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The Effects of Timbering on Plethodon hubrichti: Short Term Effects

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ABSTRACT
Effects of two types of timbering on populations of the Peaks of Otter salamander (Plethodon hubrichti) were determined using average numbers found during multiple night collections. Sampling was done prior to, and for two years after, timbering on four sites in each of three treatments (clearcut, shelterwood cuts, and reference). The average numbers of P. hubrichti at the reference and shelterwood cut sites were stable over time while those at the clearcut sites showed a significant decrease post-timbering. Two years after timbering, 30% of the pre-timbering populations remained at the clearcut sites. Jolly-Seber population estimates on one clearcut site decreased from 43 to eight animals after cutting. In contrast, one reference site had a population estimate that oscillated around a mean of 71. Of the animals marked before timbering, significantly fewer were recaptured after timbering at the clearcut site (17.5%) relative to the reference site (39.0%). Juveniles appeared to be the size class affected to the greatest degree. Adults and juveniles on clearcuts most likely emigrated and/or died after treatment.

While most investigators believe that timbering is harmful to salamanders, it is difficult to document the effects. Most studies use population censuses in timbered areas and compare these numbers to adjacent untimbered areas. Salamander populations in timbered areas are usually lower, and sometimes absent, when compared to untimbered areas (Blymer and McGinnes, 1977; Bury, 1983; Enge and Marion, 1986; Pough et al., 1987; Ash, 1988; Bury and Corn, 1988; Stiven and Bruce, 1988; Welsh, 1990; Raymond and Hardy, 1991; Petranka et al., 1993; Dupuis et al., 1995). It is thought that opening the forest canopy increases exposure of the forest floor to sun and wind. This dessicates the habitat, thus reducing habitat quality for salamanders. Plethodontid salamanders may be particularly sensitive to habitat changes due to timbering since they are lungless, requiring moist skin for gas exchange, and are fully terrestrial, requiring moist microhabitats for egg development (Pough et al., 1987).

Salamander populations are not the only part of the forest ecosystem affected by timbering. Duffy and Meier (1992) reported that the herbaceous community may not recover to the same pre-timbering species diversity in 40-150 year logging cycles. Forest floor organic matter decreased exponentially to about 50% of the initial levels within 15 yr following timbering, then recovered over the next 50 yr to within 5% of pre-timbering levels (Covington, 1981). Seastedlt and Crossley (1981) reported that microarthropod decomposers were significantly less abundant two years after timbering. Many changes can occur with loss of the forest canopy, some of which would directly affect food availability to salamanders (Mitchell et al., 1996).

There are drawbacks to most earlier assessments of the effects of timbering on salamander populations. Foremost is most earlier studies assume that the pre-timbering population levels in the treatment and reference (control) sites were similar. Since salamander populations may have clumped dispersion patterns (Kramer et al., 1993) this assumption may not be justified. In this study both pre and post-timbering population levels were assessed for an endemic species, Plethodon hubrichti.

METHODS AND MATERIALS

Initially 18 sites were searched at night for P. hubrichti. Only salamanders that were surface active were counted. No logs, rocks, or other debris were disturbed in order to minimize damage to the salamander's habitat. All sites were located within the range of P. hubrichti in the Glenwood district of the Jefferson Nation Forest off the Blue Ridge Parkway in Bedford and Botetourt counties, Virginia. From these 18 sites, 12 were selected based upon (1) having adequate numbers of P. hubrichti and (2) logistical constraints associated with timbering such as having harvestable timber or being sufficiently distant from a waterway to permit timbering.

These 12 sites were randomly assigned to three treatments (four sites per treatment): reference (no timbering), shelterwood cut (partial removal of canopy), and clearcut (total removal of canopy). At these sites P. hubrichti were monitored one year prior to and two years after timbering. At one site from each treatment, salamanders were individually marked (toe clip) and measured (snout-vent length, SVL) for a mark/recapture study which provided a more detailed picture of how the populations of P. hubrichti were being affected by timbering.

At each of the 12 sites, one 5 × 5 m plot was established. Plots at timbered sites were located at least 20 m from the edge of the timbered area which ranged from 0.6 to 1.2 ha. The size of the plot ensured that all sites could be surveyed during a single night, thus avoiding temporal variation (Kramer et al., 1993).

In 1993 baseline population levels were established for all 12 sites during 10 night surveys. The four shelterwood cut and clearcut sites were timbered in May 1994. Following timbering, eight surveys were conducted in 1994 and eight in 1995. Average numbers of P. hubrichti were calculated per site for each year. A repeated measures ANOVA with Huynh-Feldt adjustments to the probability levels (SYSTAT, 1996) was used to assess impacts since the averages were repeated, non-independent, measurements taken over time on each site. The reference sites were compared pairwise with the shelterwood cut and clearcut sites. The interaction of treatment and time was the key model parameter considered since this would indicate whether the populations at the reference sites were changing differently from those at the timbered sites. If the interaction parameter was significant ($P < 0.05$) then the sums of the squares was decomposed into linear and quadratic polynomials. The polynomials were used to determine whether the shape of the population changes over time was primarily linear or quadratic.

For the mark/recapture sites, the 5 × 5 m plots had 5 m buffer zones. The entire plot was laid out in a grid of 1 m[sup2] units. These 1 m[sup2] units were marked with a flag in the lower left-hand corner. The 1 m[sup2] units were further visually divided into quadrants with each quadrant being assigned a lower case letter (a, b, c, and d) in a clockwise fashion starting with the top left quadrant.

All the animals collected at these sites, except for unmarked animals from the buffer zone, were placed in zip lock bags and left at the capture location. Unmarked animals from the buffer zone were not marked before being released at the capture location. Following examination of the entire study plot and buffer area, animals collected were marked and measured (SVL), and released in the same location they were collected.

The marking technique consisted of digital amputation using finger nail clippers. Large salamanders received a unique mark corresponding to a numerical value. Any animal not large enough to be marked uniquely was given a non-specific digital amputation mark (one to several digits removed from the front left foot).

At the mark/recapture sites, several population parameters were estimated including population size, size class structure, losses of salamanders, growth rates, and movement rates. The Jolly-Seber method for open populations (Krebs, 1989) was used to estimate populations.

Collection days were lumped into three groups per year in order to assure that recaptures were available for each group. Size class structure was analyzed using contingency tables to test for homogeneity between sites for adults (>40 mm) and juveniles ([less or equal]40 mm). Losses of salamanders due to mortality/emigration or reduced surface activity was analyzed using contingency tables to test for homogeneity between sites for animals marked before timbering and seen again after timbering versus the number of animals marked before timbering and never seen again. Growth rates (mm/day) were measured within a calender year by change in SVL divided by the time between recaptures. A two-way ANOVA with variables of treatment and year were used to analyze the data. The growth rates were not significantly correlated with size and therefore no distinction for size classes was made in the ANOVA. Movement rates (cm/day) were calculated by dividing the distance between recaptures by the time between recaptures within a calender year. When an animal was recaptured multiple times in a calendar year an average was calculated. The analysis was then similar to that for growth rates.

RESULTS

The pattern of change over time for the average number of P. hubrichti recorded at the reference sites was significantly different from the clearcut sites but not from the shelterwood cut sites (repeated measures ANOVA for treatment*time interaction for (a) reference to clearcut sites: F = 4.5, df = 2, 12, Huynh-Feldt P = 0.03, (b) reference to shelterwood cut sites: F = 1.2, df = 2, 12, Huynh-Feldt P = 0.34; where time represents the three years of the study; Table 1). In the reference to clearcut site comparison, the linear polynomial for the significant interaction parameter (treatment*time) accounted for 79.4% (linear polynomial SS/interaction SS) of the change across time. The average number of salamanders at the reference site was stable over time while at the clearcut sites the averages declined primarily linearly over time. At the clearcut sites, the second year post-timbering average was 30% of the pre-timbering average (Table 1).

Temporal and spatial variability were high for the numbers of P. hubrichti collected. For example the June sample for Site M in 1995 produced zero animals while the August sample yielded 26 animals. Typically the coefficient of variability for a site in a given year was 0.5. Spatially, the sites showed up to a four fold difference for average number of P. hubrichti seen prior to timbering (Table 1).

Population estimates for all mark/recapture sites exceeded 40 animals in 1993 (Table 2). Reference site population levels varied widely but oscillated around a mean of 71 animals with lowest estimates immediately following hibernation. In contrast, the clear cut site population estimates were stable in 1993 at 43 to 44 animals and then, during the subsequent two years, decreased steadily to a low of eight (Table 2). The shelterwood cut site population estimates did not show any clear trend (Table 2).

Loss of salamanders was not homogeneous between the reference and clear cut mark/recapture sites. The percent of the animals seen in the reference site both before and after the timbering date was 39% (N = 46; 39% = 18/46*100 where 18 is the number seen before and after timbering and 46 is total marked pre-timbering). In contrast, for the clearcut site significantly fewer of the marked animals were seen after timbering relative to the reference site (17.5%, N = 40; x[sup2] = 5.2, df = 1, P = 0.023). The shelterwood cut site was intermediate, 23.8% (N = 42), though this value was not significantly different from the reference site (x[sup2] = 2.6, df = 1, P = 0.1).

Clearcut and shelterwood sites had similar fractions of juvenile to adult animals for all years. Juvenile animals comprised from 2.9 to 11.8% of the population across all years for the clearcut site and from 4.3 to 12.8% for the shelterwood cut site (Table 3). In contrast, the reference site had significantly different fractions across the years (Table 3). For the reference site the juvenile animals comprised 7.9% of the population in 1993 and then increased to 29.5 and 29.6% in 1994 and 1995, respectively.

Comparing size classes across sites per year indicated that all the sites were similar in 1993 and differed in the subsequent two years (Table 3). This corroborated the comparisons across years per site. For all sites in 1993 the juvenile animals comprised a small fraction of the population (12.8% or less). In 1994 and 1995 juveniles comprised an increasing percentage of the total population for the reference site while it remained low for both the shelterwood cut and clearcut sites.

Growth rates and movement rates were not significantly different between sites or years ($P > 0.05$). The average growth and movement rates were 0.03 +/- 0.04 mm/day (N = 51) and 8.5 +/- 9.4 cm/day, respectively.

DISCUSSION

We found that clearcutting significantly reduced populations of P. hubrichti. Two years after timbering, 30% of the pre-timbering populations remained at the clearcut sites. Corroborating these findings, the population estimates from the one clearcut site showed a progressive decline from pre-timbering levels while the reference site population did not decline. This finding thus supports earlier studies referenced in the introduction which indicate that clearcutting significantly lowers salamander populations.

The fate of P. hubrichti at the clearcut sites is uncertain. Fewer marked animals were recaptured after timbering at the clearcut site (17.5%) relative to the reference site (39.0%); therefore emigration, mortality, or reduced surface activity was occurring to a greater degree in the clearcut site relative to the reference site. Reduced surface activity is an inadequate explanation for the reduced number of recaptures since our searches were during the nighttime following rainfall when the humidity was high. Both emigration and/or mortality are possible explanations for the reduced number of recaptures at the clearcut site. While movement rates at each site were not significantly different, these rates were for animals recaptured within each respective site. Other marked animals may have emigrated from the clearcut site during the first few days following timbering. These animals would not be available for recapture and hence would not be included in our estimates on movement rates. Therefore emigration immediately following timbering and/or simply mortality are both possible explanations for the fate of P. hubrichti at the clearcut site.

The differences in the size structure of the populations at the reference and clearcut sites might indicate decreased reproductive success of P. hubrichti or that juveniles had higher mortality/emigration rates or were less surface active in the clearcut site relative to the reference site. At the reference site the percentage of the population that were juveniles increased significantly during post timbering years. In contrast, the percentage of the population that were juveniles in the clearcut site remained low for all three years of the study. One possible explanation is that percentage of the population that were juveniles should have increased in the clearcut site as it did in the reference site but due to clearcut timbering it remained low. Juveniles, by virtue of their small size, have a larger surface area to volume ratio compared to the adults and might be particularly sensitive to dehydration. Since clearcutting is thought to degrade forest floor microhabitats by eliminating shading and reducing soil-surface moisture (Bury, 1983) the juveniles would likely be the most heavily impacted size class of P. hubrichti.

The impact of the shelterwood cuts on P. hubrichti appeared to be minimal. The average number of P. hubrichti were stable over time and losses of salamanders were not significantly different from the reference site. Only juveniles appear to be impacted since the percentage of the population that were juveniles followed a trend similar to the clearcut site. Shelterwood cuts remove a portion of the timber which in our sites ranged from 33 to 64% of the basal area (Jefferson National Forestry staff, pers. comm.). Some damage occurred to the site during the actual logging but subsequent to the logging the forest floor habitat looked, on a qualitative level, intact and similar to the reference sites.

Ideally, sites used in pre and post-timbering studies would have similar numbers of salamanders before timbering. Analyses following random allocation of sites to treatments could then include t-tests or one-way ANOVAs for each year post-timbering (or nonparametric equivalents), or repeated measures ANOVA. In our case, after randomly allocating sites to treatments, the pre-timbering averages per treatment were not similar. Using one-way ANOVAs would be inappropriate to analyze post-timbering data since the pre-timbering means were already different. To assess effects, our approach was to consider differences in the effects over time for each treatment (treatment*time interaction) using a repeated measures ANOVA. Several other alternatives exist to analyse data with unequal pre-timbering treatment means. We could have calculated percent change where all post-timbering numbers are expressed as a fraction of the pre-timbering numbers. For example, for Site U the 1993 and 1994 averages were 5.3 and 7, respectively. The percent change would then be (7 - 5.3)/5.3*100. These data could then be used in t-tests or ANOVAs on a per year basis to assess impacts. Using percent change, the conclusions would have been the same as described here. ANCOVA might also have been used with the pretimbering averages being the covariate. In our case the slopes of the lines for each treatment were not parallel which made ANCOVA inappropriate.

In conclusion, clearcutting had an immediate impact on P. hubrichti populations. Plethodon hubrichti populations were significantly reduced due to emigration and/or mortality. Juveniles appeared to be particularly impacted. Shelterwood cuts did not have any overall adverse impacts on P. hubrichti populations in the 2 year time period following timbering. As our study is designed to assess long-term impacts as well as these short-term impacts, the significance of the above effects will be evaluated over the time course of our study.

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TABLE 1. Average number of Plethodon hubrichti collected during night surveys conducted prior to timbering (1993; N = 10 per site) and 2 years after timbering (N = 8 per site per year).

		Year	
Treatment--Site	1993	1994	1995
Reference--B	7.2	6.6	7.9
Reference--U	5.3	7.0	4.5

Reference--M	8.3	12.6	12.1
Reference--O	7.0	8.1	5.8
Mean +/- SE	7.0 +/- 1.2	8.6 +/- 2.8	7.6 +/- 3.3
Shelterwood--N	4.5	7.1	4.6
Shelterwood--C	4.4	1.8	3.5
Shelterwood--D	5.1	5.0	6.8
Shelterwood--X	3.7	2.4	3.8
Mean +/- SE	4.4 +/- 0.6	4.1 +/- 2.5	4.7 +/- 1.5
Clearcut--P	6.1	2.5	1.0
Clearcut--Q	6.2	3.3	1.1
Clearcut--W	2.1	1.8	1.0
Clearcut--Y	3.4	2.9	2.3
Mean +/- SE	4.5 +/- 2.0	2.6 +/- 0.6	1.4 +/- 0.6

TABLE 2. Jolly-Seber estimates of Plethodon hubrichti population size (N +/- SE).

Time period	Reference Site U	Shelterwood Site X	Clearcut Site Y
9/16-10/10/93	46 +/- 16	41 +/- 20	43 +/- 27
10/17-10/20/93	96 +/- 50	40 +/- 19	44 +/- 22
4/28-6/21/94	46 +/- 14	50 +/- 28	26 +/- 9
7/21-9/17/94	85 +/- 31	42 +/- 29	26 +/- 15
9/26-10/14/94	103 +/- 58	12 +/- 5	21 +/- 10
4/12-5/27/95	40 +/- 17	45 +/- 48	11 +/- 3
6/22-9/16/95	80 +/- 64	13 +/- 6	8 +/- 6

TABLE 3. Size class distribution for Plethodon hubrichti across sites and years (juvenile [less or equal]40 mm SVL and adult >40 mm SVL).

	Reference		Shelterwood		Clearcut		
Year	Juv.	Adult	Juv.	Adult	Juv.	Adult	x[sup2] (P)
1993	3 (7.9%)	35 (92.1%)	5 (12.8%)	34 (87.2%)	1 (2.9%)	34 (97.1%)	2.5 (0.29)
1994	13 (29.5%)	31 (70.5%)	1 (4.3%)	22 (95.7%)	1 (4.5%)	21 (95.5%)	10.0 (0.01)
1995	16 (29.6%)	38 (70.4%)	3 (10.7%)	25 (89.3%)	2 (11.8%)	15 (88.2%)	5.0 (0.08)
X[sup2] (P)	7.2 (0.03)		1.2 (0.56)		1.8 (0.40)		

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