

METAMORPHOSE: The change that a larva goes through as it changes into an adult.

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

NEOTENY: When a larva does not transform into an adult but still becomes sexually mature.

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.

PAROTID GLAND: A raised skin gland located at the back of the head.

PERMANENT STREAM: Streams that are fed through seepage, underground springs and glacial melt. The water table usually stands higher than the stream itself.

POOLS: Portions of the stream with reduced current velocity and deeper water than immediate surrounding areas.

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.

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.

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

REACH: A reach is a relatively homogenous section of stream having a repetitive sequence of physical characteristics and habitat types. For fast stream amphibian surveys, reaches are used as sampling units.

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.

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/]

RIFFLE: Shallow rapid flow over exposed or partially exposed submerged materials.

RUN: Areas of swiftly flowing water, without surface waves, which approximates uniform flow and in which the slope of water surface is roughly parallel to the overall gradient of the stream reach.

SAMPLE UNIT: Non-overlapping collections of elements which are cumulatively intended to be representative of a population. For fast-stream amphibians, the recommended sample unit is a stream reach within a larger reach of Potential Habitat. These sample units may be searched completely or in a time-constrained manner. “Sample unit”, as used in this manual, is synonymous with the term “Design Component” which is used in the Species Inventory Data System.

SEEP: Portions of the stream where the water flows slowly, or flows slowly out through the substrate.

SPERMATOPHORE: A jelly packet of sperm laid by a male salamander.

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

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. Surveys of fast-stream amphibians require that streams be stratified into a minimum of two strata: Potential Habitat and Other.

STREAM ORDER: The hierarchical number of a stream segment in a branching drainage system. The smallest tributaries have an order of one, and at each junction of streams with equal order the order of the next segment is one order higher. For example a stream with no tributaries is a first order stream. A second order stream is the result of the joining of at least two first order streams. A third order stream is formed from the joining of at least two second order streams.

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.

SURVEYOR MINUTE: A measure of effort in which one surveyor searches for one minute.

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

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: A search technique in which a sample unit (stream reach) is searched for pre-determined number of surveyor minutes.

TUBERCLE: A bump on the skin but not poisonous like a wart.

UROSTYLE: Rod-shaped bone (representing fused caudal vertebrae) in the vertebral column of an anuran; apparently important in providing rigidity when jumping.

VOMERINE: Located on the roof of the mouth.

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

Literature Cited

Blaustein, A.R., and D.B. Wake. 1990. Declining amphibian populations: A global phenomenon? Trends in ecology and evolution 5:203-204.

Brown, H.A. 1990. Morphological variation and age-class determination in overwintering tadpoles of the tailed frog, *Ascaphus truei.* J. Zool., Lond. 220:171-184.

Bury, R.B., and P.S. Corn. 1991. Sampling methods for amphibians in streams in the Pacific Northwest. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. PNW-GTR-275.

Corn, P.S., and R.B. Bury. 1989. Logging in western Oregon: responses of headwater habitats and stream amphibians. For. Ecol. and Man. 29:39-57.

Daugherty, C.H., and A.L. Sheldon. 1982. Age-specific movement patterns of the frog *Ascaphus truei.* Herpetologica 38:468-474.

Demarchi, D. 1993. Ecoregions of British Columbia, 3rd Ed. Map. British Columbia Ministry of Environment, Lands and Parks, Victoria, B.C.

Department of Fisheries and Oceans and Ministry of Environment. 1989. Fish habitat inventory and information program, stream survey field guide. Dep. Fisheries and Oceans and Min. Environ.

Dupuis, L.A., Friele, P.A. and F.L. Bunnell. (*In press*). Determinants of the tailed frog's range in British Columbia, Canada, Northwest Science.

Dupuis, L.A., and D. Steventon. 1999. Riparian management and the tailed frog in northern coastal forests. For. Ecol. and Manage. 124(1999):35-43.

Green, D.M., and R.W. Campbell. 1984. The amphibians of British Columbia. Handb. 45, Royal B.C. Prov. Mus., Victoria, BC.

Johnston, B. 1999. Terrestrial Pacific giant salamanders: natural history and response to the forest practices. In: L. Darling, ed. Proceedings, biology and management of species and habitats at risk, conference, 15 - 19 February 1999, Univ. College of the Cariboo, Kamloops, BC.

Johnston, B., and L. Frid. (*In prep*.) The impact of clearcutting on terrestrial Pacific Giant Salamanders (*Dicamptodon tenebrosus* Good 1989): a study of movement behaviour using radio telemetry.

Krebs, C.J. 1989. Ecological methodology. Harper Collins, New York, NY. 654pp.

Leonard, W.P., H.A. Brown, L.L.C. Jones and R.M. Storm. 1993. Amphibians of Washington and Oregon. Seattle Audobon Society, Seattle, WA.

Meidinger, D. and J.Pojar. 1991. Ecosystems of British Columbia. Special report series no. 6. Res. Br. and Forest Sciences Section, Min. For. Victoria, BC.

Ministry of Environment, Lands and Parks, and Ministry of Forests. 1998. Field manual for describing terrestrial ecosystems. Land Manage. Handb. 25. Resour. Inventory Br., Min. Environ., Lands and Parks, and Res. Br., Min. For. Victoria, BC.

Ministry of Environment, Lands and Parks. 2000. 2000 Provincial vertebrate animal tracking list. B.C. Conservation Data Center, Resour. Inventory Br. and Wildlife Br., Min. Environ., Lands and Parks, Victoria, BC. http://www.elp.gov.bc.ca/rib/wis/cdc/tracking.htm

Nussbaum, R.A. 1969. Nest and eggs of the Pacific Giant Salamander, *Dicamptodon ensatus* (Erscholtz). Herpetologica 25:257-262.

Nussbaum, R.A., E.D. Brodie and R.M. Storm. 1983. Amphibians and reptiles of the Pacific Northwest. Univ. Idaho Press. Moscow, ID.

Sutherland, G., Dupuis, L., Friele, P. and F. Bunnell. (*In prep*.). Patterns of distribution of the tailed frog in British Columbia in relation to biophysical factors and disturbances.

Welsh, H.H. Jr., and A.J. Lind. 1991. The structure of the herpetofaunal assemblage of the Douglas-fir forests of Northwestern California and Southwestern Oregon. Pages 394-413 *in* A.B. Carey and L.F. Ruggiero, eds. Wildlife-habitat relationships: sampling procedure for Pacific northwest vertebrates. USFS, Pac. N.W. Res. Sta. Portland, OR. PNW-GTR-275.

White G.C., and R.E. Bennetts. 1996. Analysis of frequency count data using the negative binomial distribution. Ecology 77:2549-2557.