

## Northwest Science Notes

Tanya R. Wahbe<sup>1</sup> and Fred L. Bunnell<sup>2</sup>, Centre for Applied Conservation Biology, Department of Forest Sciences, University of British Columbia, Vancouver, British Columbia V6T 1Z4, Canada

### Preliminary Observations on Movements of Tailed Frog Tadpoles (*Ascaphus truei*) in Streams through Harvested and Natural Forests

#### Abstract

The tailed frog (*Ascaphus truei*) is designated a species "at risk" or "of special concern" in California, Oregon, Washington, and British Columbia. Forest practices often have negative impacts on *Ascaphus* adults and larvae, including absence from some clearcut areas. Recolonization of logged sites may be critical to sustaining productive amphibian populations. Given the uncommonly long larval stage of *Ascaphus*, movements by larvae may be particularly important in the recolonization of managed forests. We investigated movement rates of *Ascaphus* larvae and the influence of stream parameters in four stream basins transecting recently harvested and unmanaged forests in southwestern British Columbia (1995, 1996, and 1999). Larvae in streams flowing through unmanaged forests moved about 7.4 times as far as those flowing through clearcuts. Streams with high levels of logjams showed low larval movement rates. Recently harvested sites may produce unfavorable conditions impeding recolonization by *Ascaphus* larvae. High gradient streams also showed low larval movement rates. The role of stream-dwelling larvae in dispersal of *Ascaphus* is unknown but would be energy-efficient, because it can be passive with the stream current.

#### Introduction

Many amphibian species live in habitats that are localized or fragmented by human activities. Some authors (e.g., Welsh 1990) have argued that recolonization of logged sites is critical to sustaining productive amphibian populations, but movement may be impeded in altered habitats. Blaustein et al. (1994) suggested that recolonization of sites vacated by local extinction may be difficult for amphibians because: 1) physiological constraints limit amphibians to moist habitats, 2) many amphibians move only short distances, and 3) many amphibian species show extreme site fidelity. Thus, when local amphibian populations become extinct, they may be less likely to recover than are other tetrapods. The mountain yellow-legged frog (*Rana muscosa*) has become extinct at many high elevation sites in the Sierra Nevada of California. Bradford (1991) suggested that recolonization may never occur because streams connecting extant populations are inhabited by introduced fish that eat tadpoles.

The tailed frog (*Ascaphus truei*) is designated a species "at risk" or "of special concern" in California, Oregon, Washington, and British Columbia. *Ascaphus* live in fast-flowing, small forest streams with clear, cold water (Corkran and Thoms 1996). The species requires an unusually long time to develop, spending two to five years as larvae (Metter 1964, 1967; Daugherty and Sheldon 1982a; Brown 1990; Wahbe 1996). Forest practices often have negative impacts on adult and larval *Ascaphus*, including complete absence from many clearcut areas (see Metter 1968; Bury 1988; Welsh 1990). Corn and Bury (1989) estimated that if *Ascaphus* were extirpated from certain areas, re-establishment might take 14 to 40 years. Daugherty and Sheldon (1982b) found that 50% of reproductively mature *Ascaphus* remained in the same 20-m area of their previous capture and concluded adult *Ascaphus* exhibit extreme site fidelity. Given the uncommonly long larval stage of *Ascaphus*, movements by larvae may be particularly important to recolonization of managed forests. After clearcutting, however, small streams often contain logging debris and sedimentation that could impede movement and recolonization by *Ascaphus* larvae.

<sup>1</sup> Email Address: wahbe@interchange.ubc.ca

<sup>2</sup> Author to whom correspondence should be addressed.

Email: fbunnell@interchange.ubc.ca

We investigated movement rates of larvae and influences of stream parameters to dispersal in managed and unmanaged forests. We tested the hypotheses that: 1) movement rates of *Ascapthus* larvae in recently harvested and unmanaged forests do not differ, 2) there is no relationship between logjams and larval movement, and 3) there is no relationship between stream gradient and larval movement.

## Methods

### Study Area

Research was conducted near Squamish in southwestern British Columbia (49° N, 122° W) within forests dominated by western hemlock (*Tsuga heterophylla*). Sites were distributed within four stream basins that flow into Howe Sound (Ashlu, Elaho, Mamquam, and Squamish Rivers), and included old growth (250+ years old), mature second growth (60 to 80 years since logging) and recent clearcut (~5 years since logging). In reaches designated as 'old growth,' the predominant forest type in the watershed upstream from the reach was old growth. In reaches designated as 'clearcut,' the predominant forest type in the watershed upstream from the reach was clearcut.

Reaches within each basin were located on three separate tributaries, with predominant forest type being old growth, mature second growth, or clearcut. In 1996, the Squamish clearcut site was replaced with the Ashlu clearcut site due to loss of road access. Three replicates of each forest treatment were selected. Streams were selected on the basis of larval presence, and were chosen upstream (except Ashlu and Mamquam clearcut sites) from logging roads.

### Stream Surveys and Parameters

We determined larval movement patterns from the original site of capture. Movements were assessed by conducting area-constrained stream surveys (adapted from Bury and Corn 1991 and Shaffer et al. 1994) together with mark-recapture techniques. Three 5-m sections (reaches) per stream were selected 25 m apart. The first (most downstream) reach was chosen at random. Larvae were marked in these three reaches. To maximize number of recaptures, two additional 10-m reaches were sampled directly below the second and third 5-m reaches (Figure 1). Area-constrained searches were

performed in all reaches by first scanning the stream for surface-active larvae, then slowly moving up the stream turning and brushing undersides of rocks and capturing larvae with dipnets as they became dislodged. Searches were conducted between 0700 and 2200 hrs, taking three people an average of three hours per stream, with an additional three hours to process larvae and record stream parameters.

Initial surveys were in June and early July. Each stream was resurveyed once in July and once in

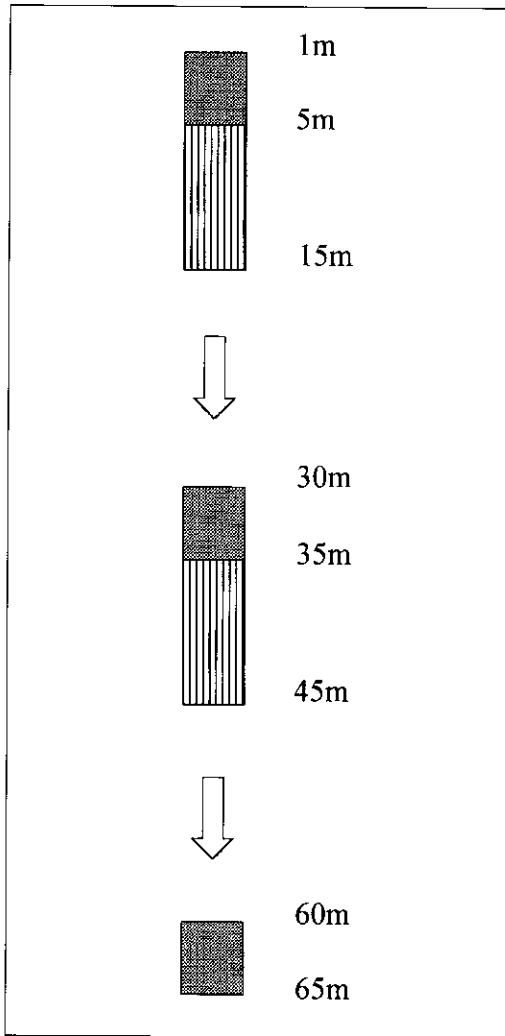


Figure 1. Sampling scheme: Initial marking occurred in three 5-m reaches (shaded) separated by 25 m; sampling for recaptures included two additional 10-m reaches (hatched). In the text recaptures noted for reaches 2 and 3 include the contiguous 10-m reaches. Arrows indicate direction of stream flow.

August (approximately 20 days apart), and yielded information on the extent of larval movements. Three sizes of dipnets each with 1-mm mesh were used for sampling; appropriate net size (width of net: small, medium, large) was based on dominant stream substrate size.

In July, we measured stream parameters we thought could influence the movement of larvae: stream gradient (using a clinometer), logjams (visually estimated low=1, medium=2, high=3), stream wetted width, and canopy closure (visually estimated as percent cover). Logjams were visually assessed and designated low, medium or high based on the density of logs found in or across streams, and degree to which logs were imbedded in the stream.

### Mark-Recapture

Larvae captured in the three 5-m reaches were marked with a code unique-to-reach (e.g., two notches for individuals captured in reach two). Taking special care not to cut into the central axis of caudal muscle, the dorsal fin of the tail was marked with "V"-shaped notches following Turner (1960). Notches were visible for at least one month and allowed for identification of recaptures by reach in subsequent stream surveys within that period. After a reach had been searched, we marked larvae, recorded data (number of notches and distance from upstream end of the reach), replaced disturbed rocks, and released larvae less than 1 meter upstream from reach of capture.

We kept a subsample of marked larvae in a lab enclosure to evaluate potential impacts of marking on larval survival. A subsample of 25 larvae were obtained and given three tailfin notches each. We kept larvae at lab conditions close to what was found in the field, providing a 6-hour light and 18-hour dark cycle, using a timer and fluorescent lamp. Larvae were kept at 5 °C in an aquarium filled with fresh stream water and algae-covered rocks, with an air pump to oxygenate the water.

### Statistical Analyses

Our completely randomized block design included two years (1995, 1996), four rivers (Ashlu, Elaho, Squamish, Mamquam), and three forest age classes (old growth, mature second growth, clearcut). The design is unbalanced because the clearcut site along the Ashlu River was sampled only in 1996, and

no recapture data were collected in the Squamish and Elaho clearcut sites in 1995. These data, however, could be evaluated by the General Linear Model Factorial Procedure (Norusis 1993).

### Results

During a 1.5-month period, no mortality was observed in larvae given three tailfin notches and kept in the lab. At 1.75 months, three larvae were found dead in the aquarium. We could not determine whether their death was related to tailfin notching, handling stress, disease or unnatural living conditions. However, time to any mortality was long enough, that marking itself would not have influenced recapture estimates.

During the initial searches (June and July), we captured and marked 737 larvae; during July and August we recaptured 52 (about 7% recapture rate). Although recapture numbers were low, larval movement patterns differed in forest age classes with most in old growth and fewest in clearcuts (Table 1). Only distances of 0 to 15 m, 30 to 45 m or 60 to 65 m could be detected because of the two stretches (15 m each) of unsampled stream between reaches (Figure 1). No 10-m reach was added below reach 1 because we wished to maintain a distance of 50 m from logging roads or clearcut edges where appropriate.

There was uneven distribution of captures across reaches, which would bias results if, for example, most tadpoles in streams through clearcuts were initially captured in reach 1. We evaluated potential pattern in initial capture data using Kendall's coefficient of concordance. Within any forest age class there was no significant difference in the proportion of initial captures across reaches 1 through 3. Kendall's coefficient of concordance was 0.86, where a coefficient of 1.0 indicates complete concordance among ranks (asymptotic significance = 0.051). Consistent with movement from upper to lower reaches, rates of recapture differed among reaches (Kendall's coefficient of concordance = 0.149; asymptotic significance = 0.719). In streams flowing through old growth and second growth, recapture rates in the two lower reaches combined (1 and 2 of Figure 1) were 12.6% and 10.7%, respectively; recapture rates in reach 3 were 2.5% and 2.4%, respectively. Conversely, in clearcuts where movements were shorter, the recapture rate in reach 3 was 10.5% but only 3.7% for the lower two reaches (consistent with less

TABLE 1. Larval *Ascaphus* recaptures in three forest habitat types ( $\pm$  SE mean)—SW B.C. 1995 and 1996. Distances are meters moved per day. Values in parentheses are total initial captures. Double values indicate years sampled (1995/1996).

Forest Type	Recaptures					Mean Distance Traveled (m/day)	Mean Gradient (°)	Mean Wetted Width (m)
	Squamish	Elaho	Mamquam	Ashlu	Total			
Old Growth	3/0 (54/9)	10/1 (62/40)	8/0 (114/36)	*	21/1 (230/85)	1.11 $\pm$ 0.30 (n=22)	10 $\pm$ 4.00	2.80 $\pm$ 0.15
Second Growth	2/0 (53/0)	2/0 (88/19)	13/1 (41/30)	*	17/1 (182/49)	0.28 $\pm$ 0.10 (n=18)	12 $\pm$ 4.36	3.63 $\pm$ 1.48
Clearcut	0/* (3/*)	0/1 (19/12)	6/1 (69/66)	*/4 (*22)	6/6 (91/100)	0.15 $\pm$ 0.02 (n=12)	8.13 $\pm$ 1.09	2.80 $\pm$ 1.02

\* not sampled

drift from the upper reaches). In clearcuts where movements were shorter, 8 of 12 recaptures had 3 tail notches.

Larvae in streams flowing through old growth moved about 7.4 times as far as those in streams flowing through clearcuts (Table 1). The need to replace one clearcut site (loss of access) obscured efforts to document a watershed effect within the General Linear Model, but distances moved differed significantly among forest age classes. Duncan's multiple range test confirmed that movements in streams surrounded by old growth were significantly greater ( $p < 0.05$ ) than movements in streams surrounded by clearcuts or second growth. Maximal movements detectable within our sampling scheme were several times farther than mean values reported in Table 1. Over the average 20-day period, larvae moved up to 3.76 meters per day in old-growth sites, up to 1.94 meters per day in mature second-growth sites, and up to 0.30 meters per day in clearcut sites. Our sam-

pling design could not detect upstream movements of less than 15 meters. However, we did observe short upstream movements of 15-30 cm during area-constrained searches.

Based on simple linear regression analyses, neither movements per day nor rate of recapture showed any relation with larval densities (Table 2). Relationships of stream parameters with larval movement rates also are shown in Table 2. We examined the potential influence of logjams on movement rates because all clearcuts contained abundant logjams that could have constrained movements. The combination of several stream parameters (stream gradient, logjams, stream wetted width, percent canopy cover) in a regression model resulted with logjams explaining 13% of the variation in movement rates ( $p < 0.05$ ). On average, levels of logging debris were 1.6 times higher in clearcuts than in old-growth streams. Large amounts of logs in streams found mainly in clearcuts (Figure 2a) were associated with lower

TABLE 2. Larval *Ascaphus* movements (meters per day) and stream parameters. Values in parentheses represent averages of three values. Levels of logjams present are rated as 1 = low, 2 = medium, and 3 = high. SW B.C. 1995, 1996, 1999.

Treat-ment <sup>1</sup>	River	Meters Moved per day	Tadpole Density (#/m <sup>2</sup> )	Stream Gradient (°)	Stream pH	Stream Temp (°C)	Logs	% Canopy	Wetted Width (m)
OG	Squamish	0.34	0.43	18.0	7.55	10.0	2.0	60	3.1
OG	Elaho	1.32 (0.92)	0.74	6.0 (10.0)	7.48 (7.34)	9.7 (8.5)	2.0 (1.7)	35 (40)	2.6 (2.8)
OG	Mamquam	1.10	2.70	6.0	7.00	5.7	1.0	25	2.7
SG	Squamish	0.36	0.85	20.0	7.45	11.5	3.0	90	2.1
SG	Elaho	1.06 (0.53)	0.58	11.0 (12.0)	7.16 (7.37)	9.8 (9.8)	2.5 (2.7)	85 (90)	6.6 (3.6)
SG	Mamquam	0.16	0.59	5.0	7.50	8.1	2.5	95	2.2
CC	Ashlu	0.19	0.52	8.5	7.65	9.5	3.0	0	2.5
CC	Elaho	0.06 (0.13)	0.36	10.0 (9.2)	7.16 (7.36)	11.8 (10.0)	2.5 (2.8)	0 (0)	3.0 (2.4)
CC	Mamquam	0.15	2.08	9.0	7.28	8.8	3.0	0	1.6

<sup>1</sup> OG = old growth; SG = second growth; CC = clearcut

rates of movement (Spearman's rho ( $r_s$ ) = -0.507;  $p < 0.05$ ; see Figure 2a-2b).

Because stream gradients differed among treatments (Table 1) we examined potential gradient effects on distance moved per day. Assuming a linear relationship, there was no significant effect of stream gradient on distance moved per day ( $r^2 = 0.01$ ,  $p > 0.05$ ), and the extremes of movement were higher at lower gradients (Figure 3). Given the possibility of a factor-ceiling distribution *sensu* Thomson et al. (1996), there was relatively little power to test the movement per day

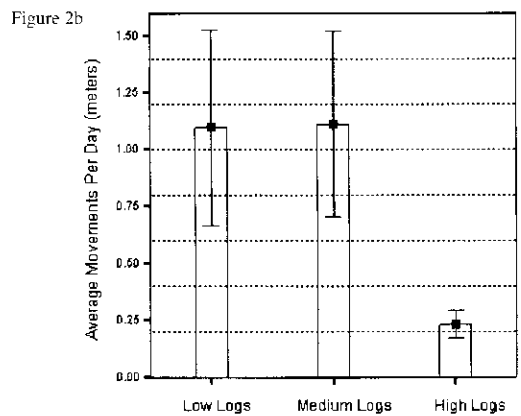
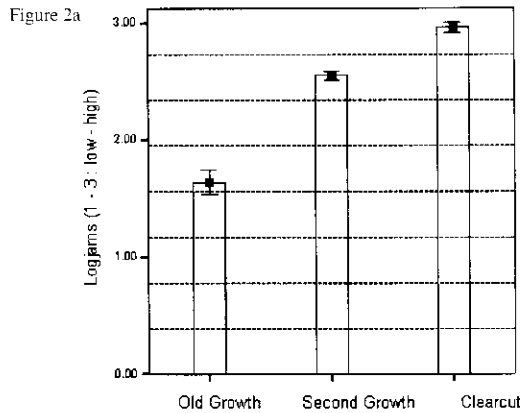


Figure 2. Logjams and larval movements. a) Extent of logjams estimated in each forest treatment: old growth, second growth, and clearcut. Error bars represent standard error of the mean ( $\pm 1.0$ ). b) Larval movements per day (meters) in streams with low, medium, and high levels of logjams. Values of 2.5 (between medium and high ratings) were lumped with values of 3 because movement values were similar. Error bars represent standard error of the mean ( $\pm 1.0$ ).

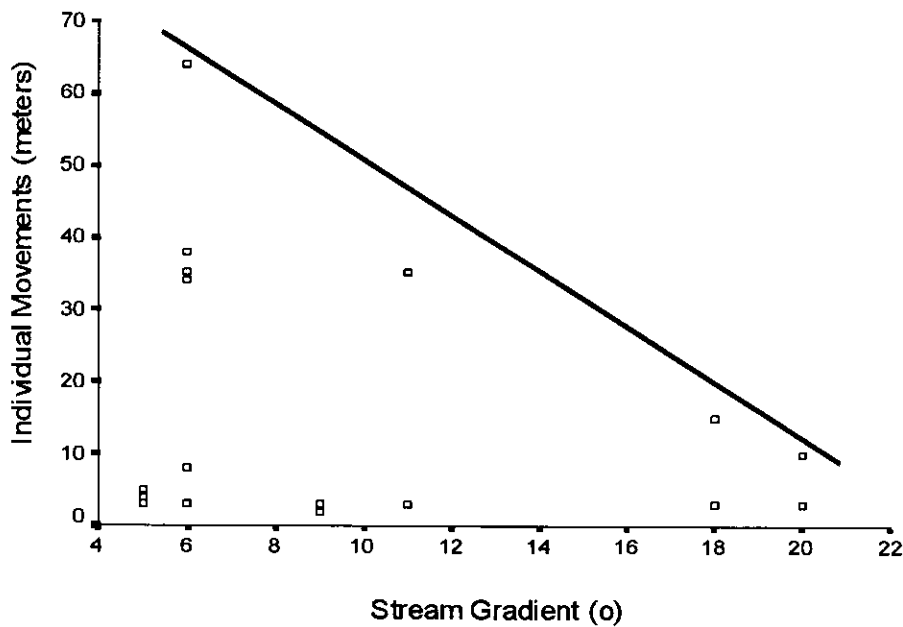
vs. gradient relationship. This inability may be due to insufficient sampling at the upper threshold rather than the result of weak relationships. Wider streams (i.e. large wetted width) were correlated with higher rates of movement (Spearman's rho ( $r_s$ ) = 0.420;  $p < 0.05$ ). There was no relationship between percent canopy closure and larval movement rates.

## Discussion

Stream ecologists use the term 'drift' to describe the downstream movement of stream organisms either passively with floods or actively as in behavioral drift. Müller (1974) hypothesized that drift would eventually wash entire populations out of streams unless organisms actively moved upstream to compensate for drift. He coined the term "colonization cycle" to describe the maintenance of stream populations through a dynamic interplay between downstream drift and upstream dispersal. It appears that *Ascaphus* may follow the colonization cycle. Significant downstream movement by larvae is confirmed by this study, however, it is still not clear the extent to which post-metamorphic *Ascaphus* move upstream.

The role of stream-dwelling larvae in the dispersal of *Ascaphus* is unknown but would be energy-efficient, because it can be passive with the stream current. We found such movement to be much greater in streams surrounded by old growth regardless of gradient over a range of 4 to 44%. On the basis of stream gradient, second-growth stands should have shown the greatest movements per day, followed by old growth, then clearcuts. That pattern was not apparent (Table 1), and maximal movements per day were inversely, but not significantly related to gradient (Figure 3).

The sampled rates of movement could be low because tadpoles moved outside the 65-m range of distances sampled. We believe that is unlikely for three reasons. First, the rate of recapture is not uncommonly low (see review of dispersal studies of Sutherland et al. 2000). Second, at least some amphibians are documented to show strong philopatry (Martof 1953; Stebbins 1954; Bellis 1965; Kleeberger and Werner 1982; Ovaska 1988). Third, the relative rates of movements among forest age classes suggest that other factors are involved. Streams in clearcuts all contained abundant debris and logjams, much of it imbedded, that could have constrained movements by serving



Note: Some points may overlap.

Figure 3. Individual distances moved per day by larvae versus stream gradient (some points overlap). Solid line above extreme movements represents a potential factor ceiling sensu Thompson et al. (1996).

as dispersal barriers. We found a negative relationship between distance moved and amount of logjams estimated in a stream. In some studies, post-harvest volumes of woody debris have been reported to increase three-fold on average over pre-harvest levels (Baillie et al 1999). Logjams may serve to reduce drift rates and possibly the recolonization potential of *Ascaphus* larvae.

Alternatively, biomass of algae likely differs in managed and unmanaged streams and may also be influencing rates of larval movement. A greater food supply in clearcut streams receiving greater solar radiation could result in lower movement rates. Primary production is often directly related to stream gradient and incident radiation (McIntyre 1966). The extreme movements (potential factor ceiling of Figure 3) are consistent with the pattern expected from associations of primary production with gradient (shorter movements with steeper gradients and potentially greater food supply). Hawkins et al. (1983) suggested that the higher autotrophic production that occurs after canopy removal or in naturally open stream sections seems to be the causative agent responsible for higher abundances of invertebrates

and stream vertebrates. Shorter movements per day in clearcuts, where incident radiation was higher and periphyton likely more abundant, also are consistent with the concept of lower food supply encouraging movement.

Our analyses indicate that movements were shorter in streams surrounded by clearcuts, and that these streams contained more woody debris. We cannot separate potential influences of logjams and food production. For whatever reason, in-stream movements from clearcut reaches were less than from unlogged reaches.

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## Literature Cited

- Baillie, B.R., T.L. Cummins, M.O. Kimberley. 1999. Harvesting effects on woody debris and bank disturbance in stream channels. *New Zealand Journal of Forestry Science* 29(1):85-101.
- Bellis, F.D. 1965. Home range and movements of the wood frog in a northern bog. *Ecology* 46:90-98.
- Blaustein, A.R., D.B. Wake, and W.P. Sousa. 1994. Amphibian declines: judging stability, persistence, and susceptibility of populations to local and global extinctions. *Conservation Biology* 8(1):60-71.
- Bradford, D.F. 1991. Mass mortality and extinction in a high-elevation population of *Rana muscosa*. *Journal of Herpetology* 25:174-177.
- Brown, H.A. 1990. Morphological variation and age-class determination in overwintering tadpoles of the tailed frog (*Ascaphus truei*). *Journal of Zoology (London)* 220:171-184.
- Bury, R.B. 1988. Habitat relationships and ecological importance of amphibians and reptiles. Pages 61-76 *In* K.J. Raedeke (editor) *Streamside Management: Riparian Wildlife and Forestry Interactions*. Institute of Forest Resources, University of Washington, Contribution No. 59, Seattle, Washington.
- Bury, R.B. and P.S. Corn. 1991. Sampling methods for amphibians in streams in the Pacific northwest. Pages 1-29 *In* A.B. Carey and L.F. Ruggiero (editors) *Wildlife-Habitat Relationships: Sampling Procedures for Pacific Northwest Vertebrates*. USDA Forest Service General Technical Report PNW-GTR-275, Portland, Oregon.
- Corkran, C.C. and C.R. Thoms. 1996. *Amphibians of Oregon, Washington and British Columbia*. Lone Pine Publishing, Alberta.
- Corn, P.S. and R.B. Bury. 1989. Logging in western Oregon: responses of headwater habitats and stream amphibians. *Forest Ecology and Management* 29:39-57.
- Daugherty, C.H. and A.L. Sheldon. 1982a. Age-determination, growth, and life history of a Montana population of the tailed frog (*Ascaphus truei*). *Herpetologica* 38(4):461-468.
- Daugherty, C.H. and A.L. Sheldon. 1982b. Age-specific movement patterns of the tailed frog *Ascaphus truei*. *Herpetologica* 38:468-474.
- Hawkins, C.P., M.L. Murphy, N.H. Anderson, and M.A. Wilzback. 1983. Density of fish and salamanders in relation to riparian canopy and physical habitat in streams of the northwestern United States. *Canadian Journal of Fisheries and Aquatic Sciences* 40(8):1173-1185.
- Kleeberger, S.R. and J.K. Werner. 1982. Home range and homing behavior of *Plethodon cinereus* in northern Michigan. *Copeia* 1982:409-415.
- Martof, B.S. 1953. Home range and movements of the green frog, *Rana clamitans*. *Ecology* 34:529-543.
- McIntyre, C.D. 1966. Some effects of current velocity on periphyton communities in laboratory streams. *Hydrobiologia* 27:559-570.
- Metter, D.E. 1964. A morphological and ecological comparison of two populations of the tailed frog, *Ascaphus truei* Stejneger. *Copeia* 1964:181-195.
- \_\_\_\_\_. 1967. Variation in the ribbed frog *Ascaphus truei* Stejneger. *Copeia* 1967:634-649.
- \_\_\_\_\_. 1968. The influence of floods on population structure of *Ascaphus truei* Stejneger. *Journal of Herpetology* 1:105-106.
- Müller, K. 1974. Stream drift as a chronobiological phenomenon in running water ecosystems. *Annual Review of Ecology and Systematics* 5:309-323.
- Norusis, M.J. 1993. *SPSS for Windows: Advanced Statistics*. SPSS Incorporated, Chicago.
- Ovaska, K. 1988. Spacing and movements of the salamander *Plethodon vehiculum*. *Herpetologica* 44:377-386.
- Shaffer, H.B., R.A. Alford, B.D. Woodward, S.J. Richards, R.G. Altig, and C. Gascon. 1994. *Standard Techniques for Inventory and Monitoring. Quantitative Sampling of Amphibian Larvae*. Pages 130-141 *In* W.R. Heyer et al. (editors) *Measuring and Monitoring Biological Diversity. Standard Methods for Amphibians*. Smithsonian Institution Press, Washington, D.C.
- Stebbins, R.C. 1954. Natural history of the salamanders of the plethodontid genus *Ensatina*. *University of California Publication Zoology* 54:47-124.
- Sutherland, G.D., A.S. Harestad, K. Price, and K.P. Lertzman. 2000. Scaling of natal dispersal distances in terrestrial birds and mammals. *Conservation Ecology* 4(1):16. [online] URL: <http://www.consecol.org/vol4/iss1/art16>.
- Thompson, J.D., G. Weblen, B.A. Thomson, S. Alfaro, and P. Legendre. 1996. Untangling multiple factors in spatial distributions: lilies, gophers, and rocks. *Ecology* 77(6):1698-1715.
- Turner, F.B. 1960. Population structure and dynamics of the western spotted frog, *Rana p. pretiosa* Baird & Girard, in Yellowstone Park, Wyoming. *Ecological Monographs* 30:251-278.
- Wahbe, T.R. 1996. Tailed frogs (*Ascaphus truei*, Stejneger) in natural and managed coastal temperate rainforests of southwestern British Columbia, Canada. M.S. Thesis, University of British Columbia, Vancouver, British Columbia.
- Welsh, H.H. Jr. 1990. Relictual amphibians and old-growth forests. *Conservation Biology* 4:309-319.

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