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Golden Gate National Recreation Area

Summer 1995 Stream Habitat and Benthic Macroinvertebrate Inventory, Redwood Creek, Marin County, California

(June 2002)

SUMMER 1995 STREAM HABITAT
And
BENTHIC MACROINVERTEBRATE INVENTORY,
REDWOOD CREEK, MARIN COUNTY, CALIFORNIA

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TABLE OF CONTENTS

INTRODUCTION

The Natural Resources Management Guideline (NPS-77) and NPS's Management Policies provide a broad directive "to restore, maintain, or enhance the quality of all surface and groundwater within the parks consistent with the Clean Water Act and other applicable federal, state, and local laws and regulations" (NPS-77, page 50). However, baseline information on existing conditions is needed before any efforts can be taken to restore, maintain or enhance wetland and aquatic sites. NPS Management Policies reflects this need and requires NPS to assemble baseline inventory data describing natural resources under its stewardship.

Baseline habitat inventories need to focus on environmental variables that are measurable and indicate habitat quality for the species of interest. Often, it is easier to measure habitat conditions for the species of interest rather than population parameters. This advantage is one of several that led to the development of the U.S. Fish and Wildlife Service's Habitat Evaluation Procedures, which is a method developed to rate the quality and quantity of habitat for impact assessment, mitigation development, and baseline habitat evaluations.

Many of the streams within the Golden Gate National Recreation Area support (or have supported) steelhead (*Oncorhynchus mykiss*), coho salmon (*Oncorhynchus kisutch)*, California freshwater shrimp (*Syncaris pacifica*), Tomales asellid (*Caecidotea tomalensis*), California red-legged frog (*Rana aurora draytonii*), foothill yellow-legged frog (*Rana boylii*), and western pond turtles (*Clemmys marmorata*)- all aquatic species of special concern.

While habitat requirements for these species are somewhat different, there is considerable overlap. For example, pool habitats and vegetated riparian zones are important features for both juvenile salmonids and red-legged frogs. Adult frogs require a dense, shrubby or emergent riparian vegetation closely associated with deep (>0.7 meters) still or slow-moving water (USFWS 1994a). The highest densities of California red-legged frogs have been associated with deep-water pools with dense stands of overhanging willows and an intermixed fringe of cattails (USFWS 1994a). Similarly, optimal habitat conditions for coho juveniles or parr seem to be deep pools created by rootwads and boulders in heavily shaded stream sections (P. Moyle, Univ. of Calif., Davis, *in litt.*, 1993).

A structurally diverse stream habitat has also been shown to be important features of shrimp, turtle, and salmonid habitat. Ideal freshwater shrimp habitat includes perennial freshwater streams where banks are structurally diverse with undercut banks, exposed roots, overhanging woody material, or overhanging vegetation.

Similarly, Holland (1991) notes that downed logs and undercut banks are important refugia for the western pond turtle and undercut banks may be a critical factor maintaining populations in small streams. The number of juvenile coho remaining in streams following winter freshets is positively correlated with the amount of woody material in streams (McMahon and Hartman 1989). During winter freshets, juvenile coho have been documented to move both upstream and downstream in search of refugia such as woody material, undercut banks, and side channels (Sandercock 1991). Specifically for coho and steelhead, substrate composition in riffle and flatwater areas influence benthic food production and the success of fry emergence.

Within Redwood Creek, past and current actions altered stream habitat conditions and ultimately, aquatic life. Portions of Redwood Creek have been directly diverted for consumptive uses, resulting in low summer and fall baseflow conditions. Several researchers (Hofstra and Anderson, 1988; Smith 1994) noted the impacts associated with low summer flow conditions on rearing salmonids. Historic stream clearing and channel protection activities have resulted in long-term changes in stream morphology. In the Muir Woods section of Redwood Creek, pools and backwater areas facilitated by downed woody debris and areas with undercut banks are infrequent. Until the late-1980's to early 90's, woody materials entering into the stream have been removed.

Consistent with NPS-77 guidelines, assessment of stream habitat conditions is the necessary first step to "restore, maintain, or enhance the quality of all surface and groundwater." Therefore, the primary objective of the stream habitat inventory was to provide information regarding habitat suitability for coho salmon and steelhead. However, as noted above, many of the measured habitat variables will provide information on habitat suitability for other sensitive aquatic animals.

PREVIOUS WORK

There is limited basin-wide information on general habitat characteristics. Denise Vore, the former Park hydrologist, surveyed the reach of Redwood Creek within Muir Woods National Monument from the concrete bridge (the downstream boundary of Muir Woods NM) to the second pedestrian bridge in 1995 and 1996. She characterized substrate conditions, habitat types, amount of woody material, and riprap within this reach. On Redwood Creek, Philip Williams and Assoc., have characterized habitat conditions within the area proposed for lagoon restoration. William Snider, CDFG, categorized Redwood Creek from the BootJack and Rattlesnake Creek confluences to the mouth into 6 reaches based on general habitat characteristics (Snider 1984).

Prior to 1995, some limited stream invertebrate surveys have been conducted. All of these studies were associated with determining presence/not found status of sensitive invertebrates (Hafernik and Mead 1992, Serpa 1986). No sensitive aquatic invertebrates were identified in their surveys.

Since the 1995 summer habitat inventory, other data collection efforts have been undertaken and will be summarized at a later date. These data include riparian habitat and topographic data (profile and cross-section) at fish index stations established by Dr. Jerry Smith, San Jose State Univ., basinwide woody debris and habitat inventory in 1998, and project-specific stream topographic data in Muir Woods and Banducci reaches.

STUDY AREA

The Redwood Creek watershed is a coastal drainage in southern Marin County California covering 7.5 square miles. The Creek flows down the southern slope of Mt. Tamalpais and joins with its last tributary, Green Gulch, to form the Big Lagoon wetland complex at Muir Beach. The entire creek length is a destination point for many of the 5 million annual visitors to Muir Woods and is largely protected as part of National Park Service, California State Park, and Marin Municipal Water District lands. On Redwood Creek, we surveyed approximately 0.5 miles of Fern Creek and 5 miles of mainstem Redwood Creek.

We designated six reaches along the creek. The reach distances and corresponding monument tag information is provided in Table 1. In 1997-98, aluminum tags were placed at every 100 m along the stream channel to assist in long-term monitoring activities. These reaches were not based solely on geomorphic conditions as described by Snider (1984) or Arnold (1971). Instead, these reaches were chosen based on areas with similar past management activities and geomorphic conditions. These reaches are as follows:

Reach 1: Big Lagoon to Pacific Way Bridge (Stream Distance 0 to 742 m): This reach has been subjected to past human disturbance for agricultural and flood control purposes. The channel is generally low gradient and a portion subject to tidal influence on high tide/surge conditions.

Reach 2: Pacific Way to Highway One Bridges (Stream Distance 742 to 1166 m): This reach is adjacent to homes on both sides of the creek. Streambed elevation may be controlled by both bridges.

Reach 3: Highway One to Frank Valley Bridge (Banducci Fields) (Stream Distance 1166 to 2578): This reach is adjacent to the former Banducci flower farm where various land management activities (seasonal dam and terrace/floodplain berms) had occurred. Streambed elevation may also be controlled by both bridges.

Reach 4: Frank Valley Bridge to Kent Canyon (Mt. Tamalpais State Park) (Stream Distance 2578 to 3640 m): This reach starts at a bridge with riprap armoring downstream to control grade and location and ends at the confluence with a major tributary, Kent Canyon. The creek in this reach has had minimal land management activity under state park management.

Reach 5: Kent Canyon to Dipsea footbridge (Stream Distance 3640 to 5938 m): This reach is all within public ownership (MUWO and Mt. Tamalpais State Park). It includes a grade control structure (vehicle bridge) at the downstream boundary of MUWO. This reach has also had minimal land management activity.

Reach 6: Dipsea footbridge to Bridge 4 (Stream Distance 5938 to 7791 m): This reach is entirely within MUWO and has been subjected to a variety of past land management activities including bank armoring (gabions and riprap), removal of large woody materials, and placement of grade control structures.

PERMITS

Field work was conducted under a Park reseach and collecting permit (WR-GOGA-95-005) issued on March 10, 1995.

METHOD

Stream Habitat Inventory

A stream habitat inventory protocol was developed using guidance from CDFG (1994), Dollof *et al.* (1993) and Overton *et al*. (1994, 1993). It is a two-staged program designed to survey relatively long distances of creek habitat. Field biologists classified the stream within the project area into discrete habitat units, measured their length along the thalweg (deepest portion of the channel profile), and visually estimated the width of each habitat unit. To minimize observer discrepancies in the classification of stream habitat types, we distinguished between the following types:

?? Pools (main channel, scour, step, & backwater)
?? Riffle and flatwater
?? Miscellaneous (cascade, dry)

More accurate width and depth estimates were conducted on 10% of the habitat units. The total estimated habitat area and volume were extrapolated using a ratio estimator that established the relationship between visual estimates and more accurate measurements (Dollof et al., 1993). Separate ratio estimators were used for the two surveyors (Darren Fong and Maya Khosla). Ratio estimators were not derived separately for specific habitat types.

We also distinguished whether the observed habitats were associated with the main channel or wetted secondary channel. We felt that mapping the extent of wetted secondary channels would provide useful information regarding habitat complexity per reach. Also, stream sections with secondary channels can provide velocity refugia because water is spread over a wider area during flood events.

We also collected other habitat information that we felt would describe the suitability of the instream and nearstream habitat for aquatic life. These habitat variables included: residual pool depth, wetted width, area, substrate composition, bankfull width and depth, entrenchment, undercut banks, overhanging cover and riparian canopy density. Modified Wolman pebble counts, bankfull measurements, and canopy density measurements were located at the calibration habitat units and, therefore, the sampled units constituted 10% of all habitat units. Woody material data were collected continuously as it was encountered along the stream. An ocular estimate of instream cover was collected for each habitat unit and residual pool depth were collected for all pools. Details on the sampling procedures for these variables are provided in Appendix I.

Stream water temperatures were measured using continuous recording temperature data loggers (Onset Stowaway). We checked the precision of three units prior to deployment. Mean air temperatures were within 0.3^{o} C of each other. However, no accuracy assessment was conducted using certified mercury thermometers. Data loggers were deployed at three locations during the winter 1995: below the Big Lagoon pedestrian bridge, below the Muir Beach Community Service District well site, and within Mt. Tamalpais State Park at Mile Post 2.25 on Muir Woods Road (Figures 1-2). Temperature data were collected at 3 hour intervals.

A review of literature indicates water temperatures between $10\text{-}20^{o}$ C are suitable for growth of juvenile steelhead (Raleigh et al. 1984). Juvenile coho have similar ranges for growth, with growth slowing at temperatures above 18^{o} C (McMahon 1983). Below 9^{o}C, coho juveniles become less active and seek deep, slow water associated with cover (McMahon 1983). Based on controlled laboratory experiments on juvenile coho and steelhead, we used the sublethal threshold for water temperature of 20^{o} C as a "red flag."

Benthic Macroinvertebrate Inventory

An inventory of benthic macroinvertebrates was conducted in August 1995 and November 1997. Sampling stations were selected within fish index stations established by Jerry Smith. An additional macroinvertebrate sampling station was established at a major tributary, Fern Creek. Sampling site locations are shown in Figures 1-2. Six stations were sampled in 1995. Three of the six stations were resampled in 1997.

At each station, three riffle units were sampled. Four Surber samples were collected and pooled from the sampled riffle unit. Field subsampling retained 1/4 of the pooled sample. A standard Surber sampler was used (1 sq. foot sampling area, mesh size 0.363 mm). Small rocks were placed along the outside edge of the Surber sampler to prevent loss of invertebrates between the streambed and sampler. Average water depth and an ocular estimate of substrate composition for each Surber sample were obtained. Substrate categories were identical to those used in the stream habitat inventory (Appendix I). Larger rocks within the sampler were hand-rubbed to detach attached organisms (particularly case caddisflies) and placed outside of Surber sampler. A hand trowel was used to stir the substrate to a depth of 5-10 cm. We standardize sampling intensity to 90 seconds. Retained samples were preserved in 70 percent ethanol in the field. In the lab, collected samples were stained (Rose Bengal) and dissecting scopes were used to sort invertebrates from debris. Sorted individuals were identified by Jon Lee Consulting to genus for most insects (generally tribe for chironomids) and family or genus for all others. Because of difficulties in removing invertebrates from the collected debris, all samples were re-examined a second time by different set of lab personnel.

The intent of the sampling was to provide a taxa list of stream macroinvertebrates and some index of relative abundance and "health." In addition, we wanted to describe the relative abundance of juvenile salmonid food items based on past diet and invertebrate drift surveys. The California Department of Fish and Game (CDFG) has taken a lead role in California in promoting the EPA's Rapid Bioassessment Protocol. The assessment of "health" uses simple, commonly accepted metrics (CDFG 1999, Karr and Chu 1999; Plafkin et al., 1989). These metrics are intended to describe the following:

- Community composition (taxa richness and abundance),
- Taxa dominance (Shannon diversity index, percent dominance of most abundant taxa),
- Pollution tolerance (taxa tolerance index, number of EPT taxa, EPT index),
- functional feeding groups (percent collectors, filterers, grazers, predators, and shredders).

The taxa tolerance index is calculated as follows:

$$ToleranceIndex = \sum \frac{n_i t_i}{N}$$

where n_i is the number of individuals in the i^{th} taxon, t_i is the respective tolerance value, and N is the total number of individuals for the sample. The tolerance values were obtained from the California Department of Fish and Game's stream bioassessment website and are similar to the Hilsenhoff Biotic Index (HBI) values, which range from 0 to 10 (Hilsenhoff 1987). Values increase with increased tolerance of taxa to pollution. EPT taxa include the number of taxa in the orders Emphemeroptera, Plecoptera, and Tricoptera. EPT index refers to the total number of individuals in the Orders Ephemeroptera, Plecoptera and Trichoptera relative to the total number of individuals in the sample.

These metrics were chosen to mirror impacts that we believe to be present in the system- namely, limited detrital storage because of the removal of large woody materials, habitat simplification because of past stream practices, and unknown instream water quality adjacent to streamside roads, businesses, and residences. CDFG developed a comprehensive list of functional feeding group and pollution tolerance values (0-most intolerant to 10-most tolerant) for macroinvertebrates most commonly encountered in California waters. Their classification data were used in our analyses and are available as downloadable Adobe Acrobat files on the CDFG website.

However, it should be noted that assessment of the health of the macroinvertebrate community may not necessarily reflect impairment that might be reflected on the organismal level (e.g., reduced growth) or ecosystem processes (e.g., rate of detrital processing) (Carlisle 2000). Neither of these elements were targeted in macroinvertebrate sampling activities.

Sample specimens have been preserved in 70% ethanol and are located within the Park's natural history museum collection currently located at Building 1061, Fort Cronkhite. Elmid specimens have also been archived at the Essig Museum of Entomology at U.C. Berkeley.

An informal effort is underway to develop species list of aquatic invertebrates. Opportunistic collections of adults have been sent to taxonomic experts. Currently, caddisfly and stonefly adults have been collected and preserved in 70% ethanol. These adults will be identified by taxonomic experts in the future. Information regarding location and date of capture will assist in strengthening life history information of the species, particularly concerning periods of emergence.

Data Analysis

Database entries were always checked with the original data. However, we found that even with post-entry data checking, some errors were still present in the database. We have plotted practically all of the data to identify outliers. In addition, computational checks on proportional data (e.g., canopy density and ocular substrate composition) were conducted to identify errors.

We used Statview? to examine the association between habitat and macroinvertebrate variables. All percentage data were transformed (arcsine square root) (Krebs 1989). Macroinvertebrate and habitat variables were compared using single-factor analysis of variance (ANOVA). Differences in mean values amongst reaches were considered significant at p-values less than 5%. However, the value of single factor ANOVA data are limited. They do not identify which of the reach means are different from each other (Zar 1984). Therefore, a multiple comparison test, Tukey-Kramer, was used when ANOVA results rejected the null hypothesis of equal means to identify pairs of reaches with significant differences (Zar 1984).

RESULTS AND DISCUSSION

Entrenchment

Entrenchment data indicated that of the six reaches, the Banducci reach exhibited the highest degree of entrenchment within the watershed (Table 2). Field reconnaissance surveys and discussions with Amadeo Banducci by Carolyn Shoulders, the Redwood Creek watershed coordinator, have shown that the lower portion of the Banducci fields have had artificial berms placed along the channel to confine flows. Not surprising given the amount of flooding that occurs yearly, the Big Lagoon-Pacific Way reach had the least amount of entrenchment, followed by the Mt Tamalpais reach.

Distribution of Habitat Types

The summer 1995 stream inventory provided a very good description of stream habitat distribution. Separate from issues of habitat quality, the total amount of available stream summer habitat for aquatic life (volume per unit stream length) was the greatest near the mouth of Redwood Creek (Reach 1) and the least in Muir Woods (Reach 6) (Figure 3). The mainstem creek had a near equal distribution of pools and shallow-water habitats (riffle and flatwater), with two exceptions (Table 3a). The two exceptions were the surveyed upstream and downstream reaches of Redwood Creek.

Pool habitat was scarce in Reach 6 (Dipsea Bridge to Bridge 4 in Muir Woods). They only occupied 32 percent of the reach length and 28 percent of total surface area of the reach (Tables 3a-3b). In contrast, shallow riffles and flatwater habitats covered 72 percent of the area. The imbalance of pools to shallow-water habitats was likely the by-product of the extensive bank protection in this reach and historic instream wood removal efforts. The high frequency of riffle and flatwater habitats in Reach 6 was consistent with stream topographic survey data collected in 2000. These riffles can often become extremely shallow during the late summer, forcing rearing fish to seek more suitable, deeper rearing habitats further downstream. The two, presumably less disturbed reaches (Reaches 4-5) within Mt. Tamalpais State Park have a much higher proportion of pools to shallow water habitats (Tables 3a-3b).

The major tributary to Redwood Creek, Fern Creek, also showed an imbalance in the proportion of pool to shallow water habitats. The surveyed portion of Fern Creek had 18 percent of total surface area as pool habitats with the remainder as shallow water types (Table 3b). The lower portion of Fern Creek may have been subjected to similar channel realignment and rip-rap bank protection as Reach 6 in Redwood Creek.

Reach 1 (Big Lagoon to Pacific Way Bridge) had the highest percentage of pool habitats in 1995. This low-gradient reach is dominated by long main channel pools from the mouth to the Muir Beach parking lot. This area appears to be a major holding area for run-back steelhead adults. A half-dozen steelhead adults have been periodically seen throughout the summer of 2001 and late spring 2002. However, between the parking lot and Pacific Way Bridge, most of the channel is characterized by shallow water habitats along the road.

A dichotomy in pool distribution in Redwood Creek can be seen when looking at the distribution of stream habitat unit volumes by reach. Reach 1, dominated by large pools, had the largest amount of habitat volume per unit distance (Figure 3). Conversely, Reach 6 had the least amount of habitat volume per unit distance.

There was a marked difference in the amount of wetted secondary channels amongst stream reaches (Table 4). Reach 1 had the largest amount of secondary channels. During large storm events, the main channel overtops its bank and flows into an adjacent borrow pit and into an adjacent pasture. While neither of these sites are entirely natural, they do allow sheet flow of floodwaters and provide refugia for fish needing to escape the high velocities of the main channel. The borrow pit/backwater area also retains water year-round and has been the only location of western pond turtle sightings in the past. The borrow pit has also been a calling location of male red-legged frogs during the winter.

Woody Material

The woody debris census data indicated substantial differences in the density of wood amongst the six reaches. In Summer 1995, the Dipsea to Bridge 4 reach contained the lowest frequency and volume of woody debris per 100 m (Table 5). The two reaches that encompassed Mt. Tamalpais State Park had the highest frequency and volume of woody debris per 100 m (Table 5). Woody materials that formed dams were the most infrequently encountered type. Only 13 wood dams were counted throughout Redwood Creek.

It is likely that the low frequency of woody materials in the Dipsea to Bridge 4 reach was associated with past practices of removing large woody materials from the channel. Because wood in these coastal streams are largely responsible for the creation of pools, it is not surprising that this reach was also characterized by the least amount of pools.

Residual Pool Volume

Residual pool depth data provided a good description of habitat conditions as well. The mean residual pool depths for the six reaches were significantly different (single-factor ANOVA, $p<0.05$). On an individual basis, mean residual pool depth in Reach 1 was significantly higher than Reaches 4 or 6 (Tukey-Kramer test, $p<0.05$). Reach 6 (Dipsea to Bridge 4) and Fern Creek had the shallowest pools (Table 6).

We used the general rule of thumb that pools greater than 0.5 m in depth offer high value to juvenile salmonids (all else being equal) (Beecher et al, 2002; Berg et al. 1998). Reach 1 has the highest portion of its length with pool habitat greater than 0.5 m. Conversely, Reach 6 and Fern Creek had the lowest percentage of pool habitat with residual pool depth greater than 0.5 m (Table 7).

Streamside Cover

Reach 2 (Pacific Way to Highway One) had habitat units with the highest percentage of habitat unit lengths with streamside cover (Table 8). However, this status has likely changed since 1995. There have been localized bank protection activities associated with adjacent property owners since 1995. By comparison, Reach 1 had the lowest mean amount of streamside cover per habitat unit (Table 8). Reach 1 also was the only location with any significant amount of instream vegetative cover (e.g., tules and cattails) along pools at Big Lagoon.

Riparian Canopy Density

Canopy density measurements along Redwood Creek indicate heavy shading. The grand mean for six reaches was 80 percent (Table 9). There were some differences between reaches. The Pacific Way to Highway One and Banducci reaches had the heaviest shading with little variation, as suggested by the low coefficient of variation (Table 9). The downstream-most reach, Big Lagoon, had the lowest canopy density and highest variability. There was an interspersion of unshaded areas at the lagoon and main channel pool by the Muir Beach parking lot and heavily shaded willow riparian areas.

Substrate Composition

The reaches had significant differences in the mean percentage of substrate types for all size categories (single-factor ANOVA, $p<0.05$). Reach 1 had the highest mean percentage of fines within sampled riffle and flatwater sites (Table 10). Reach 1 had nearly 5 times greater amount of fines than Reach 6 in MUWO. Both Reach 5 and 6, which have the lowest amount of fines, typically have the highest numbers of redds or live adult salmon during the winter (http://www.nps.gov/muwo/nature/fauna/salmon/survey/index.htm). The mean percentage of small cobbles increased in the upstream direction. Boulders were only found in Reach 6 and Fern Creek.

Comparison of ocular estimates of substrate composition and modified pebble counts provided interesting data. Two observers were used to classify substrate by eye in the field. We used a ratio estimator model to describe the relationship between the substrate composition determined by ocular and modified pebble counts methods for each observer. Both observers had a very poor ability to discriminate cobble and boulder substrate categories using ocular estimates (when compared to the 50-point pebble count).

Ratio estimator models for both observers show a strong relationship between ocular and pebble count estimate of fines (Figures 3-4). There was more uncertainty between observers in their ability to estimate gravels. The ratio estimator model for Observer 1 (Maya Khosla) described a strong relationship between ocular and pebble count estimates of gravel (Figure 5). However, the model for Observer 2 (Darren Fong) indicated a very poor relationship-- mainly due to problems classifying the intermediate percentages of gravel (Figure 6). In summary, ocular estimates of substrate composition appear to be of limited values, except for describing the amount of surficial fines in the channel.

Water Temperature

Two of the three temperature loggers experienced battery problems that resulted only in partial data records. Instream water temperature for all three stations were well within the levels established for growth of juvenile salmonids. Figures 7-10 show instantaneous water temperature for each station by month. Tables 11-13 show mean daily stream water temperatures by month. Water temperature in free-flowing streams in these coastal watersheds would only experience elevated levels during the combination of low flow and warm air temperatures that are characteristic of the fall. During this period, only juvenile salmonids are expected to be present. From July through September, differences in water temperatures became more pronounced between heavily shaded upstream stations and the more open canopy Big Lagoon station (Figure 9). Outside this period, stream water temperatures were more similar. This similarity likely corresponds to both the decreased residence time of water as stream discharge increases and the absence of deciduous tree canopy from fall to spring period for all stations.

Benthic Macroinvertebrates

A summary of taxa collected, abundance, and various metrics are provided in Appendix II. Substrate characteristics and water depth for each Surber sample station is provided in Table 14. The sampled invertebrate community at the downstream-most station in the watershed, below the Pacific Way Bridge, had significantly different metric values than other stations. This station had significantly lower Shannon diversity than two out of five stations in 1995 (Table 15). Similarly, this station also had significantly higher proportion of dominant taxa when compared to other sites (Table 15). This dominance was associated with extremely large numbers of *Malenka* larvae, a stonefly. On the genus level, *Malenka* was also the most frequently captured taxa in all samples followed by an elmid beetle, *Optioservus*. However, the midge family, Chironomidae, had the most individuals followed by the stonefly family, Nemouridae.

Data from all years were used to determine the influence of substrate composition within the area enclosed by the Surber sampler on various invertebrate metrics. Stepwise regression results indicated that the variation in $\log_{10}$ density of benthic macroinvertebrates (dependent variable, y) was best described by a negative association with small cobble within the sampling area (arcsin transformation) ($y=-0.649x+2.855$, adjusted $R^2=0.41$, $p<0.01$). Small cobble, when compared to gravel, has a much lower surface to volume ratio. In addition, the presence of small cobble in sampling areas indicates high shear stress during winter and spring flows events. Therefore, it is not surprising that areas with small cobble have lower invertebrate densities when compared to smaller substrate sizes. The percentage of small cobble also best described the percent filterers (arcsin transformation) and percent shredders (arcsin transformation) ($p<0.001$). Future analyses may wish to reexamine these relationships using non-linear techniques, particularly for habitat variables such as substrate size that may have threshold effects.

Four of stonefly species have been identified to date from adults collected in the watershed. These species include *Malenka depressa*, *Isoperla mormona*, *Sweltsa pacifica*, and *Paraleuctra vershina*.

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TABLES

Redwood Creek Stream Habitat Inventory

Table 1: Reach distance and corresponding monument tags for Redwood Creek

Reach	Stream Distance (m)	Monument Tag Number
Big Lagoon-Pacific Way	0 - 742	None
Pacific Way-H1	742 - 1166	RW-01-01 to -04
Banducci	1166 - 2578	RW-01-04 to -18
Mt. Tamalpais State Park	2578 - 3640	RW-01-18 to -28
Kent-Dipsea	3640 - 5938	RW-01-28 to -50
Dipsea-Bridge 4	5938 - 7791	RW-01-50 to -69
Fern Creek	7489-8187*	RW-07-00 to -07

*Fern Creek confluence with mainstem Redwood Creek at 7489 m

Table 2: Channel entrenchment at Redwood Creek, Marin Co., Summer 1995

Reach	n	Mean	SD	Rosgen Entrenchment Descriptor
Big Lagoon-Pacific Way	2	3.4	1.4	Slightly entrenched (well-developed floodplain)
Pacific Way-H1	3	1.4	0.4	Entrenched-moderately entrenched
Banducci	6	1.2	0.1	Entrenched
Mt. Tamalpais State Park	6	2.4	1.4	Slightly entrenched
Kent-Dipsea	9	1.7	0.3	Moderately entrenched
Dipsea-Bridge 4	6	1.5	0.7	Moderately entrenched
Fern Creek	5	1.3	0.1	Entrenched

Table 3a: Percent distribution of stream habitat types by length in Redwood Creek, Marin Co., Summer 1995

Reach	Pool	Riffle	Flatwater	Total Habitat Distance*
Big Lagoon-Pacific Way	66	16	17	782
Pacific Way-H1	55	18	28	449
Banducci	57	24	20	1597
Mt. Tamalpais State Park	58	28**	14	1188
Kent-Dipsea	56	31	13	2739
Dipsea-Bridge 4	32	58**	11	2023
Fern Creek	17	62	21	760

*Total distance (m) includes summation of habitats in secondary channels and adjacent habitat types (e.g. backwater)

**Includes a high gradient riffle/cascade

Table 3b: Surface area and volume of stream habitat types in Redwood Creek, Marin Co., Summer 1995

	Surface Area (sq. m.)			Volume (cu. m)		
Reach	**Pool**	**Riffle**	**Flatwater**	**Pool**	**Riffle**	**Flatwater**
Big Lagoon-Pacific Way	4154*	443	456	1472*	36	55
Pacific Way-H1	928	257	517	236	14	45
Banducci	3275	1322	1343	887	79	117
Mt. Tamalpais State Park	2505	1245**	627	594	85**	74
Kent-Dipsea	5070	2968	1218	1430	196	134
Dipsea-Bridge 4	2341	5135**	905	507	372**	105
Fern Creek	323	1147	329	58	64	27

* Does not include area/volume of borrow pit/backwater channel below Pacific Way Bridge
**Includes a high gradient riffle/cascade

Table 4: Distribution of wetted secondary channels and backwater pool habitats, Redwood Creek, Marin Co., Summer 1995.

Reach	**Total Habitat Distance (m)**	**2^o Channel Units (m)**	**BW pools (m)****	**% of Total Habitat Distance (m)**
Big Lagoon-Pacific Way	782	342*	68	44
Pacific Way-H1	449	2	10	3
Banducci	1597	58	165	14
Mt. Tamalpais State Park	1188	37	89	11
Kent-Dipsea	2739	216	223	16
Dipsea-Bridge 4	2023	77	91	8
Fern Creek	760	61	20	11

*Includes length of borrow pit/backwater channel (300 m) below Pacific Way Bridge
**Only includes backwater pools along main channel.

Table 5: Summer 1995 woody debris inventory, Redwood Creek, Marin Co., GGNRA

Reach	**Distance*** (m)	**Frequency** (No./100 m)	**Volume** (m^3/100 m)
Big Lagoon-Pacific Way	*744*	15.0	5.2
Pacific Way-H1	*411*	9.5	4.4
Banducci	*1402*	15.9	10.3

Redwood Creek Stream Habitat Inventory

Reach	Distance* (m)	Frequency (No./100 m)	Volume (m^3/100 m)
Mt. Tamalpais State Park	*1072*	12.9	4.8
Kent-Dipsea	*2298*	20.2	12.1
Dipsea-Bridge 4	*1854*	6.0	5.4
Fern Creek	*698*	22.6	9.7

*Main channel stream distance

Table 6: Mean residual pool depths and mean undercut in Redwood Creek, Marin Co., Summer 1995

Reach	n	Mean RPD (m)*	SD
Big Lagoon-Pacific Way	11	0.74	0.31
Pacific Way-H1	15	0.41	0.23
Banducci	80	0.50	0.26
Mt. Tamalpais State Park	61	0.43	0.28
Kent-Dipsea	135	0.46	0.31
Dipsea-Bridge 4	57	0.35	0.25
Fern Creek	28	0.28	0.20

*Mean residual pool depth (max-min depth)

Table 7: Percentage of reach length with residual pool depths greater than 0.5 m or 1.0 m, Redwood Creek, Marin Co., Summer 1995.

	RPD>0.5 m		RPD>1.0 m	
Reach	n	% of Reach Length	n	% of Reach Length
Big Lagoon-Pacific Way	7	53	2	26
Pacific Way-H1	5	25	0	0
Banducci	37	32	3	4
Mt. Tamalpais State Park	21	28	2	4
Kent-Dipsea	55	28	8	4
Dipsea-Bridge 4	17	13	2	2
Fern Creek	4	3	0	0

Table 8: Stream cover conditions (as percentage of habitat length) in Redwood Creek, Marin Co., Summer 1995.

Reach	Total Habitat Length (m)	%Uncut	%Overhang	%Instream Veg.	Total Cover
1	782	6	10	10	26
2	449	21	24	0	45
3	1597	17	10	0	27
4	1188	19	13	0	32
5	2739	13	23	<1	37
6	2023	11	19	<1	32
Fern	760	13	14	0	27

Table 9: Riparian canopy density in Redwood Creek, Marin Co., Summer 1995

Reach	n	Mean	SD	CV*
Big Lagoon-Pacific Way	6	62	48	77
Pacific Way-H1	4	96	7	7
Banducci	17	95	8	8
Mt. Tamalpais State Park	11	82	10	12
Kent-Dipsea	13	70	24	34
Dipsea-Bridge 4	15	75	24	32
Fern Creek	0	--	--	--

Table 10: Modified Wolman pebble count within bankfull channel at flatwater and riffle units in Redwood Creek, Marin Co., Summer 1995

Reach	n	Fines (<2 mm)	Gravel (2?x<64 mm)	Sm. Cobble (64?x<128 mm)	L. cobble (128?x<256 mm)	Boulder (>256 mm)
Big Lagoon-Pacific Way	3	46	53	0	1	0
Pacific Way-H1	2	21	78	1	0	0
Banducci	6	24	71	3	3	0
Mt. Tamalpais State Park	5	34	60	5	0	0
Kent-Dipsea	10	16	66	18	<1	0
Dipsea-Bridge 4	9	7	56	27	6	3
Fern Creek	5	10	48	23	14	6

Table 11: Mean daily water temperature at Muir Beach pedestrian bridge, Redwood Creek, CA, 1995

1995	January	February	March	April	May	June	July	August	September	October	November	December
1	--	12.8	11.9	11.9	13.2	13.1	15.0	16.5	14.9	15.0	13.1	10.6
2	--	13.2	12.0	11.7	12.9	13.2	14.8	15.9	15.4	15.3	12.6	10.5
3	--	12.7	11.8	11.7	12.2	13.1	14.6	15.0	15.3	15.4	11.9	9.8
4	--	12.3	10.6	11.6	12.1	13.0	14.7	--	15.3	15.5	11.3	11.3
5	--	12.1	11.1	11.9	11.9	13.6	14.9	--	15.1	14.8	11.1	12.1
6	--	11.8	10.3	12.6	11.7	13.2	15.5	--	15.4	14.1	11.1	12.6
7	--	11.8	10.3	12.6	11.6	13.6	15.4	--	15.4	14.2	11.2	12.8
8	--	11.5	11.3	11.5	12.1	12.8	15.7	16.8	15.2	14.3	11.2	12.1
9	--	11.0	12.5	11.1	11.5	13.4	16.0	16.1	15.2	13.7	11.8	12.0
10	--	10.9	12.7	11.2	12.0	13.4	15.7	15.9	15.3	13.8	11.3	11.5
11	--	11.1	12.5	11.6	12.3	14.1	15.5	14.6	15.6	14.5	11.3	12.7
12	--	11.2	12.0	12.2	11.5	13.6	15.9	14.7	15.6	13.8	11.4	13.2
13	--	10.9	12.0	12.3	11.4	13.5	15.7	15.1	15.5	13.9	11.7	12.5
14	--	9.7	12.6	11.3	11.7	13.3	15.7	15.3	16.0	14.3	12.2	11.4
15	--	8.9	11.8	10.2	11.9	13.7	16.1	15.1	15.8	14.7	12.5	12.2
16	--	9.0	12.0	10.4	12.5	13.3	16.0	15.4	15.5	15.5	12.8	10.7
17	10.2	9.4	11.7	10.4	12.5	13.6	15.4	15.6	15.6	14.5	12.8	9.9
18	9.9	10.6	12.1	10.8	12.6	14.0	15.7	15.3	15.6	13.9	12.9	10.2
19	9.9	11.1	11.7	10.7	12.5	14.0	15.7	15.4	15.4	13.5	12.6	10.5
20	9.6	11.9	11.8	11.0	12.5	13.9	15.9	15.1	15.7	13.6	11.8	10.0
21	10.3	12.2	10.8	10.7	12.2	14.1	16.5	15.1	15.4	14.0	12.2	9.4
22	10.7	12.1	10.8	11.0	12.3	14.2	16.6	15.4	15.3	13.0	12.0	9.5
23	11.4	12.1	10.2	11.6	12.5	14.4	16.7	16.1	15.3	12.5	11.8	9.6
24	11.5	12.1	10.4	11.6	12.9	14.8	16.4	15.9	15.7	12.1	11.6	9.3
25	11.4	12.1	10.5	11.8	12.5	15.4	15.9	15.4	16.7	12.4	11.3	9.2
26	11.3	12.0	10.4	11.6	12.2	14.6	15.7	14.7	15.9	12.3	11.4	9.3
27	12.0	12.1	10.4	12.0	12.6	14.5	15.7	15.0	15.2	13.0	10.7	9.4
28	12.4	11.6	10.9	12.2	12.8	14.6	15.8	14.7	15.4	12.8	10.3	9.7
29	12.4	--	11.2	12.2	12.8	14.6	16.2	14.6	15.3	12.7	10.4	10.8
30	12.5	--	11.2	12.5	12.8	14.7	16.2	14.1	15.0	12.5	10.4	12.4
31	12.8	--	11.2	--	13.0	--	16.9	14.0	--	12.7	--	12.2
Mean Daily	**11.2**	**11.4**	**11.4**	**11.5**	**12.3**	**13.8**	**15.8**	**15.3**	**15.5**	**13.8**	**11.7**	**10.9**
Instan. Max	**13.3**	**13.9**	**13.1**	**13.4**	**14.0**	**17.3**	**18.8**	**17.8**	**18.0**	**17.3**	**13.9**	**13.7**
Instan. Min	**9.2**	**7.8**	**8.9**	**9.1**	**10.5**	**11.9**	**14.0**	**13.1**	**13.7**	**10.9**	**9.7**	**8.6**

Table 12: Mean daily water temperature below Muir Beach Community Services District, Redwood Creek, CA, 1995

	January	February	March	April	May	June	July	August	September	October	November	December
1	--	--	--	--	--	--	14.3	15.5	14.0	13.8	13.0	11.0
2	--	--	--	--	--	--	14.1	15.1	14.2	13.8	12.1	10.8
3	--	--	--	--	--	--	14.1	14.8	13.9	13.9	11.9	10.2
4	--	--	--	--	--	--	14.2	14.8	13.9	14.0	11.3	11.3
5	--	--	--	--	--	--	14.2	15.1	14.3	13.6	11.0	11.9
6	--	--	--	--	--	--	14.6	15.0	14.6	12.9	11.0	12.1
7	--	--	--	--	--	--	14.6	15.3	14.3	13.4	11.2	12.4
8	--	--	--	--	--	--	14.9	15.2	14.1	13.5	11.4	11.7
9	--	--	--	--	--	--	14.8	14.8	14.3	12.8	11.8	11.8
10	--	--	--	--	--	--	14.4	14.6	14.6	13.0	11.2	11.4
11	--	--	--	--	--	--	14.4	14.0	14.6	13.8	11.2	12.5
12	--	--	--	--	--	14.0	14.8	14.4	14.5	12.9	11.4	13.2
13	--	--	--	--	--	13.0	14.7	14.3	14.4	12.4	11.7	12.5
14	--	--	--	--	--	13.0	14.9	14.4	14.6	13.7	12.0	11.4
15	--	--	--	--	--	13.1	15.3	14.2	14.6	13.8	12.2	12.1
16	--	--	--	--	--	12.9	15.2	14.4	14.4	14.1	12.5	10.7
17	--	--	--	--	--	12.9	14.9	14.4	14.5	13.6	12.3	10.0
18	--	--	--	--	--	13.2	14.9	14.2	14.4	13.3	12.5	10.3
19	--	--	--	--	--	13.1	15.1	14.4	14.5	13.1	12.1	10.5
20	--	--	--	--	--	13.3	15.2	14.1	14.6	13.3	11.8	9.9
21	--	--	--	--	--	13.4	15.3	14.4	14.4	13.5	12.3	9.4
22	--	--	--	--	--	13.6	15.4	14.7	14.4	12.8	12.0	9.6
23	--	--	--	--	--	13.9	15.1	14.9	14.1	11.9	11.8	9.6
24	--	--	--	--	--	14.3	15.0	14.3	14.5	11.2	11.6	9.4
25	--	--	--	--	--	14.8	15.1	13.9	15.1	11.6	11.5	9.4
26	--	--	--	--	--	14.0	14.9	13.7	14.4	11.6	11.6	9.4
27	--	--	--	--	--	14.0	15.0	13.6	14.1	12.4	10.8	9.4
28	--	--	--	--	--	14.0	14.9	13.6	14.6	12.4	10.6	9.7
29	--	--	--	--	--	13.9	15.0	14.0	14.0	12.6	10.8	10.7
30	--	--	--	--	--	14.0	15.3	13.6	13.8	12.5	10.6	12.3
31	--	--	--	--	--	--	15.7	13.5	--	12.7	--	12.2
Mean Daily	**--**	**--**	**--**	**--**	**--**	**13.6**	**14.8**	**14.4**	**14.3**	**13.0**	**11.6**	**10.9**
Instan. Max	**--**	**--**	**--**	**--**	**--**	**16.1**	**17.0**	**16.2**	**15.9**	**14.8**	**13.6**	**13.4**
Instan. Min	**--**	**--**	**--**	**--**	**--**	**11.9**	**13.4**	**12.5**	**12.6**	**10.3**	**9.8**	**8.6**

Table 13: Mean daily water temperature at Mile Post 2.25 (Muir Woods Road), Redwood Creek, CA, 1995

1995	January	February	March	April	May	June	July	August	September	October	November	December
1	--	12.7	11.3	11.1	12.8	12.7	14.3	15.9	--	--	--	--
2	--	12.9	11.5	11.1	12.3	12.8	14.0	15.4	--	--	--	--
3	--	12.4	11.1	11.2	11.7	12.8	14.1	14.7	--	--	--	--
4	--	12.1	10.3	10.9	11.6	12.8	14.2	--	--	--	--	--
5	--	11.7	10.8	11.4	11.3	12.9	14.4	--	--	--	--	--
6	--	11.4	9.9	12.0	11.1	12.6	14.7	--	--	--	--	--
7	--	11.5	9.9	12.1	11.1	13.0	14.7	--	--	--	--	--
8	--	11.0	10.9	10.8	11.3	12.4	15.0	--	--	--	--	--
9	--	10.6	12.2	10.3	10.9	12.9	15.0	--	--	--	--	--
10	--	10.5	12.4	10.5	11.5	12.8	14.6	--	--	--	--	--
11	--	10.6	12.2	11.1	11.7	13.4	14.4	--	--	--	--	--
12	--	10.7	11.7	11.7	10.9	13.0	14.9	--	--	--	--	--
13	--	10.3	11.8	11.4	11.1	13.1	14.9	--	--	--	--	--
14	--	9.0	12.3	10.4	11.3	12.9	15.2	--	--	--	--	--
15	--	8.3	11.6	9.5	11.4	13.0	15.6	--	--	--	--	--
16	--	8.6	11.7	9.7	12.1	12.6	15.5	--	--	--	--	--
17	10.0	8.9	11.4	9.8	11.9	12.8	15.0	--	--	--	--	--
18	9.7	10.0	11.8	10.0	12.1	12.9	15.1	--	--	--	--	--
19	9.7	10.5	11.4	9.9	12.2	12.9	15.1	--	--	--	--	--
20	9.6	11.2	11.5	10.1	11.9	13.3	15.3	--	--	--	--	--
21	10.2	11.3	10.3	9.9	11.6	13.5	15.2	--	--	--	--	--
22	10.6	11.5	10.6	10.4	11.8	13.6	15.4	--	--	--	--	--
23	11.5	11.5	9.9	11.1	12.1	14.0	15.1	--	--	--	--	--
24	11.5	11.3	10.1	11.2	12.3	14.6	15.2	--	--	--	--	--
25	11.3	11.3	10.1	11.1	11.9	15.0	15.0	--	--	--	--	--
26	11.2	11.3	9.9	10.7	11.9	14.2	15.2	--	--	--	--	--
27	11.9	11.4	10.1	11.3	12.1	14.2	15.1	--	--	--	--	--
28	12.3	11.1	10.5	11.6	12.2	14.2	15.3	--	--	--	--	--
29	12.3	--	10.7	11.8	12.3	14.0	15.2	--	--	--	--	--
30	12.4	--	10.6	12.2	12.4	14.0	15.6	--	--	--	--	--
31	12.7	--	10.7	--	12.7	--	15.9	--	--	--	--	--
Mean Daily	**11.1**	**10.9**	**11.0**	**10.9**	**11.8**	**13.3**	**15.0**	**15.4**	**--**	**--**	**--**	**--**
Instan. Max	**13.1**	**13.3**	**12.6**	**12.8**	**13.9**	**16.5**	**17.5**	**17.0**	**--**	**--**	**--**	**--**
Instan. Min	**9.1**	**7.7**	**9.1**	**8.6**	**10.0**	**11.2**	**13.3**	**14.6**	**--**	**--**	**--**	**--**

Table 14: Summary of Surber sample data by station and date, Redwood Creek, Marin Co., California

Station	Unit ID	Sample Date	n	Water Depth (m)	SD	% Fines	SD	% Gravel	SD	% Small Cobble	SD	% Large Cobble	SD
Below Pacific Way	1	Aug 3, 1995	4	0.07	0.01	5	0	95	0	0	0	0	0
	2	Aug 3, 1995	4	0.05	0.02	14	8	86	8	0	0	0	0
	3	Aug 3, 1995	4	0.09	0.02	5	0	95	0	0	0	0	0
Banducci	1	Aug 3, 1995	4	0.11	0.01	5	0	88	5	8	5	0	0
	2	Aug 3, 1995	4	0.09	0.01	5	0	93	5	3	5	0	0
	3	Aug 3, 1995	4	0.06	0.01	6	3	94	3	0	0	0	0
Upstream MUWO RD	1	Aug 3, 1995	4	0.10	0.01	5	0	80	0	15	0	0	0
	2	Aug 3, 1995	4	0.08	0.03	8	3	93	3	0	0	0	0
	3	Aug 3, 1995	4	0.07	0.02	5	0	93	5	4	8	0	0
Below Concrete Bridge	1	Aug 4, 1995	4	0.10	0.02	1	3	59	38	40	39	0	0
	2	Aug 4, 1995	4	0.10	0.02	3	5	78	22	20	18	0	0
	3	Aug 4, 1995	4	0.10	0.03	10	7	73	9	18	10	0	0
MUWO Restroom	1	Aug 4, 1995	4	0.12	0.01	9	9	59	30	18	29	15	30
	2	Aug 4, 1995	4	0.10	0.02	4	3	90	7	6	9	0	0
	3	Aug 4, 1995	4	0.07	0.01	8	3	84	11	4	5	5	6
Fern Creek	1	Aug 4, 1995	4	0.13	0.01	0	0	35	6	50	14	15	10
	2	Aug 4, 1995	4	0.12	0.04	0	0	50	18	30	16	20	27
	3	Aug 4, 1995	4	0.13	0.03	0	0	70	16	30	16	0	0
Below Pacific Way	1	Nov 10, 1997	4	0.06	0.01	5	0	95	0	0	0	0	0
	2	Nov 10, 1997	4	0.08	0.00	10	4	90	4	0	0	0	0
	3	Nov 10, 1997	4	0.05	0.00	4	2	97	2	0	0	0	0
Banducci	1	Nov 10, 1997	4	0.07	0.01	1	0	99	0	0	0	0	0

Redwood Creek Stream Habitat Inventory

Station	Unit ID	Sample Date	n	Water Depth (m)	SD	% Fines	SD	% Gravel	SD	% Small Cobble	SD	% Large Cobble	SD
	2	Nov 10, 1997	4	0.10	0.02	1	0	99	0	0	0	0	0
	3	Nov 10, 1997	4	0.05	0.01	5	0	95	0	0	0	0	0
Upstream MUWO Rd.	1	Nov 10, 1997	4	0.10	0.02	1	0	98	3	1	3	0	0
	2	Nov 10, 1997	4	0.07	0.03	1	0	97	5	3	5	0	0
	3	Nov 10, 1997	4	0.09	0.02	1	0	99	0	0	0	0	0
	4	Nov 10, 1997	4	0.10	0.02	1	0	99	0	0	0	0	0

Table 15: Tukey-Kramer multiple comparison test of macroinvertebrate data from Redwood Creek, Summer 1995

(Y-X)	Below Pacific Way	Banducci	Up MUWO RD	Below Concrete Bridge	MUWO Restroom	Fern Creek
Below Pacific Way		%dominant (+)	%dominant (+), %shredder (+), %collector (+), %predator (-)	%dominant (+), %shredder (+)	%dominant (+), %shredder(+), H' (-)	%dominant (+), logdensity (+), %shredder (+), H' (-)
Banducci			%collector (+), %predator (-)	.		
Upstream MUWO RD				%predator (+), %collector (-)	%collector (-)	%collector (-)
Below Concrete Bridge						
MUWO Restroom						logdensity (+)
Fern Creek						

FIGURES

Figure 1: Redwood Creek (Reach 1-4), Marin Co., California

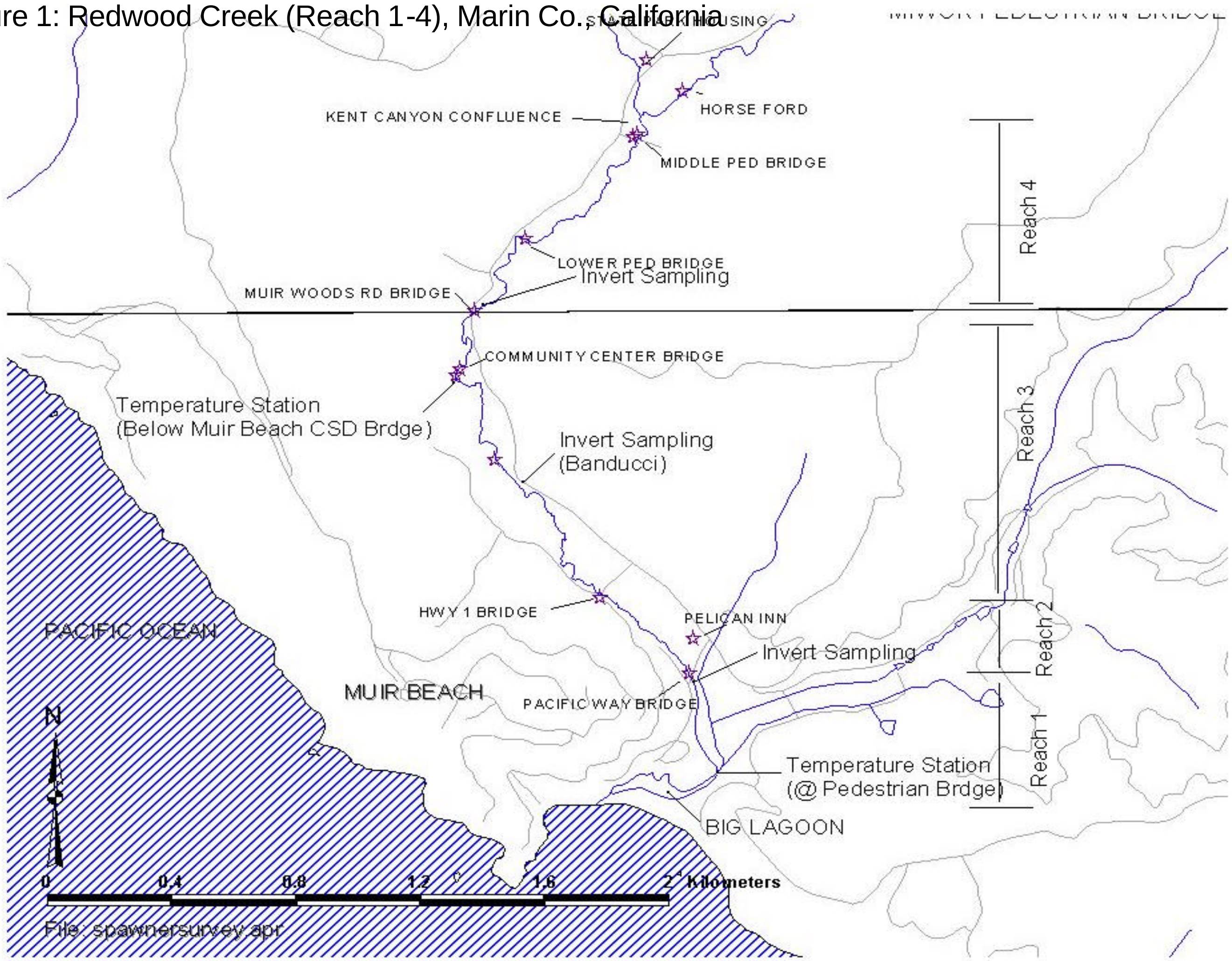


Figure 2: Redwood Creek (Reach 5-6), Marin Co., California

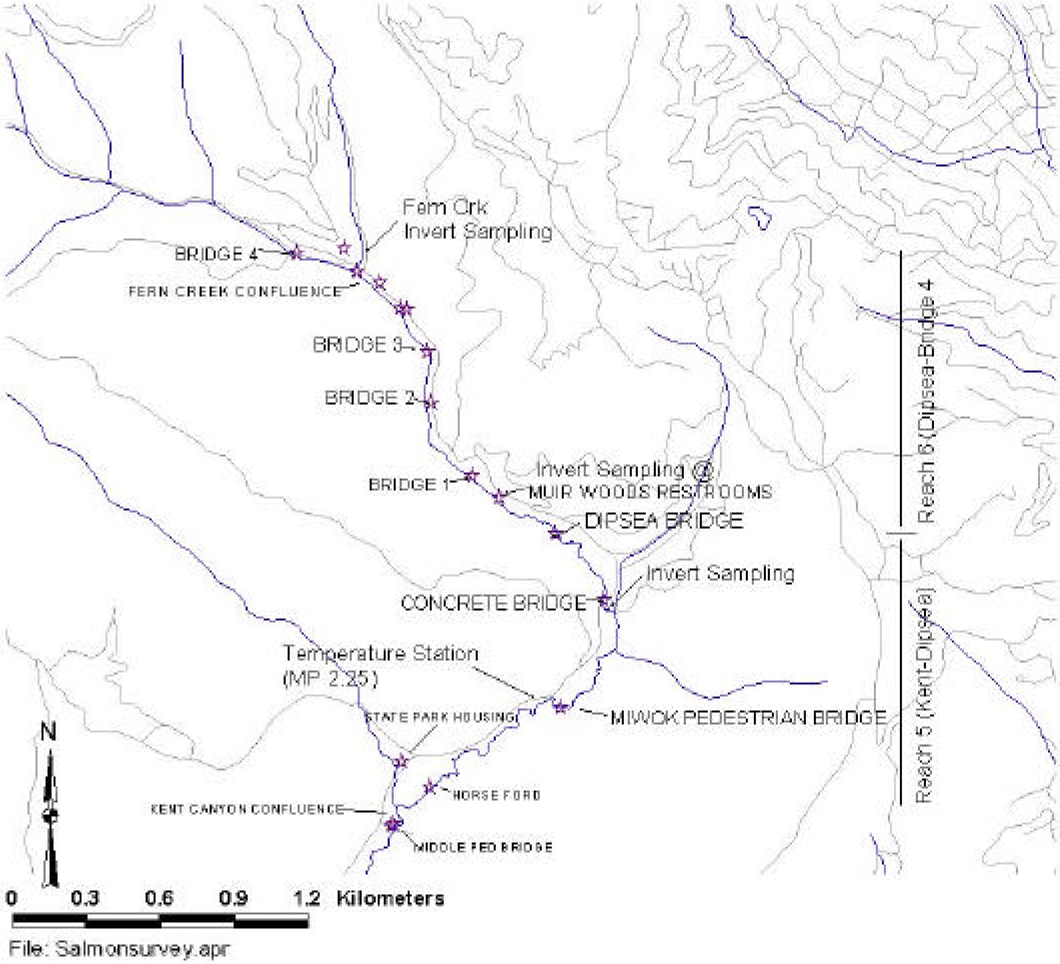


Figure 3: Total volume of stream habitat units in Redwood Creek, Marin Co., California, Summer 1995

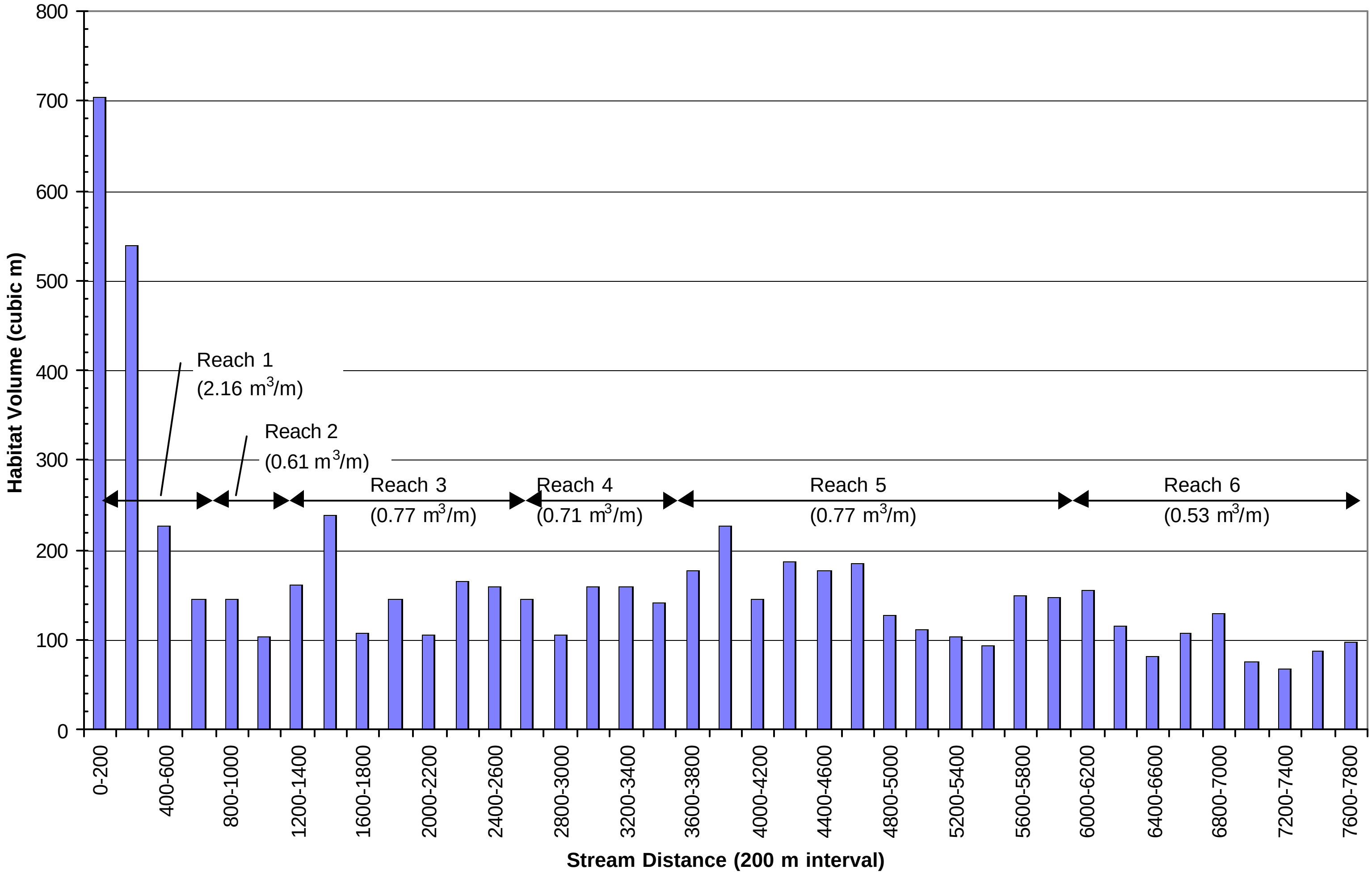


Figure 3: Observer One Comparison of Ocular Estimate of Fines (<2 mm) with Modified Pebble Count within Bankfull Channel of Riffle and Flatwater Units Using a Ratio Estimator, Redwood Creek, Marin Co., Summer 1995

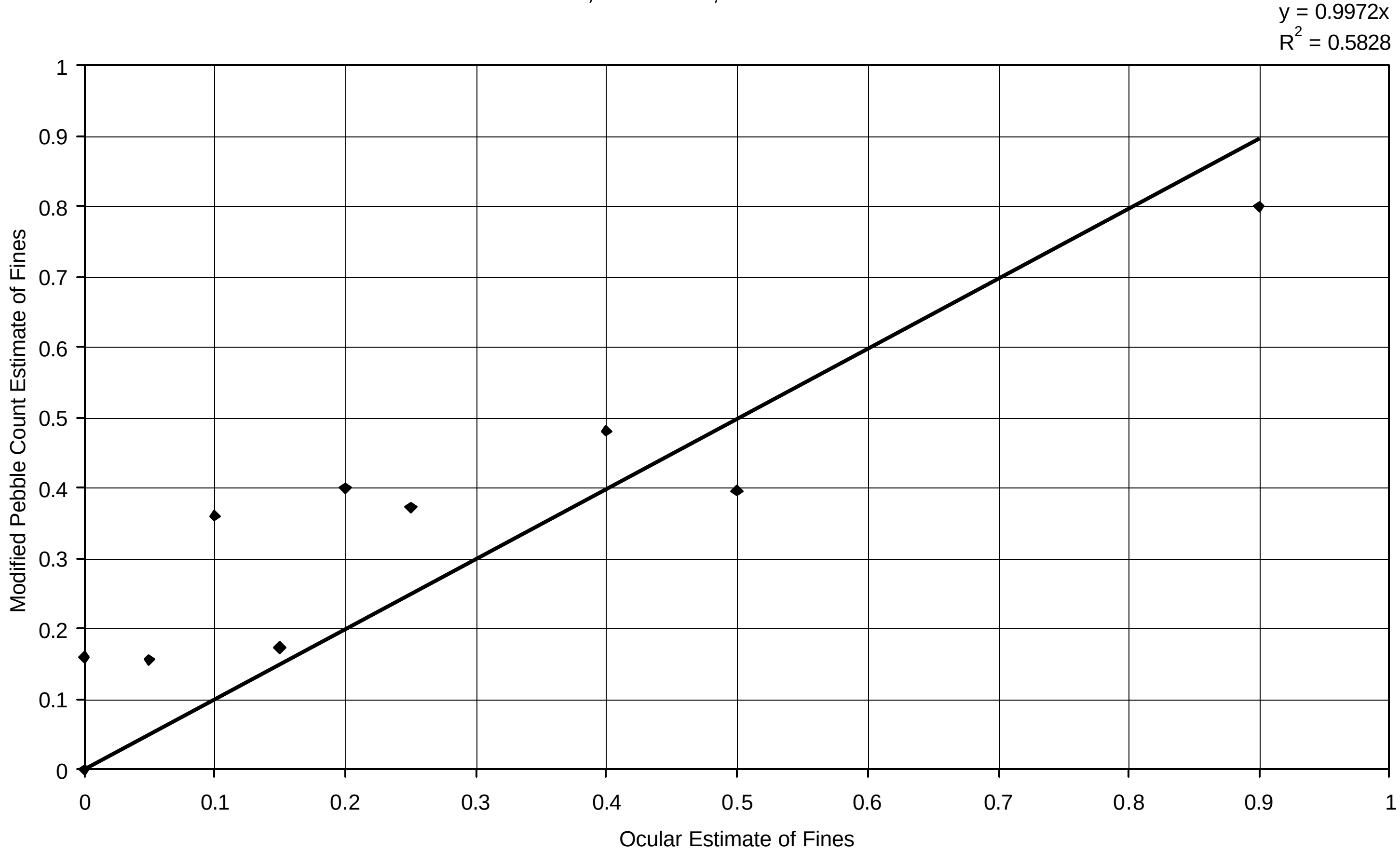


Figure 4: Observer Two Comparison of Ocular Estimate of Fines (<2 mm) with Modified Pebble Count within Bankfull Channel of Riffle and Flatwater Units Using a Ratio Estimator, Redwood Creek, Marin Co., Summer 1995

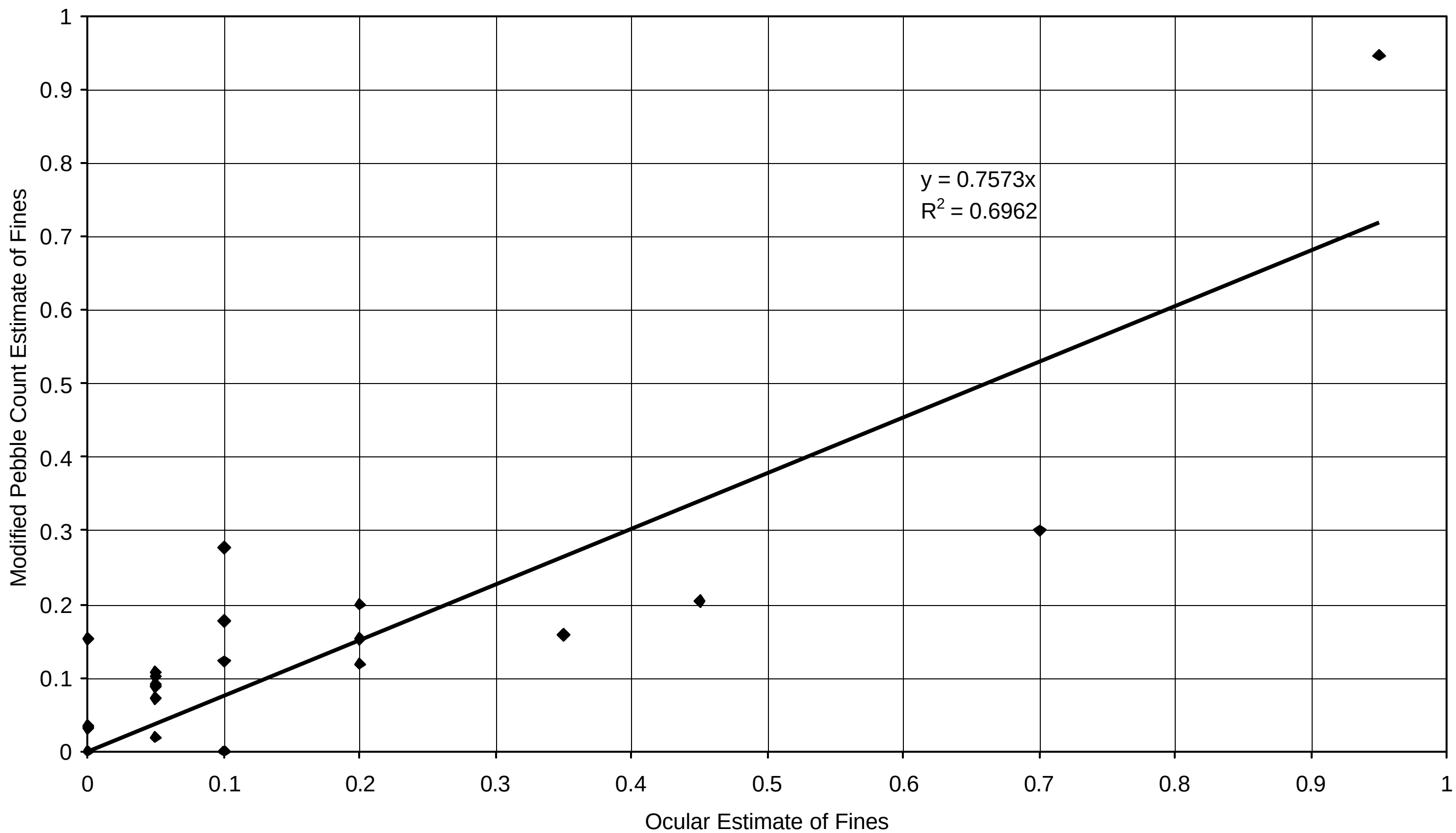


Figure 5: Observer One Comparison of Ocular Estimate of Gravel (2-64 mm) with Modified Pebble Count within Bankfull Channel of Riffle and Flatwater Units Using a Ratio Estimator, Redwood Creek, Marin Co., Summer 1995

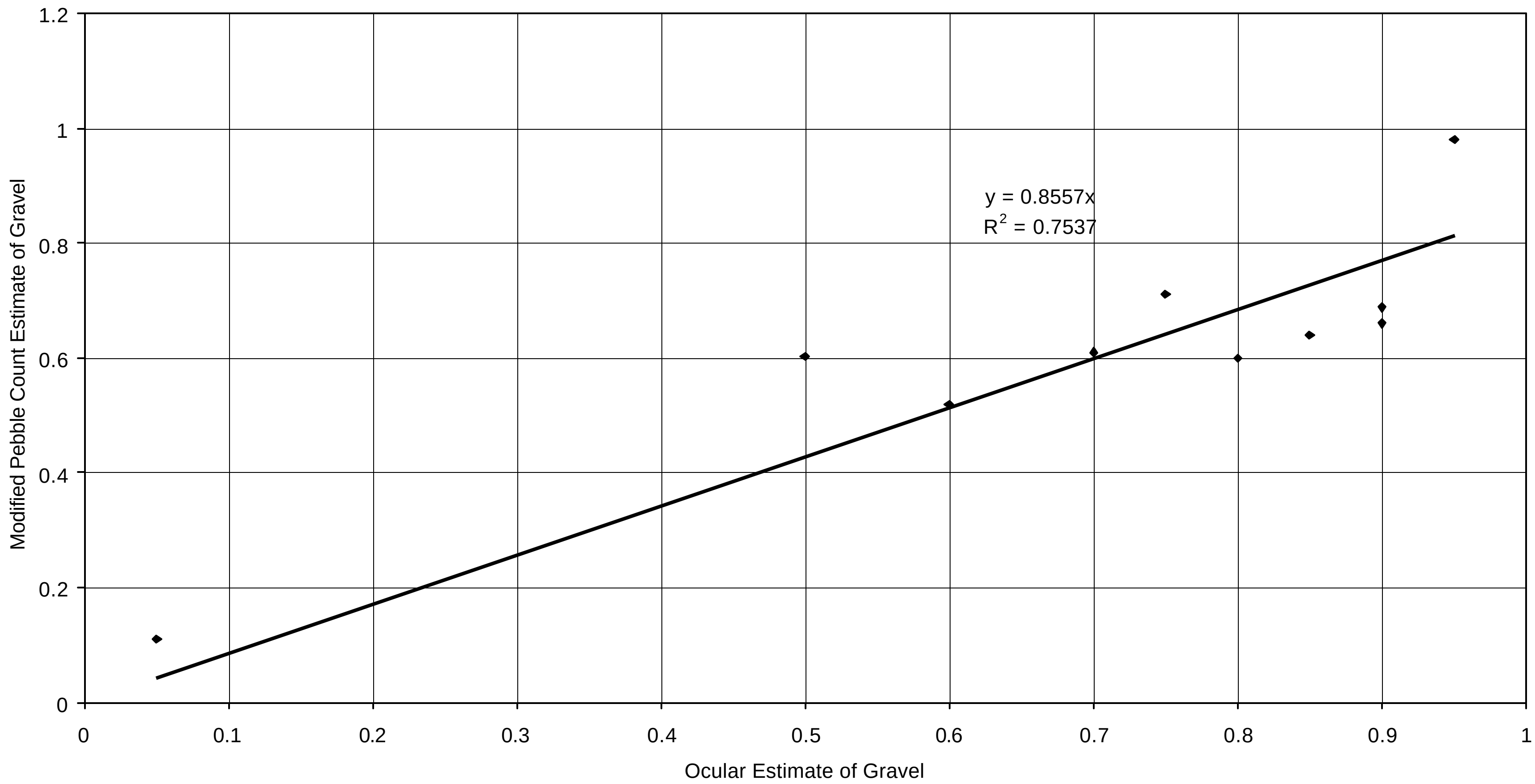
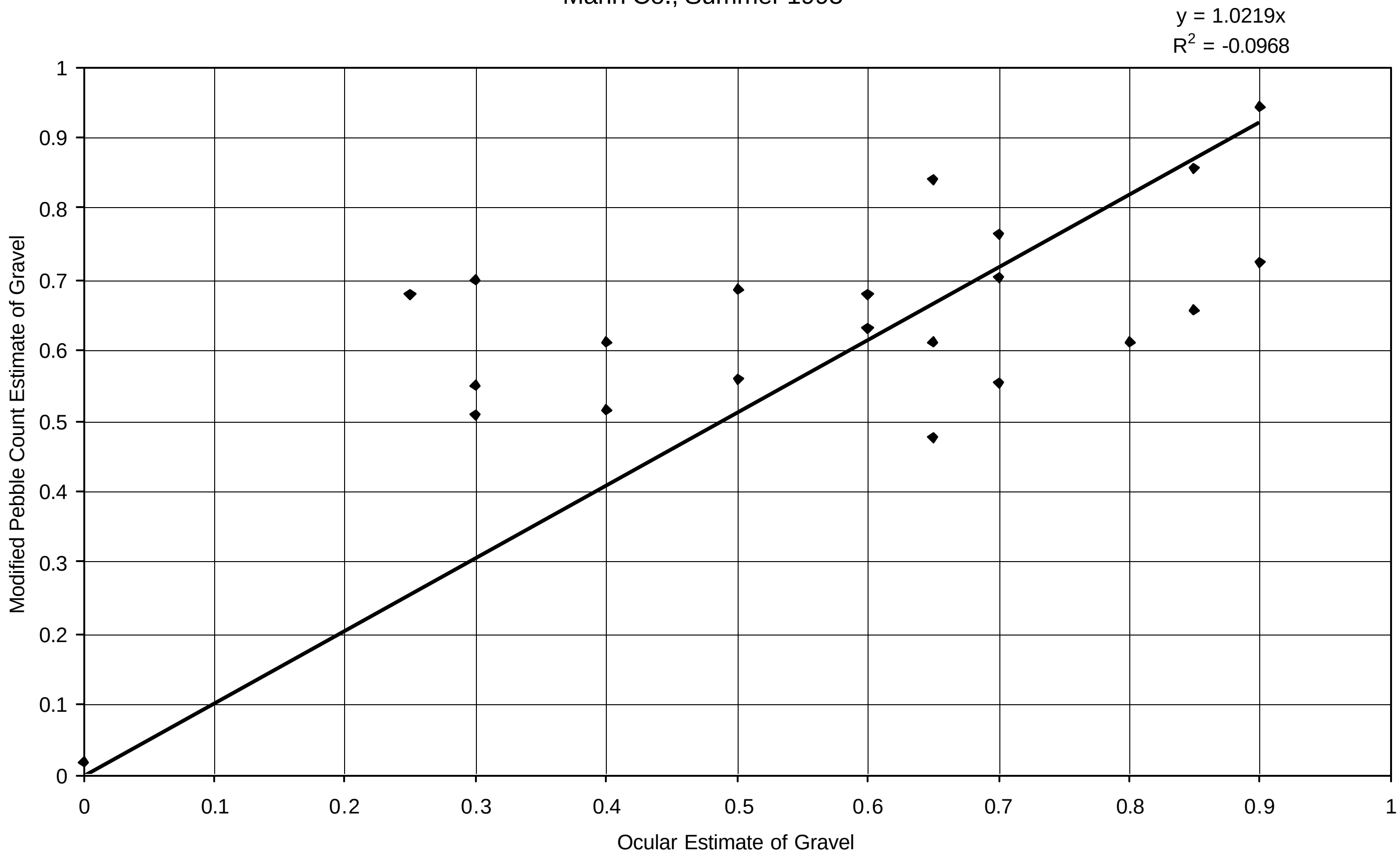


Figure 6: Observer Two Comparison of Ocular Estimate of Gravel (2-64 mm) with Modified Pebble Count within Bankfull Channel of Riffle and Flatwater Units Using a Ratio Estimator, Redwood Creek, Marin Co., Summer 1995



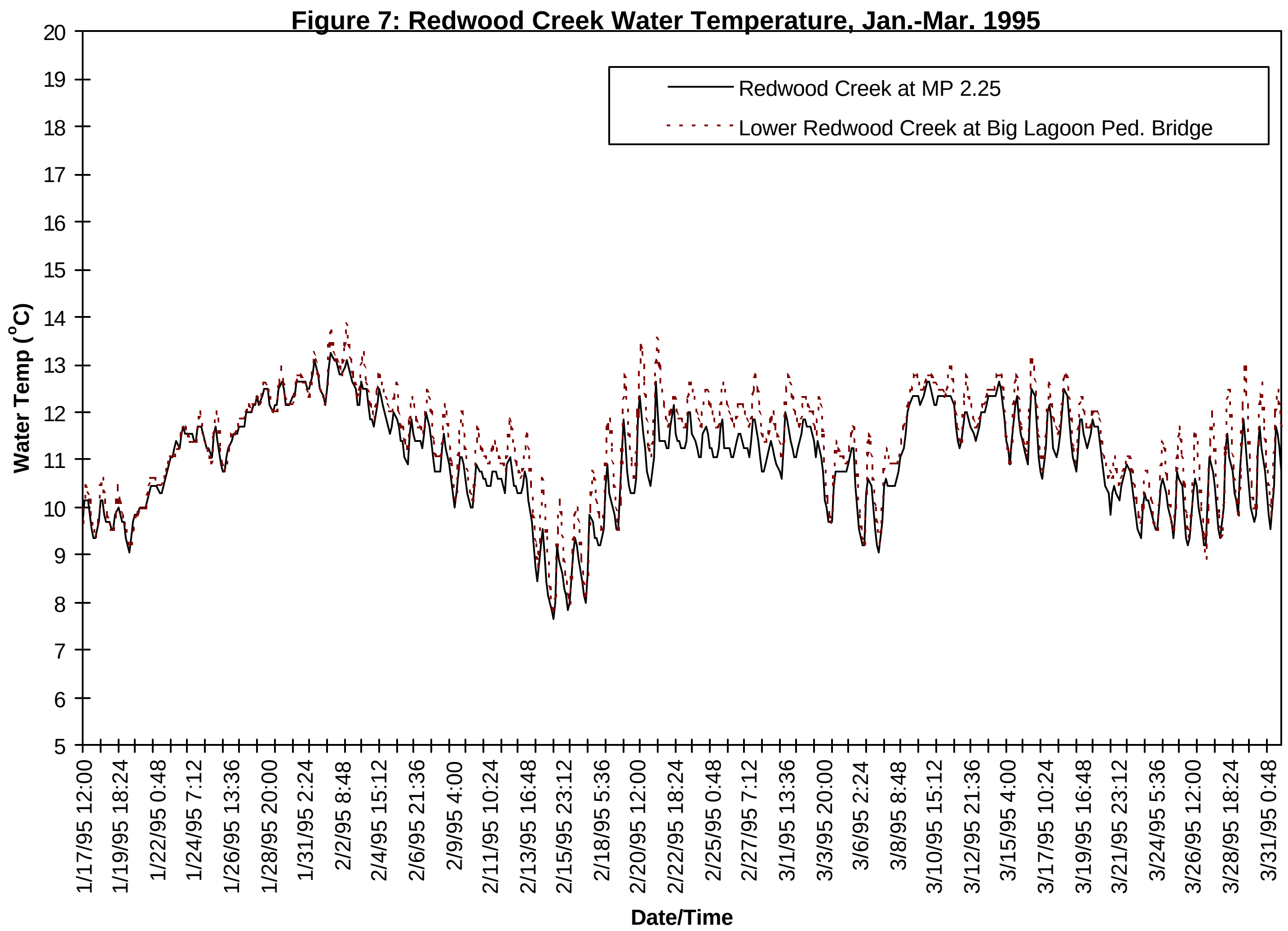


Figure 7: Redwood Creek Water Temperature, Jan.-Mar. 1995
Redwood Creek at MP 2.25
Lower Redwood Creek at Big Lagoon Ped. Bridge
Water Temp (°C)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
1/17/95 12:00
1/19/95 18:24
1/22/95 0:48
1/24/95 7:12
1/26/95 13:36
1/28/95 20:00
1/31/95 2:24
2/2/95 8:48
2/4/95 15:12
2/6/95 21:36
2/9/95 4:00
2/11/95 10:24
2/13/95 16:48
2/15/95 23:12
2/18/95 5:36
2/20/95 12:00
2/22/95 18:24
2/25/95 0:48
2/27/95 7:12
3/1/95 13:36
3/3/95 20:00
3/6/95 2:24
3/8/95 8:48
3/10/95 15:12
3/12/95 21:36
3/15/95 4:00
3/17/95 10:24
3/19/95 16:48
3/21/95 23:12
3/24/95 5:36
3/26/95 12:00
3/28/95 18:24
3/31/95 0:48
Date/Time

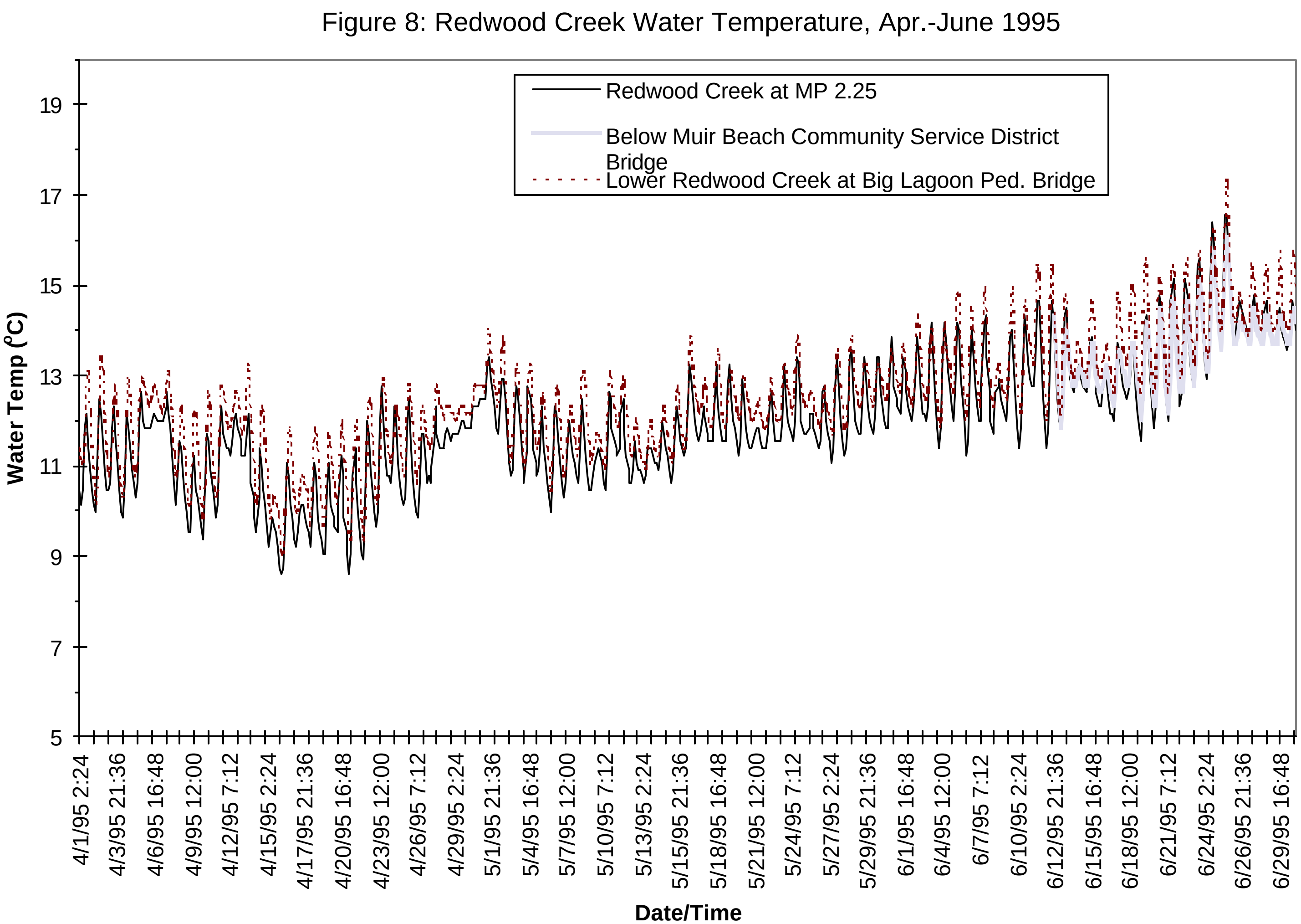


Figure 8: Redwood Creek Water Temperature, Apr.-June 1995
Redwood Creek at MP 2.25
Below Muir Beach Community Service District Bridge
Lower Redwood Creek at Big Lagoon Ped. Bridge
Water Temp (°C)
19
17
15
13
11
9
7
5
4/1/95 2:24
4/3/95 21:36
4/6/95 16:48
4/9/95 12:00
4/12/95 7:12
4/15/95 2:24
4/17/95 21:36
4/20/95 16:48
4/23/95 12:00
4/26/95 7:12
4/29/95 2:24
5/1/95 21:36
5/4/95 16:48
5/7/95 12:00
5/10/95 7:12
5/13/95 2:24
5/15/95 21:36
5/18/95 16:48
5/21/95 12:00
5/24/95 7:12
5/27/95 2:24
5/29/95 21:36
6/1/95 16:48
6/4/95 12:00
6/7/95 7:12
6/10/95 2:24
6/12/95 21:36
6/15/95 16:48
6/18/95 12:00
6/21/95 7:12
6/24/95 2:24
6/26/95 21:36
6/29/95 16:48
Date/Time

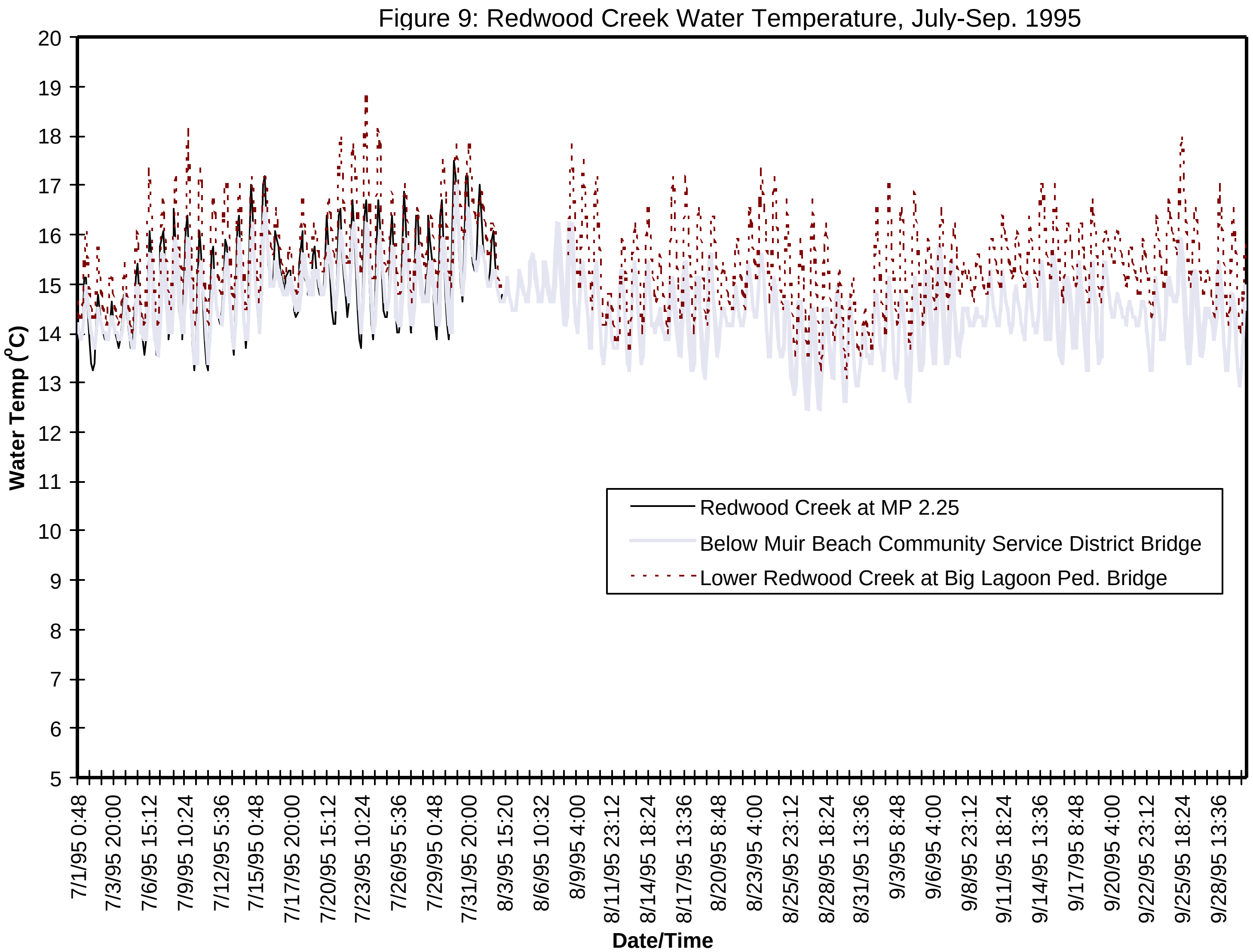
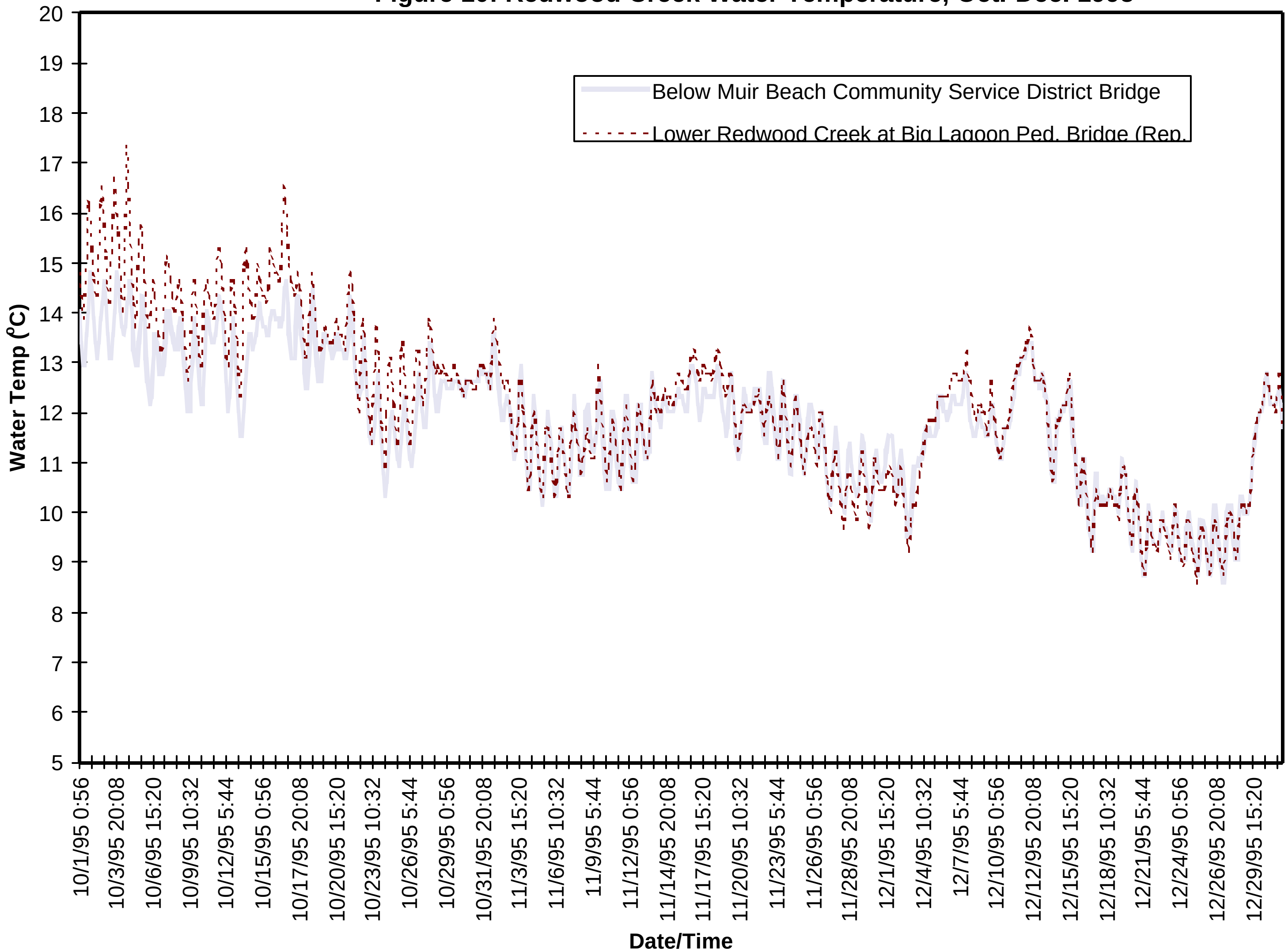


Figure 9: Redwood Creek Water Temperature, July-Sep. 1995
Water Temp (°C)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
Redwood Creek at MP 2.25
Below Muir Beach Community Service District Bridge
Lower Redwood Creek at Big Lagoon Ped. Bridge
7/1/95 0:48
7/3/95 20:00
7/6/95 15:12
7/9/95 10:24
7/12/95 5:36
7/15/95 0:48
7/17/95 20:00
7/20/95 15:12
7/23/95 10:24
7/26/95 5:36
7/29/95 0:48
7/31/95 20:00
8/3/95 15:20
8/6/95 10:32
8/9/95 4:00
8/11/95 23:12
8/14/95 18:24
8/17/95 13:36
8/20/95 8:48
8/23/95 4:00
8/25/95 23:12
8/28/95 18:24
8/31/95 13:36
9/3/95 8:48
9/6/95 4:00
9/8/95 23:12
9/11/95 18:24
9/14/95 13:36
9/17/95 8:48
9/20/95 4:00
9/22/95 23:12
9/25/95 18:24
9/28/95 13:36
Date/Time

Figure 10: Redwood Creek Water Temperature, Oct.-Dec. 1995



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Appendix I: Sampling Procedures for Stream Habitat Variables

Appendix I: Sampling Procedures for Stream Habitat Variables
The measured habitat variables are in bold.

Continuous data (all habitat units)

Length of habitat unit: thalweg length in meters (meter tape or hip chain);

Estimated average width: An ocular estimate of the average width of the wetted channel in meters (meter tape or rod);

Estimated average depth: An estimate of average depth in meters from several arbitrary placements of rod within habitat type (rod);

Estimated undercut: An estimate of undercut banks (bank angle <90°) expressed as percentage of habitat unit perimeter.

Undercut width: A rod was used to estimate the average width of undercut.

Estimated overhanging/instream cover: An estimate of overhanging cover expressed as percentage of habitat length. Overhanging cover is any vegetation or woody material within 0.3 m of the expected water surface. Instream cover refers to emergent or aquatic vegetation that is within the channel. Overhanging and instream vegetative cover was measured from the edge of the bankfull stage. A potential drawback of our instream and overhanging cover measurements lie in expressing cover conditions when the total cover along both banks exceeds habitat unit length. However, there were only 5 habitat units (out of a total of 773) that had cover conditions of 100% (or possibly greater).

Maximum residual depth (pools only): Maximum pool depth (as determined by a rod) minus water depth at pool tail crest expressed in meters (rod).

Substrate composition (flatwater and riffles only): The percentage of each substrate for the habitat unit was ocularly estimated and recorded. Substrates for riffle habitats were classified as fines (<0.2 cm), gravels (0.2-6.4 cm), small cobble (6.4-12.8 cm), large cobble (12.8-25.6), boulder (>25.6 cm), and bedrock (Overton et al. 1994). Substrate evaluation was extended over the bankfull width rather than the wetted channel.

Field notes: For all habitat units, confluence with tributaries, the beginning and end of riprap, bridge crossings and other landmarks were noted.

Calibration and Supplemental Data

Appendix I: Sampling Procedures for Stream Habitat Variables

Length of habitat unit: No additional data

Average width: Water surface widths were measured on three transects using a meter tape at roughly 1/4, 1/2, and 3/4 habitat length.

Average depth: Along each of the three width transects, depth measurements were taken at 1/4, 1/2, and 3/4 widths. Average depth was the sum of the 9 depth measurements divided by 12. This calculation assumes that the depth at right and left edges of water is zero.

Undercut length: The length of undercut banks (bank angle <90^{o}) will be measured for both banks. The maximum depth of undercut bank will be measured using a rod.

Maximum residual depth (pools only): No additional data.

Substrate composition (flatwater and riffles only): Following visual estimates of substrate composition, pebble counts across the bankfull width were conducted. Although normal Wolman pebble counts call for 100 counts, we used 50 counts to increase efficiency. We decided that it was more important to sample as many sites as possible to document basin-wide substrate conditions than to improve the confidence for site-specific substrate composition determinations. We also assumed that variation between sites was greater than that within sites.

The transects used for estimating average depth and width were also used for substrate composition assessment. The streambed was sampled by walking along the transect. Particles were sampled by touching the bottom without looking. The particles were measured with a ruler along the intermediate axis in mm. Roughly 17, evenly spaced measurement points were done per transect. Occurrences of organic matter (e.g. leaves, sticks, and detrital material) were documented; however, they were not included in substrate composition determinations.

Canopy density: A spherical densiometer was used to determine the percent canopy density (overhead cover above 0.3 m) using CDFG 1994 protocol. Measurements were taken from the center of the channel and habitat unit in four orientations (facing downstream, upstream, right and left banks).

Bankfull width and height (riffles only): Bankfull width was determined by the field indicators as described by Harrelson et al. (1994): height of depositional features, vegetation change, topographic breaks in bank, particle size change on banks, undercuts, and stain lines.

Appendix I: Sampling Procedures for Stream Habitat Variables

Entrenchment: Entrenchment is floodprone width divided by bankfull depth. The ratio of floodprone width to bankfull width is needed to classify reaches using Rosgen's stream typing system. Floodprone depth is twice the height of the maximum bankfull depth. Floodprone width was determined by stretching a tape at this height perpendicular and level until the bank was intersected.

Woody Material: Woody material was measured along the entire length of the sampled area. Work by the U.S. Forest Service indicated that extrapolation of woody material numbers from short reaches was not recommended because of its clumped and irregular distribution (D. Azuma, pers. comm. 1995).

Woody material was counted if it was found within the bankfull channel. Woody material greater than 10 cm in mid-point diameter and greater than 1 m in length was measured and counted. Clumps of wood with large number of individual pieces resulted in the measurement of overall volume and a count of woody materials meeting criteria. A volume estimate for collection of small pieces of wood was also done if the dimension of either the length or width of the small woody debris equaled or exceeded 1.0 m . Woody material was classified into the following categories: dam, jam (wood accumulation spans majority of channel cross-section), rootwad, single, and complex (more than one piece of wood and smaller materials).

Appendix II: Macroinvertebrate Data for Redwood Creek Reaches

Appendix II: Macroinvertebrate Data for Redwood Creek Reaches

Creek=>	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood Ck.	Redwood Ck.	Redwood	Redwood	Redwood	Redwood
Station_SampleID#=>	Below Pacific Way_#1	Below Pacific Way_#2	Below Pacific Way_#3	Banducci_#1	Banducci_#2	Banducci_#3	Above MUWO Rd#2	Above MUWO Rd#3	Below Concrete Br_#1	Below Concrete Br_#2	Below Concrete Br_#3	Above MUWO Restrm_#1
Sample Date=>	VIII-3-95	VIII-3-95[1]	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95
INSECTA												
Coleoptera												
Dytiscidae	5	2										
Oreodytes				1								
Elmidae		101										
Narpus			1		2				4	1	1	
Optioservus	105		55	48	40	31	95	25	17	20	24	27
Ordobrevia				1	1	8	5	8	3	1	11	20
Zaitzevia	1		1	3	1		1			1		1
Haliplidae												
Brychius	1											
Hydraenidae												
Hydraena	1											
Psephenidae												
Eubrianax												
Diptera												
Ceratopogonidae		1		2	1					1		
Atrichopogon												
Forcipomyia												
Chironomidae		174										
Chironominae												

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Creek=>	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood Ck.	Redwood Ck.	Redwood	Redwood	Redwood	Redwood
Station_SampleID#=>	Below Pacific Way_#1	Below Pacific Way_#2	Below Pacific Way_#3	Banducci_#1	Banducci_#2	Banducci_#3	Above MUWO Rd#2	Above MUWO Rd#3	Below Concrete Br_#1	Below Concrete Br_#2	Below Concrete Br_#3	Above MUWO Restrm_#1
Sample Date=>	VIII-3-95	VIII-3-95[1]	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95
Chironomini	1		3	3	2	2		1	5	8	9	14
Stenochironomus											1	
Tanytarsini	43		28	103	16	9	20	22	43	98	25	66
Orthocladiinae	41		43	162	42	6	8	22	40	25	20	19
Tanypodinae	62		26	82	17	4	72	79	4	15	8	26
Dixidae												
Dixa							1					
Empididae												
Chelifera	2			4						3	2	4
Trichoclinocera	1											
Ephydridae												
Pelecorynchidae												
Glutops												1
Simuliidae		1										
Simulium	180		2	36	7	5		9	6	4	1	10
Tipulidae		1										
Antocha		5				1						5
Dicranota	1			4	1		7	1		1	1	1
Hexatoma								1				
Limnophila	2				1							
Ephemeroptera												
Ameletidae												
Ameletus												

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Creek=>	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood Ck.	Redwood Ck.	Redwood	Redwood	Redwood	Redwood
Station_SampleID#=>	Below Pacific Way_#1	Below Pacific Way_#2	Below Pacific Way_#3	Banducci_#1	Banducci_#2	Banducci_#3	Above MUWO Rd#2	Above MUWO Rd#3	Below Concrete Br_#1	Below Concrete Br_#2	Below Concrete Br_#3	Above MUWO Restrm_#1
Sample Date=>	VIII-3-95	VIII-3-95[1]	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95
Baetidae												
Baetis	114		36	36	48	20	25	26	25	21	35	105
Diphetor	39		17	19	17	63	6	6	13	15	21	48
Ephemerellidae												32
Drunella												
Ephemerella	3		3				1		1	3	3	
Heptageniidae												56
Cinygma												
Cinygmula											2	
Epeorus												
Ironodes				1	4		1	1	1			
Leucrocuta			1			2	3				2	3
Rhithrogena	14		51	31	28	23	101	4	39	43	46	
Leptophlebiidae												
Paraleptophlebia	32	68	65	23	76	36	5	6	3	19	14	4
Hemiptera												
Veliidae												
Microvelia										1		
Plecoptera												
Capniidae	2											
Chloroperlidae		2										
Paraperla							4	1				
Sweltsa	8		6	6	20	13	54	11	3	7	13	4

Appendix II: Macroinvertebrate Data for Redwood Creek Reaches

Creek=>	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood Ck.	Redwood Ck.	Redwood	Redwood	Redwood	Redwood
Station_SampleID#=>	Below Pacific Way_#1	Below Pacific Way_#2	Below Pacific Way_#3	Banducci_#1	Banducci_#2	Banducci_#3	Above MUWO Rd#2	Above MUWO Rd#3	Below Concrete Br_#1	Below Concrete Br_#2	Below Concrete Br_#3	Above MUWO Restrm_#1
Sample Date=>	VIII-3-95	VIII-3-95[1]	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95
Leuctridae												1
Nemouridae												
Malenka	410	567	132	156	46	64	46	17	9	39	29	50
Perlidae		31										
Calineuria	1			7	3		22	33	18	9	15	16
Hesperoperla							1					1
Perlodidae												
Isoperla	11		5	2				6				
Trichoptera												
Apataniidae												
Apatania												
Brachycentridae												
Micrasema												
Calamoceratidae												
Heteroplectron												
Glossosomatidae												
Agapetus	6	17	15	14	10	9	8	2		2	4	20
Glossosoma												
Hydropsychidae												
Hydropsyche	3	1	2	37	18	2	50	32		52	10	36
Hydroptilidae											1	
Hydroptila												15
Ochrotrichia												

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Creek=>	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood Ck.	Redwood Ck.	Redwood	Redwood	Redwood	Redwood
Station_SampleID#=>	Below Pacific Way_#1	Below Pacific Way_#2	Below Pacific Way_#3	Banducci_#1	Banducci_#2	Banducci_#3	Above MUWO Rd#2	Above MUWO Rd#3	Below Concrete Br_#1	Below Concrete Br_#2	Below Concrete Br_#3	Above MUWO Restrm_#1
Sample Date=>	VIII-3-95	VIII-3-95[1]	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95
Lepidostomatidae												
Lepidostoma	8	62	11	17	16	15	51	42	7	96	21	28
Limnephilidae												
Eocosmoecus		1										
Psychoglypha												
Odontoceridae												
Parthina							1					
Philopotamidae												
Wormaldia												
Polycentropodidae												
Polycentropus												
Rhyacophilidae												
Rhyacophila	5	1	2	18	16	12	45	47		9	10	9
Sericostomatidae												
Gumaga												
Uenoidae												
Neophylax		1		1	2					1		3
CRUSTACEA												
Amphipoda												
Hyalellidae												
Hyalella												
Cladocera												
Daphniidae												

Appendix II: Macroinvertebrate Data for Redwood Creek Reaches

Creek=>	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood Ck.	Redwood Ck.	Redwood	Redwood	Redwood	Redwood
Station_SampleID#=>	Below Pacific Way_#1	Below Pacific Way_#2	Below Pacific Way_#3	Banducci_#1	Banducci_#2	Banducci_#3	Above MUWO Rd#2	Above MUWO Rd#3	Below Concrete Br_#1	Below Concrete Br_#2	Below Concrete Br_#3	Above MUWO Restrm_#1
Sample Date=>	VIII-3-95	VIII-3-95[1]	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95
Copepoda												
Cyclopidae			1									
Ergasilidae												
Ergasilus												
Ostracoda												
Cyprididae	1		1							9	5	9
ARACHNIDA												
Acarina				1								2
Anisitsiellidae			2								1	2
Aturidae				2								
Aturus								1				
Kongsbergia												
Hydryphantidae												
Protzia							1	1				
Hygrobatidae												
Atractides	3		2	2						1		1
Hygrobates							1					
Lebertiidae												
Estelloxus												
Lebertia	4		5	1			2	2				1
Mideopoidae						1						
Sperchonidae										1		1
Torrenticolidae												

Appendix II: Macroinvertebrate Data for Redwood Creek Reaches

Creek=>	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood Ck.	Redwood Ck.	Redwood	Redwood	Redwood	Redwood
Station_SampleID#=>	Below Pacific Way_#1	Below Pacific Way_#2	Below Pacific Way_#3	Banducci_#1	Banducci_#2	Banducci_#3	Above MUWO Rd#2	Above MUWO Rd#3	Below Concrete Br_#1	Below Concrete Br_#2	Below Concrete Br_#3	Above MUWO Restrm_#1
Sample Date=>	VIII-3-95	VIII-3-95[1]	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95
Torrenticola	19		34	8	8	17	73	68		27	26	47
Oribatei	1		1		2							
GASTROPODA												
Pulmonata												
Lymnaeidae												
Fossaria												
Physidae												
Physella												
Planorbidae												
Gyraulus												
BIVALVIA												
Pelecypoda												
Sphaeriidae												
Pisidium												
OLIGOCHAETA		16										
Haplotaxida												
Enchytraeidae												1
Naididae							1			12	5	12
Chaetogaster												1
Tubificidae				1								
Lumbriculida												
Lumbriculidae												
Lumbricina			3				2					

Appendix II: Macroinvertebrate Data for Redwood Creek Reaches

Creek=>	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood Ck.	Redwood Ck.	Redwood	Redwood	Redwood	Redwood
Station_SampleID#=>	Below Pacific Way_#1	Below Pacific Way_#2	Below Pacific Way_#3	Banducci_#1	Banducci_#2	Banducci_#3	Above MUWO Rd#2	Above MUWO Rd#3	Below Concrete Br_#1	Below Concrete Br_#2	Below Concrete Br_#3	Above MUWO Restrm_#1
Sample Date=>	VIII-3-95	VIII-3-95[1]	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95
HYDROZOA												
Hydroida												
Hydridae												
Hydra												
TURBELLARIA												
Tricladida												
Planariidae												
Dugesia												
NEMERTEA												
Enopla												
Tertastemmatidae												
Prostoma												
NEMATODA												
Mermithidae				22	2					1		
Total (#/sq. ft)	1130	1052	554	854	447	343	713	474	241	546	366	702
Log_{10} Total	3.05	3.02	2.74	2.93	2.65	2.54	2.85	2.68	2.38	2.74	2.56	2.85
# taxa:	33	18	29	33	28	21	31	27	18	32	30	39
#EPT taxa	14	10	13	14	13	11	17	14	10	13	15	17
EPT index	58	71	62	43	68	76	59	49	49	58	62	61
%dominant taxa	36	54	24	19	17	19	14	17	18	18	13	15
Dominant taxa	*Malenka*	*Malenka*	*Malenka*	Orthocladiinae	Paraleptophlebia	*Malenka*	*Rhithrogena*	Tanypodinae	Tanytarsini	Tanytarsini	*Rhithrogena*	*Baetis*
Weighted Tolerance Value	3.82	2.97	3.39	4.07	3.48	3.28	2.85	3.63	3.72	3.61	3.38	3.83

Appendix II: Macroinvertebrate Data for Redwood Creek Reaches

Creek=>	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood Ck.	Redwood Ck.	Redwood	Redwood	Redwood	Redwood
Station_SampleID#=>	Below Pacific Way_#1	Below Pacific Way_#2	Below Pacific Way_#3	Banducci_#1	Banducci_#2	Banducci_#3	Above MUWO Rd#2	Above MUWO Rd#3	Below Concrete Br_#1	Below Concrete Br_#2	Below Concrete Br_#3	Above MUWO Restrm_#1
Sample Date=>	VIII-3-95	VIII-3-95[1]	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-3-95	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95
%shredder	37	60	26	20	14	23	14	12	7	25	14	11
%collectors	20	35	31	29	42	40	7	15	39	19	33	37
%filterers	20	0	6	21	9	5	10	13	20	28	10	16
%grazers	11	2	22	11	19	19	29	7	24	12	22	18
%predators	9	3	8	18	14	9	29	38	10	9	14	9
%unk. funct. feeding grp	3	0	8	1	2	5	11	15	0	7	8	9
Shannon Diversity	2.20		2.55	2.61	2.75	2.54	2.68	2.68	2.42	2.71	2.96	3.02

Appendix II: Macroinvertebrate Data for Redwood Creek Reaches

Creek=>	Redwood	Redwood	Fern Creek	Fern Creek	Fern Creek	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood
Station_SampleID#=>	Above MUWO Restrm_#2	Above MUWO Restrm_#3	Fern#1	Fern#2	Fern#3	Below Pacific Way_#1	Below Pacific Way_#2	Below Pacific Way_#3	Banducci_#1	Banducci_#2	Banducci_#3	Above MUWO Rd_#1
Sample Date=>	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97
INSECTA												
Coleoptera												
Dytiscidae						1	3			4	1	
Oreodytes												
Elmidae												
Narpus	1	2				9	7		1	1	3	1
Optioservus	10	23	9	5	4	327	191	70	27	130	81	163
Ordobrevia	2	2						4	2	2	6	2
Zaitzevia						8	3	4	1	7	12	3
Haliplidae												
Brychius												
Hydraenidae												
Hydraena							2	1				
Psephenidae												
Eubrianax				1								
Diptera												
Ceratopogonidae	1	2	1		3	3	4	2			15	1
Atrichopogon			2	1	4							
Forcipomyia			1									
Chironomidae												
Chironominae												
Chironomini	29	8	5		14	2	13	4		1	3	22
Stenochironomus			1									

Appendix II: Macroinvertebrate Data for Redwood Creek Reaches

Creek=>	Redwood	Redwood	Fern Creek	Fern Creek	Fern Creek	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood
Station_SampleID#=>	Above MUWO Restrm_#2	Above MUWO Restrm_#3	Fern#1	Fern#2	Fern#3	Below Pacific Way_#1	Below Pacific Way_#2	Below Pacific Way_#3	Banducci_#1	Banducci_#2	Banducci_#3	Above MUWO Rd_#1
Sample Date=>	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97
Tanytarsini	95	50	39	11	46	9	5	29		2	3	32
Orthocladiinae	52	19	27	12	13	110	62	289	11	17	41	167
Tanypodinae	34	23	5	3	1	12	5	11		5	12	13
Dixidae												
Dixa	2			1	1							
Empididae												
Chelifera	3				1	3		2			1	5
Trichoclinocera						1		1				1
Ephydridae											1	
Pelecorynchidae												
Glutops						1	1			1		
Simuliidae												
Simulium	30	7	5	5	5	11		39	12	40	8	
Tipulidae												
Antocha	4	1										
Dicranota				1				3			1	1
Hexatoma								2				2
Limnophila						1						
Ephemeroptera												
Ameletidae												
Ameletus							2					
Baetidae												
Baetis	91	121	36	17	21			5				2

Appendix II: Macroinvertebrate Data for Redwood Creek Reaches

Creek=>	Redwood	Redwood	Fern Creek	Fern Creek	Fern Creek	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood
Station_SampleID#=>	Above MUWO Restrm_#2	Above MUWO Restrm_#3	Fern#1	Fern#2	Fern#3	Below Pacific Way_#1	Below Pacific Way_#2	Below Pacific Way_#3	Banducci_#1	Banducci_#2	Banducci_#3	Above MUWO Rd_#1
Sample Date=>	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97
Diphetor	25	42	6	1	2	55	7	41	5	7	2	12
Ephemerellidae	21	45										
Drunella		1										
Ephemerella			3	2	2	1	4	1				7
Heptageniidae	14	50										
Cinygma			1									
Cinygmula					1	20	10	16	2	2		101
Epeorus					2							
Ironodes												
Leucrocuta			1									
Rhithrogena			23	8	18		1					31
Leptophlebiidae												
Paraleptophlebia	11	6	3	1	2	4	5	6	2	5	6	103
Hemiptera												
Veliidae												
Microvelia			1									
Plecoptera												
Capniidae						122	143	148	108	113	88	6
Chloroperlidae												
Paraperla		1		1								2
Sweltsa	2	5	10	1	1		3	2		2	5	3
Leuctridae			11		3							1
Nemouridae												

Appendix II: Macroinvertebrate Data for Redwood Creek Reaches

Creek=>	Redwood	Redwood	Fern Creek	Fern Creek	Fern Creek	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood
Station_SampleID#=>	Above MUWO Restrm_#2	Above MUWO Restrm_#3	Fern#1	Fern#2	Fern#3	Below Pacific Way_#1	Below Pacific Way_#2	Below Pacific Way_#3	Banducci_#1	Banducci_#2	Banducci_#3	Above MUWO Rd_#1
Sample Date=>	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97
Malenka	56	40	6	2	10	22	22	36	14	10	13	43
Perlidae												
Calineuria	8	17	18	2	8		1	1		1	2	11
Hesperoperla		1										
Perlodidae												
Isoperla	5	2							3			4
Trichoptera												
Apataniidae												
Apatania	1	2										1
Brachycentridae												
Micrasema	4	1										
Calamoceratidae												
Heteroplectron	1											
Glossosomatidae												
Agapetus	8	15										
Glossosoma	1											
Hydropsychidae												
Hydropsyche	44	50	24		10				1	1		5
Hydroptilidae							1					
Hydroptila	11											
Ochrotrichia	1	2										
Lepidostomatidae												
Lepidostoma	23	13		1	1	3	1	6	45	130	19	26

Appendix II: Macroinvertebrate Data for Redwood Creek Reaches

Creek=>	Redwood	Redwood	Fern Creek	Fern Creek	Fern Creek	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood
Station_SampleID#=>	Above MUWO Restrm_#2	Above MUWO Restrm_#3	Fern#1	Fern#2	Fern#3	Below Pacific Way_#1	Below Pacific Way_#2	Below Pacific Way_#3	Banducci_#1	Banducci_#2	Banducci_#3	Above MUWO Rd_#1
Sample Date=>	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97
Limnephilidae												
Eocosmoecus												
Psychoglypha												3
Odontoceridae												
Parthina			4									
Philopotamidae												
Wormaldia		1	4									
Polycentropodidae												
Polycentropus												1
Rhyacophilidae												
Rhyacophila	5	16	2	1	1	1	2	5	1	4	5	62
Sericostomatidae												
Gumaga								1		3		
Uenoidae												
Neophylax					2							
CRUSTACEA												
Amphipoda												
Hyalellidae												
Hyalella							2					
Cladocera												
Daphniidae					2	1						
Copepoda												
Cyclopidae								1		4	2	

Appendix II: Macroinvertebrate Data for Redwood Creek Reaches

Creek=>	Redwood	Redwood	Fern Creek	Fern Creek	Fern Creek	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood
Station_SampleID#=>	Above MUWO Restrm_#2	Above MUWO Restrm_#3	Fern#1	Fern#2	Fern#3	Below Pacific Way_#1	Below Pacific Way_#2	Below Pacific Way_#3	Banducci_#1	Banducci_#2	Banducci_#3	Above MUWO Rd_#1
Sample Date=>	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97
Ergasilidae												
Ergasilus					1							
Ostracoda												
Cyprididae	9	13	3	2	9					2	1	12
ARACHNIDA												
Acarina		2			2			2				2
Anisitsiellidae	1											
Aturidae		1				1		1	1	1		5
Aturus			1									
Kongsbergia												
Hydryphantidae												
Protzia		1	1									
Hygrobatidae												
Atractides	1	2	2					1				
Hygrobates												
Lebertiidae												
Estelloxus	1	1										
Lebertia		2	1	1		8	3	9	7	1	3	6
Sperchonidae			3		3						1	
Stygothrombiidae										1		
Torrenticolidae												
Torrenticola	32	46	10	8	17	19	4	2	8	1	2	29
Oribatei										1		1

Appendix II: Macroinvertebrate Data for Redwood Creek Reaches

Creek=>	Redwood	Redwood	Fern Creek	Fern Creek	Fern Creek	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood
Station_SampleID#=>	Above MUWO Restrm_#2	Above MUWO Restrm_#3	Fern#1	Fern#2	Fern#3	Below Pacific Way_#1	Below Pacific Way_#2	Below Pacific Way_#3	Banducci_#1	Banducci_#2	Banducci_#3	Above MUWO Rd_#1
Sample Date=>	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97
GASTROPODA												
Pulmonata												
Lymnaeidae												
Fossaria							1			1		
Physidae												
Physella								3	1	5		
Planorbidae												
Gyraulus						16	3	15	5	271	63	3
BIVALVIA												
Pelecypoda												
Sphaeriidae												
Pisidium						2	1		1	1		
OLIGOCHAETA		4										
Haplotaxida												
Enchytraeidae			1		1		2		1	2		
Naididae	7	10		7	7	6		2	8	28	35	1
Chaetogaster	7					1			1		3	
Tubificidae							14					
Lumbriculida												
Lumbriculidae												
Lumbricina						57	22	4	9	15	18	
HYDROZOA												
Hydroida												

Appendix II: Macroinvertebrate Data for Redwood Creek Reaches

Creek=>	Redwood	Redwood	Fern Creek	Fern Creek	Fern Creek	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood
Station_SampleID#=>	Above MUWO Restrm_#2	Above MUWO Restrm_#3	Fern#1	Fern#2	Fern#3	Below Pacific Way_#1	Below Pacific Way_#2	Below Pacific Way_#3	Banducci_#1	Banducci_#2	Banducci_#3	Above MUWO Rd_#1
Sample Date=>	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97
Hydridae												
Hydra												
TURBELLARIA												
Tricladida												
Planariidae												
Dugesia											1	
NEMERTEA												
Enopla												
Tertastemmatidae												
Prostoma												
NEMATODA												
Mermithidae					1	2	5	2		1		
Total (#/sq. ft)	653	650	270	95	219	839	555	771	277	823	457	896
Log_{10} Total	2.81	2.81	2.43	1.98	2.34	2.92	2.74	2.89	2.44	2.92	2.66	2.95
# taxa:	38	40	34	24	34	32	34	37	25	37	32	40
#EPT taxa	19	20	15	11	15	8	13	12	9	11	8	19
EPT index	51	66	56	39	38	27	36	35	65	34	31	47
%dominant taxa	15	19	14	18	21	39	34	37	39	33	19	19
Dominant taxa	Tanytarsini	*Baetis*	Tanytarsini	*Baetis*	Tany tarsini	*Optioservus*	*Optioservus*	Orthocladiinae	Capniidae	*Gyraulus*	Capniidae	Orthocladiinae
Weighted Tolerance Value	4.42	3.78	3.79	4.53	4.56	4.22	3.68	4.07	2.78	4.80	4.51	3.76
%shredder	12	8	8	3	6	18	30	25	60	31	26	8
%collectors	38	40	31	44	31	23	21	46	11	9	24	36

Appendix II: Macroinvertebrate Data for Redwood Creek Reaches

Creek=>	Redwood	Redwood	Fern Creek	Fern Creek	Fern Creek	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood	Redwood
Station_SampleID#=>	Above MUWO Restrm_#2	Above MUWO Restrm_#3	Fern#1	Fern#2	Fern#3	Below Pacific Way_#1	Below Pacific Way_#2	Below Pacific Way_#3	Banducci_#1	Banducci_#2	Banducci_#3	Above MUWO Rd_#1
Sample Date=>	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95	VIII-4-95	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97	XI-10-97
%filterers	26	17	27	17	28	3	1	9	5	5	2	4
%grazers	8	14	13	15	12	43	38	13	13	50	32	33
%predators	9	11	15	9	7	3	4	4	2	2	9	12
%unk. funct. feeding grp	8	10	7	12	15	10	6	2	9	3	6	6
Shannon Diversity	2.94	2.92	2.90	2.70	2.90	2.16	2.18	2.23	2.20	2.16	2.61	2.65

Appendix II: Macroinvertebrate Data for Redwood Creek Reaches

Creek=>	Redwood	Redwood	Redwood	CDFG	Functional
Station_SampleID#=>	Above MUWO Rd#2	Above MUWO Rd#3	Above MUWO Rd_#4	Tolerance	Feeding
Sample Date=>	XI-10-97	XI-10-97	XI-10-97	Value[2]	Group[2]
INSECTA					
Coleoptera					
Dytiscidae				5	
Oreodytes				5	p
Elmidae				4	c
Narpus	1			4	c
Optioservus	55	74	85	4	g
Ordobrevia	9	6	11	4	c
Zaitzevia	10	1	2	4	c
Haliplidae					
Brychius				5	g
Hydraenidae					
Hydraena				5	p
Psephenidae					
Eubrianax			1	4	g
Diptera					
Ceratopogonidae	9		8	6	p
Atrichopogon				6	c
Forcipomyia				6	g
Chironomidae				6	c
Chironominae				6	c
Chironomini	4	10	8	6	c
Stenochironomus				5	c
Tanytarsini	11	14	29	6	f
Orthocladiinae	11	138	96	5	c
Tanypodinae	6	8	8	6	p
Dixidae				1	c
Dixa				1	c
Empididae				6	p
Chelifera	2	3	1	6	p
Trichoclinocera				6	p
Ephydridae				6	c
Pelecorynchidae				3	p
Glutops				3	p
Simuliidae				6	f
Simulium			1	6	f
Tipulidae				3	s

Appendix II: Macroinvertebrate Data for Redwood Creek Reaches

Creek=>	Redwood	Redwood	Redwood	CDFG	Functional
Station_SampleID#=>	Above MUWO Rd#2	Above MUWO Rd#3	Above MUWO Rd_#4	Tolerance	Feeding
Sample Date=>	XI-10-97	XI-10-97	XI-10-97	Value[2]	Group[2]
Antocha				3	c
Dicranota		1	1	3	p
Hexatoma	8		7	2	p
Limnophila	1		1	4	p
Ephemeroptera					
Ameletidae					
Ameletus		3	9	0	g
Baetidae				4	g
Baetis		1	1	5	c
Diphetor	13	45	34	5	c
Ephemerellidae				1	c
Drunella				0	g
Ephemerella	2	8	5	1	c
Heptageniidae					g
Cinygma				4	g
Cinygmula	64	90	116	4	g
Epeorus				0	g
Ironodes				4	g
Leucrocuta				1	g
Rhithrogena	23	19	60	0	g
Leptophlebiidae					
Paraleptophlebia	142	116	158	4	c
Hemiptera					
Veliidae					
Microvelia					
Plecoptera					
Capniidae	6	59	20	1	s
Chloroperlidae				1	p
Paraperla	3	1		1	p
Sweltsa	8	8	21	1	p
Leuctridae				0	s
Nemouridae				2	s
Malenka	105	96	46	2	s
Perlidae				1	p
Calineuria	11	8	24	1	p
Hesperoperla				2	p
Perlodidae				2	p

Appendix II: Macroinvertebrate Data for Redwood Creek Reaches

Creek=>	Redwood	Redwood	Redwood	CDFG	Functional
Station_SampleID#=>	Above MUWO Rd#2	Above MUWO Rd#3	Above MUWO Rd_#4	Tolerance	Feeding
Sample Date=>	XI-10-97	XI-10-97	XI-10-97	Value[2]	Group[2]
Isoperla	2	3	5	2	p
Trichoptera					
Apataniidae					g
Apatania		2		1	g
Brachycentridae					c
Micrasema				1	g
Calamoceratidae					s
Heteroplectron				1	s
Glossosomatidae					g
Agapetus				0	g
Glossosoma				0	g
Hydropsychidae				4	f
Hydropsyche	4	5	1	4	f
Hydroptilidae				4	g
Hydroptila			1	6	g
Ochrotrichia				4	c
Lepidostomatidae					s
Lepidostoma	22	36	75	1	s
Limnephilidae				4	s
Eocosmoecus				1	
Psychoglypha	2	1	2	2	c
Odontoceridae				0	s
Parthina				0	s
Philopotamidae				3	f
Wormaldia				3	f
Polycentropodidae				6	p
Polycentropus				6	p
Rhyacophilidae				0	p
Rhyacophila	44	20	40	0	p
Sericostomatidae				3	s
Gumaga		1	2	3	s
Uenoidae				0	g
Neophylax				3	g
CRUSTACEA					
Amphipoda					
Hyalellidae				8	c
Hyalella				8	c

Appendix II: Macroinvertebrate Data for Redwood Creek Reaches

Creek=>	Redwood	Redwood	Redwood	CDFG	Functional
Station_SampleID#=>	Above MUWO Rd#2	Above MUWO Rd#3	Above MUWO Rd_#4	Tolerance	Feeding
Sample Date=>	XI-10-97	XI-10-97	XI-10-97	Value[2]	Group[2]
Cladocera					
Daphniidae				8	c
Copepoda					
Cyclopidae		2	3	8	c
Ergasilidae					
Ergasilus					
Ostracoda				8	
Cyprididae	2	18	27	8	
ARACHNIDA					
Acarina		1	2	5	
Anisitsiellidae				5	p
Aturidae			1	5	p
Aturus				5	p
Kongsbergia		1		5	p
Hydryphantidae				5	p
Protzia				5	p
Hygrobatidae				5	p
Atractides				5	p
Hygrobates				5	p
Lebertiidae				5	
Estelloxus				5	
Lebertia	3	3	3	5	
Sperchonidae				5	
Torrenticolidae				5	
Torrenticola	9	8	14	5	
Oribatei					
GASTROPODA					
Pulmonata					
Lymnaeidae				6	g
Fossaria				6	g
Physidae				8	g
Physella	3			8	g
Planorbidae				7	g
Gyraulus		3	5	8	g
BIVALVIA					
Pelecypoda					
Sphaeriidae				8	f

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Creek=>	Redwood	Redwood	Redwood	CDFG	Functional
Station_SampleID#=>	Above MUWO Rd#2	Above MUWO Rd#3	Above MUWO Rd_#4	Tolerance	Feeding
Sample Date=>	XI-10-97	XI-10-97	XI-10-97	Value[2]	Group[2]
Pisidium				8	f
OLIGOCHAETA				8	c
Haplotaxida					
Enchytraeidae				8	
Naididae	7	54	45	8	c
Chaetogaster				8	
Tubificidae				10	c
Lumbriculida					
Lumbriculidae				8	c
Lumbricina		2		8	
HYDROZOA					
Hydroida					
Hydridae					
Hydra		1		5	f
TURBELLARIA					
Tricladida					
Planariidae				4	p
Dugesia				4	p
NEMERTEA					
Enopla					
Tertastemmatidae					
Prostoma			1		c
NEMATODA				5	p
Mermithidae				5	p
Total (#/sq. ft)	602	870	980		
Log_{10} Total	2.78	2.94	2.99		
# taxa:	32	38	41		
#EPT taxa	15	19	18		
EPT index	75	60	63		
%dominant taxa	24	16	16		
Dominant taxa	*Paraleptophlebia*	Orthocladiinae	*Paraleptophlebia*		
Weighted Tolerance Value	3.15	3.83	3.58		
%shredder	22	22	15		
%collectors	33	44	37		
%filterers	2	2	3		
%grazers	24	22	28		

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Creek=>	Redwood	Redwood	Redwood	CDFG	Functional
Station_SampleID#=>	Above MUWO Rd#2	Above MUWO Rd#3	Above MUWO Rd_#4	Tolerance	Feeding
Sample Date=>	XI-10-97	XI-10-97	XI-10-97	Value[2]	Group[2]
%predators	16	6	12		
%unk. funct. feeding grp	2	4	5		
Shannon Diversity	2.62	2.75	2.89		

[1]Identified by Morgan Hannaford

[2]Underlined tolerance values and functional feeding group categories for genus are extrapolated from family values

National Park Service
U.S. Department of the Interior

Golden Gate National Recreation Area

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