



AN ABSTRACT OF THE THESIS OF

Paula Graff for the degree of Master of Science in Wildlife Science presented on July 26, 2006

Title: Riparian Vegetation and Larval Pacific Giant (*Dicamptodon tenebrosus*) and Adult Western Redback (*Plethodon vehiculum*) Salamanders in the Oregon Coast Range.

Abstract approved:

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W. Daniel Edge

Riparian areas in the Pacific Northwest provide important biotic and abiotic features, such as down wood, moist microsites, and abundant invertebrate prey that benefit aquatic and terrestrial amphibians. Reported high densities of amphibians from streams and riparian areas in the Pacific Northwest highlight their importance in riparian food webs. Amphibians provide an important trophic link between terrestrial and aquatic systems because they may exploit both terrestrial and aquatic prey and in turn they are prey for other vertebrates. In the Oregon Coast Range, riparian vegetation is often more diverse than upland vegetation and there is typically a considerable deciduous component. However, forestry regulations in Oregon require landowners to promote the growth of conifer over deciduous trees in riparian areas to benefit salmonids and other fishes. The goal of our research was to examine associations between the distribution and diets of aquatic and terrestrial amphibians and vegetation in second- and third-order Oregon Coast Range streams and riparian areas. Sites reflected overstory conditions in managed forests of the central Oregon Coast Range, ranging from primarily red alder (*Alnus rubra*) in the riparian zone to mostly Douglas-fir (*Pseudotsuga menziesii*). The two most common amphibians detected were the aquatic Pacific Giant Salamander larvae

(*Dicamptodon tenebrosus*) and the terrestrial Western Redback Salamander (*Plethodon vehiculum*).

Our first research objective was to identify habitat characteristics with an emphasis on riparian vegetation, that could be associated with the presence of these two species. We used logistic regression to examine the presence of these salamanders among sites and the information-theoretic approach using Akaike Information Criterion (AIC) methods to compare the strength of evidence of a set of candidate models formed from *a priori* hypotheses. The highest ranked model explained 95% of the variability of the presence of *Dicamptodon tenebrosus* larvae among sites and included variables representing percent cover of Douglas-fir, elevation, amount of wood cover, and lithology type. The odds of the presence of *D. tenebrosus* increased with the percent cover of Douglas-fir over the wetted width of the stream. Two competitive models ( $\leq 2 \Delta AICc$  units) explained 54% of the variability in the presence of *Plethodon vehiculum* among sites and included variables for percent cover of western hemlock (*Tsuga heterophylla*), percent total overstory cover, elevation, and lithology type. The odds of observing *P. vehiculum* at a site increased with the percent cover of western hemlock in the riparian area.

Our second research objective was to describe diet-habitat relationships, emphasizing riparian vegetation. We evaluated a candidate set of models using generalized linear least squares regression and AIC methods; we used a measure of relative stomach fullness, based on the amount of material in a stomach sample after accounting for the size of an individual, as the response variable. For both salamander species, models that included variables representing canopy cover and stream or forest floor characteristics were among the highest ranked models. The stomach fullness of *D. tenebrosus* larvae was positively associated with the percent cover of western hemlock (*Tsuga heterophylla*) over the stream channel. *P. vehiculum* stomach fullness increased as the percent cover of red alder in the riparian zone increased. *D. tenebrosus* most frequently consumed benthic macroinvertebrates, including larval Diptera, Ephemeroptera, Plecoptera, and Trichoptera. Collembola numerically dominated *P.*

*vehiculum* stomach samples; however Gastropoda, predominantly snails, and Isopoda were eaten in greater proportion than their relative availability. Altering vegetation may potentially impact amphibians in riparian areas by changing the thermal regime, microhabitats, or prey availability. Conifers moderate forest floor microclimate year round and deciduous trees provide high quality prey resources. Our results suggest that retaining both conifers and deciduous trees in the riparian zone of small streams in the Oregon Coast Range may benefit both *D. tenebrosus* and *P. vehiculum*.

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Riparian Vegetation and Larval Pacific Giant (*Dicamptodon tenebrosus*) and Adult  
Western Redback (*Plethodon vehiculum*) Salamanders in the Oregon Coast Range.

by

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Paula Graff, Author

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## CONTRIBUTION OF AUTHORS

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## CHAPTER 1

### RIPARIAN VEGETATION AND LARVAL PACIFIC GIANT (*DICAMPTODON TENEBROSUS*) AND ADULT WESTERN REDBACK (*PLETHODON VEHICULUM*) SALAMANDERS IN THE OREGON COAST RANGE.

by Paula Graff and W. Daniel Edge

#### INTRODUCTION

In the Pacific Northwest, amphibians play an important role in the trophic dynamics of streams and riparian areas because of the high densities and biomass that they can attain (Dupuis and Bunnell 1999; Kelsey 2000; Davic and Welsh 2004). Amphibians may also transfer energy between aquatic and terrestrial ecosystems either directly through movement or dispersal as a result of a biphasic life cycle, or indirectly by exploiting prey of aquatic or terrestrial origin, or as prey for other vertebrates (Murphy and Hall 1981; Bury and Corn 1988).

Plant species in riparian areas serve important roles in thermal cover, foraging cover and substrate, and microhabitat availability to amphibians (Dumas 1956). In the Oregon Coast Range, riparian areas with their substantial deciduous component, usually have more diverse vegetation than adjacent uplands (Naiman et al. 2000; Nierenberg and Hibbs 2000; Spies et al. 2002). Tree species in riparian areas can affect allochthonous and wood inputs, stream channel morphology and hydrology (Massong and Montgomery 2000; Moore et al. 2001; Spies et al. 2002). In riparian areas dominated by deciduous trees, wood inputs represent different size classes and quantities, and in comparison to conifers, have faster decomposition rates (Nierenberg and Hibbs 2000; Beach and Halpern 2001). Conifer-dominated riparian areas provide more shade, channel stability, and larger, more persistent wood inputs than hardwoods (Newton et al. 1996; Oregon Department of Forestry 2000; Ringold et al. 2000). This in turn may affect the size and



availability of thermoregulatory cover (down wood and leaf litter) used by amphibians (Moore et al. 2001).

Declining salmonid species throughout the Pacific Northwest have motivated resource managers to adopt riparian area management strategies in the Oregon Coast Range that promote the retention of conifer trees over deciduous trees (Nierenberg and Hibbs 2000; Richard Hardt, BLM pers. commun.). Recent studies have focused attention on the role that deciduous trees play in structuring vertebrate communities and their influence on stream and riparian food webs (Wipfli 1997; Piccolo and Wipfli 2002; Allan et al. 2003). Wipfli (1997) proposed that deciduous trees offer higher quality food resources for aquatic invertebrates and subsequently higher quality food resources available to predators, such as aquatic and terrestrial amphibians. Red alder (*Alnus rubra*) provides high quality substrates for invertebrates (Borman et al. 1994) and may provide positive prey inputs for aquatic and terrestrial amphibians. In the Pacific Northwest, amphibian diet information often is limited to a list of prey from amphibians collected during a single sample period (but see Maiorana 1978; Lynch 1985; Parker 1992, 1994) with little description of vegetation. Thus, it is uncertain whether vegetation influences prey diversity or availability to amphibians. Changes to the overstory canopy and associated ecosystem components likely will affect the availability and composition of amphibian prey.

Amphibians offer an excellent opportunity to assess prey consumption habitat differences because they swallow their prey whole; amphibians have low metabolism so items remain relatively intact in their stomachs for extended periods of time (Maiorana 1978; Parker 1992; Stebbins and Cohen 1995:5). It is not clear whether prey composition or the amount of food ingested by amphibians is influenced by habitat, foraging efficiencies, or seasonal differences. Most amphibians forage opportunistically on invertebrates, (Stebbins and Cohen 1995:58), but may use prey size and density as cues for feeding (Jaeger et al. 1982; Parker 1992; Shipman et al. 1999). Larger amphibians often ingest numerous small prey as well as large, suggesting that individuals consume prey as they are encountered (Larsen 1992:379; Stebbins and Cohen 1995:55).

Terrestrial amphibians are restricted to foraging when soil and air conditions are moist and moderate (Keen 1979; Jaeger 1980; Grover 1998). The more developed understory often observed under red alder in the Oregon Coast Range (Franklin and Pechanec 1968) may be important in moderating temperature and moisture conditions near the surface of the ground, especially when forest conditions are dry. As a result, terrestrial amphibians present under a deciduous canopy may have more foraging opportunities than under a conifer canopy. Reducing the amount of deciduous trees, particularly red alder, in riparian areas could indirectly affect the quantity of aquatic invertebrate prey available to predators (Wipfli 1997).

The purpose of this study was to examine relationships among riparian vegetation, aquatic and terrestrial amphibians, and invertebrate prey. In Chapter 2, we describe habitat relationships of two widespread salamanders, the larval stage of the Pacific Giant Salamander (*Dicamptodon tenebrosus*) and the Western Redback Salamander (*Plethodon vehiculum*) in second- and third-order streams in the Oregon Coast Range. We identify stream and riparian habitat features from a range of riparian overstory conditions and we present habitat models derived from an information-theoretic approach. In Chapter 3, we evaluate larval *D. tenebrosus* and *P. vehiculum* diets using an index of stomach fullness at sites across a range of deciduous overstory. We also investigate seasonal differences in *D. tenebrosus* and *P. vehiculum* diet and invertebrate prey availability and we examine whether any invertebrate prey were consumed in greater proportion than their relative availability.

Information gained from this study can be used as a foundation to evaluate the influence of vegetation on salamander prey availability and salamander presence and distribution in Oregon Coast Range streams and riparian areas. There is an increasing interest in maintaining intact ecosystems and economic viability of managed forests in the Pacific Northwest (Irwin 2000), yet without adequate knowledge of a species needs, current management practices may not offer adequate protection from the effects of manipulation of potentially important habitat components. Amphibians are good candidates for indicator species to monitor effects of riparian vegetation alteration as they

are relatively long-lived, have small home ranges, show strong site fidelity, and are not highly mobile (deMaynadier and Hunter 1995). Our results will aid resource managers in planning for the persistence of microhabitat characteristics associated with amphibians when prescribing management actions for an area (Butts and McComb 2000).

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## CHAPTER 2

RIPARIAN VEGETATION AND THE PRESENCE OF *DICAMPTODON TENEBROSUS* LARVAE AND *PLETHODON VEHICULUM* IN THE OREGON COAST RANGE

by Paula Graff and W. Daniel Edge

## ABSTRACT

Riparian areas in the Pacific Northwest provide important biotic and abiotic features such as down wood, moist microsites, and invertebrate prey that benefit amphibians. Oregon forestry regulations require landowners to promote the growth of conifer trees in riparian areas to benefit salmonids and other fishes. Conversion to conifer-dominated riparian areas in the Oregon Coast Range may have unintended consequences for other species, including amphibians. Our objective was to identify habitat characteristics associated with the presence of amphibians, with an emphasis on riparian overstory vegetation. We surveyed for amphibians in ten second- and third-order streams and riparian areas in the central Oregon Coast Range during 2002 and 2003. Sites reflected overstory conditions in managed forests, ranging from primarily red alder (*Alnus rubra*) to mostly Douglas-fir (*Pseudotsuga menziesii*) in the riparian zone. We encountered 494 amphibians of 11 species during aquatic and terrestrial surveys. The most common aquatic amphibian was the Pacific Giant Salamander (*Dicamptodon tenebrosus*) in larval form that occurred in all but one site. The terrestrial species found most often was the Western Redback Salamander (*Plethodon vehiculum*), found in nine of ten sites. We used an information-theoretic approach using the Akaike Information Criterion (AIC) method to rank habitat models developed *a priori* to evaluate the relationship of riparian vegetation with the presence of these two salamander species. Models with forest overstory and watershed characteristics best explained their distribution and occurrence. *D. tenebrosus* occurrence was positively associated with



percent cover of Douglas-fir over the stream channel. The presence of *P. vehiculum* was positively associated with the percent cover of Western hemlock (*Tsuga heterophylla*) in the riparian area. Our results suggest that the presence of conifers in the riparian zone of small streams in the Oregon Coast Range may be used to identify potential *D. tenebrosus* and *P. vehiculum* habitat.

## INTRODUCTION

In the Pacific Northwest, aquatic and terrestrial amphibians often are associated with small streams or lakes and moist coniferous forests (Nussbaum et al. 1983:23; DeMaynadier and Hunter 1995). Previous research has focused on comparing amphibian communities across managed or unmanaged forest stands of different ages or types, between managed and unmanaged forests (Dupuis et al. 1995; Dupuis and Bunnell 1999; MacCracken 2002; and others), in riparian management areas following different harvest treatments upslope (Kelsey 2000; Vesely and McComb 2002), and habitat at various spatial scales (Welsh and Lind 2002; Stoddard and Hayes 2005). Most studies focused on whether the amount of canopy cover (shaded or open) or cover type (deciduous vs. coniferous, shrub vs. overstory) influences the abundance and distribution of amphibians in riparian areas (but see McComb et al. 1993; Gomez and Anthony 1996). The dynamic, disturbance-prone environment and ecotonal nature of riparian zones leads to spatial and temporal heterogeneity and results in high levels of plant, invertebrate, and vertebrate diversity (Gregory et al. 1991; Pollock 1998; Naiman et al. 2000). The type of vegetation in riparian areas affects allochthonous and wood inputs, channel morphology and hydrology (Gregory et al. 1991; Massong and Montgomery 2000; Spies et al. 2002). In the Oregon Coast Range, conifers dominate the landscape, but riparian vegetation generally includes a deciduous component, and there often is a row of alder trees immediately adjacent to streams (Naiman et al. 2000; Nierenberg and Hibbs 2000; Spies et al. 2002).

In riparian areas, deciduous trees provide wood inputs of different size classes and quantity, and faster decomposition rates than conifers (Nierenberg and Hibbs 2000; Beach and Halpern 2001). This may affect the size and availability of thermoregulatory cover (down wood and leaf litter), and foraging cover and substrate used by amphibians (Dumas 1956; Moore et al. 2001). Red alder is indicative of moist sites (Binkley et al. 1994; Nierenberg and Hibbs 2000) and its presence may be useful for predicting suitable habitat for terrestrial amphibians. Red alder also provides high quality substrates for invertebrates (Borman et al. 1994) and may provide prey inputs for aquatic and terrestrial amphibians.

Regulatory standards were adopted in the Oregon Coast Range that decrease the amount of deciduous trees and promote retention of conifers along fish-bearing streams (Nierenberg and Hibbs 2000; Richard Hardt, BLM pers. commun.). Increasing conifer volume in riparian areas benefits fish by providing more shade, channel stability, and large wood inputs that persist longer in streams than hardwoods (Newton et al. 1996; Oregon Department of Forestry 2000; Ringold et al. 2000). However, the possible impact of riparian hardwood conversion on aquatic and terrestrial amphibians is unclear. We hypothesized that two widely distributed species of salamanders, larval *D. tenebrosus* and *P. vehiculum*, would be more abundant under a riparian canopy dominated by deciduous trees.

Larval *D. tenebrosus* are commonly found in first- through third-order streams in the Pacific Northwest where they can be the dominant vertebrate predator (Nussbaum and Clothier 1973; Murphy et al. 1981; Parker 1994). The larvae usually are found under cover objects and in interstitial spaces, although they have also been reported on stream banks in cool, moist weather (Nussbaum et al. 1983:65; Parker 1992; Petranka 1998:155). Habitat relationships and the occurrence and distribution of larval *D. tenebrosus* have not been consistently identified across its range (Blaustein et al. 1995; Kelsey 2000; Wilkins and Peterson 2000), but this species is generally associated with small, steep streams with coarse substrates (Corn and Bury 1989; Parker 1991; Blaustein et al. 1995). *P. vehiculum* is found in Pacific Northwest coniferous stands of all ages

(Aubry and Hall 1991; Corn and Bury 1991; Aubry 2000) and types (McComb et al. 1993; Gomez and Anthony 1996). It is physiologically constrained to cool, moist microhabitats, and is typically found in areas where shade is provided by vegetation, topography, or under cover that offers protection from desiccation or freezing (Brodie 1970; Nussbaum et al. 1983:109; Petranka 1998:8, 404). Few studies have assessed whether the presence of larval *D. tenebrosus* in aquatic habitats or *P. vehiculum* in riparian areas are associated with riparian overstory species composition. How amphibians function in aquatic or riparian communities, and how habitat alteration affects the distribution, survival, and persistence of amphibians are currently not well understood (Bury et al. 1991). Understanding the role that riparian habitat features play in the distribution of amphibians is essential to ensuring their long-term persistence. The purpose of our study was to identify relationships between the presence of amphibians in small streams and riparian areas in the central Oregon Coast Range and habitat characteristics, with an emphasis on tree species composition.

## MATERIALS AND METHODS

### STUDY AREA

We conducted our study in the central Oregon Coast Range in the *Tsuga heterophylla* zone, which is dominated by forests of Douglas-fir, western hemlock, western redcedar (*Thuja plicata*), and grand fir (*Abies grandis*). Red alder and big-leaf maple (*Acer macrophyllum*) are common riparian trees in this zone (Franklin and Dyrness 1988:72). Seasons are generally mild; extremes in climate are rare due to the maritime influence (Franklin and Dyrness 1988:71). Annual precipitation ranges from 150 to 300 cm in the study area (Noti station, Oregon Climate Service). The central Coast Range is characterized by streams that are fed by winter rains and peak flood season usually occurs in early January (Poff and Ward 1989; Pabst and Spies 1998).

This project is part of an integrated study with other investigators, consequently we attempted to find sites that could be used in common with other researchers. Only sites that were held in at least 30% public land ownership, with little or no Sitka spruce (*Picea sitchensis*), and  $\leq 10\%$  large conifers were considered as possible candidates by all investigators. Additionally, we required that a potential amphibian research site incorporated a low gradient stream that could accommodate a terrestrial pitfall trap grid in the adjacent riparian area, that no logging activity occurred during the course of this study, and that all sites had similar upland conditions. We identified potential amphibian study sites in the central Oregon Coast Range using information from the Oregon Department of Fish and Wildlife's aquatic inventory database, aerial photographs, and maps. We field-checked sites in random order and selected the first ten sites meeting our criteria representing a range of conifer and hardwood riparian conditions. We located ten study sites (Figure 2.1) on second- and third-order, perennial streams in the Alsea and Siuslaw River watersheds (Greasy Creek was in the Willamette River watershed). All sites occurred within a matrix of second-growth Douglas-fir stands, approximately 40-80 years old that had been commercially thinned. Nine of the sites were on Bureau of Land Management lands and one site was on land managed by the Oregon Department of Forestry.

We conducted surveys for amphibians to characterize the occurrence and distribution of species in streams and riparian areas with varying overstory conditions. We quantified riparian vegetation and microhabitat components for inclusion in our habitat models, along with physiographic watershed characteristics to assess the importance of these variables on *D. tenebrosus* and *P. vehiculum* in these areas. An aquatic study site consisted of a 100-m stream length. Terrestrial surveys were in the adjacent riparian area, 30 m upslope on one side of the stream. We chose to survey within 30 m from the stream as microclimates have been shown to change rapidly after this distance and resemble upland conditions in unharvested western Washington forests (Brosofske et al. 1997). We incorporated an additional 10 m up- and down stream of the survey area for cover object placement (Figure 2.2). We sampled sites in random order

each season. We used information from 10-m, Digital Elevation Models (DEMs) and topographic maps to generate watershed and landform characteristics to include in our analyses, based on the Universal Transverse Mercator coordinates (Oregon Spatial Database Clearinghouse; Topozone.com; Appendix C).

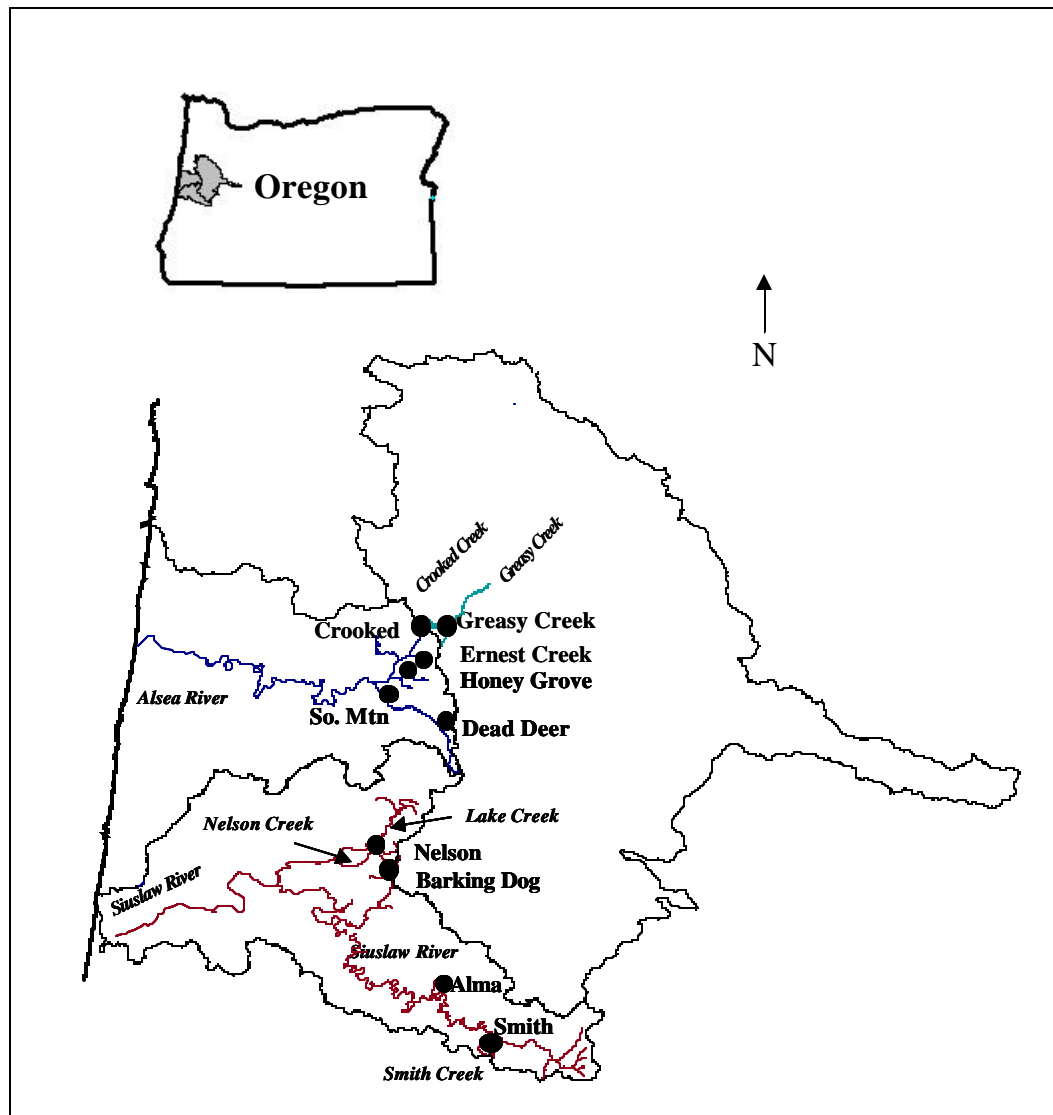


Figure 2.1. Study sites (black circles) in the Alsea River, Siuslaw River, and Willamette River watersheds, 2002-2003.

We classified the underlying lithology as marine sedimentary or volcanic basalt from DEMs, and assumed that marine lithology would consist of more unconsolidated and smaller substrate particles than volcanic substrates (Massong and Montgomery 2000; Wilkins and Peterson 2000; Bury 2005).

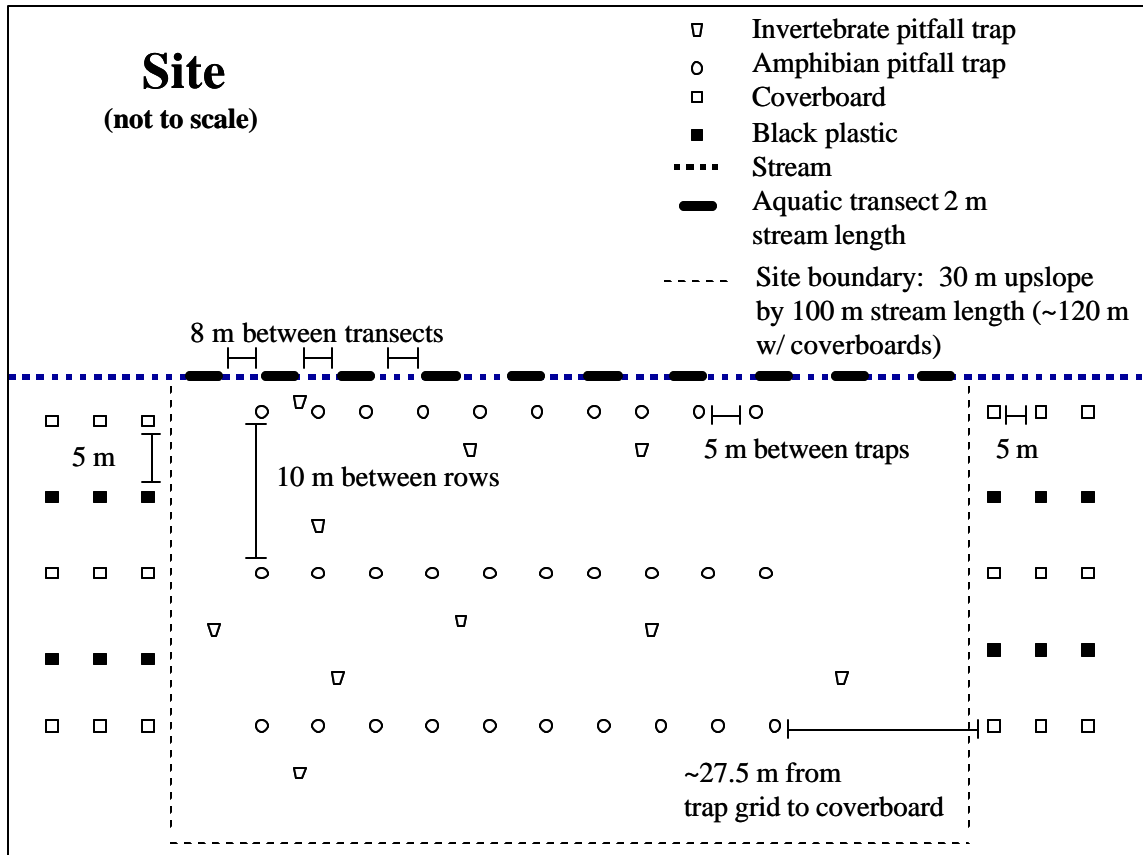


Figure 2.2. Lay-out of study site for aquatic and terrestrial amphibian surveys in ten central Oregon Coast Range streams and riparian areas, July 2002-June 2003. Not drawn to scale.

## AQUATIC SURVEYS

We conducted aquatic surveys in July and October 2002, and June 2003 in ten, 2-m long transects in each stream (Figure 2.4). October sampling occurred before significant fall rain and associated leaf fall. Stream transects were eight m apart and

spanned the bankfull width of the stream. During each survey period, starting at the first transect downstream, we searched for amphibians by lifting all cover objects and lightly probing around objects and into interstitial spaces in the stream. We also carefully swept the substrate with our fingers to expose small amphibians. We used a light-touch survey method at all times to ensure the least amount of disturbance of areas to be resampled. During each of the three aquatic sampling periods, we measured microhabitat characteristics in five transects per stream. We measured active channel width across the upper, middle, and lower end of the transect. We estimated the proportion of each transect as pool, glide, or riffle. We measured stream depth at five evenly spaced points across the lower end of the transect. We visually estimated the percent cover of herbaceous vegetation overhanging the wetted width of the stream. We used a moosehorn to measure the total shrub and overstory cover, then separately measured the three dominant shrub and overstory species over the wetted width of the transect. We took three moosehorn readings for each shrub and overstory variable; one from the center of the wetted width, and 10 cm from the water's edge on each side of the stream. Multiple measurements taken within each transect were averaged for that transect. We measured stream substrate (after Allan 1995, Table 3.3), converted this to a proportion, for each transect. Transect gradient, upslope gradient (to 30 m), and the amount of area covered by down wood (>5 cm in diameter) were measured during the first aquatic sampling period, averaged for the study site, and used for each subsequent seasonal analysis.

## TERRESTRIAL SURVEYS

We used pitfall traps, artificial cover objects, and area-constrained searches to capture terrestrial amphibians within the adjacent 30-m hill-slope. The pitfall grid was installed in the center of each site and consisted of 30 traps in three rows of ten traps running parallel to the stream (Figure 2.4). We constructed pitfall traps with two, #10 tin cans taped together and placed into the ground with the edge of the can flush with the

ground surface (Corn 1994). Traps were covered when not in use. We randomly located 1- by 2-m quadrats within the site and used a light-touch survey method to search for amphibians (Lowe 2001; McDade 2001). Quadrats were sampled once per season. In addition, we placed nine, 0.09-m<sup>2</sup> untreated Douglas-fir coverboards and six, 1-m<sup>2</sup> pieces of black plastic upstream and downstream of the pitfall trapping grid to augment terrestrial amphibian detections (Figure 2.2).

We conducted terrestrial amphibian surveys in fall 2002 and spring 2003, during the wettest times of the year (Crump 1994). Due to cool, dry weather in fall 2002, pitfalls were open for one trap night and 14 quadrats were searched at each site. In spring 2003, pitfalls were open for three consecutive nights at each site and checked each subsequent morning. We searched a total of 44 quadrats per site for amphibians in spring 2003 and characterized vegetation and microhabitat components in 28 randomly selected quadrats over the three-day sample period. We checked under cover objects daily during the survey period.

In the 28 quadrats, we visually estimated the total percent cover of non-woody vegetation, and then separately estimated the percent cover of moss, sword fern, bare ground, rock, and litter. We also estimated total percent cover of low shrubs (<1.5 m tall) overhanging each quadrat. Using a moosehorn, we measured total shrub cover >1.5 m in height and total overstory canopy cover from both downslope corners of the quadrat, then separately measured the three dominant shrub and tree species. These measurements were averaged for the quadrat each sample period. We estimated the percent cover of down wood, snags, and stumps  $\geq 10$  cm in diameter in each survey quadrat. We recorded temperature and relative humidity with Onset Hobo H8 Pro Series data loggers hung 1 m from the surface of the ground on a tree next to the stream at each site.

## DATA ANALYSIS

We used logistic regression analysis in S-Plus (Insightful Corp., version 7.0.2), to examine relationships between habitat characteristics and the presence of larval *D*.



*tenebrosus* and *P. vehiculum*; the only two species found in sufficient numbers for statistical analysis. We used the information-theoretic approach using Akaike Information Criterion (AIC) to compare the strength of evidence of a set of candidate models formed from *a priori* hypotheses. We used AICc model selection as it uses a bias-correction term for sample sizes where the number of samples/number of estimated parameters is  $<40$ . We used AICc weights ( $w_i$ ) and  $\Delta$ AICc values to determine which models were more credible at explaining the variability of the data; models that were within two  $\Delta$ AICc units of the “best” approximating model were considered to have a high level of support (Burnham and Anderson 2002:70). When more than one model was within two  $\Delta$ AICc units of the best model, we used multimodel averaging and made inferences conditional on the set of models (Burnham and Anderson 2002:149). The weight of evidence for each variable was examined by summing the relative importance weights for the models in which a variable occurred from the candidate set and comparing that against other variables (Anderson et al. 2001; Dreitz et al. 2001; Burnham and Anderson 2002:168). When the variables did not appear in the same number of models across the candidate set, we used an adjusted weight (Stoddard 2001; Sheridan and Olson 2003). When we used multimodel inference, we calculated unconditional standard errors and used those to construct 95% confidence intervals for the parameter estimates (Burnham and Anderson 2002:162-164). We also used evidence ratios to compare each model against the other models in the set (Anderson et al. 2001; Dreitz et al. 2001; Burnham and Anderson 2002:78, 168). We did not include highly correlated ( $r > \pm 0.7$ ) variables in the same model. We checked a global model for each candidate set of models for model fit; global models were not included in the analysis. All models were checked for multicollinearity and models with an Eigenvalue  $<0$  or diagonal correlation matrix value  $>10$  were not considered.

Our goal was to identify associations between amphibian presence and habitat characteristics, with a focus on vegetation. Because our analysis is exploratory, we included a substantial number of models in our candidate sets that incorporated many of the vegetation cover variables gathered over the course of the study. We included the

four most prevalent tree species found in our sites, Douglas-fir, western hemlock, red alder, and big-leaf maple, in addition to other variables reported to influence amphibians based on our literature review (Appendix A-C). For the larval *D. tenebrosus*, we checked for seasonal differences *post priori* by adding season into all models in the set. In the case of *P. vehiculum*, we considered only data from spring 2003, as fall 2002 was unseasonably dry. Because the sampling occurred over an extended period of time in the spring, we added a variable to each model in the set for *P. vehiculum* to account for spring foliage growth that occurred over the course of the spring sampling period.

## RESULTS

Study sites ranged from having few hardwoods (red alder and big-leaf maple) directly bordering the stream to sites dominated by hardwood trees. Deciduous trees dominated the canopy directly over the wetted width of the stream at eight of the ten sites (Figure 2.3), and Douglas-fir was the dominant tree species in the adjacent 30 m upslope at five sites (Figure 2.4). Salmonberry (*Rubus spectabilis*) and vine maple (*Acer circinatum*) were the main shrub species in the riparian zone, and sword fern (*Polystichum munitum*) was present at all sites (Appendices A-B). Average stream gradients ranged from 2 to 12% (mean =  $7.2 \pm 0.4\%$  SE). Average hill-slope gradients ranged from 11 to 61% (mean =  $33.9 \pm 0.2\%$  SE). Fish were observed at six of the study sites and salmonids were known to be present at only three sites. Gravel and pebble (2-64 mm) substrate dominated most streams, although one study site averaged >50% silt (Appendix A).

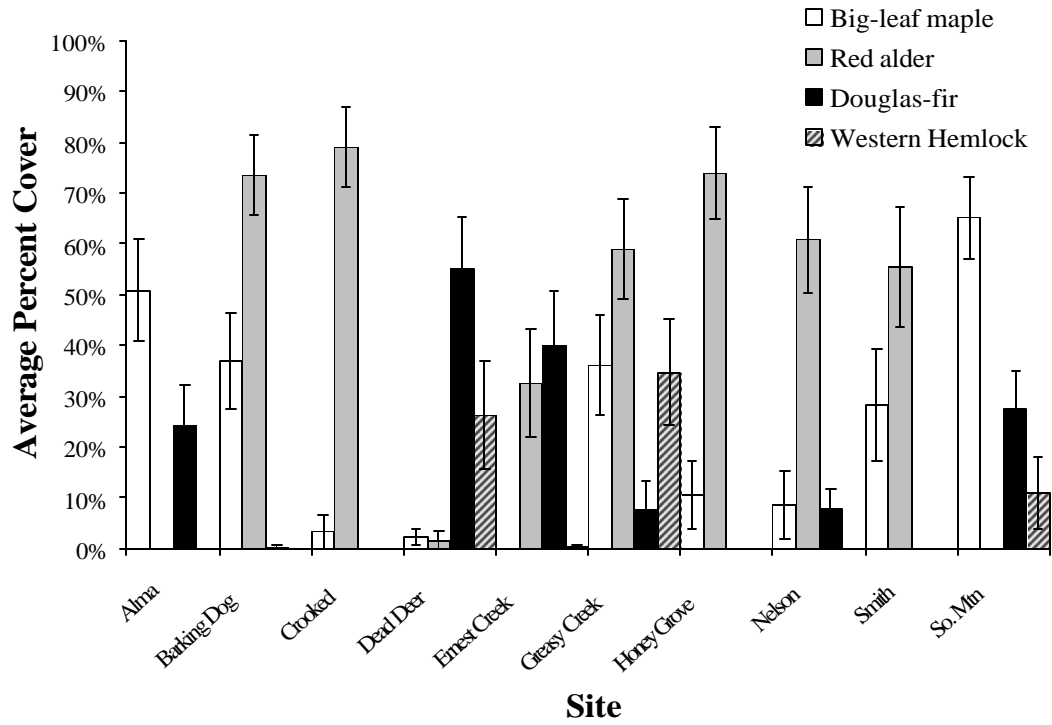


Figure 2.3. Percent canopy cover (mean  $\pm$  1 SE) above the stream channel by tree species and study site, July and October 2002 and June 2003.

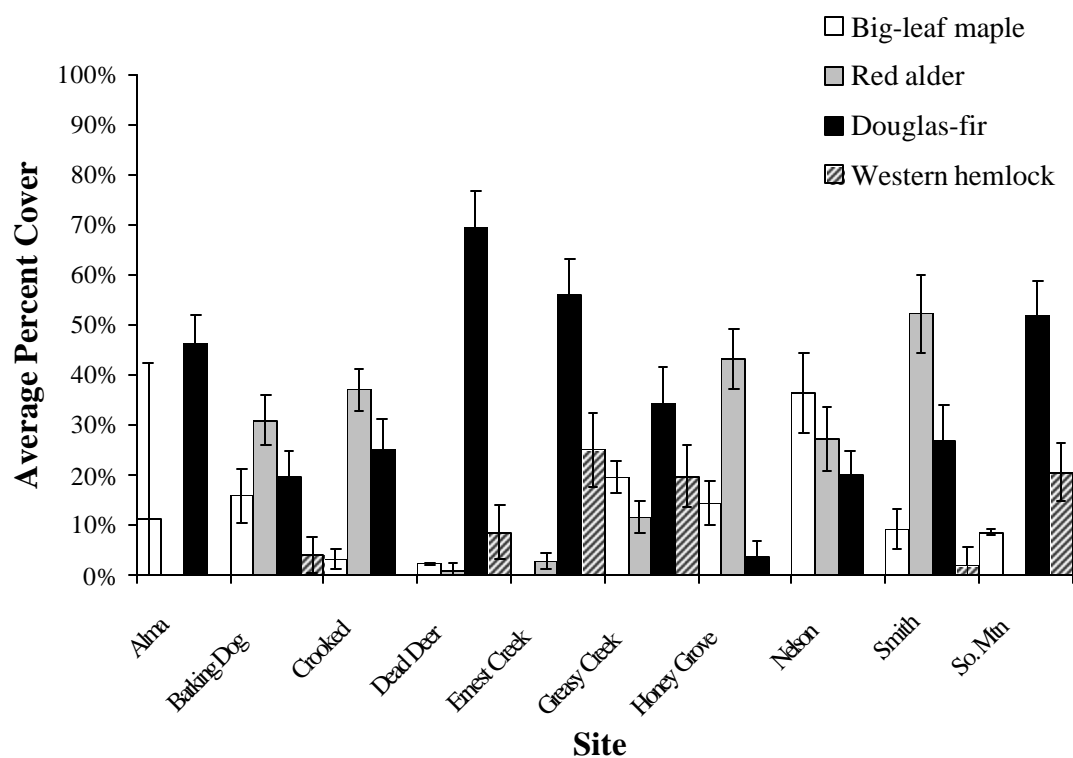


Figure 2.4. Percent canopy cover (mean  $\pm$  1 SE) in the adjacent 30 m upslope by tree species and study site, spring 2003.

We located 318 amphibians of 7 species during aquatic surveys in July and October 2002 and June 2003. However, not all species were found at all sites (Appendix D). The most common species encountered was the aquatic larval stage of *D. tenebrosus*, accounting for over 78% of all aquatic amphibian observations. Of these, 51.8% came from one site (Ernest Creek), and no aquatic amphibians were found at the Smith site. We conducted terrestrial amphibian surveys in fall 2002 and spring 2003. In fall 2002 terrestrial surveys, we found 52 amphibians representing 7 different species. In spring 2003, we detected 121 amphibians of 9 species (Appendix G). *P. vehiculum* was the most frequently detected species, making up 51.2% of terrestrial detections; 41.9% of

these were found at one site (South Mountain). No *P. vehiculum* were found at either the Smith or Nelson Creek tributary sites in spring 2003.

### *DICAMPTODON TENEBROSUS*

The amount of Douglas-fir cover over the wetted width of the stream, elevation, the amount of wood cover (>5 cm diameter), and underlying lithology were the most important habitat variables associated with the presence of *D. tenebrosus* (Table 2.1; Appendix F). The top model explained 95% of the variation associated with the presence of larval *D. tenebrosus* and was over 56 times better than the next best model at explaining the variability of the data. In the best approximating model, the odds of occurrence of *D. tenebrosus* improved as the amount of Douglas-fir cover overhanging the stream and elevation increased. The odds decreased, however, in streams underlain by volcanic lithology (compared to marine sedimentary lithology) and as the amount of wood cover increased. The odds of detecting a larval *D. tenebrosus* increased as Douglas-fir cover increased (odds ratio = 11.26, 95% CI = 0.66, 4.18) after accounting for elevation, the amount of wood cover, and lithology type. However, the adjusted variable weights indicate that elevation was the most important variable for predicting the presence of *D. tenebrosus* in our streams (Table 2.2). The order of the top eight models did not change when we checked for seasonal differences *post priori*.

Table 2.1. Summary of logistic regression model selection for the presence of *Dicamptodon tenebrosus* larvae inhabiting Oregon Coast Range streams, July and October 2002 and June 2003. Only top 10 models are shown.

Larval Pacific Giant Salamander models <sup>a</sup>	K <sup>b</sup>	Log(l)	AICc	? AICc	w <sub>i</sub> <sup>c</sup>	Evidence ratio
+ % Douglas-fir cover + elevation - wood cover - lithology	5	-74.03	158.47	0.00	0.95	
- % red alder cover + elevation - wood cover - lithology	5	-78.06	166.54	8.07	0.02	56.59
- % western hemlock cover + elevation - wood cover - lithology	5	-78.15	166.71	8.24	0.02	61.54
- % big-leaf maple cover + elevation - wood cover - lithology	5	-78.16	166.74	8.27	0.02	62.37
+ % Douglas-fir cover - fish + lithology - wood cover - stream gradient	6	-85.15	182.90	24.43	0.00	201,495.62
- % big-leaf maple cover - fish + lithology - wood cover + stream gradient	6	-86.71	186.01	27.54	0.00	954,146.92
+ % red alder cover - fish + lithology - wood cover + stream gradient	6	-87.41	187.41	28.94	0.00	1,927,863.49
- % western hemlock cover - fish + lithology - wood cover + stream gradient	6	-87.42	187.42	28.95	0.00	1,934,042.53
+ % Douglas-fir cover - wood cover + lithology	4	-89.83	187.93	29.46	0.00	2,491,380.89
+ % Douglas-fir cover + watershed - wood cover + lithology	5	-89.24	188.89	30.42	0.00	4,031,302.12

<sup>a</sup> Variables shown with sign of coefficient in model.

<sup>b</sup> Number of parameters in the model.

<sup>c</sup> Weight of evidence for the relative likelihood of each candidate model.

Table 2.2. Relative importance of variables in Oregon Coast Range streams in the best model for *Dicamptodon tenebrosus* larvae presence, July and October 2002 and June 2003.

Variable	Adjusted weight $w^a$	No. Models <sup>b</sup>
Elevation	0.70	4
% Douglas-fir cover	0.33	8
Lithology	0.12	23
Wood cover	0.06	44
% red alder cover <sup>c</sup>	0.01	8
% western hemlock cover <sup>c</sup>	0.01	8
% big-leaf maple cover <sup>c</sup>	0.01	8
% overstory cover <sup>c</sup>	0.00	4

<sup>a</sup> Relative importance of variable across the model set.

<sup>b</sup> Number of models containing the variable.

<sup>c</sup> Not included in the best approximating model.

### *PLETHODON VEHICULUM*

The odds of occurrence of *P. vehiculum* increased with the amount of western hemlock canopy cover (or total overstory cover), in volcanic lithology and decreased with increasing elevation, and date (seasonal warming and drying). The weight of evidence for the best approximating model from this candidate model set was 35%, and together the two highest ranked models explained approximately 58% of the variability of these data (Table 2.3; Appendix G). The top 6 models ( $\leq 4 \Delta AICc$  of the best model) constitute a 94% confidence set (cumulative weights), indicating uncertainty in model selection. Consequently we used multimodel inference to increase precision and lessen bias in our interpretation (Burnham and Anderson 2002:450). The odds of finding *P. vehiculum* increased as western hemlock cover increased (odds ratio = 1.6, 95% CI = 0.80, 3.33) after accounting for date, elevation, and lithology type (Appendix H). Based on the adjusted variable weights, elevation and lithology were more important in explaining the likelihood of the presence of *P. vehiculum* than either canopy variables (Table 2.4).

Table 2.3. Summary of logistic regression model selection for the presence of *Plethodon vehiculum* inhabiting Oregon Coast Range riparian areas, spring 2003. Only the top 10 models are shown.

Western Redback Salamander models <sup>a</sup>	K <sup>b</sup>	Log(L)	AICc	? AICc	w <sub>i</sub> <sup>c</sup>	Evidence ratio
- date - elevation + lithology + % western hemlock cover	5	-99.33	208.88	0.00	0.35	
- date - elevation + lithology + % overstory cover	5	-99.75	209.73	0.84	0.23	1.53
- date - elevation + lithology + % Douglas-fir cover	5	-100.49	211.20	2.31	0.11	3.18
- date - elevation + lithology	4	-101.54	211.23	2.35	0.11	3.23
- date - elevation + lithology - % red alder cover	5	-100.73	211.68	2.80	0.09	4.05
- date - elevation + lithology - % big-leaf maple cover	5	-101.16	212.55	3.66	0.06	6.25
- date + % western hemlock cover + slope + distance <sup>d</sup>	5	-103.03	216.27	7.39	0.01	40.21
- date + % overstory cover + slope + distance	5	-103.20	216.61	7.73	0.01	47.76
- date +% red alder cover + slope + distance	5	-103.37	216.97	8.09	0.01	56.99
- date - % big-leaf maple cover + slope + distance	5	-103.54	217.30	8.42	0.01	67.36

<sup>a</sup> Variables shown with sign of coefficient in model.

<sup>b</sup> Number of parameters in the model.

<sup>c</sup> Weight of evidence for the relative likelihood of each candidate model.

<sup>d</sup> Distance detected from stream.



Table 2.4. Relative importance of variables in the highest ranking models for *Plethodon vehiculum* presence in Oregon Coast Range riparian areas, spring, 2003.

Variable	Adjusted weight $w^a$	No. Models <sup>b</sup>
Elevation	0.46	6
Lithology	0.23	12
% western hemlock cover	0.10	11
% overstory cover	0.06	11
Date	0.05	60
% Douglas-fir cover <sup>c</sup>	0.03	11
% red alder cover <sup>c</sup>	0.03	11
% big-leaf maple cover <sup>c</sup>	0.02	11

<sup>a</sup> Relative importance of variable across the model set.

<sup>b</sup> Number of models containing the variable.

<sup>c</sup> Not included in the best approximating models.

## DISCUSSION

We investigated relationships between overstory tree species, microhabitat, and watershed characteristics and the presence of *D. tenebrosus* larvae and *P. vehiculum* in ten streams and associated riparian areas in the Oregon Coast Range. These two salamanders are found throughout the Pacific Northwest and have been reported from a range of forest ages and types (Murphy et al. 1981; Grialou et al. 2000; Zaradic 2003). Although we predicted that the presence of deciduous trees would increase the likelihood of amphibian presence in riparian areas, we found that conifer trees were better indicators of the likelihood of *D. tenebrosus* or *P. vehiculum* presence. The presence of Douglas-fir in the riparian canopy increased the likelihood of finding *D. tenebrosus* larvae and the odds of detecting *P. vehiculum* increased at sites with western hemlock in the riparian overstory.

*DICAMPTODON TENEBROSUS*

In contrast to our hypothesis regarding deciduous stream canopy cover, our analysis suggests that the amount of Douglas-fir overhanging streams was an important characteristic in determining the occurrence of larval *D. tenebrosus* in the central Oregon Coast Range. The positive association of Douglas-fir cover with the odds of the occurrence of *D. tenebrosus* may be indicative of less severe disturbance regimes. Frequent severe flooding may flush small larvae or salamander eggs downstream or cover them with sediment. The few *D. tenebrosus* nest sites that have been found have been located in protected sites in running water (Nussbaum 1969). Douglas-fir is less flood tolerant than the other tree species found in the Oregon Coast Range and cannot survive long periods of inundation (Spies et al. 2002). Its presence in riparian areas may indicate streams that experience less frequent or prolonged high-water events than streams dominated by more water-tolerant species, like red alder or western hemlock (Pabst and Spies 1999; Nierenberg and Hibbs 2000; Spies et al. 2002). Streams that undergo fewer high-water events may represent reasonably stable habitats for *D. tenebrosus*.

Watershed characteristics, elevation, and lithology were important in explaining the variation in occurrence of *D. tenebrosus*. There was strong support for the relative importance of elevation compared to other variables we considered (adjusted weight of 0.70, Table 2.2), although the effect of elevation in the model was small (odds ratio = 1.02, 95% CI = 1.01, 1.03). This result may be influenced by the high numbers of *D. tenebrosus* found at the Ernest Creek site, a high elevation, conifer-dominated site (Appendix A and F). Density at this site averaged 0.34 larvae/m<sup>2</sup> ( $\pm$  0.06 SD) compared to 0.04/m<sup>2</sup> ( $\pm$  0.06 SD) at all other sites combined. Higher elevation streams tend to be associated with steeper gradients and move small substrate particles downstream keeping interstices from being filled by fine particles. Because *D. tenebrosus* use coarse substrates and interstices as cover objects (Corn and Bury 1989; Parker 1991), we hypothesized that coarse substrates would be important predictors of the presence of larval *D. tenebrosus*. Although we included variables for substrate in our model set,

lithology (marine or basalt) better explained the occurrence of *D. tenebrosus* larvae. However, contrary to our expectations, we found that the odds of detecting larval *D. tenebrosus* decreased in streams underlain by volcanic lithology. We interpret this result cautiously as it does not have a high level of support in our model set (Table 2.2) or in the literature (Corn and Bury 1989; Parker 1991; but see Hunter 1998). Substrates among our sites ranged from mainly silt to mostly cobble, however, most were dominated by gravel and pebble substrate (2-64 mm). The majority of larvae we detected were small (average SVL =  $39 \pm 0.77$  SE), thus smaller substrates may have provided adequate cover. Elevation and lithology, watershed characteristics that represent a broader spatial scale, reflect the widespread distribution of this species and may be useful for predicting its presence in streams.

#### *PLETHODON VEHICULUM*

In our study, the presence of *P. vehiculum* was positively associated with western hemlock and total overstory cover in the riparian zone (Appendix H). *P. vehiculum* have previously been associated with forests with dense overstory or multi-layered canopies (Gomez and Anthony 1996; Bosakowski 1999; Welsh and Droege 2001). Western hemlock in the riparian canopy increased the odds of the occurrence of *P. vehiculum* (change in odds 1.6, CI = 0.80, 3.33) slightly more than amount of total overstory cover (change in odds 1.33, CI = 0.79, 2.25), although relative support for both variables was similar (Table 2.4). Hydroregulation has been suggested as the most significant constraint on the ecology and foraging behavior of Plethodontid salamanders (Heatwole and Lam 1961; Feder 1983). Western hemlock is indicative of moist sites (Franklin and Dyrness 1988:79-80) and provides continuous canopy cover throughout the year. Its presence in the riparian canopy may represent sites that provide stable, moist conditions for *P. vehiculum*. The similar importance of overall riparian overstory cover (Table 2.4) suggests that a closed riparian canopy may be sufficient to moderate forest floor conditions in our study sites, thus increasing the likelihood of the presence of *P.*

*vehiculum* in these riparian areas (Gilbert and Allwine 1991; Dupuis and Bunnell 1999; Grialou et al. 2000).

Elevation received the highest level of support in our model set (adjusted weight of 0.46, Table 2.4); the odds of finding a *P. vehiculum* decreased with increasing elevation (change in odds = 0.99, CI = 0.98, 1.00). Aubry (2000) proposed that the influence of elevation and aspect on stand temperature and moisture may be the most important variables influencing amphibian abundances in the Pacific Northwest. Higher sites may be drier and subject to more temperature extremes (Franklin and Dyrness 1988:42; Aubry 2000). The negative association between *P. vehiculum* and elevation in our models may reflect this environmental gradient.

Our results suggest that Douglas-fir and western hemlock in the riparian area increases the likelihood of the presence of *D. tenebrosus* and *P. vehiculum*. The importance of variables for watershed characteristics in the best approximating models for both *D. tenebrosus* and *P. vehiculum* may reflect the widespread distribution of both species. Salamanders are relatively long-lived, have small home-ranges, and are not highly mobile, thus changes to the riparian overstory have the potential to alter important microhabitat components and forest floor microclimate, at least over the short-term. Long-term impacts are unknown. We view our findings as exploratory as surveys occurred over a short period of time and at a limited number of sites. In addition, changes to riparian vegetation may have consequences that affect other aspects of salamander life history characteristics other than their presence in a stream or riparian zone. Confirmatory studies, involving experimental alteration of riparian vegetation should be implemented to assess potential long-term impacts to amphibians.

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## CHAPTER 3

RIPARIAN VEGETATION AND *DICAMPTODON TENEBROSUS* LARVAE  
AND *PLETHODON VEHICULUM* DIET IN THE OREGON  
COAST RANGE

By Paula Graff and W. Daniel Edge

## ABSTRACT

Amphibians provide an important trophic link between terrestrial and aquatic systems because they exploit terrestrial and aquatic prey and are prey for other vertebrates. Reported high densities of amphibians from streams and riparian areas in the Pacific Northwest highlight their importance in riparian food webs. We surveyed for amphibians in 2002 and 2003 in small conifer- and deciduous-dominated streams and riparian areas in the Oregon Coast Range to describe their diet-habitat relationships. We captured 450 amphibians, representing 11 different species. The most common aquatic species captured was the larval Pacific Giant Salamander (*Dicamptodon tenebrosus*), occurring in all but one site and accounting for 78.0% of all aquatic captures. The most abundant terrestrial amphibian was the Western Redback Salamander (*Plethodon vehiculum*), making up 55.1% of all terrestrial amphibians captured. We collected stomach samples from captured amphibians and collected stream benthic invertebrates and terrestrial invertebrates from the forest floor and upper soil layer each sample period and identified invertebrate taxa to Order where possible. We used generalized linear least squares regression and an information theoretic approach to examine relationships between larval *D. tenebrosus* and *P. vehiculum* stomach fullness and habitat variables in a set of models developed *a priori*. For both species, models that included variables for overstory canopy cover and stream substrate or forest floor components were among the highest ranked models. The amount of food consumed by larval *D. tenebrosus* was

positively associated with the percent cover of western hemlock (*Tsuga heterophylla*) overhanging the stream channel. *P. vehiculum* ingested a greater amount of food as the amount of red alder (*Alnus rubra*) cover in the riparian zone increased. Variability in stomach fullness for *D. tenebrosus* was better explained by seasonal effects than site effects, however site was more important than season for describing the variation in stomach fullness for *P. vehiculum*. Diptera, Ephemeroptera, Plecoptera, and Trichoptera larvae had a high frequency of occurrence in larval *D. tenebrosus* stomach samples, although this varied with sample period. Collembola numerically dominated *P. vehiculum* stomach samples, however Gastropoda (snails) and Isopods were disproportionately consumed. Changes to riparian vegetation, such as the removal of shrubs or deciduous trees may potentially affect the amount of food consumed by amphibians in these areas.

## INTRODUCTION

Amphibians play an important role in the trophic dynamics of streams and riparian areas because of their reported high densities and biomass and their ability to exploit both aquatic and terrestrial prey (Kelsey 2000; Davic and Welsh 2004). Riparian areas provide diverse biotic and abiotic features, such as down wood, forest litter, talus, and abundant invertebrate prey that benefit many terrestrial amphibians (Pollock 1998; Naiman et al. 2000; Davic and Welsh 2004). Where amphibians are the dominant predator, they are predicted to regulate stream and forest floor invertebrates (DeMaynadier and Hunter 1995; Rooney et al. 2000; Davic and Welsh 2004). However, in spite of reported high densities, the role of amphibians in riparian food webs is not well known.

Plant species composition in riparian areas may influence microclimate, availability of microsites, and the invertebrate prey for aquatic and riparian amphibian assemblages (Dumas 1956; Maiorana 1978; Moore et al. 2001). Vegetation is typically more diverse in riparian areas than adjacent uplands in the Oregon Coast Range, and

often includes a substantial deciduous component (Naiman et al. 2000; Nierenberg and Hibbs 2000; Spies et al. 2002). Deciduous trees commonly have higher invertebrate diversity and abundance than coniferous trees (Southwood 1961; Mason and MacDonald 1982). In the Oregon Coast Range, Romero et al. (2005) found that invertebrates were 30% more abundant under a riparian canopy with a deciduous component compared to coniferous dominated canopies. In some Alaska streams, the amount of red alder and associated leaf fall have a positive effect on prey availability for salmonids (Wipfli 1997). Pacific Northwest amphibian diet information is often limited to a list of prey from amphibians collected during a single sample period (but see Maiorana 1978; Lynch 1985; Parker 1992, 1994) with little description of riparian vegetation. Thus, it is uncertain whether vegetation influences prey diversity or availability to amphibians.

It is not clear whether prey composition or the amount of food ingested by amphibians reflect habitat influences, foraging efficiencies, or seasonal differences. Most amphibians forage opportunistically on invertebrates, swallow their prey whole (Stebbins and Cohen 1995:58), and may use prey size and density as cues for selection (Jaeger et al. 1982; Parker 1992; Shipman et al. 1999). Larger amphibians often ingest numerous small prey as well as large, suggesting that individuals consume prey as they are encountered rather than foraging for certain prey (Larsen 1992:379; Stebbins and Cohen 1995:55). Microclimate limits foraging opportunities for terrestrial amphibians, restricting activities to times when soil and air conditions are moist and moderate (Maiorana 1976; Keen 1979; Grover 1998). The more developed understory often observed under red alder (Franklin and Pechanec 1968) may be important in moderating temperature and moisture conditions near the surface of the ground, especially when forest conditions are dry. As a result, terrestrial amphibians under a deciduous canopy may have more foraging opportunities than under a conifer canopy.

In response to the decline of salmonids, regulatory standards have been adopted in the Oregon Coast Range that affect the amount of deciduous trees along fish bearing streams. The goal is to convert areas of deciduous trees to conifers trees (Nierenberg and Hibbs 2000; Richard Hardt, BLM pers. commun.) benefiting fish by providing more

shade, channel stability, and large wood that persist longer in streams than hardwoods (Newton et al. 1996; Oregon Department of Forestry 2000; Ringold et al. 2000). Riparian areas dominated by deciduous trees provide greater availability of small sized down wood and leaf litter for amphibians than conifer-dominated areas (Moore et al. 2001). The possible impact of riparian hardwood conversion on aquatic and terrestrial amphibians is unclear. The effect of overstory removal on the diversity and abundance of amphibians has been inconsistent (Corn and Bury 1989; Dupuis 1997; Aubry 2000; MacCracken 2002). Changes to the overstory canopy and associated ecosystem components will likely affect the availability and composition of prey available to amphibians.

In the Pacific Northwest, *D. tenebrosus* larvae may be the dominant vertebrate predator in fishless streams (Murphy and Hall 1981; Murphy et al. 1981; Zaradic 2003) and *P. vehiculum* is an abundant terrestrial salamander (Ovaska and Gregory 1989). For this study, we investigated relationships among habitat characteristics and *D. tenebrosus* and *P. vehiculum* and their invertebrate prey from ten streams and riparian areas in the Oregon Coast Range. We evaluated associations between the amount of prey consumed by these two salamanders and riparian habitat features, with an emphasis on overstory tree species. We examined seasonal differences on *D. tenebrosus* and *P. vehiculum* diet and prey consumption. We predicted that deciduous canopies would provide more prey resources for amphibians in streams and riparian areas than conifer canopies. We expected to find seasonal differences in amphibian diet related to changes in prey availability. Our goals are to provide information on diet and habitat associations of *D. tenebrosus* and *P. vehiculum* and to describe seasonal differences in their diet and prey use that may be used as a foundation for future studies and for monitoring impacts from changes to riparian vegetation in the Oregon Coast Range.



## MATERIALS AND METHODS

### STUDY AREA

We conducted our study in the central Oregon Coast Range in the *Tsuga heterophylla* zone, which is dominated by forests of Douglas-fir, western hemlock, western redcedar (*Thuja plicata*), and grand fir (*Abies grandis*). Red alder and big-leaf maple (*Acer macrophyllum*) are common riparian trees in this zone (Franklin and Dyrness 1988:72). Seasons are generally mild; extremes in climate are rare due to the maritime influence (Franklin and Dyrness 1988:71). Annual precipitation ranges from 150 to 300 cm in the study area (Noti station, Oregon Climate Service). The central Coast Range is characterized by streams that are fed by winter rains and peak flood season usually occurs in early January (Poff and Ward 1989; Pabst and Spies 1998).

This project is part of an integrated study with other investigators, consequently we attempted to find sites that could be used in common with other researchers. Only sites that were held in at least 30% public land ownership, with little or no Sitka spruce (*Picea sitchensis*), and  $\leq 10\%$  large conifers were considered as possible candidates by all investigators. Additionally, we required that a potential amphibian research site incorporated a low gradient stream that could accommodate a terrestrial pitfall trap grid in the adjacent riparian area, that no logging activity occurred during the course of this study, and that all sites had similar upland conditions. We identified potential amphibian study sites in the central Oregon Coast Range using information from the Oregon Department of Fish and Wildlife's aquatic inventory database, aerial photographs, and maps. We field-checked sites in random order and selected the first ten sites meeting our criteria representing a range of conifer and hardwood riparian conditions. We located ten study sites (Figure 2.1) on second- and third-order, perennial streams in the Alsea and Siuslaw River watersheds (Greasy Creek was in the Willamette River watershed). All sites occurred within a matrix of second-growth Douglas-fir stands, approximately 40-80 years old that had been commercially thinned. Nine of the sites were on Bureau of Land

Management lands and one site was on land managed by the Oregon Department of Forestry.

We conducted surveys for amphibians to characterize the occurrence and distribution of species in streams and riparian areas with varying overstory conditions. We quantified riparian vegetation and microhabitat components for inclusion in our habitat models, along with physiographic watershed characteristics to assess the importance of these variables on *D. tenebrosus* and *P. vehiculum* in these areas. An aquatic study site consisted of a 100-m stream length. Terrestrial surveys were in the adjacent riparian area, 30 m upslope on one side of the stream. We chose to survey within 30 m from the stream as microclimates have been shown to change rapidly after this distance and resemble upland conditions in unharvested western Washington forests (Brosofske et al. 1997). We incorporated an additional 10 m up- and down stream of the survey area for cover object placement (Figure 2.2). We sampled sites in random order each season. We used information from 10-m, Digital Elevation Models (DEMs) and topographic maps to generate watershed and landform characteristics to include in our analyses, based on the Universal Transverse Mercator coordinates (Oregon Spatial Database Clearinghouse; Topozone.com; Appendix C). We classified the underlying lithology as marine sedimentary or volcanic basalt from DEMs, and assumed that marine lithology would consist of more unconsolidated and smaller substrate particles than volcanic substrates (Massong and Montgomery 2000; Wilkins and Peterson 2000; Bury 2005).

## AQUATIC SURVEYS

We conducted aquatic surveys in July and October 2002, and June 2003 in ten, 2-m long transects in each stream (Figure 2.4). October sampling occurred before significant fall rain and associated leaf fall. Stream transects were eight m apart and spanned the bankfull width of the stream. During each survey period, starting at the first

transect downstream, we searched for amphibians by lifting all cover objects and lightly probing around objects and into interstitial spaces in the stream. We also carefully swept the substrate with our fingers to expose small amphibians. We used a light-touch survey method at all times to ensure the least amount of disturbance of areas to be resampled. During each of the three aquatic sampling periods, we measured microhabitat characteristics in five transects per stream. We measured active channel width across the upper, middle, and lower end of the transect. We estimated the proportion of each transect as pool, glide, or riffle. We measured stream depth at five evenly spaced points across the lower end of the transect. We visually estimated the percent cover of herbaceous vegetation overhanging the wetted width of the stream. We used a moosehorn to measure the total shrub and overstory cover, then separately measured the three dominant shrub and overstory species over the wetted width of the transect. We took three moosehorn readings for each shrub and overstory variable; one from the center of the wetted width, and 10 cm from the water's edge on each side of the stream. Multiple measurements taken within each transect were averaged for that transect. We measured stream substrate (after Allan 1995, Table 3.3), converted this to a proportion, for each transect. Transect gradient, upslope gradient (to 30 m), and the amount of area covered by down wood (>5 cm in diameter) were measured during the first aquatic sampling period, averaged for the study site, and used for each subsequent seasonal analysis.

## TERRESTRIAL SURVEYS

We used pitfall traps, artificial cover objects, and area-constrained searches to capture terrestrial amphibians within the adjacent 30-m hill-slope. The pitfall grid was installed in the center of each site and consisted of 30 traps in three rows of ten traps running parallel to the stream (Figure 2.4). We constructed pitfall traps with two, #10 tin cans taped together and placed into the ground with the edge of the can flush with the ground surface (Corn 1994). Traps were covered when not in use. We randomly located

1- by 2-m quadrats within the site and used a light-touch survey method to search for amphibians (Lowe 2001; McDade 2001). Quadrats were sampled once per season. In addition, we placed nine, 0.09-m<sup>2</sup> untreated Douglas-fir coverboards and six, 1-m<sup>2</sup> pieces of black plastic upstream and downstream of the pitfall trapping grid to augment terrestrial amphibian detections (Figure 2.2).

We conducted terrestrial amphibian surveys in fall 2002 and spring 2003, during the wettest times of the year (Crump 1994). Due to cool, dry weather in fall 2002, pitfalls were open for one trap night and 14 quadrats were searched at each site. In spring 2003, pitfalls were open for three consecutive nights at each site and checked each subsequent morning. We searched a total of 44 quadrats per site for amphibians in spring 2003 and characterized vegetation and microhabitat components in 28 randomly selected quadrats over the three-day sample period. We checked under cover objects daily during the survey period.

In the 28 quadrats, we visually estimated the total percent cover of non-woody vegetation, and then separately estimated the percent cover of moss, sword fern, bare ground, rock, and litter. We also estimated total percent cover of low shrubs (<1.5 m tall) overhanging each quadrat. Using a moosehorn, we measured total shrub cover >1.5 m in height and total overstory canopy cover from both downslope corners of the quadrat, then separately measured the three dominant shrub and tree species. These measurements were averaged for the quadrat each sample period. We estimated the percent cover of down wood, snags, and stumps  $\geq 10$  cm in diameter in each survey quadrat. We recorded temperature and relative humidity with Onset Hobo H8 Pro Series data loggers hung 1 m from the surface of the ground on a tree next to the stream at each site.

## INVERTEBRATE COLLECTION

We collected aquatic benthic invertebrates using a 0.09-m<sup>2</sup> surber sampler with a 500  $\mu$  mesh sieve at six randomly selected locations each aquatic sample period. Surber samples were stored in whirl packs in a 95% ethanol solution. In the lab, samples

were pooled by site and season, sorted, and invertebrates were identified under 10-30x dissecting microscopes. We sampled terrestrial invertebrates at ten randomly located invertebrate pitfall traps within each study site. Invertebrate pitfall traps were constructed of 1-quart plastic containers and were open for the duration of the terrestrial survey period (one-three trap nights). At the end of each survey period, the container was capped and returned to the lab. We collected five soil samples, 15 by 15 by 5 cm, at random locations on the last day of the survey period for each site. Each sample included the surface vegetation and litter layer and 5 cm of soil. Invertebrates were extracted over a five day period by Berlese funnel traps (Oregon State University Department of Entomology) and preserved in 95% ethanol until identified.

Aquatic invertebrates were identified to Order where possible using Merritt and Cummins (1996) and Chu and Cutkomp (1992). Terrestrial samples were pooled by site and season and invertebrates were identified to Order where possible with Borror et. al (1989).

## STOMACH SAMPLE COLLECTION

We anesthetized animals in a solution of tricaine methanesulfonate (MS-222) buffered with sodium bicarbonate to facilitate amphibian handling and stomach content collection. We measured total length, snout-vent-length (SVL) and weighed all amphibians to the nearest 0.1 g. Amphibians have low metabolic rates so food items remain relatively intact in their stomachs for 8-36 hours (Larsen 1992:390; Parker 1992). We gently flushed stomach contents with distilled water into a coffee filter (Fraser 1976; Maglia 1996; John Maerz pers. commun., Cornell University), using small, flexible tubing attached to a syringe. Filters containing the stomach sample were placed into a whirl pack and preserved in 95% ethanol until processing. All amphibians were allowed to recover after handling before being released next to a cover object at the point of capture. We collected stomach samples from all amphibians captured, except from torrent salamanders (*Rhyacotriton* spp.) due to their reported low tolerance to stress

(Nussbaum et al. 1983:69; Corkran and Thoms 1996:52) or larval tailed frogs (*Ascaphus truei*) because they do not eat macroinvertebrates (Nussbaum et al. 1983:150).

In the lab, we photographed each stomach sample in a Petri dish and a ruler (for scale) and measured the surface area (mm<sup>2</sup>) covered by stomach contents (Image Pro Plus, version 4.5.0.29, Media Cybernetics, Inc software). This approach allowed us to account for the miscellaneous and often unidentifiable and decomposed matter that was frequently present in stomach samples. We developed an index of stomach fullness by dividing stomach content surface area by the SVL of an individual, which allowed us to account for its size when making comparisons of stomach fullness. After photo measurement, we counted and identified prey items to Order where possible. We considered slugs and snails in Class Gastropoda as separate prey categories. We counted an invertebrate head found in a stomach sample as one invertebrate prey item. We calculated the seasonal mean relative proportion of each taxonomic group for *D. tenebrosus* and *P. vehiculum* to compare with invertebrates we collected from our sites.

## DATA ANALYSIS

The only two species found in sufficient numbers for statistical analysis were *D. tenebrosus* larvae and *P. vehiculum*. We examined differences in stomach fullness of *D. tenebrosus* and *P. vehiculum* between sites and seasons using a single-factor analysis of variance (ANOVA) and Tukey multiple comparison procedure ( $\alpha = 0.05$ ). We checked whether SVL and the number of prey consumed were correlated with Pearson's product moment correlations. We used generalized linear least squares, fit with maximum likelihood methods in S-Plus (Insightful Corp., version 7.0.2), to examine the association of stomach fullness with vegetation and other habitat characteristics.

We used the information theoretic approach using the Akaike Information Criterion (AIC) method to compare the strength of evidence for a set of candidate models developed *a priori*. We included the four most prevalent tree species found in our sites,

Douglas-fir, western hemlock, red alder, and big-leaf maple, in addition to other variables reported to be associated with amphibians based on our literature review in our analyses (Appendices A-C). We used AICc model selection as it uses a bias-correction term for sample sizes where the number of samples/number of estimated parameters is  $<40$ . We used AICc weights ( $w_i$ ) and  $\Delta$ AICc values to determine the most credible model for explaining the variability of the data; models that were  $\leq 2$   $\Delta$ AIC units of the best approximating model were considered to have a high level of support (Burnham and Anderson 2002:70). When more than one model was  $\leq 2$   $\Delta$ AICc units of the best model, we used multimodel averaging and made inferences conditional on the set of models (Burnham and Anderson 2002:149). The weight of evidence for each variable was examined by summing the relative importance weights for the models in which a variable occurred from the candidate set and comparing it against other variables (Anderson et al. 2001; Dreitz et al. 2001; Burnham and Anderson 2002:78, 168). When the variables did not appear in the same number of models across the candidate set, we used an adjusted weight (Stoddard 2001; Sheridan and Olson 2003). When we used multimodel inference, models were fit with reduced-estimate maximum likelihood for parameter estimation, unconditional standard error, and 95% confidence interval calculations (Burnham and Anderson 2002:162-164; Gale Olson, Oregon State University, Department of Fisheries and Wildlife). We also used evidence ratios to compare each model against the other models in the set (Anderson et al. 2001; Dreitz et al. 2001; Burnham and Anderson 2002:78). We did not include highly correlated ( $r >_{\pm} 0.7$ ) or redundant variables in the same model. We checked a global model for each candidate set of models for model fit; global models were not included in the analysis. The global model for the larval *D. tenebrosus* showed evidence of nonnormality and transformations failed to improve the fit of the data. Generalized linear regression is robust to departures of normality, however estimates of standard errors of the variables may be underestimated (Ramsey and Schafer 1997:203) and should be viewed with caution. All models were checked for multicollinearity and models with an Eigenvalue  $<0$  or diagonal correlation matrix value  $>10$  were not considered.

## DIET

We examined the diet of *D. tenebrosus* and *P. vehiculum* to determine whether certain prey taxa were consumed in greater proportion to their availability and if selection changed seasonally. We used Pearson's  $X^2$  to determine if prey items were used disproportionately to their relative availability for each survey period. We rejected the null hypothesis that selection was random if the computed  $X^2$  was larger than the critical value of the  $X^2$  distribution,  $\alpha = 0.05$  and  $df = \text{number of resource categories} - 1$  (Manly et al. 2002:60). We collected benthic invertebrates to compare to aquatic amphibian stomach samples and epigeic and forest floor invertebrates to compare to terrestrial amphibian stomach samples. We calculated the seasonal mean relative proportion of each taxonomic group for comparisons with prey consumed seasonally by amphibians. We graphically compared the mean seasonal relative proportion of prey taxa with their mean available relative proportion. We present seasonal results for select prey taxa that had a high frequency of occurrence in stomach samples and where there were visible differences between availability and consumption. We did not make site comparisons between prey use and availability due to the unequal distribution of our amphibian captures. We also computed the frequency of occurrence of prey items in the diet by season for larval *D. tenebrosus* and *P. vehiculum*. We captured *Taricha granulosa* during both aquatic and terrestrial surveys. Because we were interested in whether they differentially consumed prey of aquatic or terrestrial origin, we calculated the mean number of prey by origin (aquatic or terrestrial) for all *T. granulosa* and compared that with the location of capture (stream or riparian area). We list prey consumed by other species in Appendix N and O.

We assumed that invertebrates were equally available as potential prey items for all amphibians and that our sampling methods captured potential prey that represented all available taxa. We further assumed that no competition for prey items occurred among individuals over the course of this study. While this may not reflect the true availability



of prey to all individuals, we hope to offer some insight into spatial and temporal differences in diet among amphibians.

## RESULTS

Study sites ranged from having few hardwoods (red alder and big-leaf maple) directly bordering the stream to sites dominated by hardwood trees. Deciduous trees dominated the canopy directly over the wetted width of the stream at eight of the ten sites (Figure 2.3), and Douglas-fir was the dominant tree species in the adjacent 30 m upslope at five sites (Figure 2.4). Salmonberry (*Rubus spectabilis*) and vine maple (*Acer circinatum*) were the main shrub species in the riparian zone, and sword fern (*Polystichum munitum*) was present at all sites (Appendices A-B). Average stream gradients ranged from 2 to 12% (mean =  $7.2 \pm 0.4\%$  SE). Average hill-slope gradients ranged from 11 to 61% (mean =  $33.9 \pm 0.2\%$  SE). Fish were observed at six of the study sites and salmonids were known to be present at only three sites. Gravel and pebble (2-64 mm) substrate dominated most streams, although one study site averaged >50% silt (Appendix A).

We captured 283 amphibians representing seven species during aquatic surveys in July and October 2002, and June 2003, but did not find all species at all sites (Appendix I). The most common species encountered was the larval stage of *D. tenebrosus*, accounting for >78% of all aquatic amphibian captures. Of these, 54.3% came from one site (Ernest Creek), and no aquatic amphibians were found at the Smith site.

We conducted terrestrial amphibian surveys in fall 2002 and spring 2003 and captured 167 amphibians, representing nine species (Appendix J). *P. vehiculum* was the most frequently detected species, making up 55.1% of terrestrial captures; >50% of these were found at the South Mountain site. No *P. vehiculum* were found at either the Smith or Nelson Creek tributary sites in spring 2003. We captured 19 *T. granulosa* during aquatic surveys and 21 during terrestrial surveys. Other amphibians were captured in low numbers (Appendix I and J) and were not considered for statistical analysis.

We extracted stomach contents from 399 individuals during the study. We extracted 219 stomach samples from *D. tenebrosus* and 88 from *P. vehiculum*. We were unable to collect stomach samples from extremely small amphibians; the minimum size varied by species. We labeled as “empty” stomachs from which we were unable to extract any visible material or found no identifiable food items. Thus, the number of stomach samples with fullness measurements may be less than the number of stomach samples used in other analyses. We identified 25 and 23 different taxa from aquatic amphibian and terrestrial stomach samples, respectively (Appendix N and O). Average number of prey consumed varied by species and ranged from 0-117. Larval Ephemeroptera was the most abundant taxon recorded from larval *D. tenebrosus*, *Plethodon dunni*, and *T. granulosa* (aquatic captures) and accounted for 28.6% of total prey items (Appendix N). Larval prey from the orders Diptera, Plecoptera, and Trichoptera together made up 37.9% of the total from these three salamander species. Terrestrial diets were numerically dominated by Collembola which accounted for over 50.0% of total prey items. Acari made up an additional 11% of prey (Appendix O).

#### *DICAMPTODON TENEBROSUS*

Of 219 larval *D. tenebrosus* stomachs sampled over three seasons, only ten were “empty”. We identified prey items representing 22 taxa and >90% of all prey were of aquatic origin (approximately 3% of prey were of terrestrial origin and roughly 7% were unidentifiable). Mean number of prey per stomach was 6.1 ( $\pm 0.35$  SE), and ranged from 0 to 38. The number of prey per stomach was significantly correlated with SVL ( $r = 0.16$ ,  $n = 219$ ,  $P < 0.05$ ) indicating that larger individuals had ingested numerically more prey than smaller individuals. We found small rocks or balls of silt in 5.5% of stomachs and bits of vegetative matter in 15.5%, including conifer needles and small pieces of wood. In two individuals we found small invertebrate egg masses and in another we found a terrestrial slug. We found no evidence of cannibalism or predation on fish. Ephemeroptera larvae were the most abundant and made up 33.6% of the total prey

for all surveys. Invertebrates in the order Diptera comprised 17.1% and Trichoptera larvae accounted for 15.4% of prey for the three sample periods. Stomach fullness differed between seasons ( $F_{2,214} = 6.86$ ,  $P = 0.001$ ; Figure 3.1); June samples consistently had a higher fullness index than either July or October samples (fullness index value in June = 1.24, CI = 1.06, 1.42; July = 0.73, CI = 0.62, 0.84; October = 0.72,

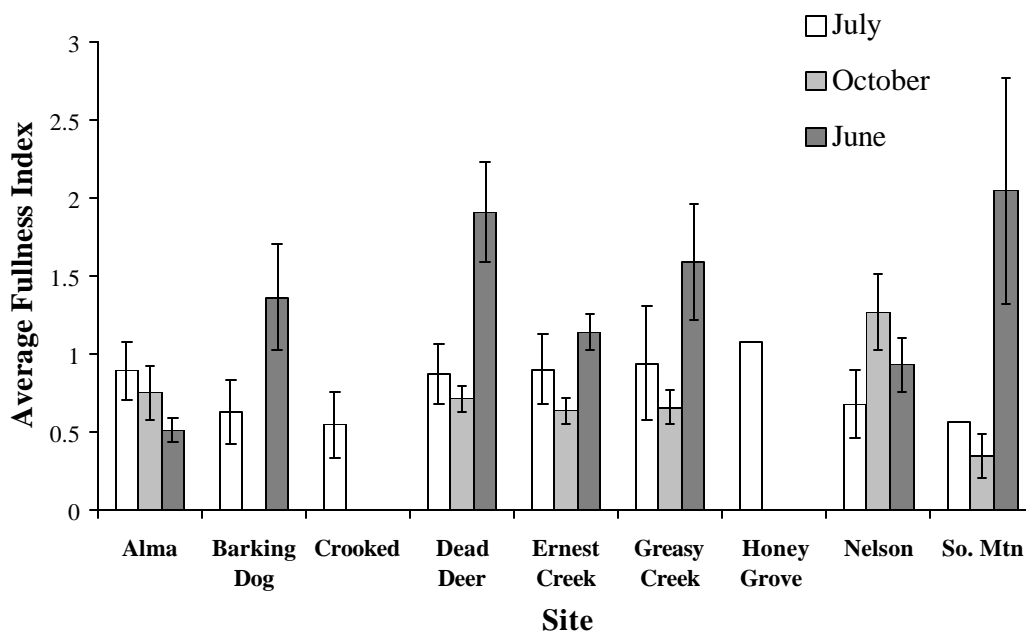


Figure 3.1 Stomach fullness (mean  $\pm$  1 SE) of larval *Dicamptodon tenebrosus* from nine Oregon Coast Range streams, July and October 2002 and June 2003 survey periods. Absence of standard error bars represents one stomach sample which was not included in ANOVA analyses.

CI = 0.58, 0.87). Stomach fullness was highly variable, and did not differ significantly among sites ( $F_{7,209} = 1.08$ ,  $P = 0.38$ ).

Competing models from the regression analysis ( $\leq 2 \Delta AICc$  units of the best model) contained variables for habitat type, stream substrate, and the amount of western

hemlock overhanging the stream channel (Table 3.1, Appendix K). The weight of evidence for the best approximating model was 34% and together the top two models explained approximately 54% of the variability of these data. The top six models ( $\leq 5 \Delta AICc$  of the best model) constitute an 88% confidence set (cumulative weights). Relative to the other models in the set, the best approximating model was only 1.69 times better than the next model at explaining the variability of the data, and less than three times better than the third ranked model. The low model weight of the best model reflects uncertainty in model selection, consequently we used multimodel inference for our interpretation (Burnham and Anderson, 2002:80). Stomach fullness was positively correlated with the amount of western hemlock overhanging the stream and the amount of pebble (16-64 mm) substrate and was negatively correlated with the amount of pool habitat and gravel (2-16 mm) substrate (Appendix M for parameter estimates). The adjusted parameter weights indicate that western hemlock was the most important habitat variable associated with stomach fullness of larval Pacific Giant Salamanders (Table 3.2).

We identified 1,326 prey items of 22 different taxa from *D. tenebrosus* in July, October 2002 and June 2003 from nine sites in the Oregon Coast Range. Fewer taxa were ingested in October compared to June or July. Prey were used disproportionately to their availability each season (July,  $X^2 = 601.82$ ,  $df = 11$ ,  $P < 0.0005$ ; October,  $X^2 = 105.73$ ,  $df = 5$ ,  $P < 0.0005$ ; June,  $X^2 = 982.0$ ,  $df = 1$ ,  $P < 0.0005$ ). Ephemeroptera larvae numerically dominated *D. tenebrosus* stomach samples and were consumed in greater proportion than they were available each season (Figure 3.2). Gastropoda (aquatic snails), Isopoda, and Trichoptera larvae were consumed in greater proportion to their relative availability all three survey periods (Figure 3.2). Aquatic snails occurred in more stomach samples and in greater relative proportion in October than June or July (Figure 3.2). Diptera larvae frequently occurred in stomach samples all three seasons, but were not consumed in greater relative proportion than they were available. Terrestrial prey, which accounted for 3% of larval *D. tenebrosus* diet all three seasons, made up a greater proportion of the diet in July. Most of the terrestrial prey taxa came from invertebrates in the orders Hymenoptera (mainly saw fly larvae) and Araneae (spiders).

Table 3.1. Summary of multiple linear regression model selection for the stomach fullness index of *Dicamptodon tenebrosus* larvae inhabiting Oregon Coast Range streams, July and October 2002 and June 2003. Only top 10 models are shown.

Larval Pacific Giant Salamander diet fullness models <sup>a</sup>	K <sup>b</sup>	Log(L)	AICc	ΔAICc	w <sub>i</sub> <sup>c</sup>	Evidence ratio
- % pool + % pebble + % western hemlock	5	-279.19	568.65	0.00	0.34	
- % pool - % gravel + % western hemlock	5	-279.74	569.75	1.10	0.20	1.69
- % pool - % cobble + % western hemlock	5	-280.29	570.86	2.21	0.11	2.93
- % pool + wood cover + % western hemlock	5	-280.29	570.87	2.21	0.11	2.94
- % gravel - % pool	4	-281.84	571.86	3.21	0.07	4.84
- % gravel - % pool - % shrub	5	-281.08	572.45	3.80	0.05	6.50
- % pool - % gravel - % Douglas-fir	5	-281.80	573.89	5.23	0.02	13.32
- % pool - % gravel + % red alder	5	-281.84	573.95	5.30	0.02	13.77
- % pool - % gravel + % big-leaf maple	5	-281.84	573.96	5.30	0.02	13.80
+ % western hemlock	3	-283.97	574.05	5.40	0.02	14.45

<sup>a</sup> Variables shown with sign of coefficient in model.

<sup>b</sup> Number of parameters in the model.

<sup>c</sup> Weight of evidence for the relative likelihood of candidate model.

Table 3.2. Relative importance of variables in the best models for stomach fullness index of *Dicamptodon tenebrosus* larvae in streams of the Oregon Coast Range, June and October 2002 and July 2003.

Variable	Adjusted weight $w^a$	No. models $^b$
% western hemlock cover	0.38	6
% gravel	0.19	6
% pebble	0.16	6
% pool	0.10	29
% Douglas-fir cover $^c$	0.01	6
% red alder cover $^c$	0.01	6
% big-leaf maple cover $^c$	0.01	6

$^a$  Relative importance of variable across the model set.

$^b$  Number of models containing the variable.

$^c$  Not included in the best approximating models.

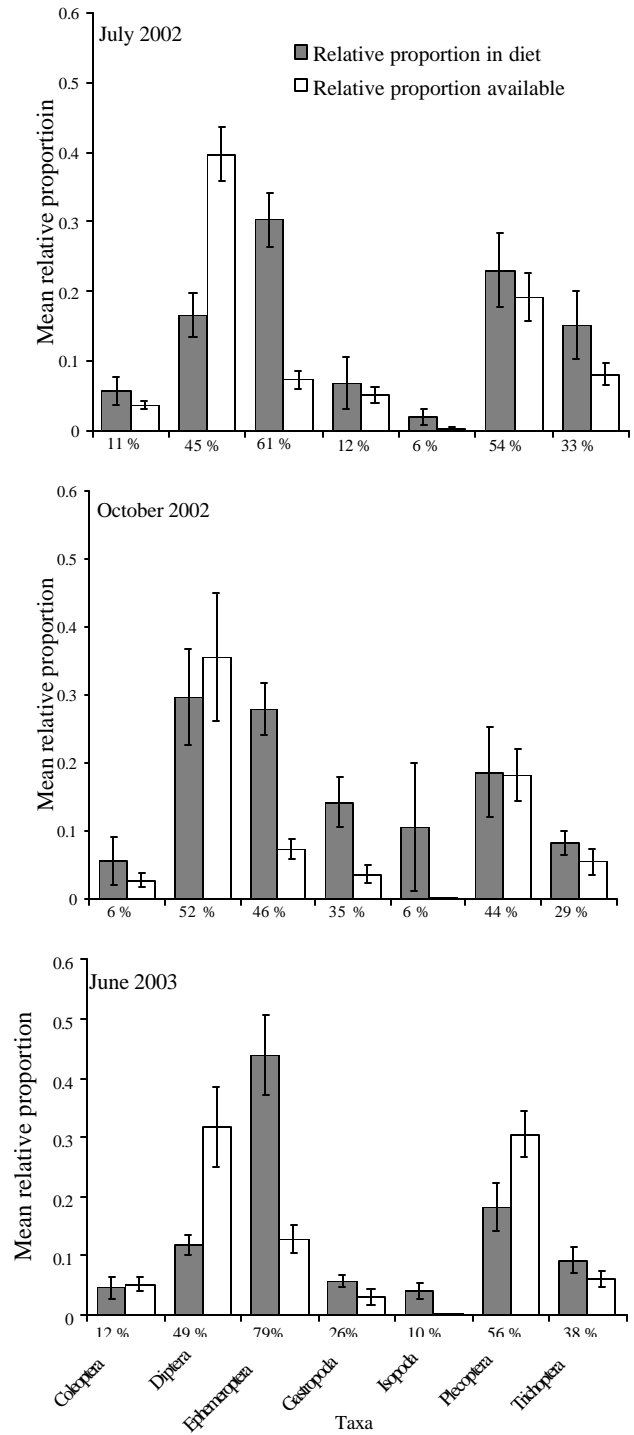


Figure 3.2. Seasonal relative proportion (mean  $\pm$  1 SE) of select prey taxa from larval *Dicamptodon tenebrosus* stomach and benthic invertebrate samples from Oregon Coast Range streams. Percentages below column represent frequency of occurrence of taxon in stomach samples.

*PLETHODON VEHICULUM*

We extracted 88 stomach samples from *P. vehiculum* in fall 2002 and spring 2003; of these, 18 were “empty”. We identified 23 different prey taxa. The mean number of prey items per stomach sample was 17.3 ( $\pm 1.9$  SE) and ranged from 0 to 93. The number of prey items was not correlated with the SVL ( $r = 0.15$ ,  $n = 80$ ,  $P = 0.17$ ), suggesting that the number of prey items consumed did not differ with the size of the salamander. Collembola numerically dominated the samples both seasons, making up 45.4% of all prey items identified. We occasionally found sand, pieces of vegetation, conifer needles, and small balls of silt in stomach samples (none occurring in  $\geq 6\%$  of stomachs sampled). There was marginal evidence that stomach fullness differed between seasons ( $F_{1,77} = 3.60$ ,  $P = 0.06$ ) and strong evidence that it differed among sites ( $F_{6,72} = 3.39$ ,  $P = 0.005$ ; Figure 3.3).

The best model for explaining *P. vehiculum* stomach fullness included variables for down wood, rock, litter, and red alder cover (Table 3.3, Appendix M). The weight of evidence for the top model was 69% and was >11 times better than the next best model at explaining the variability of the data ( $>4 \Delta AICc$  units below). *P. vehiculum* stomach fullness was positively correlated with the amount of down wood, rock, litter, and red alder cover in the riparian areas of the streams we surveyed. The adjusted parameter weights indicate that red alder and litter were the most important variables influencing the amount of food in *P. vehiculum* stomachs (Table 3.4).



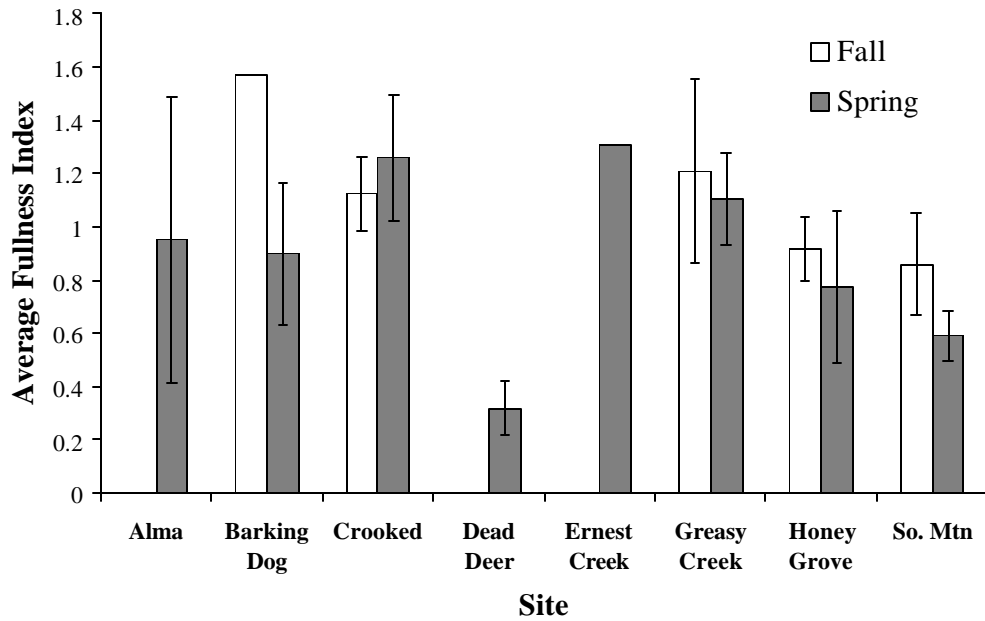


Figure 3.3 Stomach fullness (mean  $\pm$  1 SE) of *Plethodon vehiculum* from eight Oregon Coast Range streams, fall 2002 and spring 2003 survey periods. Absence of standard error bars represents one stomach sample which was not included in ANOVA analyses.

Table 3.3. Summary of multiple linear regression model selection for the stomach fullness index of *Plethodon vehiculum* in Oregon Coast Range streams, fall 2002 and spring 2003. Only top 10 models are shown.

Western Redback Salamander diet fullness models <sup>a</sup>	K <sup>b</sup>	Log(L)	AICc	ΔAICc	w <sub>i</sub> <sup>c</sup>	Evidence ratio
+ % down wood + rock + litter + % red alder	6	-52.75	118.67	0.00	0.69	
- % Douglas-fir	3	-58.58	123.48	4.82	0.06	11.12
+ % down wood + rock + litter - % Douglas-fir	6	-55.25	123.66	4.99	0.06	12.14
+ % down wood - rock + litter - moss	6	-55.92	125.02	6.35	0.03	23.91
+ % down wood + rock + % standing dead wood - % Douglas-fir	6	-56.27	125.71	7.05	0.02	33.88
+ % down wood - rock + litter	5	-57.54	125.90	7.24	0.02	37.29
- % ground cover + depth to soil - % Douglas-fir	5	-57.71	126.24	7.58	0.02	44.17
+ % big-leaf maple	3	-59.99	126.31	7.64	0.02	45.63
+ % red alder	3	-60.37	127.06	8.40	0.01	66.52
+ % down wood - rock	4	-59.44	127.43	8.76	0.01	79.90

<sup>a</sup> Variables shown with sign of coefficient in model.

<sup>b</sup> Number of parameters in the model.

<sup>c</sup> Weight of evidence for the relative likelihood of candidate model.

Table 3.4 Relative importance of variables in the best model for stomach fullness index of *Plethodon vehiculum* in riparian areas of the Oregon Coast Range fall 2002 and spring 2003.

Variable	Adjusted weight $w^a$	No. models $^b$
% red alder cover	0.34	4
% litter cover	0.22	7
% down wood cover	0.09	18
% rock cover	0.09	18
% Douglas-fir cover <sup>c</sup>	0.07	4
% big-leaf maple cover <sup>c</sup>	0.01	4
% western hemlock cover <sup>c</sup>	0.00	3

<sup>a</sup> Relative importance of variable across the model set.

<sup>b</sup> Number of models containing the variable.

<sup>c</sup> Not included in the best approximating model.

We identified 1,522 prey items from *P. vehiculum* stomach samples for fall 2002 and spring 2003 from eight sites from the Oregon Coast Range. Prey were used disproportionately to their availability both seasons (fall 2002,  $X^2 = 714.0$ ,  $df = 11$ ,  $P < 0.0005$ ; spring 2003,  $X^2 = 409.67$ ,  $df = 15$ ,  $P < 0.0005$ ). Collembola was the most numerous prey found among all sites and seasons, occurring in > 70% of stomach samples in both fall and spring. Prey in taxa Gastropoda (snails), Isopoda, Coleoptera, Araneae, and Pseudoscorpiones were eaten in greater proportion than their availability both seasons (Figure 3.4). Acari also occurred frequently in stomachs, but were consumed less than their relative availability both seasons. We did not find any prey that was of aquatic origin.

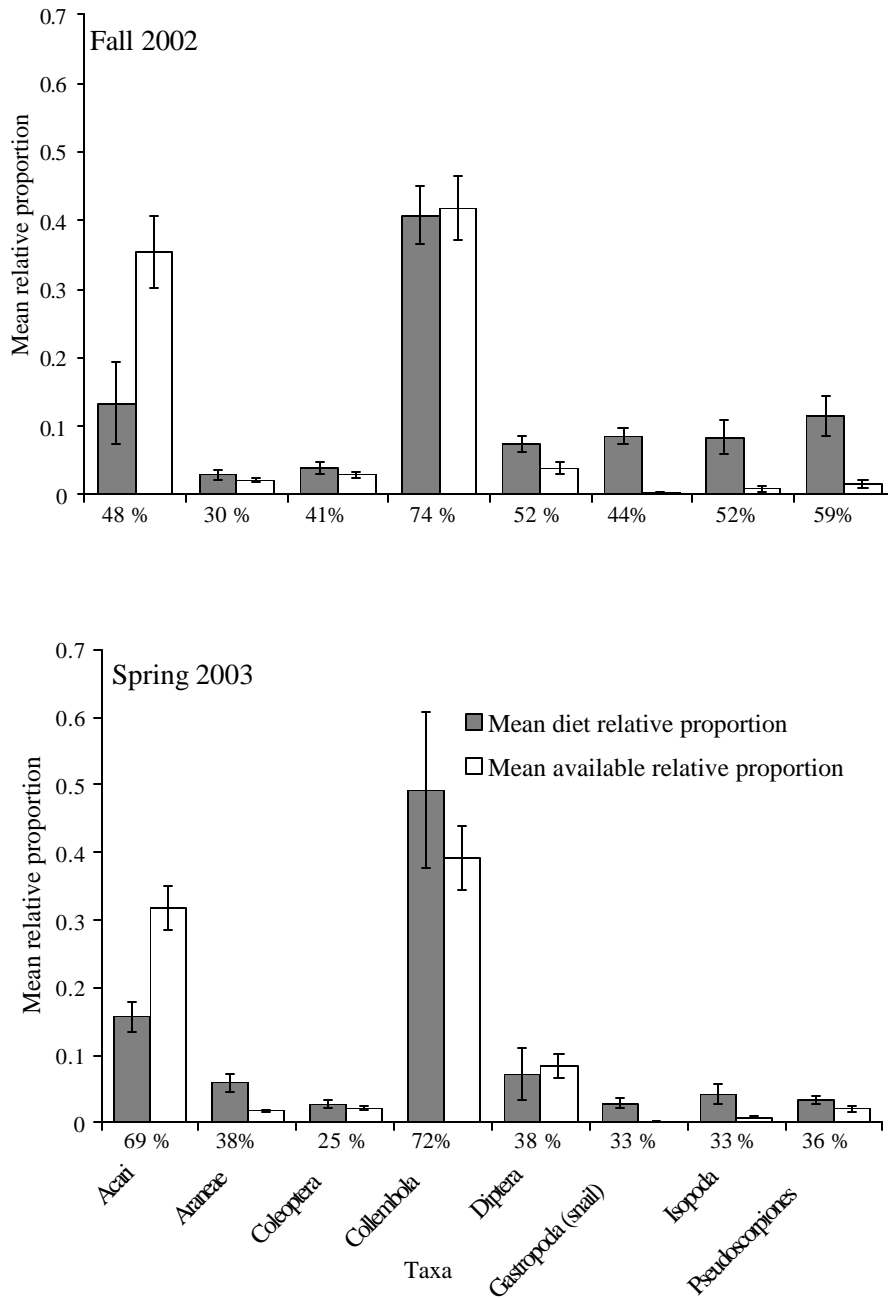


Figure 3.4. Seasonal relative proportion (mean  $\pm$  1 SE) of select prey taxa from *Plethodon vehiculum* stomach and terrestrial invertebrate samples from Oregon Coast Range riparian areas. Percentages below column represent frequency of occurrence of taxon in stomach samples.

### TARICHA GRANULOSA

We sampled 18 *T. granulosa* during aquatic surveys and 21 during terrestrial surveys. *T. granulosa* had the highest average number of prey items per individual among all species of amphibians captured (mean =  $29.6 \pm 4.75$  SE prey items per stomach, ranged from 0 to 117). Prey of terrestrial origin comprised over 75% of *T. granulosa* diets, regardless of where they were captured (Figure 3.5). Only three individuals had no identifiable prey. We considered adult invertebrates with aquatic larvae in the order of Plecoptera and Trichoptera to be of aquatic origin (Appendices N and O). We found 21 adult Plecoptera in one individual from spring 2003. Over 90% of the newts from terrestrial surveys contained Collembola while only 39% of those captured during aquatic surveys had Collembola in their stomachs. Of terrestrial newts, 33% consumed slugs and 57% snails (Gastropoda); none of the newts captured during aquatic surveys consumed slugs, but 28% consumed snails.

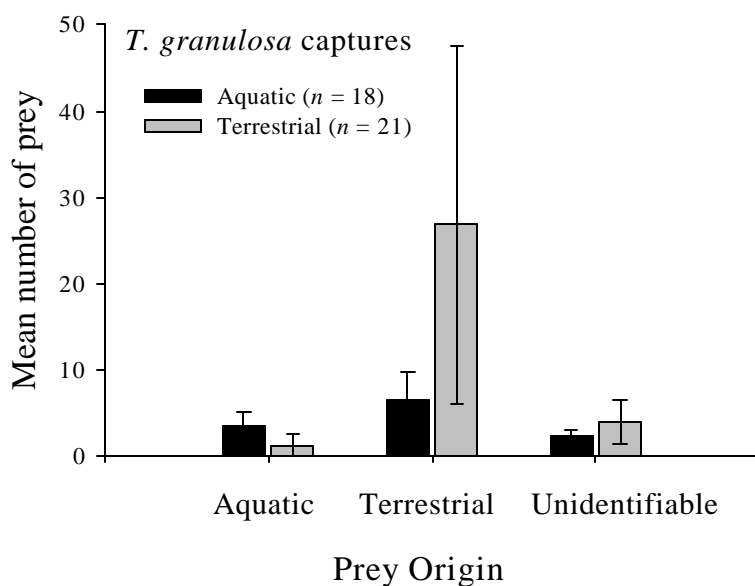


Figure 3.5 Number prey items by origin (mean  $\pm$  1 SE) from *Taricha granulosa* sampled during terrestrial surveys in fall 2002 and spring 2003 and aquatic surveys in July and October 2002 and June 2003 in the Oregon Coast Range.

## DISCUSSION

The amount of food consumed by *D. tenebrosus* larvae and *P. vehiculum* was associated with riparian tree species composition in the central Oregon Coast Range. Deciduous trees are often present in riparian areas and we predicted that they would provide a positive prey subsidy to amphibian diet. However, the amount of prey consumed by larval *D. tenebrosus* was higher in streams dominated by western hemlock than other tree species. *P. vehiculum* ingested more prey under red alder-dominated canopies. We found seasonal differences in stomach fullness for both species, although this was more pronounced for *D. tenebrosus* larvae. We characterized seasonal prey consumption in the diet of *D. tenebrosus* larvae and *P. vehiculum*. Prey species composition of amphibian diets may be an indicator of habitat quality, reflect type and seasonality of riparian inputs, and individual foraging efficiencies (Stebbins and Cohen 1995:65; Gunzburger 1999; Zaradic 2003). Many amphibians are considered sit-and-wait predators that use prey movement as visual cues to attack (Antonelli et al. 1972; Stebbins and Cohen 1995:61; Zaradic 2003). Prey availability, size, and movement, predator density, and habitat heterogeneity will affect encounter rates by amphibians and ultimately, prey selection (Allan 1995:164-174). *D. tenebrosus* diets were dominated by macroinvertebrate larvae of aquatic origin, mainly larval Ephemeroptera. *P. vehiculum* stomach samples were numerically dominated by Collembola. In general, Gastropoda (snails) and Isopoda prey were consumed in greater proportion than their relative availability by both species of salamander. Although we did not examine the impact of vegetation on the diet of the *T. granulosa*, we found that prey of terrestrial origin was important regardless of whether the newts were captured in the stream or riparian zone. One of our goals was to describe amphibian diet in the Oregon Coast Range; we provide a description of prey items for those species that were not caught in adequate numbers to allow for statistical analysis (Appendices N and O).

## PACIFIC GIANT SALAMANDER

We surveyed larval *D. tenebrosus* over three seasons and found that the amount of food consumed varied seasonally. Our analysis indicated that *D. tenebrosus* had a higher stomach fullness, after accounting for size, in June than in July or October across all sites. Foraging activity likely increased in the late spring and early summer in response to greater prey availability. Larval invertebrate emergence from streams peaks in early summer in western Oregon, and prey may be readily available in the benthos during this time, regardless of canopy cover composition (Progar and Moldenke 2002; Baxter et al. 2005). Although total benthic invertebrate density among our sites was highest in October, detritus associated with leaf fall within the stream channel may have made locating prey difficult. In addition, the number of prey items per individual was correlated with SVL indicating that larger animals were ingesting more prey items. *D. tenebrosus* larvae typically undergo metamorphosis around 53-93 mm SVL, which usually occurs in late summer or early fall in the Pacific Northwest (Nussbaum and Clothier 1973). Thus, higher stomach fullness in June may signify that larvae are increasing their prey intake to enhance growth and facilitate metamorphosis later in the season.

Our predictions regarding the relationship of higher prey availability and greater stomach fullness under a deciduous canopy were not supported by our data. Deciduous trees generally support higher abundance and diversity of terrestrial invertebrates that may fall into the stream (Mason and MacDonald 1982; Baxter et al. 2005; Hernandez et al. 2005), and *D. tenebrosus* larvae in northern California supplemented their diet with terrestrial prey, ranging from 2.2 to 25.6% of total prey seasonally (Parker 1992). However in our study, the proportion of terrestrially-derived prey in larval salamander diets was small, comprising roughly 3% of total prey, suggesting that larvae in our sites feed primarily on benthic organisms. We found that larval *D. tenebrosus* stomach fullness increased with the amount of western hemlock overhanging the stream (Figure 3.2, Appendix L). Although western hemlock needles in leaf packs decompose more

slowly and have lower invertebrate density in streams than red alder leaf packs (Richardson et al. 2004), detritus provided through continuous western hemlock needle fall may act as a year round refuge for invertebrates and a stable prey source for *D. tenebrosus* larvae. This may be especially important in the late spring or early summer when there are fewer alder leaves in streams. Alternatively, western hemlock may have an association with a habitat characteristic that we did not measure, such as stream pH, which positively affects the availability of prey for larval *D. tenebrosus* at these sites.

Other habitat characteristics were also important in explaining the variability of stomach fullness. Stomach fullness was negatively associated with pool habitats and gravel (2-16 mm) substrate and positively associated with pebble (16-64 mm) substrate. *D. tenebrosus* commonly use cover objects and interstitial spaces from which to ambush passing prey (Parker 1992). Many benthic invertebrates are more abundant in riffles and show a positive association with medium-sized substrates (Brown and Brussock 1991; Allan 1995:67; Hernandez et al. 2005). Our results suggest that riffles may provide better hiding cover than pools as they tend to be dominated by larger substrates (Hauer and Lamberti 1996:34). The average SVL of *D. tenebrosus* that we sampled was 39 mm (range 24 – 87 mm), thus pebble-sized rocks were likely large enough to hide most larvae.

Prey were used disproportionately to their availability all three sample periods, however consumption for certain prey taxa was inconsistent across seasons. This inconsistency was not unexpected as prey availability is neither homogeneous nor constant over time (Manly et al. 2002:1). Stream conditions, such as rates of discharge and allochthonous inputs, vary seasonally and affect prey availability and amphibian capture rates. We expected that prey consumption would reflect these differences. Parker (1992) found that larval *D. tenebrosus* consistently selected for large, mobile prey over small, abundant prey and Zaradic (2003) found that when prey were abundant, larval *D. tenebrosus* specialized on certain taxa. Diptera, Ephemeroptera, Plecoptera, and Trichoptera larvae had a high frequency of occurrence in *D. tenebrosus* stomach samples each sample period when compared to other prey taxa (Figure 3.2). Ephemeroptera



larvae were consistently present in stomach samples in greater proportion than their availability. Parker (1992) and Zaradic (2003) both found selection for Ephemeroptera larvae by *D. tenebrosus*. Ephemeroptera larvae were present in every stream we surveyed, averaging 209 individuals/m<sup>2</sup> (range 31 – 933) across all sites and seasons. Other large prey, such as Plecoptera larvae, were more abundant in the benthos, averaging 438 individuals/m<sup>2</sup> (range 11- 1246), and were consumed less than their availability in June (Figure 3.2). Some aspect of size, morphology, or behavior, such as movement by drifting downstream, may render Ephemeroptera larvae more vulnerable to predation by *D. tenebrosus* than other benthic invertebrates (Allan 1995:165).

*D. tenebrosus* consumed Gastropoda (aquatic snails) each sample period, however they made up a greater proportion of overall diet in October (Figure 3.2). We did not expect that consumption of hard-bodied prey would be greater than that of soft-bodied prey. In October, copious leaf litter and detritus in stream channels may have made other prey difficult to spot and capture. Snails are slow moving, relatively large, and are likely easier to capture than smaller, more mobile prey. Snail shells are comprised in part of calcium carbonate (Frest and Johannes 1999) and may have nutritional value beneficial to *D. tenebrosus* larvae, especially when more palatable, soft-bodied prey are hard to find. Other hard bodied prey that were present in stomach samples each season included many case-building Trichoptera species and Ostracods. Case building Trichoptera larvae may have also accounted for the presence of sand or empty cases recorded from 6.4% of stomach samples.

Changes to the riparian canopy in the central Oregon Coast Range through the removal of deciduous trees may not have severe, short-term consequences for the larval *D. tenebrosus*. Canopy removal has been shown to increase *D. tenebrosus* larval biomass at high-gradient streams in the western Cascades (Murphy et al. 1981) and may improve their ability to capture prey through increased light reaching the stream (Zaradic 2003). When larval *D. tenebrosus* have been added experimentally to a stream reach, they have been shown to decrease benthic macroinvertebrate abundance (Zaradic 2003). Any tree removal in the riparian zone has the potential to affect the food web by altering stream

temperatures through increased solar radiation, potentially impacting the invertebrate community. Although we sampled over three different seasons, continued sampling over a longer period of time would reveal long-term diet preferences and habitat relationships. We provided a short-term picture of season-to-season variability in the diet of *D. tenebrosus* larvae in small streams and an association with the riparian canopy. Repeated diet sampling may elucidate the relationship between the amount of food ingested by larvae and western hemlock. It is also possible that there may be a relationship between the distribution of metamorphosed, terrestrial adult *D. tenebrosus* and western hemlock, which may play a role in the habitat associations we find with the larval stage. Although we found that certain prey were disproportionately consumed, analyses linking prey at a finer taxonomic scale to riparian vegetation (for example, through invertebrate functional feeding groups) may provide a more substantial foundation on which to make riparian management decisions.

#### WESTERN REDBACK SALAMANDER

Stomach fullness of *P. vehiculum* increased with increasing amount of red alder cover, supporting our hypothesis that *P. vehiculum* diet is positively associated with riparian deciduous trees (Figure 3.4). Red alder provides a positive nutrient subsidy to riparian areas through high quality invertebrate, leaf, and litter fall and nitrogen soil enrichment (Mattson and Scriber 1987:107; Allan et al. 2003; Gullan and Cranston 2005:220; Spies et al. 2002:41). We also found a positive association between stomach fullness and the amount of litter cover. Increased decomposition rates and by implication, number of detritivores as potential prey, occur in the high quality litter layer under red alder (Borman et al. 1994). Stomach samples for *P. vehiculum* were dominated by Collembola and Acari mites, species important in the breakdown of litter (Furniss and Carolin 1977:40; Johnston 2000; Gullan and Cranston 2005:218). Additionally, red alder grows on moist sites and is more flood tolerant than conifers in the Oregon Coast Range (Binkley et al. 1994; Nierenberg and Hibbs 2000). Collembola and Acari also require

moisture and thrive in greater densities in moist soils (Gullan and Cranston 2005:218, 231). Thus, the presence of red alder may represent areas where *P. vehiculum* has access to readily available prey with less risk of desiccation than at drier conifer-dominated sites.

In addition, we found a positive relationship between stomach fullness and rock and down wood cover, which may be related to the need for stable microhabitats associated with poikilothermy. Rock and down wood provide interstitial spaces and diverse foraging substrates that *P. vehiculum* may exploit, especially as conditions become dry. These types of microhabitats may be important as refugia sites, especially in the summer dry season when *P. vehiculum* all but disappear from the forest floor (Dumas 1956; Ovaska 1988). The redback salamander of the Northeast (*Plethodon cinereus*) uses cover from which to ambush prey during daylight and switches to active foraging on the forest floor at night (Playck and Graves 2001). These cover sites may also offer temporary substrates under which to forage and take refuge during the day when conditions are dryer than at night (Dumas 1956).

We found a wide variety of taxa ingested by *P. vehiculum* and our analysis indicated that certain taxa were consumed in greater proportion than their availability (Figure 3.4). Plethodontid salamanders have low metabolic rates and assimilate energy very efficiently (Jaeger 1990; Stebbins and Cohen 1995:5). Because they are limited to foraging when conditions are adequate to meet physiological needs, they are considered “pulse feeders” (Jaeger 1990) and consume many small prey as well as large (Lynch 1985; Parker 1992; Maglia 1996). Relative to other prey, Collembola dominated stomach, soil, and pitfall samples (Figure 3.4). Their high frequency of occurrence in stomach samples suggests that they are an important prey source for *P. vehiculum*. Their high availability and use may mask diet preferences of *P. vehiculum* for other prey taxa (Stebbins and Cohen 1995:57). The closely related redback salamander (*Plethodon cinereus*) of the Northeast consumed Collembola as encountered and consumed larger prey that were not abundant (Jaeger 1990). We suggest that seasonal changes in

ingestion of Collembola may reflect seasonal changes in abundance of other prey taxa rather than strong preference for or avoidance of Collembola.

Jaeger (1990) found that volumetrically, armored prey offers similar energy benefits as soft-bodied prey and that *P. cinereus* consumed more armored prey during dry periods when prey were scarce than wet periods when prey were abundant. Acari, considered an armored prey by Jaeger (1990), had a high frequency of occurrence in stomach samples, but were consumed less than their availability in our study. Acari are very small but may represent an important nutrient source for small salamanders as mites sequester calcium (Johnston 2000). Based on our survey methods, small Collembola and Acari prey comprised 81.2% and 72.9% in the fall and spring respectively, of all invertebrates sampled in the surface layer and represent an abundant prey resource during these wet periods.

Larger prey in the taxa Gastropoda (snails) and Isopoda were taken both seasons in greater proportion than their relative availability (Figure 3.4). We anticipated that soft-bodied prey would be consumed at higher rates than hard-bodied prey, so the relatively high frequency of occurrence of snails in the diet was unexpected. The presence of snails may be an indicator of moist microsite conditions and represent high quality foraging habitat for *P. vehiculum* (Gunzburger 1999). Snails are slow moving and relatively large, and likely provide positive energetic benefits when compared to capture and handling costs (Frest and Johannes 1999).

We found a positive association between the amount of food consumed and the amount of red alder cover in the riparian zone. Reducing the amount of red alder in riparian areas in the central Oregon Coast Range may negatively impact the diet of *P. vehiculum*. Moisture affects terrestrial prey availability and may be the limiting factor influencing foraging by *P. vehiculum*. Changes to the amount of red alder in riparian areas may affect the prey base for *P. vehiculum* through the alteration of forest floor microclimate, litter composition, and reduction of nitrogen soil enrichment. Different rates or sizes of down wood associated with a conifer canopy may have positive benefits for *P. vehiculum* foraging behavior in riparian areas, but may affect the type of prey

available. Decreasing red alder cover in western Washington riparian zones by 51% produced minimal changes to the abundance and individual body mass of *P. vehiculum*, during the first two years after treatment (MacCracken 2002). The potential long-term impact of canopy composition changes on the diet of *P. vehiculum* are unknown. The positive association between the amount of red alder cover and stomach fullness highlight the need for additional long-term studies of the relationship between vegetation and the diet and foraging behavior of this common amphibian species.

### *TARICHA GRANULOSA*

In the Oregon Coast Range, prey of terrestrial origin was important in the diet of the *Taricha granulosa* regardless of whether they were captured in streams or the riparian area (Figure 3.3). We captured newts during aquatic surveys either in the water or within the stream bankfull width. Prey in the taxa Araneae, Chilopoda, Diplopoda, and Lepidoptera found in stomach samples from individuals captured during aquatic surveys were of terrestrial origin, indicating that some foraging took place out of the water column. This contrasts with newt populations resident in ponds whose diets are typically dominated by aquatically derived prey (Evenden 1948; Efford and Tsumura 1973). Regardless of origin, Diptera prey (true flies) had a high frequency of occurrence in newts captured during aquatic and terrestrial surveys (Appendices N and O). Collembola occurred in 90% of terrestrial newts and comprised 39% of total prey in newts captured during aquatic surveys. Stomach samples frequently had many individuals of one species suggesting that newts take advantage of seasonally and locally abundant prey. Newts often had a high number of prey items per stomach relative to other species we sampled, averaging 29 items (range 0- 117) per individual. We found no evidence of predation on fish, other salamanders, or amphibian eggs as others have reported (Evenden 1948; Efford and Tsumura 1973). Further seasonal sampling from riparian areas and streams is needed to better describe the diet of this species.

Amphibians are abundant in small streams and riparian areas (Kelsey 2000; Davic and Welsh 2004) and represent an important trophic level in the food webs of these systems. Our results indicate that the amount of food consumed by *D. tenebrosus* larvae and *P. vehiculum* is associated with riparian tree species composition in the Oregon Coast Range. Changes to riparian overstory has the potential to alter the prey base available to amphibians through changes to allochthonous stream inputs or to the microclimate conditions on the forest floor. The consequences on the foraging success of amphibians is unknown. We provide information on the diet of amphibians over a short period of time and present a foundation for additional research. Further diet studies, involving experimental alteration of riparian vegetation should be implemented to confirm our results and assess potential long-term impacts on amphibians and their prey. Although we examined the diet of two amphibian species in depth, we present a description of prey items for those species that were not caught in adequate numbers to allow for statistical analysis (Appendices N and O). This research highlights the general lack of knowledge of amphibian life-histories in the Pacific Northwest, and whether vegetation influences the distribution or diet of these other species is still not well known.

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## CHAPTER 4

### CONCLUSIONS

Amphibian ecology is less well known than many other groups of vertebrates (Gilbert and Allwine 1991; Grialou et al. 2000) in spite of their reported high abundance in many areas (Corn and Bury 1991; Davic and Welsh 2004; Grialou et al. 2000). Most amphibians are “relatively small, cryptic, and secretive” (Carfioli et al. 2000:464) hence their role in aquatic and riparian communities and effects of habitat alteration on their distribution and survival are not well understood (Bury et al. 1991). Amphibians are poikilotherms, thus require stable environmental conditions to meet their life history requirements (Grialou et al. 2000). There is little agreement about the effect of overstory removal on the diversity, abundance, or long-term persistence of amphibians, or on specific species (Corn and Bury 1989; Dupuis 1997; Aubry 2000). In the Oregon Coast Range, the role of *D. tenebrosus* larvae in the food web of small streams has not been well described. We found no studies that evaluated whether *P. vehiculum* diet is associated with vegetation and little is known of its diet preferences or whether seasonal differences in prey use occur. The purpose of this study was to examine relationships among riparian vegetation, habitat characteristics, aquatic and terrestrial amphibians and their invertebrate prey in the Oregon Coast Range. We found 11 species of amphibians in ten small streams and associated riparian areas surveyed in the central Oregon Coast Range in 2002 and 2003. Two species, *D. tenebrosus* larvae and *P. vehiculum* were found in sufficient numbers for statistical analysis. We evaluated relationships between the occurrence of *D. tenebrosus* and *P. vehiculum* and habitat characteristics previously found or hypothesized to be associated with these two species in Chapter 2. In Chapter 3 we investigated relationships between the amount of prey consumed by *D. tenebrosus* and *P. vehiculum* and habitat characteristics, emphasizing riparian vegetation.

*DICAMPTODON TENEBROSUS*

We found that the presence of *D. tenebrosus* is positively associated with riparian Douglas-fir cover and elevation. The presence of Douglas-fir in riparian areas may indicate stable microhabitat conditions. Not only does Douglas-fir provides more shade and channel stability than hardwoods (Newton et al. 1996; Oregon Department of Forestry 2000; Ringold et al. 2000), but it may also be an indicator of less disturbance-prone streams. Predictable microhabitat conditions are likely to be important to salamanders that may spend up to two or more years in streams as larvae before undergoing metamorphosis (Parker 1992). The presence of riparian Douglas-fir also may be indirectly related to the positive relationship between *D. tenebrosus* and elevation. Stream gradient increases with elevation, and in the Oregon Coast Range, it is not uncommon for conifers to dominate small, steep streams (Spies et al. 2002). Higher gradient streams tend to flush smaller particles downstream and keep interstitial spaces clear for use by *D. tenebrosus*.

Allochthonous inputs to small streams provide energy at the base of the food web and reflect streamside vegetation (Gregory et al. 1991; Massong and Montgomery; Spies et al. 2002). The distribution and availability of benthic invertebrates are also influenced by allochthonous inputs and the physical habitat of streams. Variability in the amount of food consumed by *D. tenebrosus* was better explained by seasonal effects than site effects, and likely reflects the seasonal availability of prey or the species' metabolic needs to complete metamorphosis. Stomach fullness also was positively associated with western hemlock cover and pebble-sized substrates. Continuous stream inputs from western hemlock may offer stable refugia for *D. tenebrosus* prey, and is one possible explanation for this relationship. However, western hemlock may also have a relationship with other habitat characteristics that may positively affect prey availability for *D. tenebrosus*. Further studies are needed to clarify this relationship.

In the Pacific Northwest, *D. tenebrosus* may select for certain prey and exploit available terrestrial prey (Parker 1992; Zaradic 2003). However we found that terrestrial



prey made up a small proportion of its overall diet. Diptera, Ephemeroptera, Plecoptera, and Trichoptera larvae frequently occurred in stomach samples each survey period. Although Gastropoda (snails) did not make up a high relative proportion of *D. tenebrosus* diet, they were consumed in greater proportion than their relative availability each season, suggesting that they may represent an important prey source.

### *PLETHODON VEHICULUM*

Our results indicated that the odds of occurrence of *P. vehiculum* in riparian areas increased with the amount of western hemlock canopy, total overstory cover, and decreased with elevation. The physiological requirements of this lungless species of salamander restricts it to moist microsites. Western hemlock typically grows on moist sites (Franklin and Dyrness 1988:79-80) and provides continuous canopy cover throughout the year. However, a closed riparian canopy may be sufficient to moderate forest floor conditions in our study sites. The negative association with elevation may reflect a temperature and moisture gradient.

The distribution of invertebrates is also affected by forest characteristics, such as canopy cover, soil and air moisture and temperature (Schowalter et al. 2003; Gullan and Cranston 2005:218). Foraging success of plethodontids is influenced by moisture, temperature, habitat heterogeneity, cover, riparian vegetation, and the patchy distribution of prey (Sites 1978; Walton et al. in press). *P. vehiculum* forages on the forest floor and under cover objects where the moderating influence of riparian vegetation on temperature and humidity increases foraging opportunities (Dumas 1956; Ovaska 1988). We found that stomach fullness of *P. vehiculum* was positively associated with the amount of red alder, rock, down wood, and litter cover in the riparian area. Red alder grows on moist sites and is associated with abundant, high quality invertebrates. Our results suggest that there may be increased foraging opportunities for this salamander under a red alder canopy. Rock and down wood offer additional foraging and cover substrate that may be important to this salamander as forest conditions dry.

Prey selection is affected by attributes of prey, such as size and movement, density, and availability (Stebbins and Cohen 1995:57). Collembola numerically dominated *P. vehiculum* stomach samples, invertebrate pitfall and soil samples and represents an important prey source. Larger prey in the taxa Gastropoda (snails) and Isopoda were consumed in greater proportion than their relative availability each survey period. Snails are abundant in moist leaf litter and may be an indicator of high quality foraging habitat for *P. vehiculum* (Gunzburger 1999).

Our study indicates that relationships with riparian vegetation and microhabitat characteristics are species specific and that altering riparian overstory composition may affect two species of salamanders, *D. tenebrosus* larvae and *P. vehiculum*. Although our research is exploratory, our findings suggest that maintaining a mix of conifer (Douglas-fir and western hemlock) and deciduous (particularly red alder) trees in riparian areas would benefit *D. tenebrosus* and *P. vehiculum* in the Oregon Coast Range. The distribution of amphibians is affected by characteristics at fine spatial scales and the availability of habitat at larger spatial scales (Welsh and Lind 1996; Stoddard and Hayes 2005). Variables representing characteristics at multiple spatial scales occurred in the best models associated with the presence of these two species and may reflect their widespread distribution. Watershed characteristics may be useful for identifying potential habitat for these species. Changes to riparian overstory have the potential to alter the prey base available to amphibians through changes to allochthonous stream inputs or to the microclimate conditions on the forest floor. The consequences on the foraging success of amphibians are unknown. Conservation strategies for amphibians, require recognition and maintenance of important microhabitat features across landscapes. Predictable, stable microhabitat conditions may be important to salamanders that are relatively long-lived and not highly mobile (Hairston 1987; Johnston 1994).

We view our findings as exploratory. We modeled general trends across the survey area; long-term consequences of riparian conversion are not clear. Confirmatory studies, involving experimental alteration of riparian vegetation should be implemented to assess potential long-term impacts to amphibians. Understanding the significance and

contribution of compositionally different vegetation within the riparian area is important for providing a foundation that may be used to assess potential impacts of management activities to amphibians in these areas .

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## APPENDICES



Appendix A. Mean values for in-stream and habitat characteristics of 10 streams used for amphibian surveys in the Oregon Coast Range in July and October 2002 and June 2003.

	<u>Alma</u>		<u>Barking Dog</u>		<u>Crooked</u>		<u>Dead Deer</u>		<u>Ernest Creek</u>	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
Wetted width (cm)	75.24	(19.70)	100.92	(27.00)	139.02	(22.30)	75.78	(26.43)	125.41	(38.52)
Depth (cm)	2.61	(1.86)	3.50	(1.88)	5.70	(1.45)	9.12	(5.48)	6.46	(4.87)
Organic debris (%)	0.17	(0.18)	0.12	(0.14)	0.16	(0.13)	0.27	(0.25)	0.13	(0.19)
Silt < 2 mm (%)	0.06	(0.11)	0.08	(0.13)	0.12	(0.16)	0.55	(0.31)	0.08	(0.09)
Sand ~ 2 mm (%)	0.22	(0.21)	0.15	(0.17)	0.12	(0.09)	0.04	(0.07)	0.06	(0.09)
Gravel 2-16 mm (%)	0.26	(0.25)	0.22	(0.15)	0.38	(0.23)	0.09	(0.17)	0.19	(0.14)
Pebble 17-64 mm (%)	0.18	(0.21)	0.28	(0.23)	0.19	(0.19)	0.01	(0.04)	0.35	(0.17)
Cobble 65-256 mm (%)	0.10	(0.14)	0.05	(0.08)	0.02	(0.03)	0.00	(0.00)	0.16	(0.18)
Boulder > 257 mm (%)	0.00	(0.02)	0.02	(0.05)	0.01	(0.03)	0.00	(0.00)	0.03	(0.06)
Bedrock (%)	0.00	(0.00)	0.07	(0.15)	0.00	(0.00)	0.03	(0.08)	0.00	(0.00)
Herb (%)	0.39	(0.23)	0.10	(0.11)	0.12	(0.21)	0.20	(0.23)	0.02	(0.02)
Stream gradient (%)	0.12	(0.06)	0.08	(0.03)	0.06	(0.05)	0.09	(0.05)	0.11	(0.08)
Wood cover (m <sup>2</sup> )	0.33	(0.17)	0.40	(0.28)	0.36	(0.21)	0.46	(0.29)	0.43	(0.40)
Pool (%)	0.11	(0.17)	0.17	(0.32)	0.10	(0.17)	0.45	(0.43)	0.27	(0.33)
Glide (%)	0.32	(0.19)	0.31	(0.35)	0.26	(0.30)	0.43	(0.41)	0.16	(0.20)
Riffle (%)	0.56	(0.21)	0.52	(0.39)	0.64	(0.34)	0.11	(0.15)	0.56	(0.36)
Shrub (%)	0.40	(0.45)	0.74	(0.29)	0.53	(0.40)	0.56	(0.38)	0.87	(0.19)
Overstory (%)	0.66	(0.43)	0.87	(0.20)	0.92	(0.19)	0.71	(0.36)	0.71	(0.36)
Vine maple (%)	0.00	(0.00)	0.32	(0.38)	0.35	(0.40)	0.33	(0.39)	0.34	(0.46)
Salmonberry (%)	0.34	(0.45)	0.52	(0.39)	0.17	(0.33)	0.00	(0.01)	0.23	(0.32)
Big-leaf maple (%)	0.51	(0.38)	0.37	(0.37)	0.03	(0.13)	0.02	(0.06)	0.00	(0.00)
Red alder (%)	0.00	(0.00)	0.73	(0.30)	0.79	(0.31)	0.02	(0.07)	0.33	(0.42)
Douglas-fir (%)	0.24	(0.28)	0.00	(0.01)	0.00	(0.00)	0.55	(0.40)	0.40	(0.42)
Western hemlock (%)	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)	0.26	(0.42)	0.00	(0.02)
Western red cedar (%)	0.10	(0.27)	0.00	(0.00)	0.23	(0.39)	0.03	(0.10)	0.00	(0.00)

Appendix A. Continued.

	<u>Greasy Creek</u>		<u>Honey Grove</u>		<u>Nelson</u>		<u>Smith</u>		<u>S. Mountain</u>	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
Wetted width (cm)	196.64	(35.81)	97.73	(24.74)	146.09	(64.62)	86.14	(28.86)	104.69	(27.32)
Depth (cm)	4.74	(3.79)	3.56	(1.26)	4.73	(3.55)	3.29	(1.64)	5.06	(1.63)
Organic debris (%)	0.08	(0.09)	0.11	(0.10)	0.07	(0.13)	0.25	(0.17)	0.20	(0.17)
Silt < 2 mm (%)	0.02	(0.05)	0.13	(0.25)	0.09	(0.17)	0.14	(0.15)	0.14	(0.14)
Sand ~ 2 mm (%)	0.05	(0.05)	0.16	(0.12)	0.04	(0.07)	0.07	(0.08)	0.07	(0.07)
Gravel 2-16 mm (%)	0.12	(0.11)	0.28	(0.19)	0.23	(0.14)	0.22	(0.18)	0.15	(0.08)
Pebble 17-64 mm (%)	0.17	(0.22)	0.26	(0.17)	0.34	(0.17)	0.10	(0.11)	0.28	(0.17)
Cobble 65-256 mm (%)	0.24	(0.17)	0.07	(0.15)	0.21	(0.17)	0.05	(0.08)	0.14	(0.12)
Boulder > 257 mm (%)	0.05	(0.08)	0.00	(0.00)	0.01	(0.03)	0.00	(0.00)	0.01	(0.05)
Bedrock (%)	0.30	(0.31)	0.00	(0.00)	0.00	(0.02)	0.16	(0.32)	0.00	(0.00)
Herb (%)	0.06	(0.09)	0.06	(0.08)	0.23	(0.26)	0.13	(0.11)	0.06	(0.08)
Stream gradient (%)	0.05	(0.04)	0.03	(0.02)	0.05	(0.01)	0.08	(0.07)	0.06	(0.06)
Wood cover (m <sup>2</sup> )	0.09	(0.08)	0.25	(0.21)	0.15	(0.13)	0.31	(0.36)	0.44	(0.24)
Pool (%)	0.23	(0.36)	0.05	(0.13)	0.24	(0.38)	0.11	(0.24)	0.33	(0.39)
Glide (%)	0.16	(0.22)	0.56	(0.38)	0.30	(0.33)	0.48	(0.41)	0.31	(0.32)
Riffle (%)	0.61	(0.38)	0.31	(0.33)	0.45	(0.42)	0.41	(0.38)	0.36	(0.29)
Shrub (%)	0.48	(0.29)	0.88	(0.20)	0.69	(0.30)	0.66	(0.32)	0.46	(0.35)
Overstory (%)	0.93	(0.08)	0.77	(0.34)	0.77	(0.36)	0.84	(0.27)	0.91	(0.08)
Vine maple (%)	0.00	(0.00)	0.32	(0.43)	0.42	(0.41)	0.43	(0.41)	0.46	(0.38)
Salmonberry (%)	0.16	(0.25)	0.53	(0.44)	0.14	(0.15)	0.26	(0.29)	0.00	(0.00)
Big-leaf maple (%)	0.36	(0.38)	0.11	(0.26)	0.09	(0.26)	0.28	(0.43)	0.65	(0.31)
Red alder (%)	0.59	(0.38)	0.74	(0.35)	0.61	(0.40)	0.56	(0.46)	0.00	(0.00)
Douglas-fir (%)	0.08	(0.22)	0.00	(0.00)	0.08	(0.15)	0.00	(0.00)	0.28	(0.29)
Western hemlock (%)	0.35	(0.40)	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)	0.11	(0.27)
Western red cedar (%)	0.00	(0.00)	0.00	(0.00)	0.09	(0.25)	0.03	(0.06)	.00	(0.00)

Appendix B. Mean values for habitat characteristics of 10 riparian areas in the Oregon Coast Range used for amphibian surveys in spring 2003

	Alma		Barking Dog		Crooked		Dead Deer		Ernest Creek	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
Temperature (deg C)	7.26	(0.47)	6.89	(1.15)	8.75	(0.38)	5.98	(1.11)	5.52	(1.35)
Relative humidity ( %)	0.96	(0.01)	0.98	(0.03)	0.95	(0.03)	1.02	(0.00)	1.01	(0.00)
Non-shrub ground cover (%)	0.58	(0.27)	0.56	(0.26)	0.63	(0.21)	0.45	(0.34)	0.40	(0.26)
Sword fern (%)	0.37	(0.28)	0.41	(0.30)	0.22	(0.22)	0.16	(0.14)	0.17	(0.18)
Bare ground (%)	0.03	(0.08)	0.02	(0.06)	0.00	(0.002)	0.00	(0.01)	0.03	(0.07)
Moss (%)	0.16	(0.22)	0.09	(0.11)	0.14	(0.14)	0.46	(0.32)	0.36	(0.25)
Rock (%)	0.00	(0.01)	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)	0.00	(0.01)
Litter (%)	0.90	(0.18)	0.92	(0.16)	0.83	(0.20)	0.68	(0.23)	0.68	(0.26)
Depth to soil (cm)	2.93	(1.88)	3.52	(2.42)	4.55	(3.24)	4.70	(2.16)	3.75	(3.34)
Trees (#/m <sup>2</sup> )	0.04	(0.19)	0.07	(0.38)	0.18	(0.55)	0.39	(1.17)	0.04	(0.19)
Standing dead wood cover (%)	0.00	(0.02)	0.00	(0.01)	0.03	(0.15)	0.01	(0.06)	0.02	(0.09)
Down wood (%)	0.06	(0.11)	0.05	(0.13)	0.09	(0.16)	0.08	(0.12)	0.22	(0.22)
Low shrub (%)	0.14	(0.19)	0.06	(0.13)	0.07	(0.11)	0.12	(0.11)	0.07	(0.09)
High shrub (%)	0.19	(0.24)	0.12	(0.19)	0.04	(0.07)	0.03	(0.07)	0.08	(0.15)
Overstory (%)	0.55	(0.33)	0.56	(0.26)	0.43	(0.27)	0.78	(0.26)	0.69	(0.32)
Vine maple (%)	0.00	(0.00)	0.04	(0.12)	0.01	(0.04)	0.01	(0.05)	0.08	(0.15)
Salmonberry (%)	0.05	(0.16)	0.07	(0.17)	0.02	(0.06)	0.00	(0.00)	0.00	(0.01)
Big-leaf maple (%)	0.22	(0.31)	0.26	(0.29)	0.04	(0.10)	0.00	(0.01)	0.00	(0.00)
Red alder (%)	0.00	(0.00)	0.15	(0.26)	0.20	(0.21)	0.02	(0.08)	0.03	(0.09)
Douglas-fir (%)	0.36	(0.30)	0.13	(0.27)	0.19	(0.32)	0.59	(0.38)	0.43	(0.38)
Western hemlock (%)	0.00	(0.00)	0.04	(0.19)	0.00	(0.00)	0.11	(0.29)	0.34	(0.39)
Western red cedar (%)	0.05	(0.15)	0.00	(0.00)	0.01	(0.07)	0.04	(0.17)	0.00	(0.00)

Appendix B. Continued.

	<u>Greasy Creek</u>		<u>Honey Grove</u>		<u>Nelson</u>		<u>Smith</u>		<u>S. Mountain</u>	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
Temperature (deg C)	7.01	(0.55)	10.18	(0.72)	9.66	(1.97)	8.29	(2.31)	8.90	(2.35)
Relative humidity ( %)	1.00	(0.02)	0.98	(0.02)	0.95	(0.02)	0.99	(0.02)	1.00	(0.01)
Non-shrub ground cover (%)	0.59	(0.27)	0.69	(0.21)	0.80	(0.15)	0.48	(0.31)	0.42	(0.25)
Sword fern (%)	0.31	(0.27)	0.23	(0.25)	0.55	(0.29)	0.34	(0.31)	0.33	(0.25)
Bare ground (%)	0.01	(0.03)	0.23	(0.23)	0.00	(0.01)	0.03	(0.07)	0.05	(0.10)
Moss (%)	0.36	(0.30)	0.14	(0.12)	0.13	(0.27)	0.28	(0.28)	0.20	(0.21)
Rock (%)	0.03	(0.16)	0.00	(0.00)	0.07	(0.12)	0.00	(0.00)	0.14	(0.27)
Litter (%)	0.86	(0.18)	0.67	(0.28)	0.90	(0.23)	0.81	(0.24)	0.75	(0.24)
Depth to soil (cm)	3.30	(2.01)	1.40	(1.34)	3.80	(2.68)	4.00	(2.11)	3.84	(2.21)
Trees (#/m <sup>2</sup> )	0.00	(0.00)	0.04	(0.19)	0.11	(0.42)	0.25	(0.44)	0.25	(0.52)
Standing dead wood cover (%)	0.03	(0.08)	0.00	(0.00)	0.00	(0.00)	0.01	(0.05)	0.01	(0.01)
Down wood (%)	0.09	(0.14)	0.05	(0.12)	0.03	(0.09)	0.03	(0.09)	0.09	(0.15)
Low shrub (%)	0.08	(0.11)	0.16	(0.19)	0.06	(0.11)	0.14	(0.18)	0.05	(0.09)
High shrub (%)	0.01	(0.04)	0.15	(0.21)	0.36	(0.34)	0.54	(0.40)	0.01	(0.03)
Overstory (%)	0.67	(0.29)	0.74	(0.26)	0.88	(0.22)	0.86	(0.18)	0.77	(0.28)
Vine maple (%)	0.00	(0.00)	0.01	(0.06)	0.26	(0.34)	0.50	(0.41)	0.01	(0.03)
Salmonberry (%)	0.00	(0.00)	0.14	(0.21)	0.03	(0.11)	0.03	(0.08)	0.00	(0.00)
Big-leaf maple (%)	0.11	(0.17)	0.17	(0.23)	0.56	(0.42)	0.06	(0.21)	0.01	(0.04)
Red alder (%)	0.08	(0.17)	0.49	(0.33)	0.23	(0.33)	0.52	(0.42)	0.00	(0.00)
Douglas-fir (%)	0.34	(0.38)	0.04	(0.17)	0.11	(0.25)	0.27	(0.37)	0.60	(0.36)
Western hemlock (%)	0.20	(0.33)	0.00	(0.00)	0.00	(0.00)	0.04	(0.19)	0.13	(0.30)
Western red cedar (%)	0.00	(0.00)	0.10	(0.29)	0.07	(0.22)	0.01	(0.03)	0.14	(0.29)

Appendix C. Watershed characteristics for the 10 Oregon Coast Range streams and riparian areas used in this study.

Site name	Alma	Barking Dog	Crooked	Dead Deer	Ernest Creek
Legal description	19s.6w.19	17s.7w.17	13s.7w.11	14s.6w.31	13s.7w.23
Site description	Unnamed tributary of the Siuslaw	Unnamed tributary of Knapp Creek	Unnamed tributary of Crooked Creek	Unnamed tributary of the Alsea River	Ernest Creek
Stream order	2nd	3rd	3rd	3rd	2nd
Watershed	Siuslaw	Siuslaw	Alsea	Alsea	Alsea
Ownership	BLM	ODF	BLM	BLM	BLM
Watershed size (km <sup>2</sup> )	61.07	64.62	62.88	50.62	52.33
Elevation (m)	306	248	300	289	535
Hill-slope (%)	0.61	0.34	0.12	0.25	0.31
Hill-slope (SD)	(0.15)	(0.11)	(0.08)	(0.05)	(0.10)
Stream aspect (degrees)	158.80	202.60	158.00	274.20	275.60
Lithology	Marine	Marine	Volcanic	Marine	Volcanic
Fish (observed)	No	Yes	Yes	No	No

Site name	Greasy Creek	Honey Grove	Nelson	Smith	S. Mountain
Legal description	13s.6w.7	13s.7w.33	17s.8w.1	20s.6w.13	14s.7w.17
Site description	Greasy Creek	Unnamed tributary of Honey Grove Creek	Unnamed tributary of Nelson Creek	Unnamed tributary of Smith Creek	Unnamed tributary of the Alsea River
Stream order	3rd	3rd	3rd	2nd	2nd
Watershed	Willamette	Alsea	Siuslaw	Siuslaw	Alsea
Ownership	BLM	BLM	BLM	BLM	BLM
Watershed size (km <sup>2</sup> )	150.49	88.89	118.08	59.24	74.81
Elevation (m)	256	137	251	194	290
Hill-slope (%)	0.39	0.21	0.26	0.36	0.54
Hill-slope (SD)	(0.04)	(0.08)	(0.10)	(0.10)	(0.06)
Stream aspect (degrees)	55.40	180.00	177.20	170.60	220.60
Lithology	Volcanic	Marine	Marine	Marine	Volcanic
Fish (observed)	Yes	Yes	Yes	Yes	No

Appendix D. Number of aquatic amphibians detected during 3 surveys of  
10 Oregon Coast Range streams.

July 2002

Site	ASTR <sup>a</sup>	DITE	PLDU	RAAU	RH spp	TAGR	TDITE	Total
Alma	0	7	1	0	0	0	2	10
Barking Dog	1	4	0	0	0	0	0	5
Crooked	0	3	0	0	0	0	0	3
Dead Deer	0	11	0	0	0	4	0	15
Ernest Creek	6	45	0	0	1	0	0	52
Greasy Creek	0	3	1	0	0	0	0	4
Honey Grove	0	1	0	0	0	4	0	5
Nelson	1	10	1	0	0	0	0	12
Smith	0	0	0	0	0	0	0	0
S. Mountain	0	3	0	0	1	0	0	4
Grand Total	8	87	3	0	2	8	2	110

October 2002

Site	ASTR	DITE	PLDU	RAAU	RH spp	TAGR	TDITE	Total
Alma	0	3	1	0	0	0	1	4
Barking Dog	0	0	0	0	0	0	0	0
Crooked	0	0	0	0	0	0	0	0
Dead Deer	0	3	0	0	0	1	0	4
Ernest Creek	0	36	0	0	1	0	1	38
Greasy Creek	0	4	2	0	0	1	0	7
Honey Grove	0	0	0	0	0	0	0	0
Nelson	0	9	1	0	0	0	0	10
Smith	0	0	0	0	0	0	0	0
S. Mountain	0	4	0	0	2	0	0	6
Grand Total	0	59	4	0	3	2	2	69

June 2003

Site	ASTR	DITE	PLDU	RAAU	RH spp	TAGR	TDITE	Total
Alma	0	5	1	0	1	0	0	7
Barking Dog	0	6	0	0	0	0	0	6
Crooked	1	1	0	0	0	0	0	2
Dead Deer	0	13	0	0	0	8	0	21
Ernest Creek	7	48	0	0	1	1	0	57
Greasy Creek	1	6	3	0	0	1	0	11
Honey Grove	0	0	0	0	0	2	0	2
Nelson	6	20	1	0	0	0	0	27
Smith	0	0	0	0	0	0	0	0
So. Mtn	0	4	0	1	1	0	0	6
Grand Total	15	103	5	1	3	12	0	139

<sup>a</sup> ASTR, larval *Ascaphus truei*; DITE, larval *Dicamptodon tenebrosus*; PLDU, *Plethodon dunni*; RAAU, *Rana aurora*; RH spp, *Rhyacotriton* spp.; TAGR, *Taricha granulosa*; TDITE, adult *Dicamptodon tenebrosus*

Appendix E. Number of terrestrial amphibians detected in riparian areas at 10 sites in the Oregon Coast Range during 2 survey periods.

Fall 2002

Site	AMGR <sup>a</sup>	ENES	HYRE	PLDU	PLVE	RAAU	RH spp	TAGR	TDITE	Total
Alma	0	0	0	0	0	0	0	0	1	1
Barking Dog	0	0	0	0	1	0	1	0	0	2
Crooked	0	0	0	0	3	0	0	0	0	3
Dead Deer	0	3	0	1	2	0	1	1	0	8
Ernest Creek	0	1	0	0	0	0	1	0	2	4
Greasy Creek	0	0	1	0	5	0	0	0	0	6
Honey Grove	0	0	0	0	10	0	0	0	0	10
Nelson	0	1	0	0	2	0	0	0	1	4
Smith	0	0	0	0	0	0	0	0	0	0
S. Mountain	0	0	0	1	12	0	0	0	1	14
Total	0	5	1	2	35	0	3	1	5	52

Spring 2003

Site	AMGR	ENES	HYRE	PLDU	PLVE	RAAU	RH spp	TAGR	TDITE	Total
Alma	0	0	0	2	2	0	3	0	0	7
Barking Dog	0	1	0	0	7	0	1	3	1	13
Crooked	0	2	0	0	4	0	0	0	0	6
Dead Deer	0	0	0	0	7	0	0	5	0	12
Ernest Creek	0	2	0	2	1	0	1	5	1	12
Greasy Creek	1	3	1 <sup>b</sup>	1	10	0	0	1	0	17
Honey Grove	0	0	2	0	5	0	0	2	0	9
Nelson	0	0	0	1	0	4	0	1	0	6
Smith	0	1	0	2	0	2	0	1	0	6
S. Mountain	0	2	0	0	26	1	1	3	0	33
Total	1	11	4	8	62	7	6	21	2	122

<sup>a</sup> AMGR, *Ambystoma gracile* ; ENES, *Ensatina eschscholtzii* ; HYRE, *Hyla regilla*;

PLDU, *Plethodon dunni* ; PLVE, *Plethodon vehiculum* , RAAU, *Rana aurora* ;

RH spp, *Rhyacotriton* spp.; TAGR, *Taricha granulosa* ; TDITE, adult *Dicamptodon tenebrosus*

<sup>b</sup> Recaptured from fall 2002

Appendix F. Candidate model set for logistic regression analysis predicting the presence of *Dicamptodon tenebrosus* larvae in 10 streams in the Oregon Coast Range, July and October 2002 and June 2003.

Model <sup>a</sup>	K <sup>b</sup>	Log(L)	AIC	AICc	$\Delta$ AICc	$w_i$ <sup>c</sup>	Evidence Ratio
+ % Douglas-fir cover + elevation - wood cover - lithology	5	-74.03	158.05	158.47	0.00	0.95	
- % red alder cover + elevation - wood cover - lithology	5	-78.06	166.12	166.54	8.07	0.02	56.59
- % western hemlock cover + elevation - wood cover - lithology	5	-78.15	166.29	166.71	8.24	0.02	61.54
- % big-leaf maple cover + elevation - wood cover - lithology	5	-78.16	166.32	166.74	8.27	0.02	62.37
+ % Douglas-fir cover - fish + lithology - wood cover - stream gradient	6	-85.15	182.31	182.90	24.43	0.00	2.01E+05
- % big-leaf maple cover - fish + lithology - wood cover + stream gradient	6	-86.71	185.42	186.01	27.54	0.00	9.54E+05
+ % red alder cover - fish + lithology - wood cover + stream gradient	6	-87.41	186.83	187.41	28.94	0.00	1.93E+06
- % western hemlock cover - fish + lithology - wood cover + stream gradient	6	-87.42	186.83	187.42	28.95	0.00	1.93E+06
+ % Douglas-fir cover - wood cover + lithology	4	-89.83	187.65	187.93	29.46	0.00	2.49E+06
+ % Douglas-fir cover + watershed - wood cover + lithology	5	-89.24	188.47	188.89	30.42	0.00	4.03E+06
+ % Douglas-fir cover + lithology + % pool - wood cover	5	-89.79	189.59	190.01	31.54	0.00	7.05E+06
+ % Douglas-fir cover + % pebble + % pool - wood cover	5	-91.10	192.20	192.61	34.14	0.00	2.59E+07
+ % Douglas-fir cover + % cobble + % pool - wood cover	5	-91.59	193.18	193.60	35.13	0.00	4.24E+07
+ % Douglas-fir cover - % gravel + % pool - wood cover	5	-93.18	196.36	196.78	38.31	0.00	2.08E+08
- % red alder cover - wood cover + lithology	4	-96.67	201.34	201.61	43.14	0.00	2.34E+09
- % red alder cover + watershed - wood cover + lithology	5	-96.12	202.23	202.65	44.18	0.00	3.92E+09
- % red alder cover + lithology + % pool - wood cover	5	-96.42	202.83	203.25	44.78	0.00	5.29E+09
+ lithology + % pool - wood cover	4	-99.32	206.65	206.92	48.45	0.00	3.32E+10
- % red alder cover + % cobble + % pool - wood cover	5	-98.32	206.64	207.06	48.59	0.00	3.56E+10
- % big-leaf maple cover - wood cover + lithology	4	-99.82	207.64	207.92	49.45	0.00	5.46E+10
- % western hemlock cover - wood cover + lithology	4	-99.93	207.86	208.14	49.67	0.00	6.09E+10
- % red alder cover + % pebble + % pool - wood cover	5	-98.95	207.90	208.31	49.84	0.00	6.66E+10

<sup>a</sup> Variables shown with sign of coefficient in model.

<sup>b</sup> K is the number of parameters in the model

<sup>c</sup> Weight of evidence for the relative likelihood of each candidate model.



Appendix F. Continued

Model <sup>a</sup>	K <sup>b</sup>	Log(L)	AIC	AICc	ΔAICc	w <sub>i</sub> <sup>c</sup>	Evidence Ratio
- % big-leaf maple cover + lithology + % pool - wood cover	5	-99.03	208.07	208.49	50.02	0.00	7.26E+10
- overstory + lithology + % pool - wood cover	5	-99.16	208.32	208.74	50.27	0.00	8.24E+10
- % western hemlock cover + lithology + % pool - wood cover	5	-99.17	208.35	208.77	50.30	0.00	8.35E+10
- % shrub cover + lithology + % pool - wood cover	5	-99.27	208.54	208.96	50.49	0.00	9.19E+10
- % big-leaf maple cover + watershed - wood cover + lithology	5	-99.73	209.45	209.87	51.40	0.00	1.45E+11
+ % cobble + % pool - wood cover	4	-100.82	209.64	209.91	51.44	0.00	1.48E+11
- % western hemlock cover + watershed - wood cover + lithology	5	-99.80	209.59	210.01	51.54	0.00	1.55E+11
Null	2	-103.97	209.94	210.03	51.56	0.00	1.57E+11
- % red alder cover - % gravel + % pool - wood cover	5	-99.91	209.83	210.24	51.78	0.00	1.75E+11
- % big-leaf maple cover + % cobble + % pool - wood cover	5	-100.45	210.90	211.32	52.85	0.00	2.99E+11
- % shrub cover + % cobble + % pool - wood cover	5	-100.61	211.22	211.64	53.17	0.00	3.51E+11
- % western hemlock cover + % cobble + % pool - wood cover	5	-100.77	211.53	211.95	53.48	0.00	4.10E+11
- % overstory cover + % cobble + % pool - wood cover	5	-100.78	211.57	211.99	53.52	0.00	4.18E+11
+ % pebble + % pool - wood cover	4	-102.07	212.13	212.41	53.94	0.00	5.16E+11
- % gravel + % pool - wood cover	4	-102.55	213.10	213.38	54.91	0.00	8.39E+11
- % big-leaf maple cover + % pebble + % pool - wood cover	5	-101.79	213.57	213.99	55.52	0.00	1.14E+12
- % shrub cover + % pebble + % pool - wood cover	5	-101.80	213.60	214.02	55.55	0.00	1.16E+12
- % overstory cover + % pebble + % pool - wood cover	5	-102.04	214.08	214.50	56.03	0.00	1.47E+12
+ % western hemlock cover + % pebble + % % pool - wood cover	5	-102.07	214.13	214.55	56.08	0.00	1.50E+12
- % big-leaf maple cover - % gravel + % pool - wood cover	5	-102.33	214.66	215.08	56.61	0.00	1.96E+12
- % shrub cover - % gravel + % pool - wood cover	5	-102.40	214.79	215.21	56.74	0.00	2.09E+12
- % western hemlock cover - % gravel + % pool - wood cover	5	-102.52	215.03	215.45	56.98	0.00	2.36E+12
- % overstory cover - % gravel + % pool - wood cover	5	-102.55	215.09	215.51	57.04	0.00	2.43E+12

<sup>a</sup> Variables shown with sign of coefficient in model.

<sup>b</sup> K is the number of parameters in the model

<sup>c</sup> Weight of evidence for the relative likelihood of each candidate model.

Appendix G. Candidate model set for logistic regression analysis predicting the presence of *Plethodon vehiculum* in 10 riparian areas in the Oregon Coast Range, fall 2002 and spring 2003.

Model <sup>a</sup>	K <sup>b</sup>	Log(L)	AIC	AICc	$\Delta$ AICc	$w_i$ <sup>c</sup>	Evidence Ratio
- date - elevation + lithology + % western hemlock cover	5	-99.33	208.66	208.88	0.00	0.35	
- date - elevation + lithology + % overstory cover	5	-99.75	209.51	209.73	0.84	0.23	1.53
- date - elevation + lithology + % Douglas-fir cover	5	-100.49	210.98	211.20	2.31	0.11	3.18
- date - elevation + lithology	4	-101.54	211.08	211.23	2.35	0.11	3.23
- date - elevation + lithology - % red alder cover	5	-100.73	211.46	211.68	2.80	0.09	4.05
- date - elevation + lithology - % big-leaf maple cover	5	-101.16	212.33	212.55	3.66	0.06	6.25
- date + % western hemlock cover + slope + distance	5	-103.03	216.05	216.27	7.39	0.01	40.21
- date + % overstory cover + slope + distance	5	-103.20	216.40	216.61	7.73	0.01	47.76
- date + % red alder cover + slope + distance	5	-103.37	216.75	216.97	8.09	0.01	56.99
- date - % big-leaf maple cover + slope + distance	5	-103.54	217.08	217.30	8.42	0.01	67.36
- date + % Douglas-fir cover + slope + distance	5	-103.81	217.62	217.84	8.96	0.00	88.10
- date + watershed + lithology + % overstory cover	5	-104.05	218.11	218.33	9.45	0.00	112.51
- date + % overstory cover - % low shrub cover + % down wood + % rock	6	-103.01	218.03	218.33	9.45	0.00	112.86
- date + watershed + lithology	4	-105.34	218.67	218.82	9.94	0.00	143.87
- date + % Douglas-fir cover - % low shrub cover + % down wood + % rock	6	-103.55	219.10	219.41	10.53	0.00	193.39
- date + temperature - humidity	4	-105.71	219.42	219.57	10.69	0.00	209.13
- date + watershed + lithology + % western hemlock cover	5	-104.71	219.41	219.63	10.75	0.00	215.59
- date + % western hemlock cover - % low shrub cover + % down wood + % rock	6	-103.73	219.47	219.77	10.89	0.00	231.66
- date - % big-leaf maple cover - % low shrub cover + % down wood + % rock	6	-103.77	219.54	219.85	10.97	0.00	241.03

<sup>a</sup> Variables shown with sign of coefficient in model.

<sup>b</sup> K is the number of parameters in the model

<sup>c</sup> Weight of evidence for the relative likelihood of each candidate model.

Appendix G. Continued

model <sup>a</sup>	K <sup>b</sup>	Log(L)	AIC	AICc	ΔAICc	w <sub>i</sub> <sup>c</sup>	Evidence Ratio
- date + watershed + lithology + % Douglas-fir cover	5	-104.84	219.68	219.90	11.02	0.00	247.10
- date + watershed + lithology - % big-leaf maple cover	5	-104.91	219.82	220.04	11.16	0.00	265.30
- date + % red alder cover - % low shrub cover + % down wood + % rock	6	-104.18	220.36	220.66	11.78	0.00	361.91
- date + % overstory cover - % high shrub cover + % down wood + % rock	6	-104.20	220.39	220.70	11.82	0.00	368.69
- date + watershed + lithology - % red alder cover	5	-105.32	220.64	220.86	11.98	0.00	399.31
- date - % big-leaf maple cover - % high shrub cover + % down wood + % rock	6	-104.45	220.90	221.20	12.32	0.00	473.83
- date + % western hemlock cover - % high shrub cover + % down wood + % rock	6	-104.62	221.24	221.54	12.66	0.00	561.61
- date + % Douglas-fir cover - % high shrub cover + % down wood + % rock	6	-104.80	221.60	221.90	13.02	0.00	672.40
- date + % overstory cover - % moss cover + % down wood + % rock	6	-104.83	221.66	221.97	13.09	0.00	695.38
- date + % red alder cover - % high shrub cover + % down wood + % rock	6	-105.08	222.16	222.47	13.59	0.00	892.39
- date + % overstory cover - depth to soil + % down wood + % rock	6	-105.28	222.55	222.86	13.98	0.00	1.09E+03
- date + % overstory cover + % litter cover + % down wood + % rock	6	-105.34	222.68	222.98	14.10	0.00	1.15E+03
- date + % western hemlock cover - % moss cover + % down wood + % rock	6	-105.42	222.84	223.15	14.27	0.00	1.25E+03
- date	2	-109.64	223.29	223.33	14.45	0.00	1.37E+03
- date + % Douglas-fir cover - % moss cover + % down wood + % rock	6	-105.56	223.12	223.43	14.55	0.00	1.44E+03
- date + % western hemlock cover - depth to soil + % down wood + % rock	6	-105.71	223.42	223.73	14.85	0.00	1.68E+03
- date + % western hemlock cover + % litter cover + % down wood + % rock	6	-105.75	223.50	223.80	14.92	0.00	1.74E+03
- date - % big-leaf maple cover - % moss cover + % down wood + % rock	6	-105.77	223.54	223.84	14.96	0.00	1.77E+03
- date + % overstory cover - % low shrub cover - depth to soil - % ground cover	6	-105.99	223.99	224.30	15.41	0.00	2.22E+03
- date + % Douglas-fir cover - depth to soil + % down wood + % rock	6	-106.06	224.12	224.43	15.55	0.00	2.38E+03
- date - % red alder cover - % moss cover + % down wood + % rock	6	-106.09	224.18	224.49	15.61	0.00	2.45E+03

<sup>a</sup> Variables shown with sign of coefficient in model.

<sup>b</sup> K is the number of parameters in the model

<sup>c</sup> Weight of evidence for the relative likelihood of each candidate model.

Appendix G. Continued

model <sup>a</sup>	K <sup>b</sup>	Log(L)	AIC	AICc	ΔAICc	w <sub>i</sub> <sup>c</sup>	Evidence Ratio
- date + % Douglas-fir cover + % litter cover + % down wood + % rock	6	-106.11	224.22	224.53	15.65	0.00	2.50E+03
- date - % big-leaf maple cover - depth to soil + % down wood + % rock	6	-106.11	224.23	224.53	15.65	0.00	2.51E+03
- date - % big-leaf maple cover + % litter cover + % down wood + % rock	6	-106.14	224.29	224.59	15.71	0.00	2.58E+03
- date + % Douglas-fir cover - % low shrub cover - depth to soil - % ground cover	6	-106.34	224.68	224.99	16.10	0.00	3.14E+03
- date - depth to soil - % ground cover + % down wood + % rock	6	-106.37	224.75	225.06	16.18	0.00	3.25E+03
- date - % red alder cover - depth to soil + % down wood + % rock	6	-106.39	224.78	225.09	16.21	0.00	3.31E+03
- date - % red alder cover + % litter cover + % down wood + % rock	6	-106.43	224.87	225.17	16.29	0.00	3.45E+03
- date + % western hemlock cover - % low shrub cover - depth to soil - % ground cover	6	-106.75	225.50	225.81	16.92	0.00	4.73E+03
- date - % big-leaf maple cover - % low shrub cover - depth to soil - % ground cover	6	-106.97	225.94	226.25	17.37	0.00	5.91E+03
- date + % overstory cover - % high shrub cover - depth to soil - % ground cover	6	-107.01	226.02	226.33	17.45	0.00	6.15E+03
- date + % overstory cover - depth to soil - % ground cover	5	-108.34	226.68	226.90	18.02	0.00	8.19E+03
- date - % red alder cover - % low shrub cover - depth to soil - % ground cover	6	-107.31	226.62	226.93	18.05	0.00	8.29E+03
- date - % big-leaf maple cover - % high shrub cover - depth to soil - % ground cover	6	-107.33	226.67	226.98	18.09	0.00	8.49E+03
- date + % western hemlock cover - % high shrub cover - depth to soil - % ground cover	6	-107.39	226.78	227.09	18.21	0.00	8.99E+03
- date + % Douglas-fir cover - % high shrub cover - depth to soil - % ground cover	6	-107.49	226.98	227.29	18.41	0.00	9.92E+03
- date + % western hemlock cover - depth to soil - % ground cover	5	-108.63	227.25	227.47	18.59	0.00	1.09E+04
- date + % Douglas-fir cover - depth to soil - % ground cover	5	-109.02	228.05	228.27	19.38	0.00	1.62E+04
- date - % red alder cover - % high shrub cover - depth to soil - % ground cover	6	-107.98	227.97	228.28	19.40	0.00	1.63E+04
- date - % big-leaf maple cover - depth to soil - % ground cover	5	-109.29	228.57	228.79	19.91	0.00	2.11E+04
- date - % red alder cover - depth to soil - % ground cover	5	-109.46	228.92	229.14	20.26	0.00	2.51E+04
Null	2	-123.44	248.88	248.92	40.04	0.00	4.95E+08

<sup>a</sup> Variables shown with sign of coefficient in model.

<sup>b</sup> K is the number of parameters in the model

<sup>c</sup> Weight of evidence for the relative likelihood of each candidate model.

Appendix H. Model-averaged estimates for variables in the best approximating models ( $\leq 2 \Delta \text{AICc}$  units) and canopy variables for *Plethodon vehiculum* logistic regression analysis.

Variable	Estimate	Unconditional SE	95 % Confidence Interval
intercept	6.74	2.23	2.38, 11.10
elevation	0.94	0.00	-0.02, 0.00
lithology	0.58	0.20	0.18, 0.98
% western hemlock cover	0.49	0.39	-0.22, 1.20
% overstory cover	0.28	0.27	0.24, 0.81
date	-0.06	0.02	-0.03, -0.09
% Douglas-fir cover	0.08	0.09	-0.10, 0.26
% red alder cover	-0.09	0.13	-0.25, 0.17
% big-leaf maple cover	-0.07	0.10	-0.27, 0.14

Appendix I. Number of aquatic salamanders captured for stomach analysis during 3 survey periods at 10 streams in the Oregon Coast Range <sup>a</sup>.

July 2002

Site	DITE <sup>b</sup>	PLDU	TAGR	TDITE	Total
Alma	6	1	0	2	9
Barking Dog	3	0	0	0	3
Crooked	3	0	0	0	3
Dead Deer	9	0	4	0	13
Ernest Creek	42	0	0	0	42
Greasy Creek	3	1	0	0	4
Honey Grove	1	0	3	0	4
Nelson	9	1	0	0	10
Smith	0	0	0	0	0
S. Mountain	1	0	0	0	1
Total Captured	77	3	7	2	89

October 2002

Site	DITE	PLDU	TAGR	TDITE	Total
Alma	2	0	0	0	2
Barking Dog	0	0	0	0	0
Crooked	0	0	0	0	0
Dead Deer	3	0	0	0	3
Ernest Creek	33	0	0	0	33
Greasy Creek	3	2	1	0	6
Honey Grove	0	0	0	0	0
Nelson	8	2	0	0	10
Smith	0	0	0	0	0
S. Mountain	3	0	0	0	3
Total Captured	52	4	1	0	57

<sup>b</sup> DITE, larval *Dicamptodon tenebrosus* ; PLDU, *Plethodon dunni* ;  
 RAAU, *Rana aurora* ; TAGR, *Taricha granulosa* ;  
 TDITE, adult *Dicamptodon tenebrosus*

## Appendix I. Continued.

June 2003

Site	DITE	PLDU	TAGR	TDITE	Total
Alma	5	1	0	0	6
Barking Dog	6	0	0	0	6
Crooked	1	0	0	0	1
Dead Deer	11	0	7	0	18
Ernest Creek	45	0	1	0	46
Greasy Creek	5	3	1	0	9
Honey Grove	0	0	2	0	2
Nelson	15	1	0	0	16
Smith	0	0	0	0	0
So. Mtn	4	0	0	0	4
Total Captured	92	5	11	0	108

<sup>a</sup>21 larval *Ascaphus truei* and 8 *Rhyacotriton* spp. also captured

<sup>b</sup>DITE, larval *Dicamptodon tenebrosus* ; PLDU, *Plethodon dunni* ; TAGR, *Taricha granulosa*

Appendix J. Number of terrestrial amphibians captured for stomach analysis during 2 survey periods at 10 sites in the Oregon Coast Range <sup>a</sup>.

Fall 2002

Site	AMGR <sup>b</sup>	ENES	HYRE	PLDU	PLVE	RAAU	TAGR	TDITE	Total
Alma	0	0	0	0	0	0	0	1	1
Barking Dog	0	0	0	0	1	0	0	0	1
Crooked	0	0	0	0	3	0	0	0	3
Dead Deer	0	3	0	1	1	0	1	0	6
Ernest Creek	0	1	0	0	0	0	0	2	3
Greasy Creek	0	0	1	0	5	0	0	0	6
Honey Grove	0	0	0	0	7	0	0	0	7
Nelson	0	1	0	0	2	0	0	1	4
Smith	0	0	0	0	0	0	0	0	0
S. Mountain	0	0	0	1	12	0	0	1	14
Total Captured	0	5	1	2	31	0	1	5	45

Spring 2003

Site	AMGR	ENES	HYRE	PLDU	PLVE	RAAU	TAGR	TDITE	Total
Alma	0	0	0	2	2	0	0	0	4
Barking Dog	0	1	0	0	7	0	2	1	11
Crooked	0	2	0	0	4	0	0	0	6
Dead Deer	0	0	0	0	7	0	5	0	12
Ernest Creek	0	2	0	2	1	0	5	1	11
Greasy Creek	1	3	1 <sup>c</sup>	1	9	0	1	0	16
Honey Grove	0	0	2	0	5	0	2	0	9
Nelson	0	0	0	1	0	4	1	0	6
Smith	0	1	0	2	0	2	1	0	6
S. Mountain	0	2	0	0	26	1	3	0	32
Total Captured	1	11	3	8	61	7	20	2	113

<sup>a</sup> 9 *Rhyacotriton* spp. Captured

<sup>b</sup> AMGR, *Ambystoma gracile*; ENES, *Ensatina eschscholtzii*; HYRE, *Hyla regilla*; PLDU, *Plethodon dunni*; PLVE, *Plethodon vehiculum*; RAAU, *Rana aurora*; TAGR, *Taricha granulosa*; TDITE, adult *Dicamptodon tenebrosus*

<sup>c</sup> Same individual caught both seasons



Appendix K. Candidate model set for generalized linear least squares regression analysis examining larval *Dicamptodon tenebrosus* stomach fullness relationships with habitat features in 10 streams in the Oregon Coast Range during 3 survey periods.

Model <sup>a</sup>	K <sup>b</sup>	Log(l)	AIC	AICc	$\Delta$ AICc	$w_i$ <sup>c</sup>	Evidence Ratio
- % pool + % pebble + % western hemlock cover	5	-279.19	568.37	568.65	0.00	0.34	
- % pool - % gravel + % western hemlock cover	5	-279.74	569.47	569.75	1.10	0.20	1.69
- % pool - % cobble + % western hemlock cover	5	-280.29	570.58	570.86	2.21	0.11	2.93
- % pool + wood cover + % western hemlock cover	5	-280.29	570.58	570.87	2.21	0.11	2.94
- % gravel - % pool	4	-281.84	571.67	571.86	3.21	0.07	4.84
- % gravel - % pool - % shrub cover	5	-281.08	572.17	572.45	3.80	0.05	6.50
- % pool - % gravel - % Douglas-fir cover	5	-281.80	573.60	573.89	5.23	0.02	13.32
- % pool - % gravel + % red alder cover	5	-281.84	573.67	573.95	5.30	0.02	13.77
- % pool - % gravel + % big-leaf maple cover	5	-281.84	573.67	573.96	5.30	0.02	13.80
+ % western hemlock cover	3	-283.97	573.94	574.05	5.40	0.02	14.45
- % pool + wood cover - salmonberry	5	-283.09	576.17	576.45	7.80	0.01	48.06
+ fish + wood cover + % western hemlock cover	5	-283.65	577.30	577.58	8.93	0.00	84.54
- % cobble - % pool	4	-285.35	578.69	578.88	10.22	0.00	161.56
- % pool - % cobble + % Douglas-fir cover	5	-285.00	580.00	580.28	11.63	0.00	325.55
- % pool - % cobble - % big-leaf maple cover	5	-285.21	580.42	580.70	12.05	0.00	401.86
- % cobble - % pool - % shrub cover	5	-285.25	580.50	580.78	12.13	0.00	419.02
- % pool - % cobble - % red alder cover	5	-285.32	580.65	580.93	12.27	0.00	450.34
- elevation - % pool + wood cover	5	-286.07	582.15	582.43	13.77	0.00	953.42
- % pool + wood cover - % shrub cover	5	-286.35	582.71	582.99	14.34	0.00	1.26E+03
- % pool - elevation	4	-287.57	583.14	583.33	14.68	0.00	1.50E+03

<sup>a</sup> Variables shown with sign of coefficient in model.

<sup>b</sup> K is the number of parameters in the model.

<sup>c</sup> Weight of evidence for the relative likelihood of each candidate model.

Appendix K. Continued

Model <sup>a</sup>	K <sup>b</sup>	Log(L)	AIC	AICc	ΔAICc	w <sub>i</sub> <sup>c</sup>	Evidence Ratio
Null	2	-289.82	583.65	583.70	15.05	0.00	1.80E+03
- % pool + wood cover	4	-287.77	583.55	583.74	15.08	0.00	1.83E+03
- % pebble - % pool	4	-287.94	583.88	584.06	15.41	0.00	2.16E+03
- % pool - watershed	4	-288.02	584.05	584.24	15.58	0.00	2.35E+03
+ % pebble - % pool - % shrub cover	5	-287.05	584.09	584.38	15.72	0.00	2.53E+03
- elevation	3	-289.18	584.36	584.47	15.81	0.00	2.64E+03
- % pool - % pebble + % Douglas-fir cover	5	-287.21	584.42	584.70	16.05	0.00	2.97E+03
- % pool - wood cover + % Douglas-fir cover	5	-287.26	584.51	584.80	16.14	0.00	3.12E+03
- % western red cedar cover	3	-289.37	584.75	584.86	16.21	0.00	3.22E+03
- % pool - % pebble - % red alder cover	5	-287.30	584.60	584.89	16.23	0.00	3.26E+03
- % pool + wood cover - % red alder cover	5	-287.33	584.66	584.95	16.29	0.00	3.36E+03
- % red alder cover	3	-289.59	585.18	585.29	16.64	0.00	3.99E+03
+ % big-leaf maple cover	3	-289.74	585.48	585.59	16.94	0.00	4.63E+03
+ % Douglas-fir cover	3	-289.78	585.56	585.67	17.02	0.00	4.83E+03
- % pool + wood cover + vine maple	5	-287.72	585.43	585.72	17.06	0.00	4.94E+03
- % pool + wood cover - % big-leaf maple cover	5	-287.77	585.54	585.82	17.17	0.00	5.21E+03
- % pool - % pebble - % big-leaf maple cover	5	-287.87	585.74	586.03	17.37	0.00	5.76E+03
+ fish + wood cover - % red alder cover	5	-289.30	588.61	588.89	20.24	0.00	2.41E+04
+ fish + wood cover + % big-leaf maple cover	5	-289.67	589.34	589.62	20.97	0.00	3.48E+04
+ fish + wood cover + % Douglas-fir cover	5	-289.71	589.41	589.70	21.04	0.00	3.61E+04

<sup>a</sup> Variables shown with sign of coefficient in model.

<sup>b</sup> K is the number of parameters in the model.

<sup>c</sup> Weight of evidence for the relative likelihood of each candidate model.

Appendix L. Model-averaged estimates for variables in the best approximating models ( $\leq 2 \Delta \text{AICc}$  units) and canopy variables for *Dicamptodon tenebrosus* generalized linear least squares analysis.

Variable	Estimate	Unconditional SE	95 % Confidence Interval
Intercept	1.20	0.47	0.28, 2.12
% pool	-0.93	0.53	-1.96, 0.10
% pebble	0.35	0.30	-0.23, 0.94
% gravel	-0.93	0.70	-2.31, 0.45
% western hemlock cover	1.53	0.64	-0.27, 2.78
% Douglas-fir cover <sup>a</sup>	0.00	0.01	-0.03, 0.02
% red alder cover	0.00	0.01	-0.02, 0.02
% big-leaf maple cover <sup>a</sup>	0.00	0.01	-0.02, 0.02

<sup>a</sup> Sign of parameter is negative

Appendix M. Candidate model set for generalized linear least squares regression analysis examining *Plethodon vehiculum* stomach fullness relationships with habitat features in 10 riparian areas in the Oregon Coast Range during 2 survey periods.

Model <sup>a</sup>	K <sup>b</sup>	Log(l)	AIC	AICc	$\Delta$ AICc	$w_i$ <sup>c</sup>	Evidence Ratio
+ down wood + rock + litter + red alder cover	6	-52.75	117.50	118.67	0.00	0.69	
- Douglas-fir cover	3	-58.58	123.16	123.48	4.82	0.06	11.12
+ down wood + rock + litter - Douglas-fir cover	6	-55.25	122.49	123.66	4.99	0.06	12.14
+ down wood - rock + litter - moss	6	-55.92	123.85	125.02	6.35	0.03	23.91
+ down wood + rock + standing dead wood - Douglas-fir cover	6	-56.27	124.55	125.71	7.05	0.02	33.88
+ down wood - rock + litter	5	-57.54	125.08	125.90	7.24	0.02	37.29
- ground cover + depth to soil - Douglas-fir cover	5	-57.71	125.42	126.24	7.58	0.02	44.17
+ big-leaf maple cover	3	-59.99	125.99	126.31	7.64	0.02	45.63
+ red alder cover	3	-60.37	126.74	127.06	8.40	0.01	66.52
+ down wood - rock	4	-59.44	126.89	127.43	8.76	0.01	79.90
+ down wood - rock + litter + big-leaf maple cover	6	-57.48	126.97	128.13	9.47	0.01	113.59
+ down wood - rock + litter - low shrub	6	-57.49	126.98	128.14	9.47	0.01	114.14
+ down wood - rock + litter - high shrub	6	-57.50	126.99	128.16	9.49	0.01	115.13
+ ground cover + depth to soil + big-leaf maple cover	5	-58.69	127.39	128.21	9.54	0.01	118.06
+ ground cover + depth to soil + red alder cover	5	-58.77	127.54	128.36	9.69	0.01	127.15

<sup>a</sup> Variables shown with sign of coefficient in model.

<sup>b</sup> K is the number of parameters in the model.

<sup>c</sup> Weight of evidence for the relative likelihood of each candidate model.

Appendix M. Continued

Model <sup>a</sup>	K <sup>b</sup>	Log(l)	AIC	AICc	?AICc	w <sub>i</sub> <sup>c</sup>	Evidence Ratio
+ down wood - rock + standing dead wood + red alder cover	6	-57.65	127.29	128.46	9.79	0.01	133.60
+ ground cover + depth to soil + high shrub	5	-58.82	127.64	128.46	9.79	0.01	133.68
+ down wood - rock + ground cover	5	-59.08	128.16	128.98	10.31	0.00	173.50
+ down wood - rock - bare ground	5	-59.22	128.44	129.26	10.60	0.00	200.10
Null	2	-62.67	129.34	129.50	10.83	0.00	224.95
+ down wood - rock + standing dead wood	5	-59.37	128.75	129.57	10.90	0.00	233.08
+ ground cover + depth to soil + low shrub	5	-59.63	129.25	130.08	11.41	0.00	300.25
+ ground cover + depth to soil + western hemlock cover	5	-59.67	129.34	130.16	11.49	0.00	313.18
+ salmonberry	3	-62.03	130.07	130.39	11.72	0.00	351.06
+ down wood - rock + ground cover + depth to soil	6	-58.70	129.40	130.57	11.90	0.00	384.23
+ down wood - rock + standing dead wood - low shrub	6	-58.73	129.46	130.63	11.96	0.00	395.05
+ down wood - rock + standing dead wood + big-leaf maple cover	6	-58.83	129.66	130.83	12.16	0.00	437.12
+ down wood - rock + standing dead wood - western hemlock cover	6	-58.85	129.71	130.88	12.21	0.00	447.96
- western hemlock cover	3	-62.57	131.13	131.45	12.79	0.00	597.96
+ vine maple	3	-62.58	131.16	131.48	12.81	0.00	604.63
+ air temperature	3	-62.67	131.34	131.66	12.99	0.00	662.96
+ down wood - rock + standing dead wood - high shrub	6	-59.36	130.72	131.89	13.22	0.00	741.85

<sup>a</sup> Variables shown with sign of coefficient in model.

<sup>b</sup> K is the number of parameters in the model.

<sup>c</sup> Weight of evidence for the relative likelihood of each candidate model

Appendix N. Number, frequency, and relative abundance of prey items removed from stomachs of salamanders captured in 9 Oregon Coast Range streams, July and October 2002 and June 2003.

Dunn's salamander ( <i>Plethodon dunni</i> )			
Prey Items	<i>N</i> <sup>a</sup>	% Occurrence <sup>b</sup>	RA <sup>c</sup>
Acari	5	33.33%	9.80%
Araneae	2	22.22%	3.92%
Coleoptera	4	33.33%	7.84%
Collembola	14	44.44%	27.45%
Diptera	13	44.44%	25.49%
Homoptera	2	22.22%	3.92%
Hymenoptera	4	44.44%	7.84%
Isopoda	3	11.11%	5.88%
Lepidoptera	1	11.11%	1.96%
Nematoda	1	11.11%	1.96%
Plecoptera	1	11.11%	1.96%
Unknown	1	11.11%	1.96%

9 individuals sampled.

<sup>a</sup>Total number in each taxon.

<sup>b</sup>% of stomachs in which each taxon occurs.

<sup>c</sup>Proportion of total prey items.

## Appendix N. Continued

Roughskin newt ( <i>Taricha granulosa</i> )			
Prey Items	<i>N</i> <sup>a</sup>	% Occurrence <sup>b</sup>	RA <sup>c</sup>
Acari	7	11.11%	2.46%
Araneae	6	11.11%	2.11%
Chilopoda	2	11.11%	0.70%
Coleoptera	13	38.89%	4.56%
Collembola	62	38.89%	21.75%
Decapoda	1	5.56%	0.35%
Diplopoda	2	5.56%	0.70%
Diptera	33	66.67%	11.58%
Ephemeroptera	31	33.33%	10.88%
Gastropoda (snail)	6	27.78%	2.11%
Hemiptera	1	5.56%	0.35%
Homoptera	15	27.78%	5.26%
Hymenoptera	50	44.44%	17.54%
Isopoda	7	27.78%	2.46%
Lepidoptera	19	38.89%	6.67%
Nematoda	1	5.56%	0.35%
Neuroptera	1	5.56%	0.35%
Opiliones	2	11.11%	0.70%
Orthoptera	1	5.56%	0.35%
Plecoptera	17	27.78%	5.96%
Trichoptera	3	11.11%	1.05%
Unknown	5	16.67%	1.75%

18 individuals sampled.

<sup>a</sup>Total number in each taxon.

<sup>b</sup>% of stomachs in which each taxon occurs.

<sup>c</sup>Proportion of total prey items.

Appendix O. Number, frequency, and relative abundance of prey items removed from amphibians captured in 10 Oregon Coast Range riparian areas, fall 2002 and spring 2003.

Dunn's salamander ( <i>Plethodon dunni</i> )			
Prey Items	<i>N</i> <sup>a</sup>	% Occurrence <sup>b</sup>	RA <sup>c</sup>
Acari	5	30.00%	5.56%
Araneae	8	40.00%	8.89%
Chilopoda	1	10.00%	1.11%
Coleoptera	7	40.00%	7.78%
Collembola	32	60.00%	35.56%
Diplopoda	6	30.00%	6.67%
Diptera	9	50.00%	10.00%
Gastropoda (snail)	1	10.00%	1.11%
Homoptera	1	10.00%	1.11%
Hymenoptera	5	20.00%	5.56%
Isopoda	11	50.00%	12.22%
Opiliones	1	10.00%	1.11%
Pseudoscorpiones	2	20.00%	2.22%
Unknown	1	10.00%	1.11%

10 individuals sampled, terrestrial surveys

Oregon ensatina ( <i>Ensatina eschscholtzii</i> )			
Prey Items	<i>N</i> <sup>a</sup>	% Occurrence <sup>b</sup>	RA <sup>c</sup>
Acari	12	40.00%	10.26%
Araneae	12	33.33%	10.26%
Chilopoda	5	26.67%	4.27%
Coleoptera	2	13.33%	1.71%
Collembola	65	53.33%	55.56%
Diplopoda	5	26.67%	4.27%
Diptera	2	6.67%	1.71%
Gastropoda (snail)	1	6.67%	0.85%
Isopoda	6	26.67%	5.13%
Lepidoptera	1	6.67%	0.85%
Opiliones	4	13.33%	3.42%
Pseudoscorpiones	2	13.33%	1.71%

15 individuals sampled

<sup>a</sup>Total number in each taxon

<sup>b</sup>% of stomachs in which each taxon occurs

<sup>c</sup>Proportion of total prey items



## Appendix O. Continued

Northern red-legged frog ( <i>Rana aurora aurora</i> )			
Prey Items	<i>N</i> <sup>a</sup>	% Occurrence <sup>b</sup>	RA <sup>c</sup>
Acari	3	14.29%	13.64%
Araneae	1	14.29%	4.55%
Chilopoda	1	14.29%	4.55%
Coleoptera	1	14.29%	4.55%
Collembola	1	14.29%	4.55%
Diptera	2	28.57%	9.09%
Hymenoptera	1	14.29%	4.55%
Isopoda	2	14.29%	9.09%
Lepidoptera	1	14.29%	4.55%
Mecoptera	8	14.29%	36.36%
Unknown	1	14.29%	4.55%

7 individuals sampled

Northwestern salamander ( <i>Ambystoma gracile</i> )	
Prey Items	<i>N</i> <sup>a</sup>
Araneae	1
Coleoptera	1
Collembola	1
Diplopoda	2
Nematoda	1

1 individual sampled

Pacific chorus frog ( <i>Hyla regilla</i> )			
Prey Items	<i>N</i> <sup>a</sup>	% Occurrence <sup>b</sup>	RA <sup>c</sup>
Acari	1	25.00%	3.13%
Araneae	4	50.00%	12.50%
Coleoptera	3	25.00%	9.38%
Collembola	21	25.00%	65.63%
Diptera	3	25.00%	9.38%
Isopoda	1	25.00%	3.13%

4 individuals sampled

<sup>a</sup>Total number in each taxon<sup>b</sup>% of stomachs in which each taxon occurs<sup>c</sup>Proportion of total prey items

## Appendix O. Continued

Adult Pacific giant salamander ( <i>Dicamptodon tenebrosus</i> )			
Prey Items	<i>N</i> <sup>a</sup>	% Occurrence <sup>b</sup>	RA <sup>c</sup>
Acari	2	14.29%	10.53%
Chilopoda	1	14.29%	5.26%
Coleoptera	1	14.29%	5.26%
Collembola	2	28.57%	10.53%
Diplopoda	3	42.86%	15.79%
Gastropoda (snail)	2	28.57%	10.53%
Gastropoda (slug)	1	14.29%	5.26%
Isopoda	1	14.29%	5.26%
Lepidoptera	1	14.29%	5.26%
Nematoda	4	14.29%	21.05%
Unknown	1	14.29%	5.26%

7 individuals sampled

Roughskin newt ( <i>Taricha granulosa</i> )			
Prey Items	<i>N</i> <sup>a</sup>	% Occurrence <sup>b</sup>	RA <sup>c</sup>
Acari	17	47.62%	1.95%
Araneae	32	52.38%	3.68%
Coleoptera	12	28.57%	1.38%
Collembola	564	90.48%	64.83%
Diplura	3	9.52%	0.34%
Diplopoda	10	23.81%	1.15%
Diptera	76	90.48%	8.74%
Gastropoda (snail)	34	57.14%	3.91%
Gastropoda (slug)	18	33.33%	2.07%
Homoptera	11	14.29%	1.26%
Hymenoptera	1	4.76%	0.11%
Isopoda	16	33.33%	1.84%
Lepidoptera	3	14.29%	0.34%
Nematoda	16	47.62%	1.84%
Oligochaeta	7	19.05%	0.80%
Opiliones	3	9.52%	0.34%
Orthoptera	1	4.76%	0.11%
Plecoptera	33	28.57%	3.79%
Pseudoscorpiones	4	19.05%	0.46%
Trichoptera	1	4.76%	0.11%
Unknown	8	19.05%	0.92%

21 individuals sampled, terrestrial surveys

<sup>a</sup> Total number in each taxon<sup>b</sup> % of stomachs in which each taxon occurs<sup>c</sup> Proportion of total prey items