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Impact of chaparral wildfire-induced sedimentation on oviposition of stream-breeding California newts (*Taricha torosa*)

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Abstract We examined the effects of chaparral wildfire on stream-breeding California newts (*Taricha torosa*) in a 750-m stretch of a perennial Santa Monica Mountain stream (Los Angeles County). Detailed field surveys of 1992 and 1993 established the composition (run, riffle, pool) of this habitat and determined the oviposition sites of newts. We also quantified California newt egg mass density and estimated the density of newt adults. A chaparral wildfire burned the entire study site on 2 November 1993. Using the same methods, we collected field survey data in 1994 and 1996. Erosion following the 1993 wildfire produced major changes in stream morphology and composition. Pools and runs represented approximately 40–50% of pre-fire stream area. In the spring following the fire, the stream consisted of less than 20% run and pool. Pools that did remain were often smaller and shallower. The average density of adult California newts did not differ among years. The total number of newt egg masses observed in the spring after the fire was approximately one-third of egg mass counts from pre-fire surveys. Most California newt egg masses were laid in pools and runs; California newts prefer deeper slow-moving water. We conclude that fire-induced landslides and siltation have eliminated pools and runs, thus reducing the amount of habitat suitable for oviposition. Habitat alterations caused by fire likely account for the observed reduction of egg masses at the stream.

Key words Amphibians · Fire ecology · Oviposition · Stream morphology · *Taricha torosa*

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Introduction

The effects of chaparral wildfire on native plants are well studied (reviewed by Moreno and Oechel 1994), as are the ecological roles of wildfire in plant community interactions (e.g., competition, succession) (reviewed by Whelan 1995). Animals that inhabit burned areas are also affected by fire, but research on animal responses to fire is much more limited. Research in this area generally focuses on the short-term changes in abundances and subsequent recolonization of birds or small mammals after fire (e.g., Lawrence 1966). Few publications specifically examine the effects of fire on aquatic animals (but see Bozek and Young 1994; Kirkland et al. 1996). Because most research in fire ecology focuses on terrestrial impact, effects of fire on aquatic species are not well documented.

The health and composition of riparian vegetation influences stream bank stability and subsequent stream sediment load (Gordon et al. 1992). Consequently, the loss of vegetation due to fire may cause perturbations in streams of burned areas (Minshall et al. 1989). Most studies have focused on water chemistry changes in post-burn areas (Schindler et al. 1980; Tiedemann et al. 1979). Suspended sediments are often higher in burned areas following rainfall (Minshall and Brock 1991). In addition to changes in water chemistry, fire and subsequent rainfall may produce changes in stream geomorphology (Minshall et al. 1989). The loss of vegetation in burned areas produces soil instability; slides and other land modifications often occur as a result. In this study, we examine fire-induced changes in a perennial stream and their effects on a stream-breeding amphibian, the California newt (*Taricha torosa*).

California newts spend most of the year on land and return to the streams to breed during winter rains (Stebbins 1972). After courtship and mating, female newts oviposit in streams on roots and undersides of rocks. On 2 November 1993, a chaparral wildfire occurred at Cold Creek Canyon; this canyon had not burned in over 20 years. The purpose of this study was to determine if wildfire affects the habitat make-up (run, riffle, pool) of Cold Creek, if the geomorphology (area, depth) of pools in Cold Creek was different in post-fire surveys, and if oviposition sites of California newts are disturbed by these indirect effects of wildfire.

Materials and methods

Cold Creek is a perennial, first-order stream located in the Santa Monica Mountains (Los Angeles County). We conducted detailed surveys of a 750-m stretch of Cold Creek on matched dates before (11 May 1992; 11 May 1993) and after the fire (2 May 1994; 2 May 1996) during the breeding season when California newts typically mate and oviposit in streams (Stebbins 1972). In each survey we recorded the dimensions (length, width, and depth) of the wetted channel of each pool, run, and riffle. Pools were the deepest, slowest-moving sections of the stream and contained fine bed materials (Gordon et al. 1992). Riffles had coarse bed materials and shallow, fast-moving water. Runs were considered to be intermediate to pools and riffles where flow was slower than riffles but moving faster than pools (Gordon et al. 1992). Dimensions were measured using an electronic distance finder, meter stick, and/or measuring tapes. We also recorded the number of California newt egg masses and adults. All areas were systematically searched and dive masks were worn as needed to carefully examine each pool, run, and riffle. Submerged rocks and vegetation were searched with an aquatic periscope or by hand for newt egg masses. Early May is an ideal time to count egg masses because oviposition is nearing completion and hatching of masses laid early in the season does not begin until mid-May. Southern California winter rains are over by April and there is little chance that flood will affect newt or egg mass numbers. Scouring floods did not occur in any of the years that we surveyed newts and newt egg masses. To control for possible impacts of stream volume on habitat areas we also measured stream flow and calculated stream discharge for 1992–1994 on one occasion each year during the last 2 weeks in April using a Marsh-McBirney flowmeter. Flow was measured at a narrow run mid-way up the 750-m stretch of stream studied. We analyzed pool sizes differently depending on whether they were observed only during a single year (annual pools) or observed each year (permanent pools). We used one-way ANOVAs to compare pool depth and area among years for annual pools; Fisher's PLSD was used for pairwise comparison. Areas and depths of each permanent pool in 1992 and 1993 (pre-fire) were averaged and compared to 1994 (post-fire) measurements using a two-tailed paired *t*-test.

Because the number of adult newts seen varies between surveys, we did not rely on one survey to estimate the number of adult newts at Cold Creek. We averaged the results of five surveys conducted between mid-March and mid-May in each year. The complete surveys described above were included, and each additional survey was at least 100 m (mean = 329.5; SD = 251.8).

Results

In pre-fire surveys of 1992 and 1993, total run and pool area was 48.4% and 37.1%, respectively, of the total area surveyed (Table 1). Fire burned the entire survey area on 2 November 1993, and landslides and heavy siltation occurred in the winter of 1993/1994. In the first spring following the fire, runs and pools made up only 16.6% of total area. Riffle constituted over 80% of total stream area. Three years after the fire, riffle still constituted 71% of the area surveyed. Pools were also smaller in area and more shallow after the fire. Annual pools were significantly deeper in both pre-fire surveys than in 1994 following the fire (one-way ANOVA; $F = 3.6$, $df = 3, 102$, $P = 0.016$). Pools were significantly larger in area in 1993 than in the other three surveys (one-way ANOVA; $F = 6.5$, $df = 3, 102$, $P = 0.005$). This result is likely due to above average rainfall in the winter of 1992/1993. Stream discharge increased from 0.024 $m^3 s^{-1}$ in 1992 to 0.072 $m^3 s^{-1}$ in 1993. In 1994, the first breeding season after the fire, discharge was intermediate at 0.053 $m^3 s^{-1}$. Permanent pools were not significantly smaller after the fire ($t = 1.4$, $df = 5$, $P = 0.23$, two-tailed paired *t*-test). However, they were significantly shallower after the fire ($t = 4.0$, $df = 5$, $P = 0.01$, two-tailed paired *t*-test).

Most California newt egg masses were observed in pools and runs; 89% of all egg masses observed in the study were oviposited in pools, and 9.5% were oviposited in runs. California newts rarely oviposited in riffles. Table 2 shows the density of egg masses in pools, runs, and riffles in each year. The total number of egg masses observed in Cold Creek was 160 in 1992 and 158 in 1993. In 1994, the first year after the fire, only 51 egg masses were observed in the same stretch of Cold Creek. In 1996, 3 years after the fire, 67 egg masses were observed. For each year, masses had either just begun hatching or not hatched at all, thus eliminating the possibility that early hatching in some years could account for decreased mass numbers. We observed approximately the same number of adult California newts in Cold Creek each year (Table 2).

Table 1 Comparison between years of stream composition (run, riffle, pool) and mean pool sizes (area, depth) of 750 m of Cold Creek. Annual pools are pools observed only in one year (1992, $n = 24$; 1993, $n = 31$; 1994, $n = 17$; 1996, $n = 34$). Permanent pools are pools that were observed each year ($n = 6$). 1992 and 1993 data are before wildfire and 1994 and 1996 are after wildfire. Different alphabetic superscripts indicate means that differ using Fisher's PLSD post-hoc comparison for one-way ANOVAs

Year	Breakdown of area			Mean Pool size (SE)			
	%Pool	%Run	%Riffle	Annual Pools		Permanent Pools	
				Area (m^2)	Depth (m)	Area (m^2)	Depth (m)
1992	19.3	29.1	51.6	5.4 (0.6)[a]	0.37 (0.02)[a,b]	11.7 (3.4)	0.56 (0.11)
1993	21.8	15.3	62.9	9.4 (1.6)[b]	0.42 (0.02)[a]	15.9 (4.7)	0.66 (0.09)
1994	13.1	3.5	83.4	3.3 (0.6)[a]	0.28 (0.03)[c]	7.9 (1.6)	0.34 (0.08)
1996	20.5	8.5	71.0	4.7 (0.4)[a]	0.34 (0.03)[b,c]	9.6 (2.4)	0.43 (0.05)

Table 2 Comparison between years of egg mass number, egg mass density, and adult density of California newts in 750 m of Cold Creek

Year	Mean (SE) no. of adults/10 m^2	Total no. of egg masses	California newt egg masses/10m^2			
			Total	Pool	Run	Riffle
1992	0.84 (0.18)	160	1.4	7.2	0.5	0.0
1993	0.51 (0.15)	158	0.8	3.4	0.8	0.03
1994	0.66 (0.23)	51	0.6	4.4	0.4	0.06
1996	0.52 (0.19)	67	0.6	2.8	0.5	0.0

Discussion

Winter storm erosion of burned lands in California drastically increases sediment input into streams (reviewed by Booker et al. 1993). The water storage capacity of the soil mantle can be reduced 20 times or more as a result of fire (Wells 1981). Slopes that are devegetated by fire are often unstable (Abe and Zeimer 1991). Rock and soil that was supported by vegetation, roots, and leaf litter often falls under the direct force of gravity after fire (Splittler 1995). Landslides following the November 1993 fire in Cold Creek Canyon caused major changes in the morphology of Cold Creek. While we realize that we have not provided information on other burned streams or on control streams we are confident that the patterns observed before and after wildfire are general to other streams in southern California. The strength of before-and-after-perturbation studies is often dependent on having a control site (Stewart-Oaten et al. 1992). We study eight other streams in the Santa Monica Mountains (map in Gamradt and Kats 1996). None of our other streams were included in the area consumed by the 1993 fire and we observed no major sedimentation or mudslides at these sites anytime during 1993–1996. Sedimentation changes at Cold Creek were clearly fire-induced given that we observed no major changes in pool structure or sediment loads in any of our nearby unburned study streams (L. Kats and S. Gamradt, personal observations).

Our surveys indicate that the vast majority of California newt egg masses were oviposited in pools and runs. Pre-fire Cold Creek was composed of approximately 40–50% pools and runs. California newts prefer this deeper, slow-moving water for mating and oviposition. The number of egg masses found in Cold Creek in the spring following the fire decreased to about one-third of pre-fire levels. Pools and runs were reduced to less than 20% of total stream area in the spring following the fire. Given that the numbers of adults migrating to the stream remained relatively unchanged, this reduction in egg mass number at Cold Creek is likely due to the post-fire loss of pools and runs. During the spring after the fire, Cold Creek consisted of over 80% riffle; California newts rarely oviposited in riffles before or after fire. It appears that fire-induced landslides eliminated many pools and runs at Cold Creek, thus reducing the amount of habitat suitable for oviposition. Since stream discharge in 1994 was greater than in 1992, changes in available pool and run habitat were likely unrelated to discharge levels. Our data indicate that newts usually oviposit in the largest and deepest stream pools. Pools that were not completely eradicated after the fire at Cold Creek were often smaller and more shallow. In 1992 and 1993, two of the largest pools in the stream contained 31% and 17% of egg masses laid (Table 3). These pools were deep and contained high densities of California newt egg masses in 1992 and 1993 before the fire (Table 3). After the fire in 1994 and 1996, the pools were shallow and contained no newt egg masses; suitable oviposition sites were covered by sediment. Thus, habitat loss likely occurred at two spatial scales; pool area decreased and available oviposition microsites (e.g., bedrock ledges, undersides of large flat rocks) were covered over with sediments. It is unclear if newt adults that used these pools for breeding before the fire successfully found alternative breeding sites. Adult newts are long lived (10–15 years) and are very site tenacious (Twitty 1942). Recaptures of electronically tagged adult California newts indicate that newts return to within a few meters of the original capture site in subsequent years. (L. Kats, unpublished data). Disturbances to preferred breeding sites of site-tenacious newt adults likely contributed to the observed decline in egg mass quantity at Cold Creek.

Three years after the November 1993 chaparral wildfire, the largest and deepest pools are still absent at Cold Creek, and the number of California newt egg masses has not returned to pre-fire levels; however data from 1996 show more egg masses than in 1994, a pos-

Table 3 Data from two pools that were changed by erosion after chaparral wildfire. The dimensions of each pool and the number of California newt egg masses present are reported for each year

Year	Angel Falls Pool			Low Nose Pool		
	Area (m^2)	Depth (m)	Egg mass no.	Area (m^2)	Depth (m)	Egg mass no.
1992	27.5	0.70	31	10.4	0.70	20
1993	38.3	0.85	10	15.0	0.73	18
1994	6.6	0.20	0	6.9	0.25	0
1996	6.3	0.35	0	7.3	0.56	0

sible indication that recovery has begun. Oviposition sites may not be permanently lost; new pools do exist and pre-fire pools may be slowly returning to their original sizes and depths. Habitat disturbance due to fire-induced erosion has disrupted oviposition by California newts. However, as adult densities have not decreased, and as oviposition sites may gradually return, California newt egg mass density may return to pre-fire levels.

The success of conserving stream amphibians in southern California may depend on limiting anthropogenic increases of stream sediment loads. The average fire frequency of Santa Monica Mountain chaparral stands is between 12.4 and 20.7 years (Radtke et al. 1982). Nearly all chaparral wildfires in recorded history were set accidentally or intentionally by humans; lightning is not a primary source of ignition because it occurs during the wet season and because it does not coincide with hot and dry *foehn* winds which characterize fire season (Radtke et al. 1982). Thus, fire frequency and resulting stream sediment loads have probably increased above natural levels in southern California. Conservation efforts in burned habitats of California will benefit from studying the response of both terrestrial and aquatic habitats to chaparral wildfire.

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