The Distribution of Amphibian Assemblages of Zero-order (Headwater) Catchments and their Relationships to the Landscape Mosaic in the Mill Creek Watershed and Adjacent Parklands in Del Norte County, California

Final Report to the California State Parks, Northern Section

Attention: Jay Harris

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Garth R. Hodgson

and

Hartwell H. Welsh, Jr.

USDA Forest Service

Pacific Southwest Research Station

1700 Bayview Drive

Arcata, CA 95521

ABSTRACT

The primary goal for the 25,000 acre commercially logged Mill Creek redwood forest property is to restore it to the historical late-seral forest conditions. To this end, managers are implementing a comprehensive assessment and monitoring strategy to gather baseline data with which to compare and track trends over time in order to evaluate the effectiveness of restoration measures. Headwaters amphibians have proven advantages for use as biological indicators of ecosystem status because of their relatively high abundances, high site fidelity, long lives, ease of sampling, and sensitivity to disturbance. Furthermore, their use offers large cost savings compared with sampling other less tractable vertebrates. Amphibians occur in larger numbers and greater diversity in healthy forest ecosystems where they play an important role in regulating invertebrate communities. In 2006 we conducted time-constrained upland searches, and aquatic area-constrained searches at 28 zero-order catchment sites in four forest seral stages of redwood forest on the Mill Creek property and adjacent parklands. Results showed significant differences in assemblage metrics, species abundances, and assemblage composition between stand classes on the harvested Mill Creek property and those on adjacent late-seral parklands. For example, in the upland, we detected an average of 5.5 animals per hour on the property versus 12.7 animals per hour in the parkland. We suggest that as managed forests on the property recover, species numbers and their relative abundances will approach that of the adjacent late-seral forest. We propose future periodic efforts to compare these amphibian baseline values with future trends in these assemblages over decades as surrogate indicators for tracking changes in the entire Mill Creek biota as these forests recover their late-seral characteristics.

INTRODUCTION

Timber harvesting on the Mill Creek property began in the 1850's. Hobbs, Wall, & Company began logging in the 1920's. Harold Miller purchased the Mill Creek portion of the property around 1940, and the Rock Creek portion in 1965. Today, less than one percent of late-seral stands remain, and 69 % of stands are less than 28 cm (11") DBH. The 25,000 acre property has been heavily logged for the past 60 years but still supports the best remaining Coho salmon stream in California (Mill Creek) and three state-listed amphibian species of special concern (IRM 2002). We designed a sampling scheme to track the recovery of amphibians on this heavily logged landscape as it is restored to late-seral conditions. We have a unique opportunity to document changing habitat conditions and document the response of this sensitive vertebrate taxon. In so doing, our intent is to simultaneously demonstrate the use of amphibians as metrics of watershed recovery and health (e.g., Welsh and Ollivier 1998, Welsh and Droege 2001). The Mill Creek property is bordered on two sides by large tracts of now rare late-seral redwood forest –Del Norte Redwoods State Park on the coast and Jedediah Smith Redwoods State Park to the north – providing ideal reference habitats with which to compare the Mill Creek property recovery trajectory. In addition, the restoration of the property is important as a migration corridor for both the terrestrial and aquatic wildlife and fishes, both between the interior and the coast, and between north and south latitudes (IRM 2002).

Goals for the of Future of the Property

The main objective is to return these heavily managed forest stands to late-seral conditions by reducing the extensive road system and applying silvicultural treatments to maximize tree growth and augment stand structure while protecting watercourses and minimizing fire hazards. Ultimately, success or failure will be partly determined by the response of the native animal communities. To that end, managers need to know the current status of the animal communities as a baseline to compare with future distributions and abundances (IRM 2002).

Need for Baseline Assessment of Current Conditions

State Park managers have been given the task of converting the 25,000 acre, heavily logged property back to late-seral conditions. To achieve this, they need baseline data in order to compare with future conditions. A healthy late-seral forest is more than just large trees, so they need baseline data on a representative portion of the entire biota. Since this is cost prohibitive, they have adopted an indicator species approach. They are monitoring the salmonids, spotted owls, and marbled murrelets, and plan to monitor songbirds. They have asked us to monitor the amphibians.

Because amphibians are small and usually extremely cryptic, their importance in ecosystems has been largely overlooked. Recent studies have shown that amphibians can be quite abundant in natural forests (more biomass than birds and small mammals combined) (Burton and Likens 1975). As the primary predators of invertebrates on the forest floor, salamanders play a keystone role in transferring energy up the food web (Davic and Welsh 2004). Both terrestrial and aquatic amphibians have been found to be sensitive to forest disturbances such as timber harvesting (deMaynadier and Hunter 1995). Amphibians make up a divergent group of animals with a wide range of natural histories and habitat requirements, and they are relatively easy to sample, thus providing a reasonable and cost effective means of assessing ecosystem health (e.g., Welsh and Ollivier 1998, Welsh and Droege 2001).

Objectives

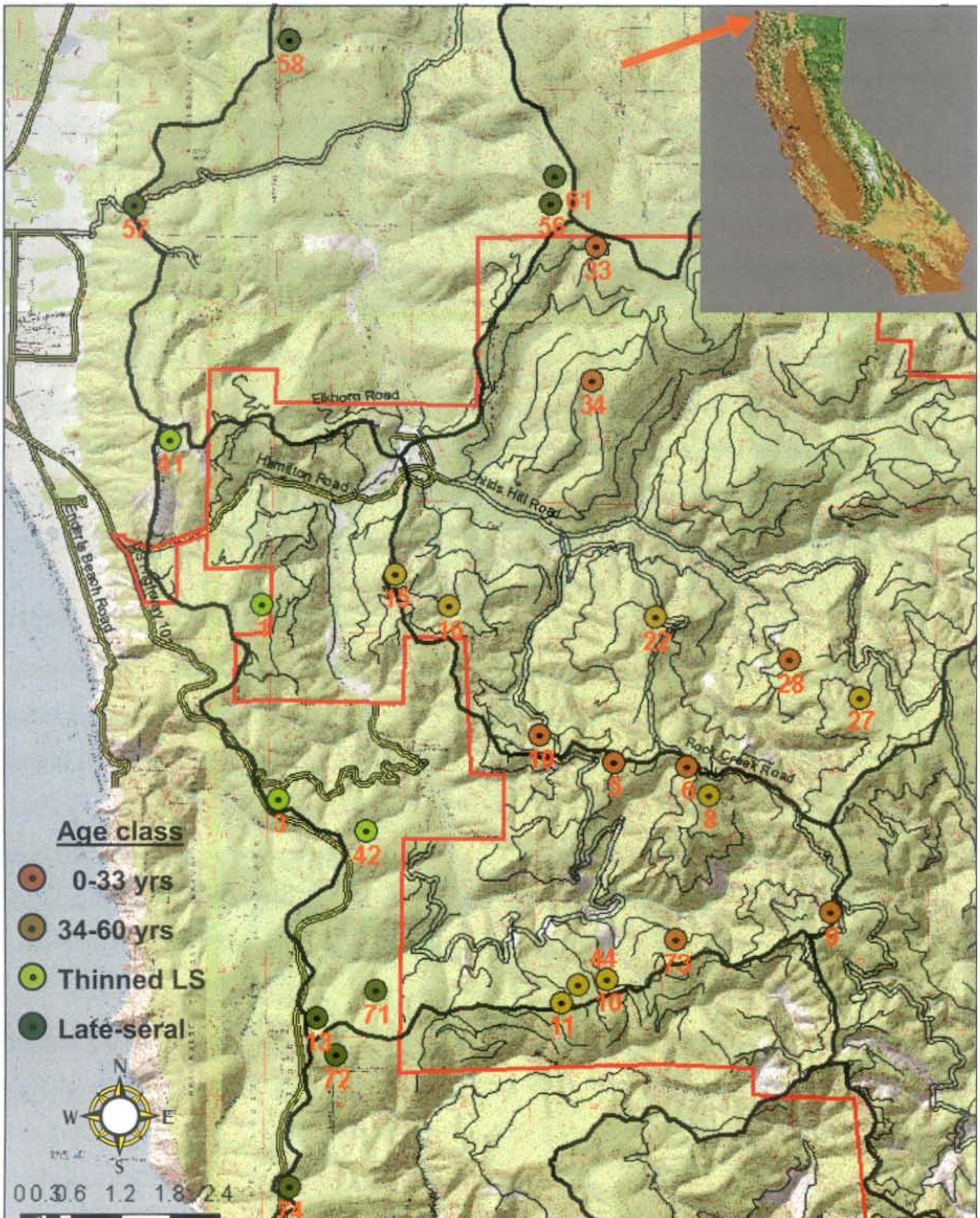
Our objectives were to quantify the distributions of the zero-order (terrestrial/headwater stream interface) amphibians at a set of sites representing the existing seral stages in the East and West fork basins of Mill Creek and on comparable reference sites in adjacent parklands. This sampling design is intended to provide baseline data on current distributions and abundances and provide a set of sites that can be used for future monitoring. These "zero-order" and "first-order" habitats are known to yield the highest amphibian diversities (Sheridan and Olson 2003). Short-term goals include collecting baseline data on current environmental conditions and documenting how the amphibian distributions and abundances relate to these conditions.

By documenting amphibian population responses to forest seral advancement we intend to demonstrate their applicability as metrics of ecosystem recovery processes. By understanding the conditions that allow for recovery of sensitive forest amphibians, our research will help establish forestry criteria useful for maintaining populations on managed lands and for mitigating damage to potential habitat. We will work with managers to identify source populations of sensitive amphibian species, and prioritize sampling in areas which may be impacted by early restoration efforts. Ultimately we envision a long-term monitoring study which documents the changes of the herpetofaunal assemblage as the landscape recovers its original late-seral characteristics.

Study Location

The Mill Creek property is 103 km^2 (40 mi^2) of a costal redwood and Douglas-fir forest land that reaches within 2 km of the Pacific Ocean. Mill Creek was historically grown to old-growth redwood forest, but has undergone extensive logging and is now dominated by various seral stages of second-growth forest. The property is situated between the late-seral forests of Jedediah Smith Redwoods State Park to the north, and Del Norte Coast Redwoods State Park to the west, in Del Norte County, CA. (Fig. 1). The Mill Creek property encompasses portions of five watersheds, but is primarily on the Mill Creek and Rock Creek watersheds; which are tributaries of the Smith River. Our study areas were restricted primarily to the Mill Creek drainage, with the exception of two late-seral sites in the Wilson Creek drainage which borders the West Branch to the south and drains to the ocean. Four other late-seral sites were in the Mill Creek drainage to the north, below the confluence of the East Fork and West Branch.

Figure 1. Locations of the 28 study areas in and around the Mill Creek property (denoted by a red line). Brown circles are in stands < 33 years old, olive circles are 33 to 60 years old, light green are historically thinned late-seral, and dark green are late-seral. Thick black lines represent sub-basin boundaries, and thin black lines are gravel roads.



METHODS AND ANALYSIS

Sampling Methods

We sampled terrestrial and aquatic amphibians at 16 heavily managed zero-order catchments on the Mill Creek property, four historically thinned zero-order catchments on adjacent parkland, and eight late-seral zero-order catchments on adjacent parkland (total of 28). Of the 16 sites on the property, eight were in the West Branch sub-basin and eight were in the East Fork sub-basin. Of the eight streams within these two sub-basins, four were at stands that were less than 33 years old, and four were greater than 33 years old. The 16 selected zero-order catchments on the property represented a broad range in levels of woody debris loading and streamside vegetation structure. The headwaters areas sampled had streams that were selected to be independent of each other in the sense that one is not located upstream of another. The primary assumption in this effort was that the headwaters areas on the Mill Creek property had similar structure and amphibian densities as the adjacent parkland streams prior to the intensive timber management. This design enabled us to compare headwaters and terrestrial amphibian species richness and relative abundances between the two properties in general, and among the existing seral stages in Mill Creek using the late-seral forests on the adjacent parklands to represent reference conditions.

<u>Slope and aspect</u>

We measured percent slope with a handheld clinometer at one location to characterize the upland amphibian sampling zone. Often slopes varied across the search area. If this was the case, we visually determined an area of average slope and measured there.

We determined the aspect of the upland amphibian search area by visually estimating the average aspect of the area searched and recording the value from a hand compass while looking down slope. For statistical analysis aspect was converted by the formula,

$$Asp = \cos(\pi \times (Aspect - 45)/180) + 1$$

so that northeast had a value of 2, southwest had a value of 0, and both northwest and southeast had a value of 1 (adapted from Beers et al. 1966). Southwest sites tend to be the warmest and driest, and northeast sites tend to be the coolest and wettest.

<u>Canopy</u>

We characterized the canopy closure of the upland amphibian search area by sampling at three locations distributed across the area sampled. Each location was selected to characterize the surrounding area. If there were distinct areas, such as left bank, right bank, and headwall, we would place stations in each of those. At each station we employed a spherical densiometer and measured percent open canopy in four directions. Later, the four readings were averaged to give one value for each station.

Surface rock and large woody debris cover

The Del Norte salamander has been associated with talus (rocky) areas across most of its range (Jones et al. 2005). However, at coastal sites such as this, the Del Norte salamander will utilize other cover objects, like wood and leaf litter. We estimated the percent surface rock for the upland search area to see if its occurrence has any relationship to salamander captures, particularly Del Norte salamander abundance. For each upland amphibian sampling area, we visually estimated the percent of loose rock on the forest floor.

Upland amphibians often utilize cover objects on the forest floor during daylight hours to provide cover from predators and to maintain themselves in a cool moist environment. Logs often will stay wet inside throughout the summer months. We visually estimated the percent large woody debris (at least 10 cm diameter and at least one meter long) in the upland search area.

Landscape level variables (GIS)

In addition to data collected in the field, we created variables in the GIS environment which we reasoned could help explain amphibian distributions. For example, we were concerned that the distance to the ocean could affect amphibian abundances. In order to test this, we measured the straight line distance from each site to the ocean in ArcMap (ArcMap 2004) and included it as an independent variable in our analysis. We also determined elevation for each of the sampling locations in ArcMap (ArcMap 2004) from electronic versions of 7.5 minute quadrangle maps.

For aquatic amphibians, the size of the stream can affect abundances. Although we measured stream width and depth in the field, discharge is a more accurate metric of stream size. Since our sampling period was in the spring, the streams were still dropping during our sampling period and would have biased our sample. However, since basin area is highly correlated with discharge (T. Lisle, per. comm.), we calculated the drainage area above each aquatic sampling location in ArcMap (ArcMap 2004) as a surrogate for discharge.

Aquatic Conditions

Surface Flow

Because headwaters streams are quite small, they often have dry sections caused by hill slope processes, such as slumps in the stream bank or fallen trees. Although these streams can be considered intermittent, they often have perennial sections with year-round surface flow. Even though these perennial sections appear isolated, they can be prime habitat for aquatic amphibians. Results from our previous research on intermittent streams showed significantly higher densities of coastal giant salamanders in intermittent reaches relative to perennial reaches within the same stream (Welsh et al. 2005). We selected only headwaters streams that initiate first-order streams, so there was connectivity to lower reaches; at least in the winter months. At each of our animal sampling locations we visually estimated the percent of the stream channel which had surface flow for a 30 meter section.

Stream Canopy

Percent canopy closure over the stream channel was determined by averaging four readings from a concave spherical densiometer at each animal sampling station. Vegetation below chest high was not recorded.

Embeddedness

Percent embeddedness is a visual estimate of the amount that large substrates (i.e., cobbles or boulders) are embedded in smaller substrates (i.e., fines or sand). Embeddedness was visually estimated at every aquatic sampling location and than averaged to characterize each sampling reach.

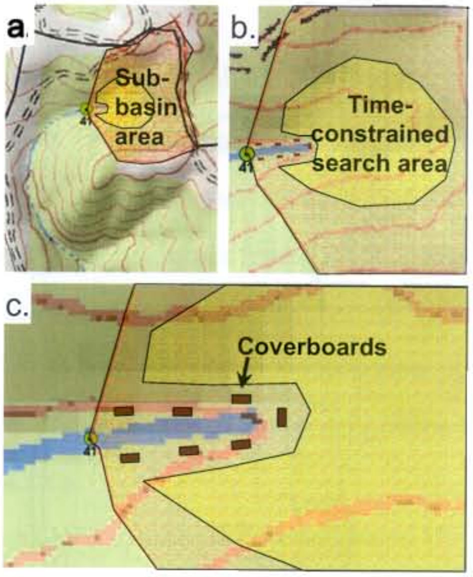
Amphibian Sampling

Terrestrial Sampling Methods

At each of the 28 study sites we conducted a one hour time-constrained search (TCS) and deployed seven coverboards (Fig. 2). The TCS's consisted of sampling the riparian and upland environment just above the initiation of overland flow by using a four prong (potato) rake with a four foot handle to move cover objects or rake through debris. Cover types were sampled in proportion to occurrence, and areas not likely to have amphibians were avoided (bare soil or sparse leaf cover). The time spent processing animals was not counted as search time.

The coverboards consisted of two cedar shakes (15 x 40 cm) stacked with a 0.8 cm spacer between them. They were held together with a metal clip which can be removed to inspect the space between the shakes. Animals may be found under the coverboard or in the space between the shakes. Each coverboard was placed on soil within three meters of the stream and spaced approximately three meters apart at the top of the initiation of overland flow (Fig. 2).

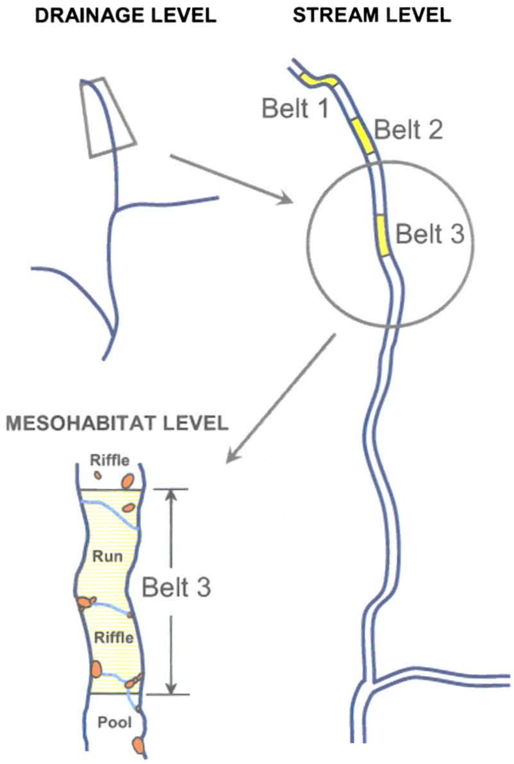
Figure 2. Three views at different scales showing, (a) catchment area, (b) terrestrial time-constrained search area within catchments, and (c) coverboard deployment around initiation of overland flow.



Aquatic Sampling Methods

Area-constrained searches (ACS) were employed to sample 10 linear meters of wetted stream channel for aquatic amphibians (see Welsh and Hodgson 1997). Sample belts (Fig. 3) were located in headwaters areas, near the initiation of overland flow, but where there was evidence of perennial water. Determination of perennial water in spring conditions consisted of finding evidence of scour, less angular substrates relative to terrestrial substrates, moss-free stream bed, and presence of aquatic invertebrates. If these criteria were met, a quick search for aquatic amphibians was performed, and if an aquatic amphibian was found within two minutes, the site was considered perennial. Once a section of the stream was determined to be perennial, one to three bank-to-bank belts were distributed in the area to represent the available aquatic conditions (Fig. 3). Areas considered unsafe or difficult to sample, such as under logs, were avoided. Typically, three belts were distributed within a 30 m section, and each belt would be three or four meters long, so that the sum of the belt lengths was 10 meters. Occasionally, perennial surface flow was so patchy and limited that belts had to be placed close together, or even merged together (Fig. 3).

Figure 3. Schematic representation of our headwaters aquatic sampling design. Three area-constrained search zones (belts) located in the headwaters of a first-order stream. Each belt may span multiple mesohabitats. Each belt is three or four meters long so that the sum of the three belts cover 10 linear meters of stream channel.



Clear acrylic view boxes and small aquarium dip nets were used to locate and capture submerged animals. All movable cover objects were turned in an attempt to capture every animal within each belt. A net was held immediately downstream of objects being turned, to prevent animals from escaping in the current When an animal was captured the following data were collected: species, sex, life stage, snout-vent length, total length, weight, water depth, cover, substrate, and if there were missing body parts (limbs or tails). Additional information was recorded to characterize each belt These include stream wetted width (max., mean, and min.), maximum depth, water temperature, canopy closure, substrate composition, and embeddedness. Data were also recorded for each mesohabitat unit within each belt. These include mesohabitat type, length, and width.

Incidental Amphibian and Reptile Observations (observed species list)

Incidental observations of aquatic and terrestrial amphibians and reptiles were recorded whenever they were observed on the property or adjacent parkland. Species and location was always recorded. If an amphibian was captured incidentally, location, snout-vent length, total length, weight, and body condition were recorded (unless common in our sample). Incidental observations were not intended for comparisons between streams because individual animals may have been observed multiple times, and the observation time and area was not standardized between reaches. Incidental observations were only included on the observed species list.

Analysis Methods

In order to characterize the Mill Creek landscape we randomly selected these zero-order catchments without controlling for known sources of variability, such as slope and aspect; our primary selection criterion being forest seral stage. With a large enough sample size these sources of variability should be similar within groups being tested. Since we didn't control for these variables, we tested to see if they were similar between our four seral stage groups. Unfortunately, at this sample size, there are some differences between groups for several variables that can influence amphibian distributions.

Evenness is an index from zero to one of how balanced the numbers of individuals are by species. For example a stream where we detected 10 coastal giant salamanders and 10 southern torrent salamanders would have a perfect evenness of 1.0. Evenness does not favor a particular species, so a stream with 5 coastal giant salamanders and 10 southern torrent salamanders would have the same value as a stream with 10 coastal giant salamanders and 5 southern torrent salamanders.

Aquatic Amphibians

Usually for ACS the count of animal captures are divided by the area sampled to get animals per square meter. This metric standardizes capture rates across different sized streams. Because we sampled only headwater reaches, the stream sizes were similar. The mean wetted width was 0.57 meters, with one standard deviation of 0.166. The range of channel widths was 0.33 to 1.07 meters. The correlations between coastal giant salamanders and wetted width (0.121) and between southern torrent salamanders and wetted width (0.110) were both low. Therefore for this report we used captures per 10 linear meters of stream, rather than animals per square meter sampled. We did this because in such small stream channels we believe the distribution of the two common aquatic amphibians was more a function of linear stream channel, rather than area. For example, southern torrent salamander primarily inhabits the shoreline of streams, thus a linear measure was more appropriate. For coastal giant salamander, an aggressive and often cannibalistic predator with a home range larger than these stream widths, competitive interactions would mean that densities were more a function of linear stream rather than square meters.

Because nearly all aquatic captures were of these two species, we created a variable which is the ratio of the two. RHVA/DITE is ratio of southern torrent salamander (RHVA) to coastal giant salamander (DITE), and allows the reader to note the relative proportions these two species.

Terrestrial Amphibians

Since we occasionally observed three or more species per site, we included Shannon diversity index, evenness, and richness in the terrestrial amphibian results. Since the majority of terrestrial captures were California slender salamanders, we created a variable which was the proportion of the total number of captures (all observations) that were California slender salamander (BAAT/Total).

T tests and ANOVA's

The zero-order catchment was the unit of analysis for questions investigated for this report. Variables with multiple measurements at each site were averaged across samples within a site. Student's *t* was employed to test for differences between the Mill Creek property and the adjacent parkland (control sites) on a variety of physical environmental measures and amphibian relative abundances. In the cases where unequal variances were detected between groups, we used Aspen-Welch unequal-variance *t* tests. For all *t* ratios reported here, positive *t* statistics indicated higher values on the Mill Creek property. Conversely, negative *t* statistics indicated lower values on the Mill Creek property (e.g. fewer logs). ANOVA's were employed to compare between seral stage groups and sub-basins. For ANOVA's, mean square error (MSE), F-Ratio value (*F*) and the associated probability level (*P*) were reported, as well as Tukey-Kramer multiple comparisons. We used NCSS analysis program (Hines 2000) and SAS statistical software (SAS 2003) to conduct all data analyses.

Box plots were occasionally presented to give the reader a visual example of the data. Box plots were always of the untransformed data, even if variables were transformed for the statistical test. The top and bottom of the box represents the 25th and 75th percentiles (IQR), and the middle line represents the median value. The lines extend to 1.5 times the IQR.

We applied a moderate $\alpha = 0.10$ for comparison of the stream groups, as this provides a criterion more appropriate for the detection of ecological trends (Toft and Shea 1983, Toft 1991). A Bonferroni adjustment was applied for multiple tests (Zar 1999). Only two-tailed *t* test results were reported, however, dividing the *P* value of the two-tailed test in half will give the *P* value of a one-tailed test (only in the direction of the effect). The *t* statistic remained the same. When data was not normal due to excessive skewness, natural log or square root transformations were applied.

RESULTS

Comparisons between the Mill Creek Property and the Adjacent Parkland

Terrestrial Physical Attributes

We collected data on five physical variables in the field and three in a GIS environment for the 28 zero-order catchment locations (Table 1). These data was used to compare sites and help explain differences we found in amphibian distributions.

Table 1. Means, standard deviations (SD), and Student's *t*-tests for physical attributes at the terrestrial amphibian sample locations comparing the Mill Creek property (MCP) to the adjacent parkland sites (including thinned stands).

Physical parameter	Location	N	Mean	SD	*t*	*P*
Slope† (%)	MCP	16	40.68	20.889	2.801	0.0095**
	Parkland	12	19.50	18.228		
Aspect (Beers)	MCP	16	1.24	0.747	-0.907	0.3729
	Parkland	12	1.49	0.660		
Canopy (%)	MCP	15†	97.87	2.800	2.800	0.0097**
	Parkland	12	95.33	1.557		
Basin area (ha)	MCP	16	5.07	3.672	-0.997	0.3281
	Parkland	11††	6.51	3.723		
Elevation (ft)	MCP	16	1256.87	361.215	3.614	0.0013**
	Parkland	12	835.00	207.200		
Ocean dist. (m)	MCP	16	6487.37	1488.271	4.329	0.0002***
	Parkland	12	3502.17	2164.539		
Rock (% surface)	MCP	16	2.28	1.118	3.477	0.0018**
	Parkland	12	0.08	2.181		
LWD (% cover)	MCP	16	2.72	0.620	0.548	0.5887
	Parkland	12	2.60	0.494		

†Natural log transformed
†Removed site 9, an extreme outlier with a canopy closure of only 57%.
††Removed site 71, an extreme outlier with a sub-basin area of 43.3 ha.
*** Significant at $P = 0.001$, ** Significant at $P = 0.05$

Aquatic Physical Attributes

We collected data on 16 physical variables in the field and in a GIS environment for the 28 aquatic environments at each of the zero-order catchments (Table 2). These data was used to help explain the distributions of the aquatic amphibians.

Table 2. Means, standard deviations (SD), and Student's t-tests for 16 physical variables sampled in aquatic environments at the 28 zero-order catchments (belt data) comparing the Mill Creek property (MCP) to the adjacent parkland (including thinned stands). Since woody debris has been divided into two groups, a Bonferroni adjustment of the *P* value was necessary. Significance at *P* = 0.1 is divided by two so that for each size class a *P* value of 0.05 is required for significance.

Physical parameter	Location	N	Mean	SD	*t*	*P*
Slope† (%)	MCP	16	20.47	13.249	3.939	0.0005***
	Parkland	12	7.95	5.007		
Aspect (Beers)	MCP	16	1.21	0.645	-0.619	0.5412
	Parkland	12	1.36	0.653		
Canopy (%)	MCP	16	99.26	0.586	7.667	<0.0000***
	Parkland	12	94.97	2.667		
Maximum depth (cm)	MCP	16	10.34	5.560	-0.200	0.8433
	Parkland	12	10.74	4.712		
Embeddedness (%)	MCP	16	31.28	20.601	0.111	0.9125
	Parkland	12	20.42	19.688		
Water temperature (^{0}C)	MCP	16	11.21	0.836	-1.441	0.1614
	Parkland	12	11.72	1.047		
Channel width (m)	MCP	16	0.60	0.182	1.101	0.2810
	Parkland	12	0.53	0.139		
Inorganic substrates (%)						
Fines† (<0.06mm)	MCP	16	18.23	14.440	2.035	0.0521*
	Parkland	12	11.26	9.487		
Sand† (2 - 0.07mm)	MCP	16	13.69	6.956	-0.668	0.5100
	Parkland	12	16.75	10.088		
Gravel (32-2.1mm)	MCP	16	29.64	11.279	-0.689	0.4969
	Parkland	12	32.32	8.458		
Pebble (64-32.1mm)	MCP	16	23.39	9.061	0.239	0.8127
	Parkland	12	22.58	8.428		
Cobble (256-64.1mm)	MCP	16	10.19	5.182	-1.206	0.2388
	Parkland	12	13.06	7.407		
Boulder† (>256mm)	MCP	16	2.21	4.277	-1.110	0.2770
	Parkland	12	4.18	4.705		
Organic substrates (%)						
Organic fines†	MCP	16	20.78	17.439	-0.829	0.4147
	Parkland	12	26.26	17.117		
Small woody debris	MCP	16	11.61	7.144	1.156	0.2583
	Parkland	12	8.86	4.738		
Large woody debris†	MCP	16	3.706	2.801	3.245	0.0032**
	Parkland	12	0.967	1.468		

*** Significant at *P* = 0.001, ** Significant at *P* = 0.05, * Significant at *P* = 0.10
†Natural log transformed

Terrestrial Amphibians

The upland amphibian species observed within TCS protocol on the property were, California slender salamander (*Batrachoseps attenuatus)*, ensatina (*Ensatina eschscholtzii*), Del Norte salamander (*Plethodon elongatus*), metamorphosed coastal giant salamander (*Dicamptodon tenebrosus*), and one wandering salamander (*Aneides vagrans*) under a coverboard. Upland amphibian species that were observed within TCS protocol on the adjacent parkland, were the four species above, with the addition of northern red-legged frog (*Rana aurora*) at a single site. By far the most common terrestrial species across both landscapes was the California slender salamander. This resulted in the "All captures" variable being highly correlated with California slender captures (correlation = 0.92).

Comparisons of upland salamanders between the Mill Creek property and the adjacent parkland showed significantly more detections overall ($t = -3.81, P = 0.0008$) in the parkland (Table 3). Shannon diversity index, evenness, and richness also resulted in significantly higher values in the parkland (Table 3). Both ensatina and California slender salamander were significantly more abundant in the parkland ($P < 0.01$). However, the proportions of California slender salamanders to total captures were not different; nor were counts of Del Norte salamanders (Table 3).

A total of 28, 1 hour time-constrained searches (TCS's) performed between 12 April 06 and 17 May 06 yielded six amphibian species, totaling 230 individuals. Sixteen of the 28 sites were on the Mill Creek property, which yielded four species, totaling 87 individuals. By contrast, the 12 parkland sites yielded six species, totaling 143 individuals. In terms of capture rate, sites on the property averaged 5.4 animals per hour, compared to the parkland at 11.9 animals per hour. These differences between the Mill Creek property and the adjacent parkland were quite significant (Fig. 4, Table 3).

The coverboards had been deployed only about two months before they were checked, yielding only14 individuals of four species, or 0.071 animals per coverboard. The capture rate on the

Table 3. Student's t-tests of upland amphibian assemblage metrics and species comparing combined TCS and coverboard data for the Mill Creek property sites (MCP) and sites on adjacent parkland (including thinned stands). BAAT/Total is the proportion of total captures that were California slender salamander.

Variable	Location	N	Mean	SD	*t*	*P*
All observations†	MCP	16	5.69	4.438	-3.807	0.0008***
	Parkland	12	12.75	5.379		
Shannon diversity	MCP	16	0.36	0.355	-2.518	0.0183**
	Parkland	12	0.68	0.303		
Evenness	MCP	16	0.45	0.426	-1.709	0.0993*
	Parkland	12	0.69	0.263		
BAAT/total	MCP	16	0.61	0.401	-0.827[†]	0.4175
	Parkland	12	0.70	0.163		
Richness	MCP	16	1.62	0.957	-2.815	0.0092**
	Parkland	12	2.58	0.793		
Ensatina	MCP	16	0.62	1.025	-3.616	0.0013**
	Parkland	12	2.25	1.357		
Cal. slender sal.	MCP	16	4.12	3.964	-3.161	0.0040**
	Parkland	12	9.08	4.295		
Del Norte Sal.	MCP	16	0.75	1.183	-0.467	0.6441
	Parkland	12	1.00	1.651		

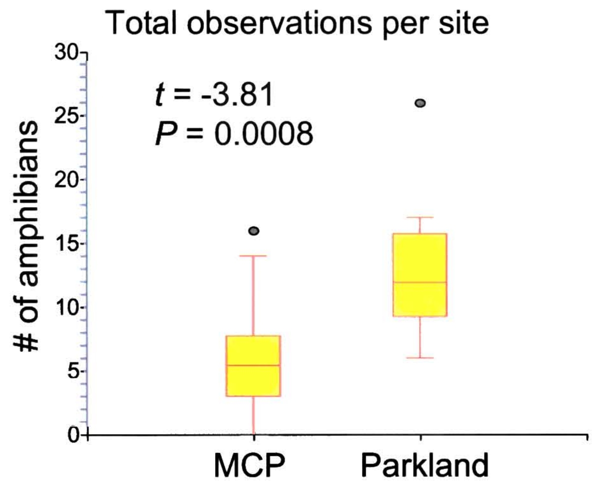
*** Significant at $P = 0.001$, ** Significant at $P = 0.05$, * Significant at $P = 0.10$

† Raw counts of all captures not standardized among species.

[†] Aspin-Welch unequal-variance *t* test

property was 0.036 animals per coverboard, compared to the parkland at 0.119 animals per coverboard. We plan on revisiting the coverboards in spring of 2007 when they will likely provide considerably more detections. The primary intention of using coverboards along with TCS was not to increase the number of observations so much as it was to detect new species. On this first run, only one new species was added to one site. It was a juvenile wandering salamander (*Aneides vagrans*) at site 33, which increased the number of terrestrial species on the Mill Creek property to five. Because of the low numbers of animals, the coverboard data was combined with the TCS data for analysis, bringing the total number of terrestrial amphibians observed to 244.

Figure 4. Student's t-test comparing total observations of amphibians from TCS and coverboards on the Mill Creek property and the adjacent parkland.



We also compared three metrics of amphibian assemblage structure, including Shannon diversity index, species evenness, and species richness, in addition to comparing individual species. All were significantly lower values ($\alpha = 0.1$) on the Mill Creek property, with the exception of the Del Norte salamander (Table 3).

__Aquatic Amphibians__

A total of 80 area-constrained searches (belts) were performed at 28 zero-order catchment sites, consisting of 280 linear meters of stream (161 m^2), between 01 June 06 and 03 August 06. We commonly observed two species and detected one individual of a third species, totaling 557 animals. The two common species were coastal (Pacific) giant salamander (*Dicamptodon tenebrosus*), and southern torrent salamander (*Rhyacotriton variegatus*). The third species observed was a single adult tailed frog (*Ascaphus truei*), which we inadvertently disturbed on a stream bank adjacent to a belt. We expected to detect larval tailed frogs but our sites appeared to be above suitable breeding habitat for this frog. The nocturnal adults may have been more common but they were difficult to detect by our method and during the day time.

At the 16 sites on the Mill Creek property, 241 animals were detected. At the 12 sites on the adjacent parkland 316 animals were detected. In terms of animals per linear meter of stream, the property averaged 1.51 animals/m, and the parkland averaged 2.63 animals/m; a statistically significant difference with salamanders on the parklands more abundant than on the Mill Creek property ($t = -1.79$, $P = 0.0845$) (Fig 2, Table 3). However, evenness was significantly higher on the Mill Creek property, as was the ratio of torrent salamanders to giant salamanders (Table 4). The two common aquatic salamander species were detected differently between the two areas. The coastal giant salamander was more abundant in the parkland ($t = -2.54$, $P = 0.0309$), but southern torrent salamander was the opposite ($t = 0.94$, $P = 0.3562$) (Fig. 6). There was a single outlier in the numbers of coastal giant salamanders. At site 72, a late-seral site in the Wilson

Figure 5. Student's t-test on total aquatic amphibians comparing the Mill Creek property and the adjacent parkland.

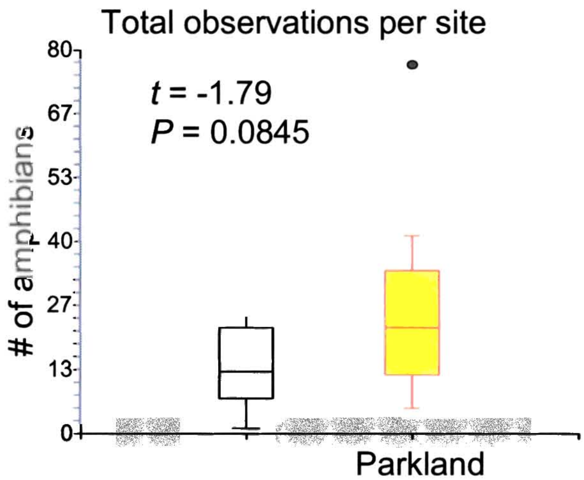
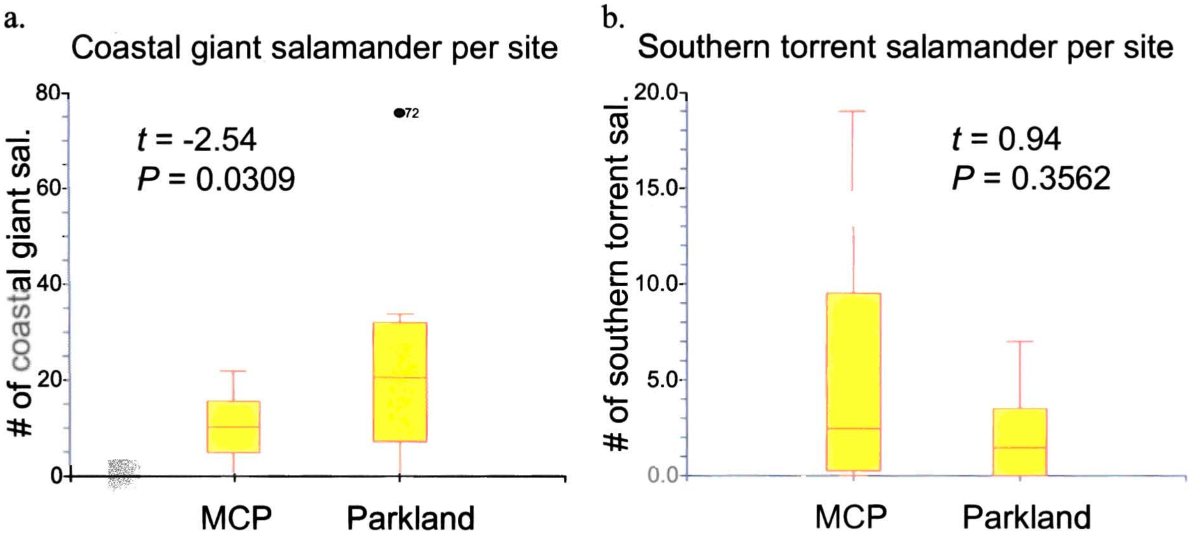


Figure 6. Student's *t*-tests comparing coastal giant salamander (a.) and southern torrent salamander (b.) between the Mill Creek property and the adjacent parkland.



Creek watershed, we observed 76 individuals in 10 meters of stream. With this one site removed, these data did not need to be transformed, however, and the result was similar ($t = -2.49$, $P = 0.0199$). Although not statistically significant, the numbers of southern torrent salamander was nearly twice as high on the Mill Creek property. This species averaged 5.0 observations on the property, compared to 2.5 observations per 10 meters of stream in the parkland (Fig. 6b).

Table 4. Student's *t*-test comparing aquatic ACS data for Mill Creek property sites (MCP) to the adjacent parkland sites (including thinned stands).

Variable	Location	N	Mean	SD	*t*	*P*
All captures[†]	MCP	16	15.06	10.497	-1.794	0.0845*
	Parkland	12	26.25	19.707		
Evenness	MCP	16	0.54	0.414	2.349†	0.0270**
	Parkland	12	0.24	0.247		
RHVA/DITE[†]	MCP	16	0.29	0.293	1.807	0.0824*
	Parkland	12	0.13	0.280		
Coastal giant sal. [††]	MCP	16	10.06	6.718	-2.091†	0.0523*
	Parkland	12	23.75	20.014		
S. torrent Sal. [††]	MCP	16	5.00	6.196	1.221	0.2332
	Parkland	12	2.50	3.656		

** Significant at $P = 0.05$, * Significant at $P = 0.10$
†Aspin-Welch unequal-variance *t* test
[†]Natural log transformed
[††]Square root transformed

Comparisons Between Forest Seral Stages

In order to assess effect of seral stage on amphibian distributions and abundances, and to elucidate stage-related trajectories for recovery of the amphibian assemblage, we grouped the 28 sites into four classes based on their stand ages. To this end, we sampled an equal proportion of younger second-growth (< 33 yrs.) and older second-growth (> 33 yrs.) on the Mill Creek property. We selected this breakpoint so that it coincided with the implementation of the Z'Berg Nejedly Forest Practice Act of 1973. The sampling locations on the site map, (Fig. 1) are color coded to reflect these four groups. Group 1 is 0-33 year old stands on the property, group 2 is 34-60 year old stands on the Mill Creek property, group 3 is thinned (selectively harvested) late-seral in the Del Norte Coast Redwoods State Park, and group 4 consists of late-seral stands on the Del Norte Coast Redwoods State Park and Jedediah Smith State Park.

Using age as a continuous variable would probably have produced a more powerful analysis than using age categories, however, late-seral forests are uneven aged, and the thinned parkland sites are predominantly uneven aged.

Terrestrial Conditions

The variables which were significant in the earlier comparison of the Mill Creek property and the parkland remained significant when we ran ANOVA's with the four seral groups (Table 5). Although five of these eight physical variables were significantly different, we don't necessarily consider them as having a significant influence on terrestrial amphibian distributions or abundances.

Table 5. One factor ANOVA tests between four forest age classes on terrestrial conditions. Group 1 is 0-33 yrs, group 2 is 34-60 yrs, group 3 is thinned late-seral, and group 4 is late-seral.

Factor	d. f.	MSE	*F*	*P*	Multiple comparisons
Slope	3, 24	411.562	2.75	0.0645*	4<1
Aspect	3, 24	0.459	1.86	0.1625	
Canopy†	3, 24	2.127	2.94	0.0518*	4<1
Area†	3, 24	0.672	0.96	0.4254	
Elevation	3, 24	100918.23	4.06	0.0183**	3<1, 3<2, 4<1, 4<2
Ocean dist.	3, 24	2999366.6	8.21	0.0006***	3<1, 3<2, 3<4, 4<1, 4<2
Rock †	3, 24	2.854	4.17	0.0165**	4<1, 4<2, 4<3
LWD	3, 21	92.666	0.47	0.7079	

†Natural log transformed.
*** Significant at $P = 0.001$, ** Significant at $P = 0.05$, * Significant at $P = 0.10$

Aquatic Conditions

The variables which were significant in the t-tests comparing the property to the parkland are also significant when we ran ANOVA's with the four seral groups (Table 6). These results did however provide further refinement on what seral stages were different. For example, the slope from the late-seral sites (group 4) is significantly less than the slopes of the other three groups (Table 6). Also, large woody debris substrate from the older second-growth group is significantly more than the late-seral group (Table 6).

Table 6. One factor ANOVA tests between the four forest seral stage groups and the status of their aquatic environments. Group 1 is 0-33 yrs, group 2 is 34-60 yrs, group 3 is thinned late-seral, and group 4 is late-seral. Because the inorganic substrates have been divided into six groups, a bonferronni adjustment of the *P* value is necessary. Significance at $P = 0.1$ is divided by six so that for each substrate class a *P* value of 0.016 is required for significance. Because woody debris has been divided into two size classes a *P* value of 0.05 is required for significance.

Physical parameter	df	MSE	*F*	*P*	Multiple comparisons
Slope† (%)	3, 24	0.281	9.91	0.0002**	4<1, 4<2 , 4<3
Aspect (Beers)	3, 24	0.402	1.19	0.3349	
Canopy† (%)	3, 24	0.525	19.00	<0.0001***	3<1, 3<2, 4<1, 4<2
Maximum depth (cm)	3, 24	0.920	0.45	0.3373	
Embeddedness (%)	3, 24	428.166	0.28	0.8396	
Water temperature (^{0}C)	3, 24	0.932	0.71	0.5573	
Channel width (m)	3, 24	0.028	0.69	0.5653	
Inorganic Substrates (%)					
Fines† (<0.06mm)	3, 24	0.617	3.07	0.0472**	4<1
Sand† (2 - 0.07mm)	3, 24	0.272	0.36	0.7820	
Gravel (32-2.1mm)	3, 24	102.796	0.90	0.4558	
Pebble (64-32.1mm)	3, 24	82.693	0.13	0.9402	
Cobble (256-64.1mm)	3, 24	40.502	0.75	0.5358	
Boulder† (>256mm)	3, 24	3.770	1.17	0.3425	
Organic substrates (%)					
Organic fines	3, 24	0.577	0.70	0.5604	
Small woody debris	3, 24	38.626	1.19	0.3354	
Large woody debris†	3, 24	1.863	5.35	0.0058**	4<2

*** Significant at $P = 0.001$, ** Significant at $P = 0.05$

†Natural log transformed.

Terrestrial Amphibians

Comparisons between the upland salamanders among the four seral stage groups showed statistically significant differences in overall captures (1<4, 2<4), Shannon diversity index (1<3), richness (1<3, 1<4), and counts of ensatina (1<3, 1<4, 2<3, 2<4), and the California slender salamander (1<4, 2<4) (Table 7). There were no differences for Del Norte salamander among any age class (Table 7).

Results were similar to the tests comparing the property to the parkland (Table 3) with the exception that evenness was not significant (Table 7). In terms of overall captures, the late-seral group had significantly more animals than both second-growth age classes on the Mill Creek property (Table 7). Richness, or the number of species, was significantly greater in the parkland than in the younger second-growth (Table 7). Ensatina and California slender salamander result, since southern torrent salamanders are more sensitive to disturbance than coastal giant salamanders (see Welsh and Ollivier 1998) and we would expect them to be doing better on the parkland. The proportion of southern torrent salamanders to the total captures was not significant at an alpha of 0.1. Although the data was normal after a natural log transformation, the removal of one outlier from forest seral category 2, resulted in significantly higher proportion of southern

Figure 7. One factor ANOVA between four forest seral groups for all aquatic amphibian captures. Group 1 is 0-33 yrs., group 2 is 34-60 yrs., group 3 is thinned late-seral, and group 4 is late-seral.

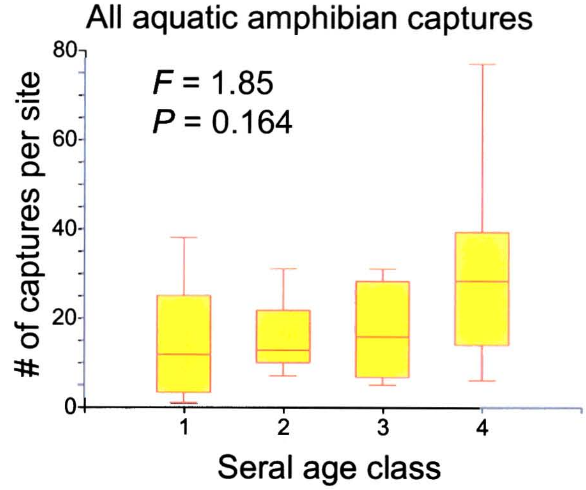


Table 8. One factor ANOVA tests between four forest seral groups for number of aquatic amphibians. Group 1 is 0-33 yrs., group 2 is 34-60 yrs., group 3 is thinned late-seral, and group 4 is late-seral.

Factor	d. f.	MSE	*F*	*P*	Multiple comparisons
All captures†	3, 24	0.776	1.85	0.1643	
Evenness	3, 24	0.123	2.44	0.0894	3<2
RHVA/DITE†	3, 24	5.377	2.13	0.1225	
Coastal giant sal.††	3, 24	3.186	1.82	0.1708	
S. torrent sal.††	3, 24	1.770	1.28	0.3028	

†Natural log transformed.
††Square root transformed.

torrent salamander in group 2 compared to group 3 ($F = 3.24$, $P = 0.0406$).

A *post hoc* power analysis indicated that we did not have a sufficient sample size to confidently detect a difference by seral stage for the "all captures" variable, the coastal giant salamander, and the southern torrent salamander. The power for the "all captures" variable was 0.56. That is to say, there is a 56% chance that this is the correct result (at $\alpha = 0.1$). Statisticians consider power of 80% to 90% sufficient to confidently accept a non-significant result. The *post hoc* power for abundances were significantly higher in the late-seral age class than either of the second-growth age classes on the property (Table 7). However, the Del Norte salamander showed no preference among the seral stage groups (Table 7).

Table 7. One factor ANOVA tests between four forest seral groups for terrestrial amphibians. Group 1 is 0-33 yrs., group 2 is 34-60 yrs., group 3 is thinned late-seral, and group 4 is late-seral.

Factor	d. f.	MSE	*F*	*P*	Multiple comparisons
All captures	3, 24	24.740	4.88	0.0087**	1<4, 2<4
Shannon diversity	3, 24	0.111	2.79	0.0623*	1<3
Evenness	3, 24	0.137	1.38	0.2730	
% BAAT	3, 24	0.024	0.22	0.8842	
Richness	3, 24	0.812	3.06	0.0474**	1<3, 1<4
ENES	3, 24	1.474	4.24	0.0155**	1<3, 1<4, 2<3, 2<4
BAAT	3, 24	17.177	3.78	0.0235**	1<4, 2<4
PLEL	3, 24	2.098	0.17	0.9174	

** Significant at $P = 0.05$, * Significant at $P = 0.10$

Aquatic Amphibians

Results comparing the four seral stage groups are somewhat different than the previous tests comparing aquatic amphibians between the Mill Creek property and the parkland. Overall captures averaged considerably higher in the late-seral group than the two early seral categories or the thinned late-seral group (Fig. 7, Table 8). The mean number of total aquatic amphibian captures in the young second-growth was 13.1, the mean of the older second-growth was 15.6, the thinned late-seral was 17.0, and the late-seral was 30.9. Although the mean of the late-seral forest was about twice that of either of the early seral sites, there was considerable variation among the sites in each group such that the differences were not statistically significant at this sample size. These differences in total captures were predominantly a result of detecting more coastal giant salamanders in the older seral groups (young to old: Gp. 1: 10.1, Gp 2: 10.0, Gp. 3: 16.5, Gp. 4: 27.4). The southern torrent salamander distribution was quite different, averaging more captures in the second growth stands (young to old: Gp. 1: 4.4, Gp. 2: 5.6, Gp. 3: 0.5, Gp. 4: 3.5).

Although evenness was still significant, the number of coastal giant salamanders, and the overall captures were not. The evenness variable was indicating there was a more equal distribution of coastal giant salamanders and southern torrent salamanders on the Mill Creek property than on the parkland; although the significant differences were between the older second growth (>33 yrs) and the historically thinned late-seral forest (Table 8). This was an unexpected coastal giant salamander and southern torrent salamander ANOVA's were 0.54, and 0.44, respectively. Data from this pilot study can be used in an *a priori* power analysis to calculate a sufficient sample size for future studies.

DISCUSSION

Not unexpectedly, we found significant differences in both terrestrial and aquatic site attributes between the commercially logged Mill Creek property and the parklands (Tables 1 & 2), and these differences in physical attributes may contribute to the differences we found in amphibians between the two landscapes (see below). We detected strong differences in most species of both terrestrial and aquatic headwaters amphibians between sites on the two properties, with the upland species showed stronger differences than the aquatic species (Tables 3 & 4). The pattern of higher terrestrial amphibian species diversity and higher individual species abundances for the parklands is consistent with numerous other studies of terrestrial forest amphibians conducted across North America (see Davic and Welsh 2004: their Fig. 3). These studies have all demonstrated key differences in amphibian diversity and relative abundances between disturbed and undisturbed forests (see also DeMaynadier and Hunter 1995). The pattern of a single dominant terrestrial salamander species in a given assemblage (i.e. the California slender salamander), previously reported for the redwoods (Cooperrider et al. 2000), is also consistent with patterns for salamander assemblages throughout the forests of North America (Davic and Welsh 2004). When we compared between the four seral stages, the older seral classes nearly always had significantly more species and more animals (Table 7). This pattern, while somewhat refined over the comparison between the two landscapes, is also reflective of the differences that would be expected to occur between disturbed and undisturbed forests (Davic and Welsh 2004). The one species of terrestrial salamander that did not fit this pattern was the Del Norte salamander, which was equally common across both landscapes (Tables 3 & 7). Our data for this species support the contention that this species is common on commercial timberlands of the redwood forest ecosystem, and little affected by timber harvesting (Diller and Wallace 1994). This resilience on the part of the Del Norte salamander is not the case at more interior forest sites (Welsh and Lind 1995, Welsh et al. 2006).

Forestry practices in western North America are having a significant negative impact on headwater and riparian environments and there is a great need for improvement (Olson et al. 2007). Therefore it was not surprising that we found differences in numbers of aquatic amphibians on the two properties (see also Welsh and Ollivier 1998). However, this trend did not hold up when we compared across seral groups (Fig. 7). This is probably due to the high counts of the southern torrent salamanders on the Mill Creek sites. Frankly, we were surprised to find these high numbers of torrent salamanders on the Mill Creek sites, a result that is in conflict with most previous studies (Welsh and Lind 1996, but see Diller and Wallace 1996), where harvesting has been shown to reduce their numbers and relegates them to steeper stream reaches where fine sediments are more readily flushed (Welsh and Karraker 2005). We examined several sources of variability in order to explain why southern torrent salamander appeared to be doing better on the property than the parklands. Because of prior research on this salamander we focused on the variable slope, which was significantly higher on the property (Table 2). Earlier studies on managed lands (e.g., Diller and Wallace 1996) suggested that southern torrent salamanders do better on steeper slopes where fine sediments are more easily flushed (see Welsh and Karraker 2005). However, we found no significant relationship between southern torrent salamanders and belt slope on the property ($r^2 = 0.0010$; $t = 0.117$, $P = 0.9087$). Given the significant differences we found for this attribute between the properties, the lack of a correlation may be the result of using our belt values for slope, or it just may not be important on this landscape. The geology of Mill Creek is of sufficient hardness that it does not readily decompose and create large quantities of fine sediments (Table 2) that would then clog interstices and eliminate habitat for this species, as appears to commonly be the case in response to timber harvesting on more gentle slopes throughout much of its range in California (i.e. Welsh and Lind 1995).

We did find significantly more coastal giant salamander larvae on the parklands (Table 4, Fig. 6a), however, this species was also fairly common on the Mill Creek property. It is unclear why the seemingly more resilient coastal giant salamander (see Welsh and Ollivier 1998) is not doing as well as the torrent salamander on the Mill Creek property. This question will require further investigation.

Overall, the study was highly successful in demonstrating the applicability of amphibian assemblages as indicators of forest ecosystem status. This approach is gaining greater acceptance as others test and verify the use of amphibians as biometrics (e.g., Ashton et al. 2006, Perkins and Hunter 2006).

We recommend continued monitoring of these amphibian assemblages in five or ten-year intervals at these same sites in order to track the recovery of the Mill Creek redwood ecosystem as it returns to late-seral conditions.

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APPENDIX I

Observed species list

The observed species list is a list of all the amphibians and reptiles we observed during our field effort, including incidentals, on the Mill Creek property. This is not a complete list of all potential species.

Amphibians

Southern torrent salamander - *Rhyacotriton variegatus*

Coastal giant salamander - *Dicamptodon tenebrosus*

Del Norte salamander - *Plethodon elongatus*

Ensatina salamander - *Ensatina eschscholtzii*

California slender salamander - *Batrachoseps attenuatus*

Wandering salamander - *Aneides vagrans*

Black salamander - *Aneides flavipunctatus*

Northwestern salamander - *Ambystoma gracile*

Rough-skinned newt - *Taricha granulosa*

Tailed frog - *Ascaphus truei*

Northern red-legged frog - *Rana aurora*

Pacific treefrog - *Hyla regilla*

Reptiles

Northern alligator lizard - *Elgaria coerulea*

Western fence lizard - *Sceloporus occidentalis*

Northwestern garter snake - *Thamnophis ordinoides*

Common garter snake - *Thamnophis sirtalis*

APPENDIX II

Site locations and animal counts

This table includes site names and locations in UTM coordinates, NAD 27, zone 10, and species capture numbers. The first five species were from 1h upland TCS sampling, and the last two species were from 10 linear meters of headwater stream sampling. The species code names are the first two letters of the genus, then the first two letters of the species (see Appendix I for names).

Site ID	UTMe	UTMn	ENES	PLEL	BAAT	ANVA	RAAU	RHVA	DITE
1	406968	4618886	1	0	4	0	1	0	12
3	407163	4616540	4	0	11	0	0	0	5
5	411204	4616986	0	0	4	0	0	0	19
6	412078	4616936	0	0	0	0	0	16	22
8	412352	4616588	1	2	0	0	0	5	18
9	413810	4615186	0	0	0	0	0	3	5
10	411122	4614377	0	0	3	0	0	2	5
11	410573	4614195	0	0	7	0	0	0	12
13	407624	4613908	0	0	12	0	0	7	34
15	408566	4619251	0	0	6	0	0	13	5
16	409220	4618881	1	0	4	0	0	1	9
19	410310	4617312	3	0	11	0	0	11	16
22	411709	4618743	1	3	4	0	0	19	12
27	414154	4617773	3	0	0	0	0	2	12
28	413313	4618233	0	2	14	0	0	1	15
33	410984	4623220	0	3	4	1	0	0	1
34	410936	4621594	1	0	4	0	0	0	3
41	405860	4620883	4	0	6	0	0	0	20
42	408228	4616164	1	3	8	0	0	2	29
44	410767	4614299	0	2	4	0	0	3	7
56	410436	4623739	2	4	18	2	0	12	0
57	405431	4623714	4	0	13	0	0	0	6
58	407293	4625696	3	1	3	0	0	0	33
61	410497	4624055	3	4	6	0	0	2	18
71	408335	4614242	2	0	12	1	0	4	30
72	407853	4613453	2	0	7	0	0	1	76
73	411948	4614849	0	0	1	0	0	4	0
74	407293	4611867	1	0	9	0	0	2	22

APPENDIX III

Important sites for management consideration

Site 22, between Cull Spur and Rock Creek Road is an important site for both terrestrial and aquatic amphibians. The rocky substrate, north facing slope, and older second-growth, made terrestrial amphibians easy to find. Because of its accessibility, we used it to confirm that Del Norte salamander were on the surface during our summer sampling period. In addition, there were multiple springs which had high densities of aquatic salamanders. In one four meter length of stream we detected 12 larval southern torrent salamanders and 10 larval coastal giant salamanders. Interestingly, only a about 30 meters below the headwall, the stream was diverted down Rock Creek Road for nearly 100 meters in the inboard ditch.

Site 19, along West Branch Road, is an important site for aquatic amphibians. We found high numbers of both southern torrent salamander and coastal giant salamander, and we have seen two adult tailed frogs with minimal searching. The headwall is a large seep in the winter months and both southern torrent salamander and tailed frog were incidentally detected about 15 meters up the headwall slope. This is the only headwaters site where we detected juvenile salmonids. Unfortunately, there was a channel which drains from the road side and was clogged with sediment. We were unable to detect any aquatic salamanders in that channel.

Site 16 had the most aquatic animals detected, with 16 southern torrent salamander larvae and 22 coastal giant salamanders within 10 meters of stream. The stream channel was significantly degraded, however there was a considerable amount of courser substrates.

Site 9 was the youngest stand we sampled, having been harvested in 1987. The stream was considerably silty, however we detected both southern torrent salamander and coastal giant salamander in a small stream channel above Cedar Spur. There is a perched culvert below the road. The upland canopy closure was a significant outlier and much more open the any other site. We detected no upland salamanders in 2006.

There was a manmade pond along Rock Creek Road (Plaque: 13.10; UTM: 413880 e, 4615662 n) which has become a breeding site for northwestern salamander (*Ambystoma gracile*) and rough-skinned newt (*Taricha granulosa*). This is the only lentic site we observed on the property.