Monitoring of Sensitive Mollusk Populations Following Low-intensity Wildfire in Old Growth Coniferous Forest

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Abstract

We monitored the survival of four species of terrestrial mollusks (*Prophysaon coeruleum, Monadenia chaceana, Monadenia fidelis,* and *Helminthoglypta hertleini*) following a natural wildfire in old growth Douglas fir forests in southwestern Oregon during the summer of 2002, in order to investigate the short-term effects of such disturbance events on local abundance and distribution and to gain insight into the dynamics of survival and recolonization following low and moderate intensity fires. Mollusk sites had been located prior to the fire event, during protocol surveys conducted in support of proposed timber sale projects. The same survey method was repeated in the two years immediately following the fire during this study. Each site was revisited at least twice to document abundance, habitat condition and mortality. Reference sites in unburned units were also sampled at the same time to determine bias due to weather, survey efficiency, or other effects not related to the fire. We found that these four mollusk species were negatively affected by the fire: both distribution and abundance were reduced. Only 10 of 26 original locations still contained live mollusks in burned units and the total number of live individuals detected in the burned units was reduced from 42 to 35. Seven new locations were discovered. There appeared to be differences in sensitivity between the taxa groups. Adult snails were most severely affected, with only one live adult individual located post-fire, while slugs were least affected but reduced from 24 occupied sites pre-fire to 15 sites post fire. Habitat features such as down wood, tree canopy cover and groundcover did not appear to be correlated with survival. Coarse rock substrate with deep fissures and access to underground moisture was present at most sites that had continued occupancy, suggesting that these features provide for deep vertical movement and shielding from heat during wildfires. The distribution of these features in the landscape may play an important role in maintaining long-term species distribution within a range.

Key Words: mollusks, wildfire, old growth, monitoring, survival, recolonization

Introduction

Very little is known about the effects of disturbance on mollusk occupancy in forests of the northwest. The effects of fire, in particular, are very poorly understood. It has been reported from work on mollusks in spruce forests in northeastern USA that mollusk species richness and abundance are both reduced by fire events (Strayer, 1986). The snails in the spruce forest study were minute species, however, which may not respond in the same manner that larger terrestrial slugs and snails do. Another study, conducted in low elevation pine and oak forests in the Mediterranean region of France, found that fire resulted in decrease in diversity and abundance of mollusks. In this study, unburned refugia within and on the edges of fire areas did not play an important role in survival and recolonization, but rather other "scattered refuges" within the landscape allowed for continued permanence in the malocological community (Kiss and Magnin, 2003).

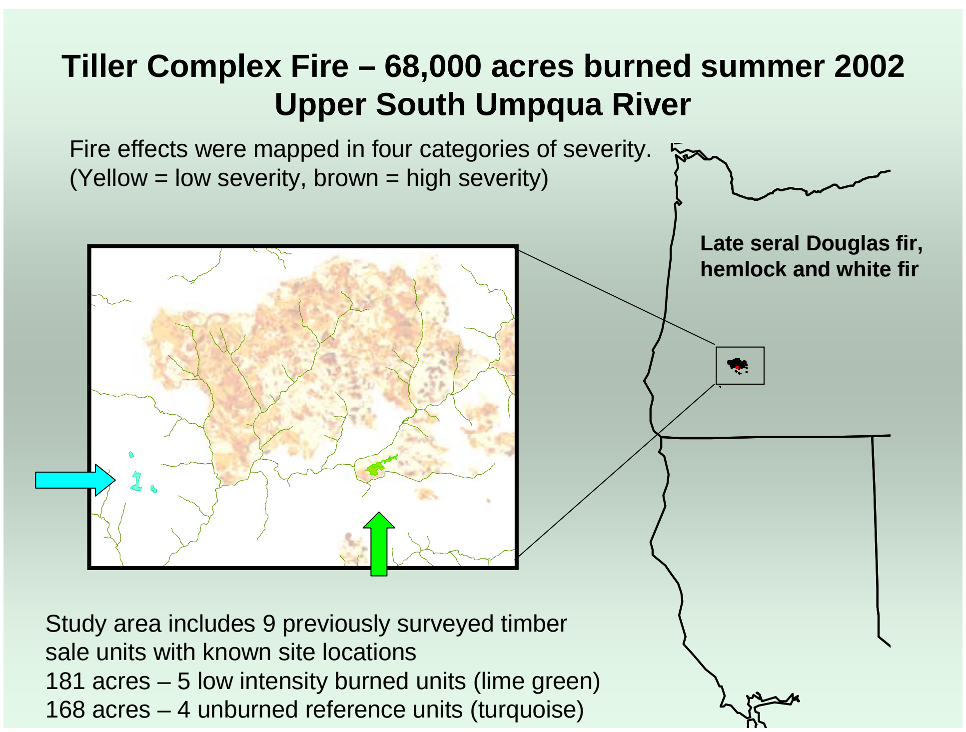
Caution must be used in assuming the same effects and behaviors would occur in the far different habitats found in the Pacific Northwest. There is evidence from survey reports of live mollusks within previously burned areas in northern California that suggests that some survival occurs, and that fire may even play a role in creating forest openings and allow increases in herbaceous forage for some species (Gausen, 2001, Schlick, 2002). The mechanisms or behaviors that allow this survival to occur had not been investigated.

The occurrence of a catastrophic wildfire in 2002, which burned previously surveyed timber sale units containing known mollusk sites, offered a unique opportunity to investigate the survival of four species of mollusks at those sites, and to compare habitat variables and fire effects between sites to discover any correlations which could help explain the results.

Methods

Study area

This study was conducted in old growth Douglas fir/ white fir forests in southwestern Oregon, approximately 30 miles northeast of Tiller, Oregon, in the Buckeye Creek drainage (see vicinity map). The study area was part of the Tiller Fire Complex, which burned over 68,000 acres during the summer of 2002 (USDA, 2003). The average elevation in the study area is 3500 ft. above sea level. We surveyed 181 acres in 5 burned units and 168 acres in 4 unburned reference units during the two years following the fire. The burned timber sale units had been previously surveyed during 1998-1999. During pre-fire surveys, 40 known sites for four species of sensitive mollusk species had been located and mapped. Reference units outside of the fire perimeter were selected to match burned units for stand age, aspect and elevation.



Mollusk sampling

All post-fire visits to the study area were made during the spring and fall seasons of 2002-2004, when mollusk activity was greatest, using standard survey protocols established for the Survey and Manage program of the Northwest Forest Plan (Duncan, et. al., 2003). The intent was to repeat the methodology used during the previous surveys of these sale units, which also used this survey protocol. This method uses hand sampling techniques in time/area constrained surveys within selected plots, combined with opportunistic sampling of key habitat features throughout the unit.

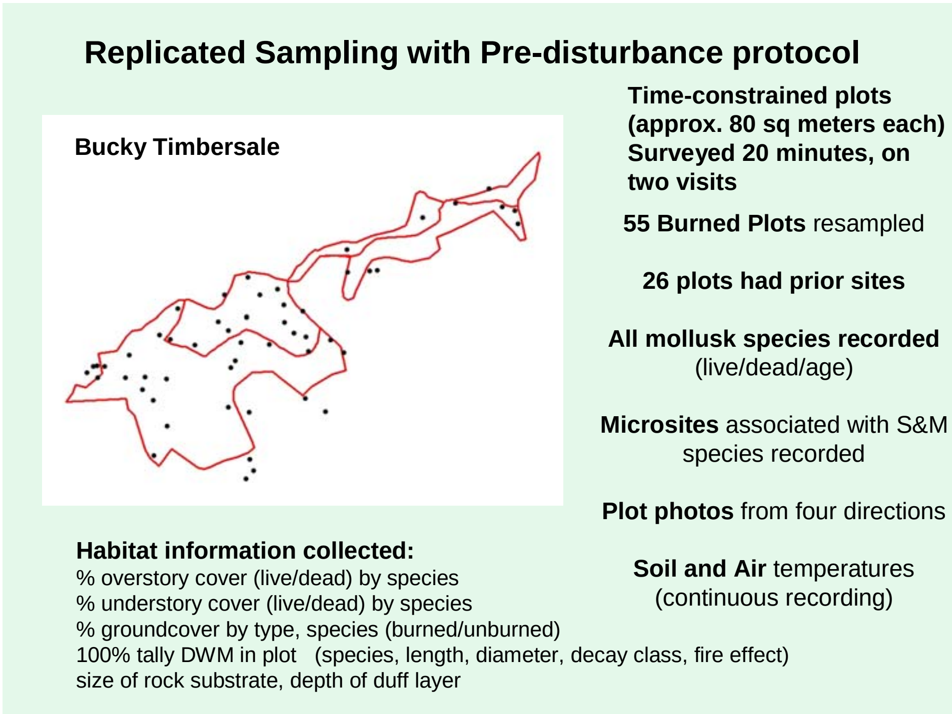
The time constrained portions of the surveys were conducted in 30 ft. diameter plots, located in areas with concentrations of key habitat features used by the target species. These plots were marked in the field during the pre-fire surveys, using flagging and aluminum tags. As each plot was relocated after the fire, it was re-marked and GPS coordinates recorded. Post-fire surveys, conducted in the two years immediately following the fire, re-sampled plots previously searched during the pre-fire surveys. In cases where a pre-fire sample area could not be relocated in the field by any recognizable marking, a replacement plot was designated in the closest approximation of the original location. Each plot was searched for twenty minutes per visit, using a hand rake to examine litter and duff down to the mineral soil, as well as a visual inspection of all vegetation to eye level for the presence of mollusks or shells. All shells and live mollusks were recorded, as well as habitat variables, and representative specimen vouchers were collected. Two such plots were searched for every ten acres of habitat within the sale units. At least two visits to each sample plot were conducted post-fire.

The opportunistic portions of the surveys consisted of a brief visual examination of individual habitat features outside of sample plots, totaling at least twenty minutes for every ten acres surveyed. These searches normally occurred along the routes between the sample plots, and used a hand rake to briefly examine rocks, logs, bark and moist groundcover vegetation that could conceal shells or live mollusks. Routes used during pre-fire surveys were followed, as well as possible, during the post-fire surveys.

Visits to reference units alternated with visits to the burned units, in order to minimize differences in results due to weather conditions. A total of 75 hours of search time was spent in surveys from fall 2002 to spring 2004.

Habitat variables

Habitat information collected at each sample plot and site location included 1) percent overstory cover (live/dead) by tree species, 2) percent understory cover (live/dead) by species, 3) percent groundcover (burned/unburned) by species, 4) 100% tally of down woody material in plot (species, length, diameter, decay class, fire effect), size of rock substrate and depth of duff layer. Other information such as moisture condition, aspect, slope and elevation were recorded both pre- and post-burn. Location (GPS) coordinates and plot photos, taken from four cardinal directions, also documented conditions at each sample plot and species location. Continuous soil and air temperatures were recorded using remote sensors located in both the burned units and the reference units.



Analysis of data

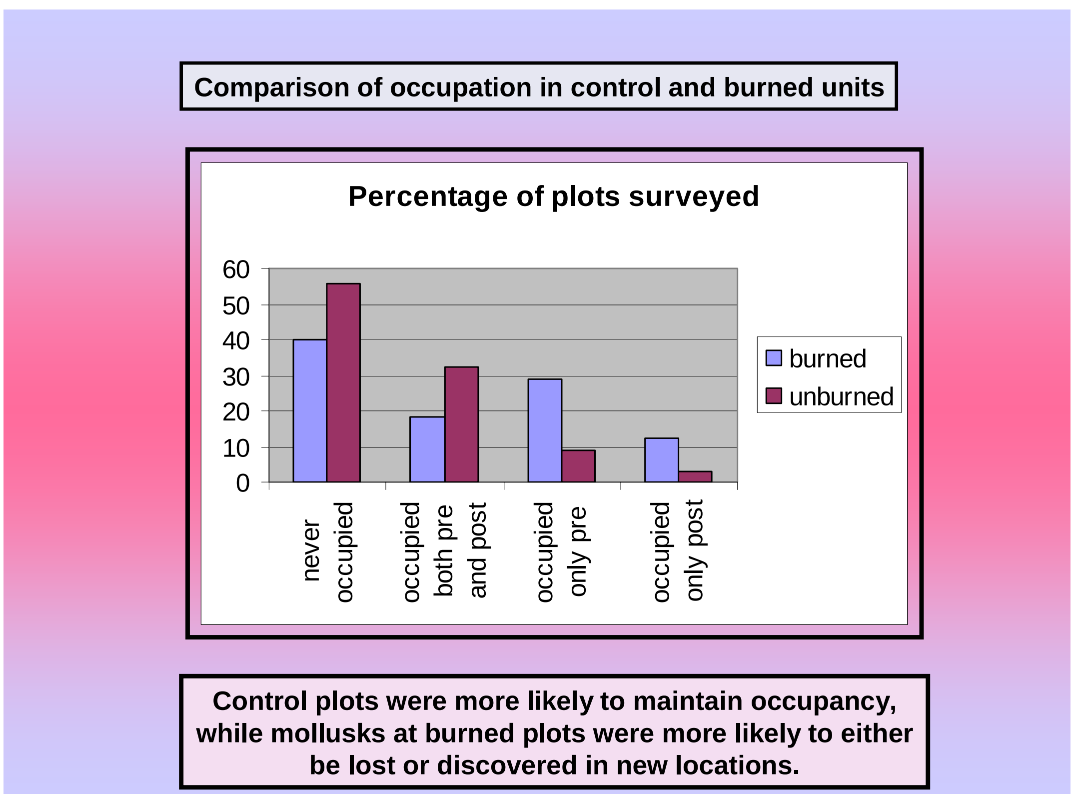
Since the plots sampled in this study were few in number and not randomly chosen, but rather replicated previous locations of sample plots, statistical analysis of the results could not meet the assumptions of normal distribution. Instead, we used non-parametric analysis and a simple presence/absence matrix to compare pre- and post-fire occupation at each location, and to compare the pre- and post-fire results of the total survey of the burned units. The results of surveys in the unburned reference units were used to test the efficiency or repeatability of the survey method (ie. how well animals could be detected again after four years at sites that previously contained mollusks) and were compared with the results from burned units. Spatial analysis was done using ArcGIS software, overlaying sites with other spatial layers such as contours, fire severity, geology, hydrology and forest stand inventory data.

Results

Mollusks

We revisited four unburned timber sale units which had been surveyed 4-5 years earlier in 1998 and 1999. Although field marking for old routes and sample areas was difficult to find, we were able to relocate 34 of the original sample plots in these units, 14 of which (41%) had previously contained sensitive mollusks. In the first survey of these plots in 2002, we detected live mollusks at 11of the 14 locations **(79%)** where they had been detected before. One additional animal was discovered at a plot which had not had mollusks detected before. The proportion of all resurveyed plots in the sale units with live mollusks was 35%, a **6% reduction in the proportion of plots occupied**. The total number of individuals found during the second survey was lower than the number found during previous survey, 15/17 (88%), **a reduction of 12% in total abundance**. These numbers indicate that the survey methodology was highly effective, although the results of the two surveys were not identical.

Surveys in the burned units yielded different results. Of the 55 original plots resurveyed, 26 (47%) had previously contained live mollusks. After the fire event, only 10 **(38%)** of those 26 previous sites still contained live mollusks. However, 3 additional locations were discovered at plots which had not had mollusks detected previously, and 4 other sites were located at new plots. Even so, only **31%** of the plots sampled after the fire had live animals detected, a **16% reduction in the proportion of plots occupied**. The total number of individuals found after the fire was 39, compared to 45 individuals before the fire, a **14% reduction in total abundance**. These results indicate that although there was a loss of mollusks at plots where they had previously been located, the total number of sites and individuals in the survey area, though reduced, was not severely affected, but the pattern of distribution of mollusks was changed somewhat. (See Figure 1)



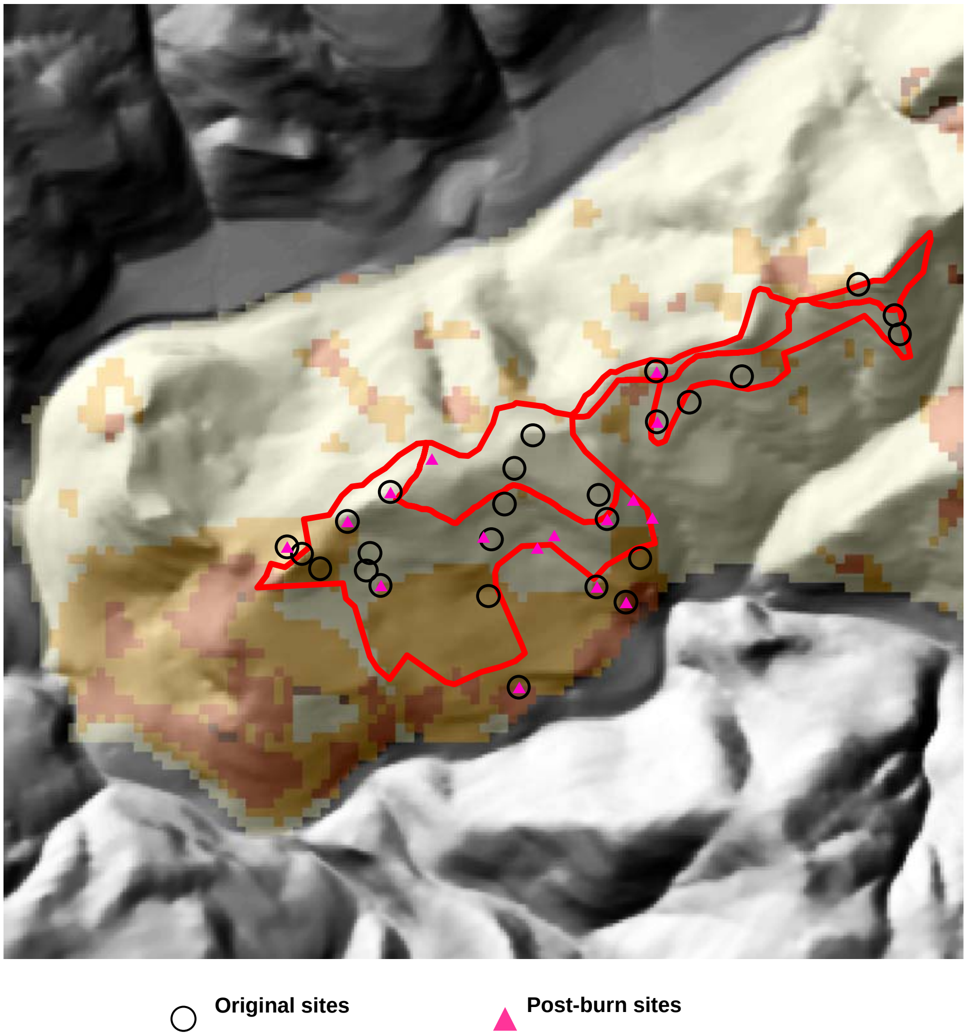
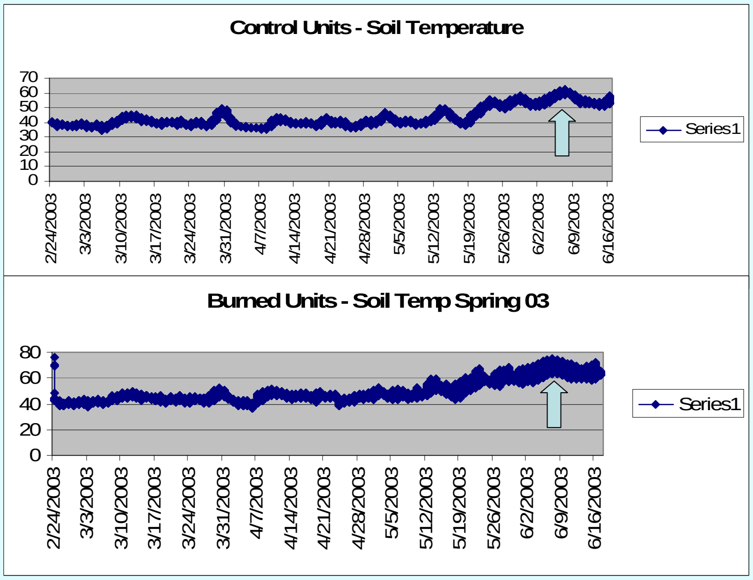


Figure 1. Comparison of site locations and fire intensity on relief map of burned units. (darker colors represent higher fire intensity: light yellow = low, tan = moderate)

Environmental variables

Continuous recordings of soil and air temperature within the burned stands and the undisturbed old growth stands showed a generally warmer, less stable environment in the burned area. (See example, Figure 2) Both the soil and the air average temperatures were many degrees warmer in burned units. The range of daily fluctuation in soil temperature reached almost 20 degrees during the late spring in the burned units as compared to <10 degrees in the undisturbed stand. The combination of warmer temperatures and greater daily variation resulted in a shorter effective season for mollusk activity in these areas.



Soil temperatures in burned units warmer, 10-20 degree daily fluctuation, reached **80 degrees** on June 8. Control temperatures cooler, <10 degree daily fluctuation, **still low 60s on June 8**.

Unburned areas had more stable temperatures, longer effective season.

Figure 2. Comparison of soil temperatures in sampled units during a four month period.

Habitat correlations

One of the more interesting results that we found had to do with the locations of the surviving mollusks. Habitat variables such as volume of down woody material, canopy cover and percent of groundcover are typically used to predict the "suitability" of habitat in undisturbed forest settings. These variables did not seem to be related to the continued occupation by mollusks in burned plots. Figure 3 illustrates the relationship of these features with mollusk presence. There was no positive correlation with either average canopy cover, volume of down wood or percent live groundcover at plots with mollusks in the burned units. On the contrary, even though two mollusk sites were found in unburned patches within the fire mosaic, plots with mollusks present had an average of 83% of the groundcover burned, compared to 80% burned in unoccupied plots. The volume of down wood was also less in plots with mollusks (133 cu. ft.) compared to unoccupied plots (266 cu. ft.). Two plots having a large volume of down wood, but which did not have mollusks detected, largely explain the DWM data. No tests of significance of these differences could be performed due to the non-random nature of the data, however results do suggest that most plots were similar with regards to these variables, and that continued mollusk presence could not be predicted based on them.

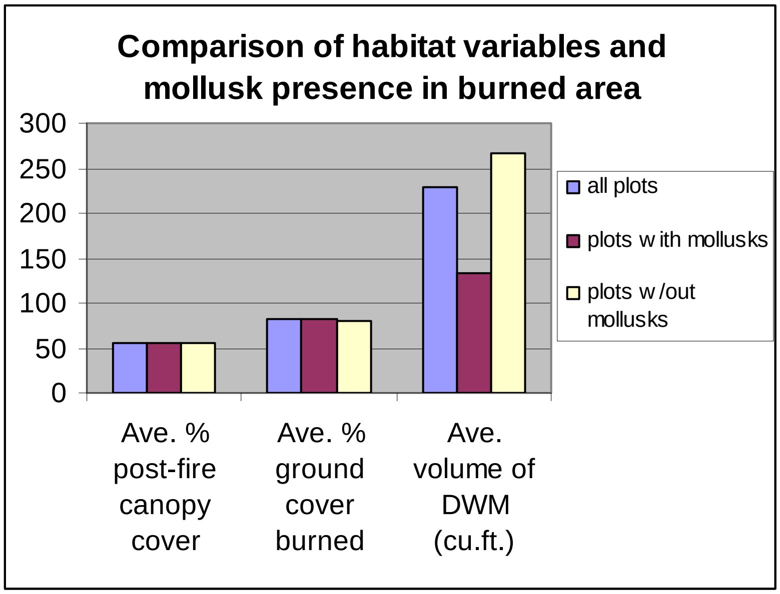


Figure 3. Habitat variables

The habitat features that did seem to be associated with surviving mollusks were the presence of coarse rock talus and outcrops, deep fissures and nearness to the water table. (Figure 4) In situations where edges of outcrops or fissures between rocks led deeply into the ground and provided access to cool, moist environments, animals apparently could migrate vertically and escape from the heat of the fire. These underground sites also provided stable environmental conditions after the fire, which allowed animals to emerge to exploit the limited food resources available, such as ephemeral fungi fruiting bodies, and then retreat back into cool, moist refugia.

Figure 4. Plot photo of rock outcrops and coarse substrate

The sites that had the highest numbers of individuals were located in wet, saturated ground on benches below the outflow of small seeps that developed after the fire. (See

Figure 5). These seeps were located at contour breaks, at the interface of an impervious bedrock layer and an overlying stratum of porous volcanic rock. From the orientation of the strata, we can hypothesize that in response to the decrease in transpiration by trees killed by the fire at higher elevations, fissures and passages in the porous layer filled up and ground water accumulated above the impervious layer. This water then was expressed above ground as a seep and small pond, which was not apparent prior to the fire. The available surface water then generated a bloom in green herbaceous vegetation adjacent to wet, rocky refugia sites, providing a beneficial combination of features.

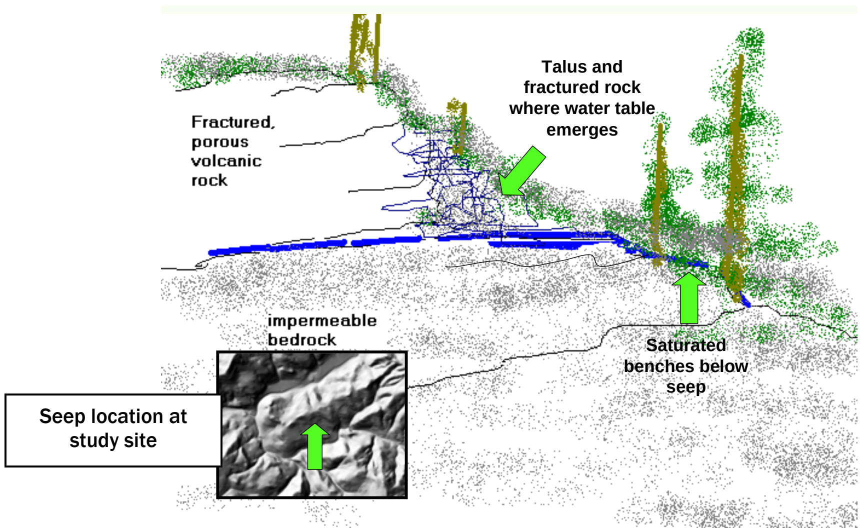


Figure 5. Fissures in rock provide access to underground water

Species results

The species of mollusk that survived this fire best was the small (ave. 10 mm) slug, *Prophysaon coeruleum*. Of the 39 live individuals located in the burned units after the fire, 34 were this species. We hypothesize that their small size and flexibility may have allowed them to penetrate more deeply into the rock substrate to avoid the heat of the fire and later dessication. Two juvenile specimens of the moderate-sized (20-25 mm diameter), low-spired snail species, *Monadenia chaceana*, were found alive after the fire at one very rocky site, compared to seven original locations. Sites for this species, both before and after the fire, were located only on one particular ridge. This formation extends roughly north to coincide with the South Umpqua Falls. To the south, adjacent to the unit, it ends in a large quarry which uses the material for road construction. It is interesting to speculate on the possible connection between this geologic material and this species' distribution. Many dozens of charred shells of the larger snail (up to 40 mm diameter), *Monadenia fidelis* (sp. nov), were found throughout the study area, but only two specimens were found alive in one location, one juvenile and one adult. The one prior location of *Helminthoglypta hertleini* that was monitored during the study was in a moderate-intensity burn area where all of the trees were killed. Although one live snail was found immediately after the fire during the fall of 2002, none were found subsequent to salvage operations the following summer which cut, piled and burned the dead trees in the immediate vicinity of the site.

Discussion

The results of this monitoring suggest that this wildfire caused the direct mortality of many individual mollusks in the study area. The population density was reduced, and the distribution altered. The survival of many individuals over two years, on the other hand, indicates that, although recolonization may be slower for some, most of the species in this study should continue to be represented in the new wildlife community that develops after the fire.

Disproportionately larger numbers of slugs and small juvenile snails survived as compared to large adult snails, possibly as a consequence of their ability to penetrate more deeply into the rock substrate to avoid heat from the fire. The snail *Monadenia chaceana*, due to its flatter shell shape may be better adapted for surviving fire events by penetrating deeper into the interstitial spaces in rock refugia than the larger *Monadenia fidelis*. The poorer survival of larger snail species may reflect a more serious threat to those species from fire. There is also the potential for larger live snails to have remained buried in aestivation and not be detected during surveys immediately after the fire.

The long-term effect of the fire on the distribution of mollusk populations may be more important, but less well understood. Surviving mollusks were found in several new locations, most of which were associated with deep rock talus substrate and access to water. The landscape distribution of such rock/water interfaces, forming “deep refugia”, may well form the backbone of fluctuating mollusk population distribution patterns which contain many acres of seemingly suitable but unoccupied habitat, a phenomenon well-known to terrestrial malacologists. In geographic regions where wildfire is a major environmental factor affecting the composition of the vegetation in the landscape, effective habitat may develop faster after a fire event than the surviving mollusk fauna can colonize it. Deep refugia locations determine where survival occurs and are the centers of successive areas of recolonization. These sites may have had continuous occupation by the species over many thousands of years and may represent the oldest genotypes in the area. These are the locations that are critical to maintain in order to maintain good long term population distribution across the landscape.

Other notes:

Commercial harvest of fungi, especially morels, after the fire may have had negative effects on mollusk populations. The slug species, *Prophysaon coeruleum*, is known to be mycophagous (McGraw and Duncan, 2000). Several individual slugs were located on and inside of morel fruiting bodies during surveys in the spring following the fire, apparently using them as moist mini-environments and food sources. Mushroom harvesters working in the area must have inadvertently removed many other individuals and reduced the number of morels available for the remaining animals.

Prescribed fire may be expected to result in similar survival patterns, if done under similar conditions. Typically, however, fire operations windows do not allow for mid-summer or early fall burning during the dry season when mollusks could be expected to be aestivating as they were during this event. The heat generated during fires that occur when the ground is wet penetrates deeper into the soil, and may cause steam to form in underground spaces which could kill aestivating animals. It is expected that the survival results would be different if a fire occurred while animals were active at the surface. The original vegetation type is also important in predicting the effects of fire. In this study, the stand was an old growth fir forest, with multiple canopies and large amounts of down wood. The overstory was not affected by this fire, and the site retained it’s pre-fire canopy cover. Fire behavior may be different with fuel loading found in other vegetation types or seral stages. Prior harvesting of thinned trees during fuels reduction treatments could also change the fuel loading and cause compaction from heavy equipment operation, changing the survival dynamics.

Delectability differences may have been present between plots in unburned stands and those in the fire area. Since many of the burned plots had all of their ground cover and woody material burned away during the fire, they contained fewer places for concealment of slugs and snails. The detectability of live animals may have been greater in those plots, especially during the first season. Conversely, animals may have been less likely to forage above ground where they could be detected in plots with no cover. Detectability under these circumstances would increase during weather conditions which would allow surface browsing. Undisturbed forest plots, on the other hand, typically contained much more complex woody debris and groundcover layers to search. Detectability may have been less in these plots and the potential greater for animals to be present, but not detected. The results of the second surveys in the unburned control units were comparable to those of the first surveys, however the reduced number of individuals may reflect this decreased detectability.

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