Verh. Internat. Verein. Limnol.	28	1–5	Stuttgart, July 2002

Annual variation in the density of stream tadpoles in a northern Idaho (USA) watershed

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Introduction

Tailed frogs (*Ascaphus truei*) are a common and conspicuous vertebrate in many forested streams in the Pacific Northwest region of North America. They occur in small, high-gradient streams in the coastal and Cascade Mountains from northern California to southern British Columbia (NUSSBAUM et al. 1983). Disjunct populations also occur in montane streams draining coniferous watersheds in Idaho, Montana, south-eastern Washington and north-eastern Oregon (NUSSBAUM et al. 1983). NIELSON et al. (2001) have suggested that these inland populations are genetically distinct and merit species designation as *Ascaphus montanus*.

The genus *Ascaphus* is characterized by a prolonged larval period which may last for as little as 1 year in coastal populations of Oregon and California (WALLACE & DILLER 1998, BURY & ADAMS 1999) to more than 3 years in Cascade and northern Rocky Mountain populations (METTER 1967, DAUGHERTY & SHELDON 1982, BROWN 1990, BULL & CARTER 1996). Adults lay 40–75 eggs under large rocks in early summer and hatchlings emerge in late summer to early fall (METTER 1967). In northern Idaho streams, tadpoles typically metamorphose to juvenile frogs in August and September, 3 years after hatching (METTER 1967).

Ascaphus tadpoles are cold-water stenotherms that prefer unembedded, coarse substrates (METTER 1964, 1967, HAWKINS et al. 1988). Several studies have investigated the distribution and abundance of *Ascaphus* in relation to timber harvest practices and have generally shown tailed frog declines in areas where clear-cut logging has occurred, presumably a consequence of either increased stream temperature or sedimentation (BURY & CORN 1988, CORN & BURY 1989, WELSH & OLLIVIER 1998, DUPUIS & STEVENTON 1999).

Assessing the impact of watershed disturbance on stream amphibians is difficult without good estimates of densities, as well as some knowledge of annual variability in abundance. Although a few studies have compared *Ascaphus* tadpole densities from different streams and among watersheds with varying levels of disturbance (HAWKINS et al. 1988, CORN & BURY 1989, BURY et al. 1991, DUPUIS & STEVENTON 1999), few have reported densities from more than a single year. In this study, midsummer densities of *Ascaphus* tadpoles are reported from six sites within an undisturbed watershed over a 4-year period. The objectives were to characterize both spatial and temporal variation in tadpole abundance within a small undisturbed watershed in northern Idaho and to describe the status of *Ascaphus* populations prior to timber harvest and road construction activities.

Methods

Mica Creek drains a forested watershed in northern Idaho (Shoshone County) and empties into the St. Joe River and Lake Coeur d'Alene. This study was conducted in the headwaters of Mica Creek within a 27-km^2 area owned by the Potlatch Corporation known as the Mica Creek Experimental Watershed. Elevation within the Potlatch area of the watershed ranges from 975 to 1725 m. The Mica Creek drainage is characterized by western red cedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), and grand fir (*Abies grandis*). Much of the drainage was extensively logged in the 1920s and 1930s, but little harvest has occurred since that time and considerable amounts of old-growth forest remain, particularly in riparian zones along Mica Creek.

Tadpoles were collected at six sites within the Mica Creek drainage where the Potlatch Corporation has established long-term water quality monitoring stations. Surveys were conducted over a 3-day period in July of each of 4 consecutive years (8–10 July 1997, 7–9 July 1998, 20–22 July 1999, 8–10 July 2000). At each site, block nets were placed at the lower end of randomly selected sampling reaches. Working upstream, a minimum of either 10 m in length or a total area of at least 10 m^2 was sampled by lifting or removing all large cover items and kicking through

0368-0770/02/0028-0001 $ 1.25

the substrate in front of a D-frame net (0.8-mm mesh).

Tailed frog tadpoles in northern Idaho require 3 years to complete metamorphosis (METTER 1967) and are present in forested streams throughout the year. Metamorphosis of third-year tadpoles is typically completed in late July–early August; thus, in early July when the surveys were conducted, three distinct age classes were present. Tadpoles were assigned to age classes based on a combination of length and limb development. The smallest tadpoles captured lacked any developed limbs and would have hatched the previous fall. These were designated the 1+ age class. Tadpoles hatched two falls prior to being collected were slightly larger, had some hind limb development, and were designated as 2+ tadpoles. Individuals hatched three falls prior to collection were the largest, had well-developed hind legs and generally some fore-limb development. These tadpoles would metamorphose later in the summer and were designated 3+ tadpoles. The total lengths of a subsample of tadpoles were measured in each age class (15–30 individuals), and then all individuals within an age class were weighed en masse to determine the average weight of tadpoles in a given class. Numbers captured and biomass of each age class were divided by the area sampled in each reach to calculate density and standing crop.

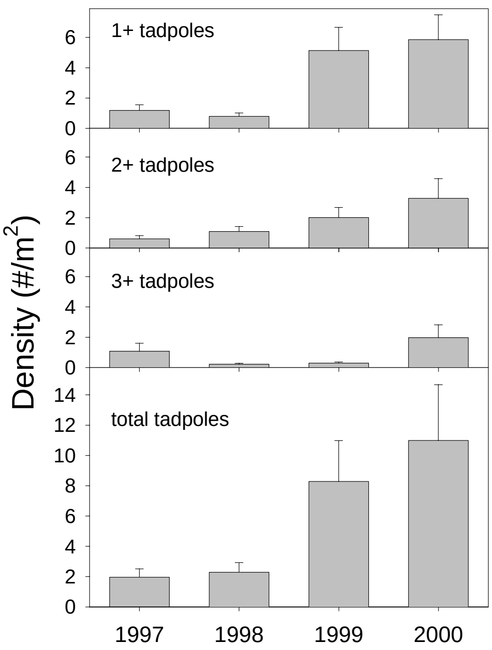

Fig. 1. Mean *Ascaphus* tadpole density (± 1 SE) in the Mica Creek drainage (Idaho, USA). Means are based on values from six sites sampled in July of 4 consecutive years (1997–2000).

Results

Mean total tadpole density in the Mica Creek drainage as a whole ranged from a low of 1.96/m^2 ± 0.55 (mean ± 1 S.E.) in 1997 to a high of 10.99/m^2 ± 3.68 in 2000 (Fig. 1). Mean densities were similar in 1997 and 1998, but increased by 4-fold in 1999 and by 5-fold in 2000. Total density increased at all six sites between 1997 and 2000 from as little as 2-fold (site 6) to as much as nearly 20-fold (site 3). When broken down by age class, similar increasing trends were seen in the mean densities of both first- and second-year tadpoles. The highest density of third-year tadpoles was also observed in 2000, although abundance was lower in both 1998 and 1999 than in either 1997 or 2000.

Similar trends across the drainage were observed with mean total tadpole biomass (Fig. 2). Mean total tadpole biomass ranged from a low of 1.20 ± 0.31 g/m^2 in 1997 to a high of 5.70 ± 2.27 g/m^2 in 2000. Increases in mean biomass were seen with all three age classes between 1997 and 2000: mean biomass of first-year tadpoles increased from 0.41 ± 0.15 g/m^2 to 1.18 ± 0.31 g/m^2, second-year tadpoles from 0.51 ± 0.11 g/m^2 to 2.12 ± 0.86 g/m^2, and third-year tadpoles from 0.28 ± 0.08 g/m^2 to 2.40 ± 1.14 g/m^2. Although the densities of second- and third-year tadpoles were less than that of first-year tadpoles in all years, these two older age classes made up from 66% (1997) to 89% (1998) of the total tadpole biomass in the Mica Creek drainage.

Tadpole density and biomass varied substantially among sites as well as across years. Mean total tadpole density varied by an order of magnitude between the least and most dense sites in all years (Fig. 3). The range was 0.36–4.08/m^2 in 1997, 0.38–4.07/m^2 in 1998, 3.27–19.55/m^2 in 1999, and 2.24–24.09/m^2 in 2000. Notwithstanding interannual variability, the relative abundance of tadpoles among sites was similar from year to year, i.e. sites with the highest and

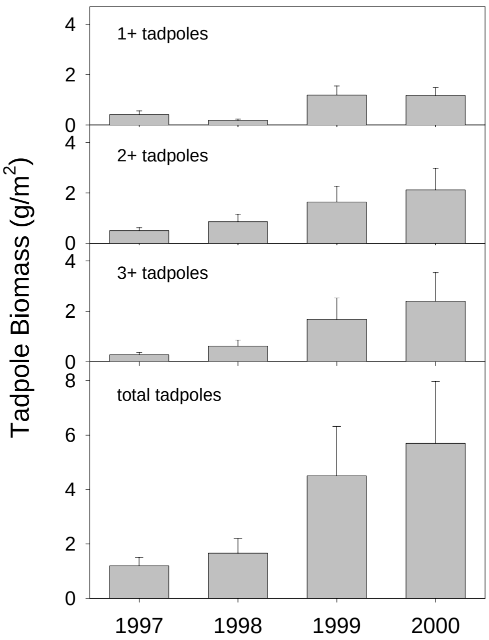

Fig. 2. Mean *Ascaphus* tadpole biomass (± 1 SE) in the Mica Creek drainage (Idaho, USA). Means are based on values from six sites sampled in July of 4 consecutive years (1997–2000).

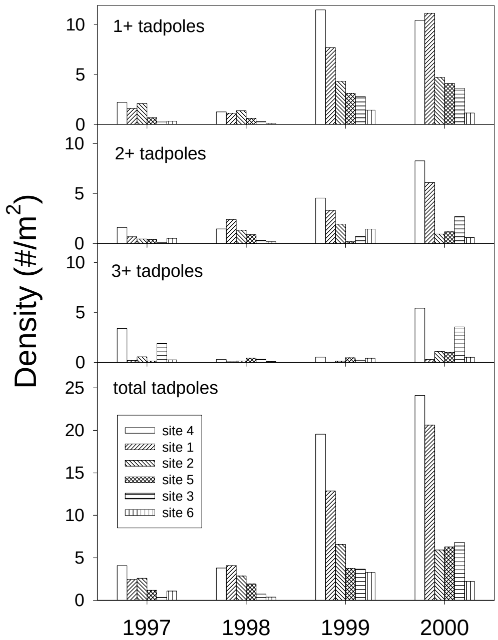

Fig. 3. *Ascaphus* tadpole density broken down by year and age class for six sites in the Mica Creek drainage.

lowest densities in 1997 also tended to have the highest and lowest densities in subsequent years (Fig. 3). Lowest total tadpole densities generally occurred at sites 3 and 6, whereas highest numbers were seen at sites 1 and 4. Variability in tadpole biomass among sites displayed a similar trend to that seen with density.

Tadpole age class structure was similar in 3 of the 4 years (Fig. 4). Except in 1998, first-year tadpoles made up 58–64% of the total tadpole population, second-year tadpoles were 24–27% of the total, and third-year tadpoles were 8–15%. In 1998, first-year tadpoles were proportionately less abundant, making up only 35%, whereas second-year tadpoles were 46% and third-year tadpoles were 18% of the population.

Discussion

Tailed frogs were abundant within the Mica Creek drainage in 1997 and tadpole numbers increased substantially in the subsequent 3 years. Although there was considerable variability in density among sites, two sites in the upper sections of the drainage (sites 1 and 4) had among the highest densities of *Ascaphus* tadpoles that have been observed in northern Idaho (12.88–24.09/m^2) and mean densities within the drainage as a whole (1.96–11.00/m^2) exceeded those from other areas in the Pacific Northwest. Bury et al. (1991) reported mean densities of 0.76/m^2, 0.25/m^2, and 1.72/m^2 for 59 streams in the Oregon Coast Range, Oregon Cascades, and southern Washington Cascades, respectively. In 13 streams near Mt. St. Helens in southern Washington, *Ascaphus* tadpole density ranged from 0.27 to 8.70/m^2 (Hawkins et al. 1988), and Dupuis & Steventon (1999) reported a range of 0–9.7/m^2 for 53 streams in south-western British Columbia. Stream habitat conditions in Mica Creek, particularly in the headwaters, seem to be ideal for tailed frog tadpoles. Those conditions include cold midsum-

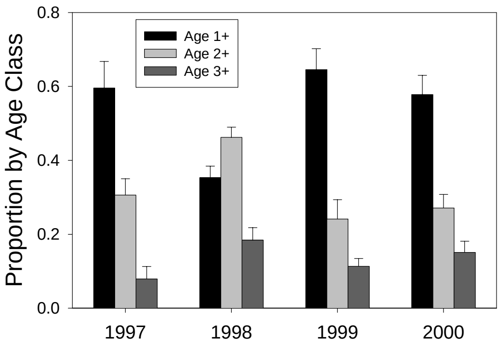

Fig. 4. Proportion of *Ascaphus* tadpoles within each of three age classes. Bars represent the mean proportion (± 1 SE) of the total number of tadpoles collected from six sites in each of 4 years.

mer water temperatures, loose and unembedded substrate, and generally closed canopy.

HAWKINS et al. (1988) compared mean densities from sites within forested, forested headwater, and non-forested watersheds in the Mt. St. Helens area over a 3-year period, but few other studies have reported densities from more than a single season at individual sites. In their study, mean densities varied by 2- to 4-fold over 3 years within watersheds with varying levels of disturbance. In comparison, mean *Ascaphus* densities in the Mica Creek drainage varied by 5-fold overall, and fluctuated by an order of magnitude at some sites.

Biomass estimates from Mica Creek were higher than those reported from other streams, ranging from 1.20 to 5.70 g/m^2, but there are few data available from other locations. In a comparison of *Ascaphus* biomass from streams draining logged and forested watersheds in the Oregon Coast Range, CORN & BURY (1991) estimated biomass at 0.46 g/m^2 in logged and 1.63 g/m^2 in forested watersheds.

Tadpole densities were strongly influenced by the success of first-year age classes and numbers of first-year tadpoles dramatically increased at all Mica Creek sites over the 4-year period. Tadpole survivorship is probably affected by a number of factors, not the least of which is flow regime (METTER 1968). Large, destructive high-flow events did not occur within the drainage during 1997–2000 and the absence of such events may account for the significant increases in the number of *Ascaphus* tadpoles. Extensive flooding did occur in the area during the winter of 1996–1997 and the numbers of *Ascaphus* may have been depressed when sampling began. Catastrophic flow events in the future can be expected to reduce tadpole numbers below that seen in 1999 and 2000; nevertheless, even at the levels seen in 1997 and 1998, Mica Creek supports far higher densities than most other small streams within the range of *Ascaphus*.

Although there is evidence that *Ascaphus* populations are influenced by watershed activities that increase sedimentation and water temperature (BURY & CORN 1989, CORN & BURY 1989, DUPUIS & STEVENTON 1999), the factors that regulate tadpole abundance remain poorly understood. Even less is known about the population dynamics of adult *Ascaphus* than about their tadpoles. Without a better understanding of what limits tadpole abundance and how, or if, adult numbers are affected by variation in larval success and recruitment, maintaining *Ascaphus* populations in watersheds managed for timber harvest will be a continuing challenge.

Acknowledgements

This work was supported by grants from the Potlatch Corporation and the University of Idaho Research Office. I thank W. WALL and P. HEGLUND for logistical assistance and B. HOSSACK, S. STRUHS, and M. NIELSON for their help in the field.

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