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(Appendices w/ taxa breakdown not copied)

Marin County Macroinvertebrate Survey Fall 1999- Spring 2000

Prepared by the Sustainable Land Stewardship Institute
for the Marin County Stormwater Pollution Prevention Program

EXECUTIVE SUMMARY

The macroinvertebrate faunas of four Marin County watersheds (Arroyo Corte Madera Creek, Corte Madera Creek, Miller Creek, and Novato Creek) were sampled in fall 1999 and spring 2000 using the California Stream Bioassessment Procedure. Sampled stations differed in the quality of aquatic habitats, and ranged from heavily urbanized sites to undisturbed natural sites. Macroinvertebrate taxonomic composition and biological metrics were used to evaluate the habitat quality of each station.

The macroinvertebrate fauna reflected the environmental quality of the aquatic habitat. In general, the four Marin County watersheds exhibited similar patterns of habitat quality, with poorer habitats in the urbanized, lower elevation stream reaches and better habitats in the natural, higher elevation stream reaches. Thus, gradients of habitat quality and macroinvertebrate taxa were observed along the continuum of most streams. In some streams, the improvement in habitat quality from lower to higher elevations was slight or possibly questionable, in other streams distinct changes from poor to good quality occurred.

Macroinvertebrate faunas exhibited remarkable similarity between the four Marin County watersheds. Dominant or common taxa were often the same in all watersheds. Seasonal variations in the faunas were also similar for the fall 1999 and spring 2000 samplings in all watersheds. These variations were dependent on growth and development characteristics of each macroinvertebrate taxa. All drainage basins were impacted by seasonal cycles of streamflow, which was intermittent at many stations.

Introduction

In August 1999, the Marin County Storm Water Pollution Prevention Program , with the assistance of the ustainable Land Stewardship Institute (SLSI) initiated an ambient water quality monitoring program in four Marin County watersheds: Arroyo Corte Madera del Presidio(AMC); Corte Madera Creek (CM); Miller Creek(MC) and Novato Creek (NC). This program will:

1) evaluate the biological and physical integrity of targeted inland surface waters in these four streams and four tributaries;
2) Provive base line data for the Storm Water Program;
3) Assess the condition of the Region's waters relative to attainment of water quality standards; and
4) Provide recommendations and strategies in the use of volunteer monitors

Information and data generated could also contribute to the biannual Water Quality Assessment [Clean Water Act, Section 305(b) Report], the Section 303(d) list of impaired water bodies, development of TMDLs, assessments of nonpoint sources, assessments of the effectiveness of nonpoint source management measures. It can also be used to define issues, set priorities, evaluate effectiveness of actions within the Watershed Management Initiative, and provide information towards the selection of reference condition and a regional Index of Biological Integrity (IBI).

Marin County is using the technical guidance and laboratory support of the Sustainable Land Stewardship Institute (SLSI) in Sacramento, for the biological and physical/ habitat quality assessment portion of the ambient program. The California Stream Bioassessment Procedure (CSBP), developed by the Department of Fish and Game's Aquatic Bioassessment Laboratory (ABL) was used to evaluate the benthic macroinvertebrate community (Harrington 1996). The CSBP is a regional adaptation of the U.S. Environmental Protection Agency (U.S. EPA) Rapid Bioassessment Protocols (Plafkin et al. 1989) and is recognized by the U.S. EPA as California's standardized bioassessment procedure (Davis et al. 1996).

The CSBP is a cost-effective tool which utilizes measures of the stream's benthic macroinvertebrate (BMI) community and its physical/ habitat structure. BMIs can have a diverse community structure with individual species residing within the stream for a period of months to several years. They are also sensitive, in varying degrees, to temperature, dissolved oxygen, sedimentation, scouring, nutrient enrichment and chemical and organic pollution (Resh and Jackson 1993). Together, biological and physical assessments integrate the effects of water quality over time, are sensitive to multiple aspects of water and habitat quality, and provide the public with more familiar expressions of ecological health (Gibson 1996).

This report presents results from benthic macroinvertebrates samples collected in September 1999 and April 2000.

Materials and Methods

Location

Arroyo Corte Madera, Corte Madera, Miller, and Novato Creeks are small streams flowing to the east and southeast toward San Pablo Bay from the low hills of Marin County, California. In all drainage basins, sampling stations were located in a range of possible stream environments, from relatively natural undisturbed upper reaches to highly altered lower urban reaches. Samples were taken at several locations along the main stream and its tributaries. Monitoring reach descriptions are summarized in **Table 1** and a map of Marin County Watersheds and monitoring reaches is shown in **Figure 1**. All sites were sampled in September 1999 and April 2000 except for the sites which were dry during the September sampling period. Monitoring reaches were

Table 1. Benthic macroinvertebrate sampling location information for selected reaches sampled September 18-21, 1999 and April 14, 15, 22 and 23, 2000 within the Arroyo Corte Madera, Corte Madera, Miller and Novato watersheds.

Stream Name	Location Description	Station Code	Latitude/ Longitude/Elevation
Arroyo Corte Madera	**Arroyo Corte Madera Watershed** Reach begins d/s of Goma Bridge, and consists of 4 riffles.	**ACM1**	37.89763900/ -122.53501700 Elev.: 26ft
Arroyo Corte Madera	**Arroyo Corte Madera Watershed** Reach begins 25M below footbridge and ends @ Gardner St. bridge, ~ 50M.	**ACM2**	Elev.:
Arroyo Corte Madera	**Arroyo Corte Madera Watershed** Reach begins @ Xing @ Blithedale Park sign.	**ACM3**	37.92284800/ -122.55542300 Elev.: 353 ft
Old Mill Cr.	**Arroyo Corte Madera Watershed** Reach begins @ Cascade Rd bridge and ends @ sewer pipe Xing. (7 riffles)	**ACM4**	37.90537900/ -122.55328400 Elev.: 93ft.
Old Mill Cr.	**Arroyo Corte Madera Watershed** Reach begins at bridge and ends with cement riprap (8 riffles)	**ACM5**	37.91075400/ -122.56093600 Elev.: 172ft
Stream Name	**Location Description**	**Station Code**	**Latitude/ Longitude/Elevation**
Corte Madera Cr.	**Corte Madera Watershed** Reach bissected by Lagunita Rd. Xing, extend 3 riffles u/s from wire fencing entry to 1 riffle d/s. (4 riffles)	**CM1**	37.96308100/ -122.55613100 Elev.: 19ft
Corte Madera Cr.	**Corte Madera Watershed** Reach consist of 3 riffles only, begins where creek comes out from under buildings, and ends at the heights of wisteria arbor.	**CM2**	37.97533400/ -122.56095200 Elev.: 63
Ross Cr.	**Corte Madera Watershed** Reach Reach begins at last footbridge, extends 50M u/s to change in reach gradient and type.	**CM3**	Elev.:
Billy Williams Cr.	**Corte Madera Watershed** Reach is above reservoir and extends from ~30M above culvert for 100M	**CM3b**	37.95181300/ -122.57229500 Elev.: 325ft.
San Anselmo Cr.	**Corte Madera Watershed** Reach begins 30M u/s of fish ladder @ bridge and ends at temporary buildings.	**CM4**	37.98213500/ -122.57251100 Elev.: 60ft.
Sleepy Hollow Cr.	**Corte Madera Watershed** Reach begins @ footbridge by school and u/s ~ 150M	**CM5**	37.98390700/ -122.57137000 Elev.: 63ft.
Sleepy Hollow Cr.	**Corte Madera Watershed** Reach begins @ footbridge by school and extends u/s ~ 100M.	**CM6**	37.99086600/ -122.57560800 Elev.:96ft.
Sleepy Hollow Cr.	**Corte Madera Watershed** Reach begins under block wall and ends Vanwinle Rd. Xing.	**CM7**	38.01634500/ -122.58570800 Elev.: 247

Sleepy Hollow Cr.	**Corte Madera Watershed** Reach begins up from parking lot 50M u/s from catholic school nursery (garden) and ends @ Y trib. split.	**CM7b**	Elev.:
San Anselmo Cr.	**Corte Madera Watershed** Reach begins at Fairfax Cr. confluence and ends at fence.	**CM8**	37.98570600/ -122.58240500 Elev.: 97ft.
San Anselmo Cr.	**Corte Madera Watershed** Reach begins at 6th riffle above confluence of Fairfax Cr. and ends 1 riffle d/s of confluence. Sampled above and below.	**CM8b**	Elev.: 97ft
Cascade Cr.	**Corte Madera Watershed** Reach begins @ Bolinas Bridge Xing extends u/s 70M.	**CM9**	37.98080000/ -122.59262800 Elev.: 132
Cascade Cr.	**Corte Madera Watershed** Reach begins @ footbridge Xing and extend ~ 400M to small waterfall/treestump in creek	**CM10**	37.98255800/ -122.61973300 Elev.: 303ft.
Stream Name	**Location Description**	**Station Code**	**Latitude/Longitude/Elevation**
Miller Cr.	**Miller Creek Watershed** Reach begins after turning right at the end of the park rd. (5 riffles)	**MC1**	38.03066500/ -122.53820500 Elev.: 22ft.
Miller Cr.	**Miller Creek Watershed** Reach begins to left of large stump after entering from right of playground. (7 riffles)	**MC2**	38.03042800/ -122.54525300 Elev.: 38ft.
Miller Cr.	**Miller Creek Watershed** Reach begins at large tree that crosses the stream, .3 miles from where road starts Past Oak Canyon. (6 riffles)	**MC3**	38.02689900/ -122.55226500 Elev.: 62
Miller Cr.	**Miller Creek Watershed** Reach begins u/s from path off Shasta Rd. (8 riffles)	**MC4**	38.02926800/ -122.57595500 Elev.: 134
Miller Cr.	**Miller Creek Watershed** Reach begins 120M d/s of bridge and extends to ~ 20M d/s of estgate bridge.	**MC5**	38.03778500/ -122.59778500 Elev.: 200
Miller Cr.	**Miller Creek Watershed** Reach begins @ eroded bank by stables and ends @ bridge.	**MC6**	Elev.:
Stream Name	**Location Description**	**Station Code**	**Latitude/Longitude/Elevation**
Novato Cr.	**Novato Watershed** Reach begins u/s of bridge. (6 riffles)	**NC1**	38.10737200/ -122.57846000 Elev.: 25
Novato Cr.	**Novato Watershed** Reach begins at the end of path long wood fence. (4 riffles)	**NC2**	38.11422900/ -122.58741700 Elev.: 43

Novato Cr.	**Novato Watershed** Reach begins ~ 50M u/s of Novato Blvd bridge @ Eucalyptus Blvd and ends ~50M of large riprap in thalweg.	**NC3**	38.11503100/ -122.60355500 Elev.: 73
Novato Cr.	**Novato Watershed** Reach begins just u/s of horse stables, until reach gradient changes (30 riffles)	**NC4**	38.11662700/ -122.60993700 Elev.: 76
Novato Cr.	**Novato Watershed** Reach begins at stump and ends @ turnstile (7 riffles)	**NC5**	38.12218300/ -122.62383500 Elev.: 122
Novato Cr.	**Novato Watershed** Reach begins above reservoir in Stafford Park, ~ 50M u/s of footbridge (skipped 1st 3 riffles u/s of bridge, and ends barbed wire.	**NC6**	38.11279500/ -122.64866600 Elev.: 186
Warner Cr.	**Novato Watershed** Reach begins 20M u/s of culvert under Mill Rd., and extends to house near stream.	**NC7**	38.10449300/ -122.60689500 Elev.: 101
Warner Cr.	**Novato Watershed** Reach begins @bridge. (6 riffles)	**NC8**	38.10857600/ -122.58592700 Elev.: 44

Figure 1: Marin County Watersheds

selected to correspond, when appropriate, to the site were water samples for chemical and toxicological analysis are collected.

enthic Macroinvertebrate Sampling

Aquatic macroinvertebrate samples were collected in fall 1999 and spring 2000 from the four Marin County drainage basins using the California Stream Bioassessment Procedure Protocols (CSBPs) for non-point source assessments (Harrington 1996). In addition, 4 sites were selected for point source assessments (Harrington 1996). Some monitoring reaches were comprised of 3 rather than 5 riffles due to the lack of good riffle habitat. Five to thirteen sampling stations were located within each drainage basin and three samples were collected at each station. A total of 96 samples were taken during the study (Arroyo Corte Madera 15, Corte Madera 39, Miller 18, and Novato 24), in addition to several reference samples. The five Arroyo Corte Madera sampling stations were labeled ACM1 to ACM5. The thirteen Corte Madera sampling stations were labeled CM1 to CM10 and CM3b, CM7b, and CM8b. The six Miller sampling stations were labeled MC1 to MC6. The eight Novato sampling stations were labeled NC1 to NC8. Samples were taken within each drainage basin from stations located along the main named creek and from tributary creeks having other names.

Riffle length was determined for each riffle and a random number table was used to establish a point randomly along the length of the riffle from which a transect was established perpendicular to the stream flow. Starting with the transect at the lowermost riffle, the benthos within a 2 ft^2 area was disturbed upstream of a 1 ft wide, 0.5 mm mesh D-frame kick-net. Sampling of the benthos was performed manually by rubbing cobble and boulder substrates in front of the net followed by "kicking" the upper layers of substrate to dislodge any invertebrates remaining in the substrates. The duration of sampling ranged from 60-120 seconds, depending on the amount of boulder and cobble-sized substrates that required rubbing by hand; more and larger substrates required more time to process. Three locations representing the habitats along the transect were sampled and combined into a composite sample (representing a 6 ft^2 area). This composite sample was transferred into a 500 ml wide-mouth plastic jar containing approximately 200 ml of 95% ethanol. This technique was repeated for each of 3 riffles in each reach. In the case of the point source assessments, this technique was repeated 3 times for each riffles above and below the suspected point of impact.

BMI Laboratory Analysis

The 96 samples were processed in the laboratory according to the California Stream Bioassessment Procedure. Rose Bengal was added to each sample to stain the macroinvertebrates, aiding their discovery and removal. Each sample was rinsed through a No. 35 standard testing sieve (0.5 mm brass mesh) and transferred into a tray marked with twenty, 25 cm^2 grids. All detritus was removed from one randomly selected grid at a time and placed in a petri dish for inspection under a stereomicroscope. All invertebrates from the grid were separated from the surrounding detritus and transferred to vials containing 70% ethanol and 2% glycerol. This process was continued until 300 organisms were removed from each sample. The material left from the processed grids was transferred into a jar with 70% ethanol and labeled as "remnant" material. Any remaining unprocessed sample from the tray was transferred back to the original sample container with 70% ethanol and archived. Macroinvertebrates were then identified to a standard taxonomic level, (typically genus level for insects and order or class for non-insects) using standard taxonomic keys (Brown 1972, Edmunds et al. 1976, Klemm 1985, Merritt and Cummins 1995, Pennak 1989, Stewart and Stark 1993, Surdick 1985, Thorp and Covich 1991, Usinger 1963, Wiederholm 1983, 1986, Wiggins 1996, Wold 1974).

Data Analysis

A taxonomic list of benthic macroinvertebrates identified from the samples was entered into a Microsoft Excel® spreadsheet program. Excel® was used to generate a taxa list and to calculate and summarize macroinvertebrate community based metric values. Descriptions of the metric values used are presented in **Table 2**.

'able 2. Bioassessment metrics used to describe characteristics of the benthic macroinvertebrate (BMI) community and the metric value response to impairment.

BMI Metric	Description	Response to Impairment
Richness Measures		
1. Taxonomic Richness	Total number of individual taxa.	decrease
2. EPT Taxa	Number of taxa in the orders Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly)	decrease
3. Ephemeroptera Taxa	Number of mayfly taxa	decrease
4. Plecoptera Taxa	Number of stonefly taxa	decrease
5. Trichoptera Taxa	Number of caddisfly taxa	decrease
Composition Measures		
6. EPT Index	Percent composition of mayfly, stonefly and caddisfly larvae	decrease
7. Sensitive EPT Index	Percent composition of mayfly, stonefly and caddisfly larvae with Tolerance Values less than 3	decrease
8. Percent Hydropsychidae	Percentage of organisms in the caddisfly family Hydropsychidae	increase
9. Percent Baetidae	Percentage of organisms in the mayfly family Baetidae	increase
Tolerance/Intolerance Measures		
10. Tolerance Value (TV)	TVs between 0 and 10 weighted for abundance of individuals designated as pollution tolerant (higher values) and intolerant (lower values).	increase
11. Percent Intolerant Organisms	Percentage of organisms that are highly intolerant to water and/ or habitat quality impairment as indicated by TVs of 0, 1 or 2.	decrease
12. Percent Tolerant Organisms	Percentage of organisms that are highly tolerant to water and/ or habitat quality impairment as indicated by TVs of 8, 9 or 10.	increase
13. Percent Dominant Taxon	The highest percentage of organisms represented by one taxon.	increase
Functional Feeding Groups (FFG)		
14. % Collectors	Percent of macroinvertebrates that collect or gather material	increase
15. % Filterers	Percent of macroinvertebrates that filter suspended material from the water column	increase
16. % Grazers	Percent of macroinvertebrates that graze upon periphyton	variable
17. % Predators	Percent of macroinvertebrates that prey on living organisms	decrease
18. % Shredders	Percent of macroinvertebrates that shred leaf litter	decrease

The Index of Biological Integrity (IBI) scores were determined using the IBI developed for the Russian River (DFG, 1996). A conceptual model described by the U.S. Environmental Protection Agency for development of biocriteria was followed to produce a first iteration of an Index of Biological Integrity for the Russian River Watershed (RRIBI). Benthic macroinvertebrate (BMI) were collected from 35 reaches within 21 tributary streams and the mainstem Russian River during the fall 1995 and spring 1996 and 1997 using the California Stream Bioassessment Procedure. A set of core biological metrics, commonly used for bioassessment of California stream were used to describe the BMI communities in the 35 reaches. Monitoring reaches within the first to third order streams classified as similar with different channel type having no influence on mean biological metric values. The biological metrics, Taxa Richness, EPT Taxa, Modified EPT Index, Shannon Diversity, Tolerance Value and Percent Dominant Taxa were chosen as the most appropriate to be included in producing the RRIBI. These six metrics were integrated into a single scoring criteria by producing a histograms of the values for each of the biological metrics and visually determining breaks in their distribution. This approach of determining scoring criteria was more intuitive and probably most appropriate given the data came from streams that could have been moderately impaired and not actually representative of pristine reference conditions. Although there was no indication of strong seasonal variability in the BMI communities, it was recommend that the index period for the Russian River tributary streams be in the spring. It was also recommend that the RRIBI be considered preliminary and that data on more Russian River tributaries and the mainstem be collected to 1) test the effectiveness of this scoring criteria on other first to third order Russian River tributaries, 2) test the appropriateness of using other biological metrics, 3) evaluate the use of the RRIBI in other north coast California streams to test its effectiveness at assessing biological integrity of streams outside the Russian River watershed, and 4) produce an IBI for fourth order and larger stream reaches.

Physical Habitat Quality Assessment

Physical habitat quality was assessed for the monitoring reaches using U.S. Environmental Protection Agency (EPA) Rapid Bioassessment Protocols (RBPs) (Plafkin *et al.* 1989). Habitat quality assessments were recorded for each monitoring reach during macroinvertebrate sampling events within riffle/ run habitats in late April 1998. Photographs were taken within each of the monitoring reaches to document overall reach condition at the time of sampling. Description of reach scale habitat parameters used to document local habitat conditions along stream corridors is shown in **Table 3**.

Results

Data Consistency

Before analyzing the macroinvertebrate data in detail for each creek, it is often instructive to quickly examine the overall identification data and metrics calculations for variability between the three replicates. Generally similar results between the three replicates at a station suggest that field collections and laboratory sub-sampling were done consistently. Data sets with wide variability between replicates suggest the possibility of inconsistent methods. However, some variability is expected because of naturally clumped macroinvertebrate populations.

In general, the data collected from the four Marin County drainage basins showed remarkable consistency between replicates. This observation added validity to the following results and discussions.
For this study, benthic macroinvertebrate populations in all four drainage basins were affected by three overriding environmental factors – seasonal changes (fall 1999 vs. spring 2000), flow conditions (perennial vs. intermittent), and watershed quality (undisturbed vs. urban).

Table 3. Description of reach scale habitat parameters used to document local habitat conditions along stream corridors.

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate sand: <0.08" gravel: 0.08-2.5" sm cobble: 2.5-5" lg cobble: 5-10" boulder: >10"	Small and large cobble comprises >70% of substrate. Range of substrate types present from sand to boulder but sand, gravel and/or boulder comprise <30% of substrate. Substrate provides ample and variably sized interstitial space.	Small and large cobble ranges from 40 to 70%. Range of substrate types more limited or present from sand to boulder but amount of sand, gravel and/or boulder accounts for >30-60% of substrate.	Small and large cobble comprises between 20-40% of available substrate. Substrate complexity and ranges of interstitial space limited. Sand, gravel and/or boulder accounts for 60-80% of substrate.	Substrate with little complexity and interstitial space; substrate >90% silt, sand, boulder, bedrock or rip-rap; or, channel is impervious due to concrete or asphalt lining
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Optimal	Suboptimal	Marginal	Poor
	Gravel, cobble and boulder particles are 25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble and boulder particles are >75% surrounded by fine sediment. May be completely covered.
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	Optimal	Suboptimal	Marginal	Poor
	All four velocity depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is <0.3 m/s, deep is >0.5 m)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 regimes present (if fast-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Optimal	Suboptimal	Marginal	Poor
	Little or no enlargement of point bars just above or below riffle. Less than 5% of the bottom of riffle affected by fine sediment.	Some new increases in bar formation just above or below riffle. 5 - 30% of the bottom of the riffle affected by fine sediment.	Moderate deposition of new gravel, sand or fine sediment on bars just above or below riffle. 50-80% of the bottom of the riffle affected by fine sediment.	Heavy deposition of new gravel, sand or fine sediment on bars just above or below riffle. >80% of the bottom of the riffle affected by fine sediment.
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Optimal	Suboptimal	Marginal	Poor
	Water reaches both banks; wetted channel width is equal to bankfull width.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel; or most of channel substrate is exposed.	Very little water present in channel and mostly present as standing pools.
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Table 3, continued

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration	No channel alteration; no dredging, levees, rip-rap, gabion structures or bridge abutments	Some channelization present, usually in areas of bridge abutments; evidence of past channelization from dredging	Channelization extensive; embankments or shoring structures present on both banks and 40 to 80% of riffle channelized and disrupted.	Banks shored with gabion or cement; entire riffle affected by channelization.
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Riffle Frequency	**Optimal**	**Suboptimal**	**Marginal**	**Poor**
	Occurrence of riffle relatively frequent; ratio of distance between riffles divided by the width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the with of the stream is between 15 to 25.	Generally all flat water or shallow riffles ; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability	Optimal	Suboptimal	Marginal	Poor
	Both banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of banks adjacent to riffle and just upstream affected.	Banks moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of banks adjacent to riffle and just upstream affected.	Banks moderately unstable; 30-60% of banks adjacent to riffle and just upstream affected.	Unstable banks; 60-80% of banks adjacent to riffle and just upstream affected having "raw" areas and erosional scars.
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
9. Bank Vegetation	Optimal	Suboptimal	Marginal	Poor
	More than 90% of the streambank surfaces adjacent to and near riffle covered by native vegetation including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption by livestock grazing or mowing not evident.	70 - 90% of the streambank surfaces adjacent to and near riffle covered by native vegetation including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption by livestock grazing or mowing not evident.	50-70%of the stream bank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 cm or less in average stubble height.
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
10. Riparian Zone Width	Optimal	Suboptimal	Marginal	Poor
	Width of riparian zone >18 m; human activities (eg. Parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 m; human activities have impacted zone only minimally.	Width of riparian zone 6-12 m; human activities have impacted zone substantially.	Width of riparian zone <6 m; little or no riparian zone due to human activities
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Taxonomic Notes, Dominant Macroinvertebrate Taxa , IBI and Physical Habitat Quality and Taxonomic Metric Means

Arroyo Corte Madera Creek and tributaries

Taxa lists for ACM Fall and Spring sampling are presented in Appendix A and B respectively. The five dominant taxa for each season are listed in **table 4**. IBI for ACM are listed in **table 5**. Physical habitat quality scores for each seasons are listed in **table 6**. Taxonomic metrics means for the Fall are listed in **table 7,** and Spring in **table 8.**

Table 4. Dominant macroinvertebrate taxa and their percent contribution () by reach from samples collected September 1999 and April 2000 within the Arroyo Corte Madera watershed.

Reach	Dominant Taxa				
	1	2	3	4	5
ACM1 F 99	Orthocladiinae 155 (52%)	Oligochaeta 104 (35%)	*Baetis sp.* 17 (6%)	Chironomini 13 (14%)	Tanytarsini 3 (1%)
Sp 00	Planorbidae 92 (31%)	*Baetis sp.* 81 (27%)	Tanytarsini 61 (21%)	*Lepidostoma sp.*13 (4%)	Oligochaeta 7 (2%)
ACM2 F 99	-	-	-	-	-
Sp 00	Orthocladiinae 76 (25%)	*Drunella sp.*64 (21%)	Chironomini 46 (15%)	Oligochaeta 36 (12%)	*Baetis sp.* 16 (5%)
ACM3 F 99	Tanytarsini 61 (21%)	Chironomini 47 (16%)	*Hydropsyche sp.*20 (7%)	Orthocladiinae 16 (5%)	Optioserce 14 (5%)
Sp 00	Orthocladiinae 51 (18%)	*Epeorus sp.* 40 (14%)	Linygma 30 (10%)	*Baetis sp.* 26 (9%)	Malenka 22 (8%)
ACM4 F 99	-	-	-	-	-
Sp 00	Orthocladiinae 79 (27%)	Oligochaeta 74 (25%)	Chironomini 40 (13%)	*Drunella sp.*21 (7%)	*Baetis sp.* 21 (7%)
ACM5 F 99	Chironomini 50 (17%)	lepidostomatidea 31 (10%)	*Hydropsyche sp.*25 (8%)	Orthocladiinae 25 (8%)	Optioservus sp 24 (8%)
Sp 00	Orthocladiinae 62 (26%)	Chironomini 52 (21%)	Optioservus sp 22 (9%)	Oligochaeta 16 (7%)	Acari 15 (6%)

Table 5. IBI scores by reach from samples collected September 1999 and April 2000 within the Arroyo Corte Madera watershed.

Reach		IBI						
		taxa richness	% dominance	EPT taxa	Modified EPT	Shannon	Tolerance value	SCORE
ACM1	F 99	(16) 1	(42) 1	(2)	(5) 1	(1.7) 1	(5.8) 1	6, poor
	Sp 00	(9) 1	(65 1	(2) 1	(0) 1	(1.0) 1	(6.1) 1	6, poor
ACM2	F 99	-	-	-	-	-	-	-
	Sp 00	(24) 1	(26) 3	(10) 1	(29) 3	(2.2) 1	(4.3) 3	12, fair
ACM3	F 99	(31) 3	(25) 3	(17) 3	(48) 3	(2.7) 3	(3.5) 3	18, good
	Sp 00	(29) 3	(19) 3	(13) 3	(22) 3	(2.8) 3	(4.5) 3	18, good
ACM4	F 99	-	-	-	-	-	-	-
	Sp 00	(19) 1	(30) 3	(9) 1	(18) 3	(2.1) 1	(5.1) 1	7, poor
ACM5	F 99	(25) 1	(21) 3	(11) 1	(25) 3	(2.7) 3	(4.2) 3	14, fair
	Sp 00	(26) 3	(31) 3	(12) 3	(14) 1	(2.4) 3	(4.9) 1	14, fair

Table 6. Habitat assessment results for reaches within Arroyo Corte Madera Watershed, September 1999 and April 2000. Numbers in parentheses are ranges of ranks. (see Table 1 for a description of habitat parameters and ranking criteria)

Ranked Habitat Parameter	ACM1 F 99	ACM1 SP00	ACM2 F 99	ACM2 SP00	ACM3 F99	ACM3 SP00	ACM4 F99	ACM4 SP00	ACM5 F99	ACM5 SP00
1. Instream Cover (0 - 20)	8	12	dry	10	16	18	dry	15	15	16
2. Embeddedness (0 - 20)	12	15		17	17	17		17	17	17
3. Velocity/Depth Regime (0 - 20)	12	14		12	16	15		15	15	15
4. Sediment Deposition (0 - 20)	10	15		17	17	17		15	17	17
5. Channel Flow (0 - 20)	5	13		10	6	11		8	7	9
6. Channel Alteration (0 - 20)	8	9		5	16	16		15	18	15
7. Riffle Frequency (0 - 20)	16	14		16	18	18		18	18	18
8. Bank Stability (LB: 0 - 10/RB: 0-10)	12	13		18	19	17		10	16	15
9. Vegetative Protection (LB: 0 - 10/RB: 0-10)	10	8		5	17	13		11	15	15
10. Riparian Vegetative Zone Width (LB: 0 - 10/RB: 0-10)	4	5		4	16	14		12	18	16
Reach Total	97	118		114	158	156		136	156	153
condition	marginal	suboptimal		suboptimal	optimal	optimal		suboptimal	optimal	optimal
Other Reach Descriptions										
Vegetative Canopy Cover Estimate (%)	26	15		73	80	68		58	86	77
Water Temperature (°C)	15	12		12	16	12		12	13	13
Specific Conductance (µS/cm at 25°C)	280	161		165	200	153		173	560	150
Comments	stormdrain @ riffle 2	water turbid		water turbid, some foam. stormdrain between r-2 & 3	Pacific giant salamander larvae	Pacific giant salamander larvae. stormdrain bewteen r-2 & 3		stormdrain below r-1. bareground in park source of sediment	10cm crayfish released. Pacific giant salamander larvae	

Table 7. Cumulative total, mean and coefficient of variation values of biological metrics by reach for benthic macroinvertebrates sampled from the Arroyo Corte Madera del Presidio Creek drainage in Sept. 1999, Marin County

	Arroyo Corte Madera del Presidio Creek						Old Mill Creek		
	ACM-1			ACM-3			ACM-5		
	CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV
Taxonomic Richness	19	16	7	45	31	4	31	25	10
EPT Taxa	3	2	25	18	13	13	13	11	14
Ephemeroptera Taxa	1	1	0	5	5	12	5	4	13
Plecoptera Taxa	0	0	-	3	2	50	3	2	25
Trichoptera Taxa	2	1	43	10	6	18	5	4	25
EPT Index	32	32	30	34	34	24	40	39	47
Sensitive EPT Index (TV<4)	5	5	97	17	17	22	19	19	41
Shannon Diversity	1.9	1.7	17	3.0	2.8	7	2.8	2.7	4
Tolerance Value	5.8	5.8	5	4.5	4.5	5	4.2	4.2	15
Percent Intolerant Organisms	5	5	97	19	19	23	23	23	36
Percent Tolerant Organisms	5	5	85	2	2	25	3	3	53
Percent Hydropsychidae	0	0	-	7	7	67	8	8	88
Percent Baetidae	27	27	24	5	5	51	6	6	61
Percent Dominant Taxon	31	42	21	21	25	39	17	21	41
Percent Collectors	7	7	44	32	32	25	30	30	61
Percent Filterers	22	22	88	30	30	43	20	20	48
Percent Grazers	62	62	31	18	17	27	24	24	40
Percent Predators	5	5	26	11	11	22	13	13	33
Percent Shredders	5	5	99	9	9	15	14	14	55
Abundance									
(organisms per sample X 1000)	12	4.1	15	10	3.3	10	8.0	2.7	61

Table 8. Cumulative total, mean and coefficient of variation values of biological metrics by reach for benthic macroinvertebrates sampled from the Arroyo Corte Madera del Presidio Creek drainage in April 2000, Marin County

	Arroyo Corte Madera del Presidio Creek									Old Mill Creek			Old Mill Creek		
	ACM-1			ACM-2			ACM-3			ACM-4			ACM-5		
	CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV
Taxonomic Richness	15	9	55	37	24	14	37	29	13	28	19	17	34	26	12
EPT Taxa	4	2	49	16	10	11	20	17	3	13	9	22	15	12	13
Ephemeroptera Taxa	3	2	50	8	7	9	11	9	0	9	6	24	6	5	11
Plecoptera Taxa	0	0		3	2	69	3	3	0	0	0		4	3	22
Trichoptera Taxa	1	0		5	2	50	6	5	12	4	3	57	5	4	16
EPT Index	6	6	58	36	36	24	60	60	5	26	26	22	18	18	30
Sensitive EPT Index (TV<4)	1	1	92	25	25	19	30	30	19	15	15	34	8	9	52
Shannon Diversity	1.2	1.0	28	2.3	2.2	8	2.8	2.7	4	2.2	2.1	11	2.5	2.4	9
Tolerance Value	6.1	6.1	14	4.3	4.3	11	3.5	3.5	8	5.1	5.1	9	4.9	4.9	5
Percent Intolerant Organisms	1	1	92	25	25	21	29	29	13	15	15	34	9	10	49
Percent Tolerant Organisms	35	35	85	13	13	71	5	5	57	25	25	26	7	7	21
Percent Hydropsychidae	0	0		1	1	99	1	1	79	1	1	58	3	3	59
Percent Baetidae	6	6	67	6	6	69	11	11	47	7	7	47	1	1	17
Percent Dominant Taxon	52	65	5	25	26	16	18	19	25	26	30	4	26	31	24
Percent Collectors	91	91	6	58	58	17	36	36	6	66	67	14	58	58	21
Percent Filterers	1	1	173	2	2	46	3	3	52	2	2	76	11	11	36
Percent Grazers	6	6	55	34	34	24	43	43	8	26	26	28	16	15	46
Percent Predators	1	1	104	5	5	30	6	6	8	5	5	69	13	14	27
Percent Shredders	0	0		1	1	44	11	11	18	1	1	99	2	2	40
Abundance															
(organisms per sample X 1000)		4.3	39		1.9	68		1.8	12		1.1	27		0.85	80

Distinct differences existed in the aquatic macroinvertebrate fauna in the Arroyo Corte Madera drainage basin. In particular, the lowest station, ACM1, had the poorest macroinvertebrate fauna, and all stations upstream were significantly better. Two stations (ACM2, 4) were not sampled in fall 1999 because they were dry.

The poor macroinvertebrate fauna at ACM1 was well demonstrated by the taxonomic composition and metrics found at this station. Very low values were found for TaxonomicRichness (9-16) and Shannon diversity (1.0-1.7) in both fall and spring. Likewise, very low values occurred in both seasons for EPT Taxa, Ephemeroptera Taxa, Plecoptera Taxa, Trichoptera Taxa, Sensitive EPT Index, and Percent Intolerant Organisms.

Only four taxonomic groups dominated the macroinvertebrate fauna at ACM1 – chironomid midges, *Baetis* mayflies, snails, and oligochaete worms. Seasonally, dominance changed between groups, with Tanytarsini midges, baetids, and snails abundant in fall and Orthocladinae midges, baetids, and oligochaete worms abundant in spring. Abundant *Baetis* mayflies, especially during fall 1999, greatly increased the EPT Index, diminishing its habitat predictive value. This taxa is known to be adaptable to a wide range of freshwater environments, including both warmer and cooler waters. They can be especially abundant in urban or disturbed creeks with warm, sunlit waters and abundant filamentous algae.

In contrast to the lowest station, all stations upstream (ACM2-5) showed improved taxonomic compositions and biological metrics, indicating better habitats for macroinvertebrates. Taxonomic Richness typically ranged from 25 to 30 and Shannon diversities were normally well above 2.0, reaching a maximum of 2.8 at ACM3. Diversities approached typical values for undisturbed, small, low-elevation streams in the California Coast Range. Similar improvements occurred in EPT Taxa, Ephemeroptera Taxa, Plecoptera Taxa, Trichoptera Taxa, Sensitive EPT Index, and Percent Intolerant Organisms. Other metrics showing improved habitat quality upstream were declines in Tolerance Values, Percent Tolerant Organisms, and Percent Dominant Taxon.

Although all four upstream stations were higher quality habitats than ACM1, some differences were noted between these four sites. As measured by most biological metrics, habitat quality continuously improved along the mainstem of Arroyo Corte Madera Creek, from ACM1 to ACM2 to ACM3. These continuous improvements were most obvious for the spring 2000 samples in Taxonomic Richness (9 to 29), EPT Taxa (2 to 17), EPT Index (6 to 60), Sensitive EPT Index (1 to 30), Shannon Diversity (1.0 to 2.7), Tolerance Value (6.1 to 3.5), Percent Intolerant Organisms (1 to 29), Percent Tolerant Organisms (35 to 5), and Percent Dominant Taxon (65 to 19). While these habitat quality trends were also observed for some metrics along the stream gradient ACM1 to ACM4 to ACM5, the results were less distinct. Clearly, the habitats at ACM4 and ACM5 were of lower quality for macroinvertebrates than was ACM3.

Fall and spring samples at Arroyo Corte Madera had an inverse relationship between macroinvertebrate abundance and diversity, demonstrating a widespread ecological principal of animal communities. Mean abundance values were always highest (about 4,200) at ACM1, the site with the lowest diversity. Abundance values for the other four stations ranged from 850 to 3,300, and higher diversities were present. Similar macroinvertebrate abundances were found for both fall and spring samplings.

Conclusions already drawn about macroinvertebrate habitat quality in the Arroyo Corte Madera watershed were reinforced by determination of the Index of Biological Integrity. These values ranged from a low of 6, indicating poor biotic conditions at ACM1, to a high of 18, indicating good conditions at ACM3. Intermediate values occurred at ACM2 (12, fair), ACM4 (7, poor), and ACM5 (14, fair).

While it is difficult to isolate specific environmental factors causing a poorer habitat at ACM1, increases in fine sediments, warmer waters, and loss of riparian vegetation in urban areas were likely important. Chironomid midges, baetid mayflies, snails, and oligochaete worms often dominate disturbed or altered aquatic habitats having sunny, warm waters and fine substrates. Based upon the macroinvertebrate taxa collected and the Index of Biological Integrity, it was possible that intermittent flow conditions in fall 1999 at ACM2 and ACM4 caused both habitats to be rated lower than they would have been if perennial flow had existed. It is unknown how often these two stations are dry in the autumn. Future monitoring of Arroyo Corte Madera would answer this question. If perennial flows are more typical of both stations, their faunas and biological metrics would likely improve.

Although the Arroyo Corte Madera watershed had intermittent flow conditions during fall 1999, the macroinvertebrate fauna was composed of taxa typical of perennial flow habitats. Both ACM2 and ACM4 were dry in fall 1999, but apparently resumed flowing during the winter rains and extending into spring 2000. When sampled in the spring, their macroinvertebrate faunas were very similar to upstream perennial stations. Undoubtedly, the two dry stations were recolonized by drifting and migrating taxa from upstream. Macroinvertebrate taxa typical of truly intermittent streams were absent from Arroyo Corte Madera.

The distributions of several macroinvertbrate taxa within the Arroyo Corte Madera watershed suggested that fine sediments predominated at ACM1 and coarser sediments predominated upstream. The psychodid *Maruina* is unique in having ventral sucker-like adaptations for clinging to clean, coarse substrates on which it grazes. The stoneflies *Suwallia, Sweltsa,* and Leuctridae have small, elongated bodies at least partially adapted for moving within the pore spaces of the upper hyporheic zone of stream sediments. Suitably-sized pore spaces only exist in coarser substrates, not in silt or sand. Both *Maruina* and the stoneflies were only collected at the upstream stations of Arroyo Corte Madera, not at ACM1. Fine sediments would completely exclude both groups.

It is of interest that only stations with perennial flow contained macroinvertebrate taxa having a life cycle of greater than one year. For example, the perlid stoneflies, *Calineuria* and *Hesperoperla* have at least a two-year life cycle and only inhabited ACM5. Likewise, the crawfish, *Pacifasticus,* has a long life cycle and was only found at ACM5.

In general, the macroinvertebrates fauna of Arroyo Corte Madera remained remarkably similar between fall 1999 and spring 2000. Notable differences were the much greater abundances of oligochaete worms and ephemerellid mayflies, and greater variety of heptageniid mayflies in spring 2000. In contrast, snails were much more abundant in fall 1999. Tanytarsini and Orthocladinae midges appeared to be most abundant in fall and spring, respectively. Many of these differences were likely caused by natural seasonal changes in growth and development.

Few predictable and distinct changes occurred in the macroinvertebrate Functional Feeding Groups of Arroyo Corte Madera. During spring, collectors were most abundant at the lowest station (ACM1) and decreased upstream. Over 90% of the macroinvertebrate fauna were collectors at ACM1, primarily oligochaetes and chironomids. Shredders were almost absent from ACM1 and increased upstream, possibly caused by the amount of riparian vegetation. Both trends in collectors and shredders were predicted by the River Continuum Concept; however, distinct changes in filterers, grazers, and predators were less clear. As might be expected with coarser substrates, grazers were more abundant upstream during the spring sampling.

Corte Madera Creek

Taxa lists for CM Fall and Spring sampling are presented in **Appendix C** and **D** respectively. The five dominant taxa for each season are listed in **table 9**. IBI's are listed in **table 10**. Physical habitat quality scores for Fall are listed in **table 11 and Spring in table 12**. Taxonomic metrics means for the Fall are listed in **table 13**, and Spring in **table 14**.

Table 9. Dominant macroinvertebrate taxa and their percent contribution () by reach from samples collected September 1999 and April 2000 within the Corte Madera watershed.

Reach	Dominant Taxa				
	1	2	3	4	5
CM1 F 99	Planariidae 91 (30%)	Oligochaeta 45 (15%)	*Baetis sp.* 33 (11%)	Orthocladiinae 29 (10%)	Acari 15 (6%)
Sp 00	Orthocladiinae 221 (74%)	Oligochaeta 39 (13%)	Acari 9 (3%)	Simuliidae 6 (2%)	Chironomini 5 (2%)
CM2 F 99	Acari 61 (28%)	Tanypodinae 42 (19%)-	Tanytarsini 31 (14%)	Oligochaeta 21 (10%)	Planorbidae 8 (4%)-
Sp 00	Orthocladiinae 135 (48%)	*Baetis sp.* 35 (12%)	Acari 35 (12%)	Oligochaeta 31 (11%)	*Tanypodinae 13 (5%)*
CM3 F 99	-	-	-	-	-
Sp 00	Orthocladiinae 110 (37%)	Simuliidae 44 (15%)	*Baetis sp.* 35 (12%)	Tanytarsini 23 (8%)	*Paraleptophlebia sp.* 20 (7%)
CM3b F 99	-	-	-	-	-
Sp 00	Orthocladiinae 67 (23%)	*Baetis sp.* 44 (15%)	*Calineuria Californica* 30 (10%)	*Paraleptophlebia sp.* 22 (7%)	*Amphinemura/Malenka sp.* 15 (5%)
CM4 F 99	-	-	-	-	
Sp 00	Orthocladiinae 158 (53%)	Simuliidae 30 (10%)	*Baetis sp.* 24 (8%)	Oligochaeta 24 (8%)	Acari 19 (6%)
CM5 F 99	-	-	-	-	
Sp 00	Orthocladiinae 132 (43%)	Oligochaeta 66 (21%)	Simuliidae 57 (19%)	Tanytarsini 21 (7%)	*Baetis sp.* 20 (7%)
CM6 F 99	-	-	-	-	-
Sp 00	Orthocladiinae 185 (52%)	Tanytarsini 45 (15%)	Simuliidae 26 (8%)	*Baetis sp.* 23 (8%)	Oligochaeta 19 (6%)
CM7 F 99	-	-	-	-	-
Sp 00	Orthocladiinae 192 (64%)	Tanytarsini 23 (8%)	*Baetis sp.* 22 (7%)	Oligochaeta 16 (5%)	Ameletus sp. 14 (5%)
CM7b F 99	-	-	-	-	-
Sp 00	*Baetis sp.* 108 (36%)	*Paraleptophlebia sp.* 62 (21%)	Ameletus sp. 44 (15%)	Orthocladiinae 30 (10%)	*Amphinemura/Malenka sp.* 17 (6%)
CM8 F 99 A	Orthocladiinae 129 (42%)	Chironomini 51 (17%)	Lepidostoma sp 22 (7%)	Acari 22 (7%)	Tanytarsini 15 (5%)
B	Orthocladiinae 155 (52%)	Lepidostoma sp 41 (14%)	Chironomini 35 (12%)	Tanytarsini 27 (9%)	Acari 14 (5%)
Sp 00	Orthocladiinae 68 (30%)	Oligochaeta 28 (12%)	Tanytarsini 27 (12%)	Lepidostoma sp 24 (11%)	*Baetis sp.* 17 (7%)
CM9 F 99	-	-	-	-	-
Sp 00	Suwallia sp. 78 (28%)	Lepidostoma sp. 76 (27%)	Orthocladiinae 31 (11%)	Serratella sp. 20 (9%)	*Drunella sp.* 16 (7%)
CM10 F 99	Lepidostoma sp. 123 (42%)	Eubrianax sp. 25 (9%)	Chironomini 24 (8%)	Tanypodinae 15 (5%)	Paraleptophlebia sp 13 (4%)
Sp 00	Baetis sp 48 (17%)	Orthocladiinae 36 (13%)	Suwallia sp. 33 (12%)	Hexatoma sp 28 (10%)	Serratella sp. 15 (5%)

Table 10. IBI scores by reach from samples collected September 1999 and April 2000 within the Corte Madera watershed.

Reach	IBI						
	taxa richness	% dominance	EPT taxa	Modified EPT	Shannon	Tolerance value	SCORE
CM1 F 99	(17) 1	(36) 3	(3) 1	(1) 1	(2.0) 1	(5.5) 1	8, poor
Sp 00	(12) 1	(74) 1	(2) 1	(0) 1	(1) 1	(5.4) 1	6, poor
CM2 F 99	(17) 1	(34) 3	(4) 1	(7) 1	(2.0) 1	(5.6) 1	8, poor
Sp 00	(15) 1	(48) 1	(7) 1	(5) 1	(1.6) 1	(5.2) 1	6, poor
CM3 F 99	-	-	-	-	-	-	-
Sp 00	(21) 1	(37) 3	(7) 1	(11) 1	(2.1) 1	(5.3) 1	8, poor
CM3b F 99	-	-	-	-	-	-	-
Sp 00	(30) 3	(23) 3	(18) 3	(44) 3	(2.6) 3	(3.7) 3	18, good
CM4 F 99	-	-	-	-	-	-	
Sp 00	(20) 1	(53 1	(9) 1	(4) 1	(1.7) 1	(5.3) 1	6, poor
CM5 F 99	-	-	-	-	-	-	
Sp 00	(11) 1	(43) 1	(2) 1	(1) 1	(1.5) 1	(5.3) 1	6, poor
CM6 F 99	-	-	-	-	-	-	-
Sp 00	(9) 1	(61) 1	(2) 1	(1) 1	(1.2) 1	(5.4) 1	6, poor
CM7 F 99	-	-	-	-	-	-	-
Sp 00	(17) 1	(64) 1	(9) 1	(11) 1	(1.5) 1	(4.8) 1	6, poor
CM7b F 99	-	-	-	-	-	-	-
Sp 00	(18) 1	(40) 1	(10) 1	(50) 5	(1.9) 1	(3.6) 3	12, fair
CM8 F 99	-	-	-	-	-	-	-
Sp 00	(24) 1	(27) 3	(12) 3	(34) 3	(2.4) 3	(4.2) 1	14, fair
CM8b F99	(18) 1	(42) 1	(4) 1	(12) 1	(1.9) 1	(4.9) 1	6, poor
SP00	-	-	-	-	-	-	-
CM9 F 99	-	-	-	-	-	-	-
Sp 00	(13) 1	(40) 1	(12) 3	(77) 5	(2.0) 1	(2.1) 5	16, fair
CM10 F 99	-	-	-	-	-	-	-
Sp 00	(27) 3	(18) 3	(17) 3	(44) 3	(2.7) 3	(3.0) 5	20, good

Table 11. Habitat assessment results for reaches within Corte Madera Watershed, September 1999. Numbers in parentheses are ranges of ranks. (see Table 1 for a description of habitat parameters and ranking criteria)

Ranked Habitat Parameter	CM1 F 99	CM2 F 99	CM3 F 99	CM3b F 99	CM4 F 99	CM5 F 99	CM6 F 99	CM7 F 99	CM7b F 99	CM8 F 99	CM8b F 99	CM9 F 99	CM10 F99
1. Instream Cover (0 - 20)	8	7	dry	dry	dry	dry	dry	dry	dry	12	not sample d	dry	12
2. Embeddedness (0 - 20)	12	12								14			18
3. Velocity/Depth Regime (0 - 20)	9	7								12			11
4. Sediment Deposition (0 - 20)	5	9								7			17
5. Channel Flow (0 - 20)	5	7								7			4
6. Channel Alteration (0 - 20)	11	6								14			20
7. Riffle Frequency (0 - 20)	8	3								14			18
8. Bank Stability (LB: 0 - 10/RB: 0-10)	16	16								16			15
9. Vegetative Protection (LB: 0 - 10/RB: 0-10)	17	9								14			15
10. Riparian Vegetative Zone Width (LB: 0 - 10/RB: 0-10)	13	6								14			18
Reach Total	104	82								124			148
condition	subopt imal	margi nal								subopt imal			suboptim al
Other Reach Descriptions													
Vegetative Canopy Cover Estimate (%)	32	78								53			90
Water Temperature (°F)	16	15								15			14

Ranked Habitat Parameter	CM1 F 99	CM2 F 99	CM3 F 99	CM3b F 99	CM4 F 99	CM5 F 99	CM6 F 99	CM7 F 99	CM7b F 99	CM8 F 99	CM8b F 99	CM9 F 99	CM10 F99
Specific Conductance (µS/cm at 25°C)	not colected	not colected								not colected			not collected
Comments										sculpin in r-4. many yoy fingerlings			spotsampled due to possible steelhead habitat

Table 12. Habitat assessment results for reaches within Corte Madera Watershed, April 2000. Numbers in parentheses are ranges of ranks. (see Table 1 for a description of habitat parameters and ranking criteria)

Ranked Habitat Parameter	CM1 SP00	CM2 SP00	CM3 SP00	CM3b SP00	CM4 SP00	CM5 SP00	CM6 SP00	CM7 SP00	CM7b SP00	CM8 SP00	CM8b F00	CM9 SP00	CM10 SP00
1. Instream Cover (0 - 20)	8	10	17	14	15	15	13	15	8	9		16	17
2. Embeddedness (0 - 20)	11	12	12	18	14	13	12	12	12	17		16	17
3. Velocity/Depth Regime (0 - 20)	9	14	15	15	15	15	13	14	11	13		16	15
4. Sediment Deposition (0 - 20)	8	9	18	17	14	15	12	14	17	5		14	18
5. Channel Flow (0 - 20)	8	10	9	6	14	11	7	7	12	8		11	8
6. Channel Alteration (0 - 20)	14	6	20	20	15	15	9	10	19	12		17	19
7. Riffle Frequency (0 - 20)	14	5	17	17	6	14	11	11	17	15		14	16
8. Bank Stability (LB: 0 - 10/RB: 0-10)	17	18	18	18	11	14	15	14	16	16		13	17
9. Vegetative Protection (LB: 0 - 10/RB: 0-10)	16	10	16	18	13	16	13	15	19	16		16	18
10. Riparian Vegetative Zone Width (LB: 0 - 10/RB: 0-10)	13	6	19	20	7	10	6	9	14	10		11	19
Reach Total	116	100	161	163	124	138	111	121	145	121		144	164
condition	suboptimal	marginal	optimal	optimal	suboptimal	suboptimal	suboptimal	suboptimal	suboptimal	suboptimal		suboptimal	optimal
Other Reach Descriptions													
Vegetative Canopy Cover Estimate (%)	43	63	72	77	42	48	60	47	37	47		63	77

Ranked Habitat Parameter	CM1 SP00	CM2 SP00	CM3 SP00	CM3b SP00	CM4 SP00	CM5 SP00	CM6 SP00	CM7 SP00	CM7b SP00	CM8 SP00	CM8b F00	CM9 SP00	CM10 SP00
Water Temperature (˚ C)	15	15	16	11	13	13	14	12	13	13		15	12.5
Specific Conductance (µS/cm at 25°C)	330	370	162	155	188	358	520	347	307	276		265	305
Comments		r-2 under bridge abutmen t	reach may be missing sand substrate	Pacific giant salamande r	sculpin. stromdra in under u/s r-3		low water. filament ous algae. 4 stromdar ins in reach. r-3 under house		algae. minimal flow. wild bamboo. scotch/fren ch broom.	heavy sediment behind dam. yoy trout. sculpin. riffle sculpin.	Pacific giant salamande r		

Table 13. Cumulative total, mean and coefficient of variation values of biological metrics by reach for benthic macroinvertebrates sampled from the Corte Madera Creek drainage in September 1999, Marin County.

	Corte Madera Cr.			San Anselmo Cr.			San Anselmo Cr.			San Anselmo Cr.		
	CM-1			CM-2			CM-8a			CM-8b		
	CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV
Taxonomic Richness	27	17	9	25	17	10	28	18	6	30	19	9
EPT Taxa	6	3	33	5	4	16	6	4	43	9	5	40
Ephemeroptera Taxa	2	1	43	1	0	173	2	1	43	2	2	35
Plecoptera Taxa	0	0	-	0	0	-	2	1	100	2	1	87
Trichoptera Taxa	4	2	69	4	3	17	2	2	35	5	3	43
EPT Index	13	13	110	11	10	53	15	15	83	19	19	96
Sensitive EPT Index (TV<4)	1	1	125	1	2	118	12	12	76	15	14	107
Shannon Diversity	2.3	2.0	17	2.2	2.0	14	2.0	1.9	17	2.0	1.8	12
Tolerance Value	5.5	5.5	6	5.7	5.6	7	4.9	4.9	5	4.7	4.7	14
Percent Intolerant Organisms	1	1	125	2	2	96	8	8	18	15	15	101
Percent Tolerant Organisms	22	22	50	13	11	78	4	4	52	2	2	28
Percent Hydropsychidae	0	0	-	1	1	34	0	0	-	0	0	-
Percent Baetidae	12	12	129	0.2	0.2	173	3	3	112	4	4	81
Percent Dominant Taxon	30	36	33	28	34	28	42	42	38	45	45	29
Percent Collectors	38	38	28	37	40	37	65	65	20	58	59	20
Percent Filterers	2	2	134	15	17	50	5	5	37	12	12	45
Percent Grazers	14	14	89	16	14	81	3	3	107	4	4	34
Percent Predators	44	44	36	30	27	36	14	14	17	10	10	23
Percent Shredders	1	1	132	1	2	118	12	12	76	16	15	102
Abundance												
(organisms per sample X 1000)	3.7	1.2	35	1.3	0.4	103	9.5	3.2	35	10	3.3	43
CRT: Cumulative Reach Total												
CV: Coefficient of Variation												

Table 14. Cumulative total, mean and coefficient of variation values of biological metrics by reach for benthic macroinvertebrates sampled from the Corte Madera Creek drainage in Spring 2000, Marin County.

	Corte Madera Cr.						Ross Cr.			Bill Williams			San Anselmo			Sleepy Hollow		
	CM-1			CM-2			CM-3			CM-3b			CM-4			CM-5		
	CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV
Taxonomic Richness	17	12	5	23	15	21	32	21	6	45	30	2	32	20	6	18	11	22
EPT Taxa	2	2	35	11	7	29	10	7	14	23	18	6	14	9	24	3	2	69
Ephemeroptera Taxa	2	2	35	7	4	13	4	3	17	11	9	16	7	4	53	1	1	0
Plecoptera Taxa	0	0		1	0	173	2	1	43	4	3	17	4	3	43	0	0	
Trichoptera Taxa	0	0		3	2	49	4	2	25	8	5	11	3	2	35	2	1	173
EPT Index	2	2	43	18	18	26	23	23	34	64	64	7	12	12	17	7	7	36
Sensitive EPT Index (TV<4)	1	1	89	5	5	44	4	4	47	31	31	21	3	3	15	0	0	173
Shannon Diversity	1.0	1.0	11	1.7	1.6	6	2.1	2.1	10	2.7	2.6	7	1.8	1.7	3	1.5	1.5	2
Tolerance Value	5.4	5.4	3	5.2	5.2	7	5.3	5.3	2	3.7	3.7	4	5.3	5.3	3	5.9	5.9	2
Percent Intolerant Organisms	1	1	89	5	5	51	4	4	40	32	32	20	4	4	11	0	0	173
Percent Tolerant Organisms	13	13	49	11	11	85	6	6	19	3	3	89	8	8	84	22	22	10
Percent Hydropsychidae	0	0		0	0		0	0		1	1	142	0	0		0	0	
Percent Baetidae	2	2	40	13	13	41	12	12	20	19	19	55	8	8	11	6	6	38
Percent Dominant Taxon	74	74	7	48	48	5	37	37	25	23	23	35	53	53	5	43	43	16
Percent Collectors	89	89	3	60	60	19	58	58	9	34	34	10	67	67	13	66	66	9
Percent Filterers	3	3	87	9	9	73	22	22	2	10	10	49	14	14	47	25	25	22
Percent Grazers	3	3	37	17	17	29	13	13	20	25	25	31	10	10	17	7	7	34
Percent Predators	4	4	34	13	13	88	3	3	29	20	20	43	9	9	4	1	1	25
Percent Shredders	0	0		1	1	25	3	3	61	10	10	28	1	1	65	0	0	
Abundance																		
(organisms per sample X 1000)		1.4	67		0.84	48		2.5	5		1.1	22		2.5	32		4.1	57

Table 14. (cont.) Cumulative total, mean and coefficient of variation values of biological metrics by reach for benthic macroinvertebrates sampled from the Corte Madera Creek drainage in Spring 2000, Marin County.

												San Anselmo/					
Sleepy Hollow			Sleepy Hollow			Sleepy Hollow			San Anselmo			Cascade Cr.			Cascade Cr.		
CM-6			CM-7			CM-7b			CM-8*			CM-9			CM-10		
CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV
13	9	22	24	17	18	27	18	3	35	24	11	31	19	21	37	27	12
3	2	35	11	8	22	14	10	10	15	12	5	18	12	13	23	17	3
2	1	43	3	3	0	6	5	20	6	5	11	10	7	16	11	9	7
0	0		7	5	25	5	4	0	6	4	0	5	2	25	6	4	25
1	0	173	1	0	173	3	1	100	3	2	25	3	2	50	6	5	12
8	8	35	18	18	31	86	86	4	37	42	36	80	80	5	64	64	16
0	0	173	10	10	38	30	30	19	28	31	36	73	73	6	39	39	10
1.3	1.2	21	1.5	1.5	18	2.0	1.9	2	2.5	2.4	8	2.2	2.0	11	2.8	2.7	6
5.4	5.4	1	4.8	4.8	2	3.6	3.6	9	4.4	4.2	12	2.1	2.1	7	3.0	3.0	6
0	0	173	10	11	42	30	30	17	27	30	31	73	73	7	47	48	8
6	6	33	6	6	45	1	1	26	13	12	19	1	1	45	0	0	
0	0		0	0		0	0		0	0		0	0		1	1	48
7	7	38	7	7	24	36	36	34	7	8	44	3	3	51	19	19	26
61	61	19	64	64	13	36	40	12	30	27	39	28	40	20	17	18	20
69	68	18	71	71	7	32	32	34	51	47	29	21	21	18	26	26	34
23	23	44	8	8	10	1	1	70	9	8	54	1	1	83	3	3	42
8	8	35	12	12	21	53	53	17	16	19	53	13	14	39	38	38	16
1	1	133	9	9	37	8	8	17	13	14	29	37	37	41	29	29	9
0	0		1	1	68	7	7	48	12	13	43	27	27	59	4	4	28
	5.7	22		4.3	54		0.68	32		0.45	80		1.4	33		0.71	9

Thirteen stations were sampled for macroinvertebrates within the Corte Madera Creek watershed. This included two stations on Corte Madera Creek (CM1-2), one station on Ross Creek (CM3), one station on Bill Williams Creek (CM3b), three stations on San Anselmo Creek (CM4, 8, 8b), four stations on Sleepy Hollow Creek (CM5-7, 7b), and two stations on Cascade Creek (CM9-10). Station CM1 was the lowest in the watershed and contained the most urban drainage area upstream. In contrast, Stations CM3b, 7b, and 10 were located highest in the watershed and were the least disturbed. The nine other stations were intermediate in urban disturbance.

Similar to most creeks in Marin County, the small streams in the Corte Madera Creek drainage basin were susceptible to the drying conditions of summer and autumn. Thus, many stations were dry during the fall 1999 sampling period. Only four stations at low elevations (CM1-2, 8a, 8b) had sufficient flow for collection of macroinvertebrates. Because so few stations were sampled, it was difficult to find distinct differences in the biological metrics for fall 1999. However, several metrics indicated slightly improving habitat quality between downstream and upstream stations. Improvements occurred in EPT Taxa, Ephemeroptera Taxa, Plecoptera Taxa, EPT Index, Sensitive EPT Index, Tolerance Value, Percent Intolerant Organisms, and Percent Tolerant Organisms. When taken together, these metrics must reflect true habitat improvements at higher stations. Macroinvertebrate abundance varied erratically from 400 to 3,300. Dominant taxa during fall 1999 were chironomid midges, *Baetis* mayflies, *Lepidostoma* caddisflies, water mites, and oligochaete worms.

By spring 2000, streamflow had resumed at all stations, allowing twelve stations to be sampled along larger gradients of watershed disturbance and elevation. In contrast to the somewhat ambiguous results of fall 1999, most biological metrics in spring 2000 had distinct changes between lower and upper elevation stations. For example, dramatic differences existed in the metrics along at least three elevation and continuum gradients – (1) CM1 to CM3b, (2) CM5 to CM7b, and (3) CM4 to CM10. Other continuum and elevation comparisons were also possible with similar, though occasionally erratic, results. Comparison of the biological metrics for CM1 (elevation 19') and CM3b (elevation 325') provided one example of improving habitat quality with increasing elevation -- Taxonomic Richness (12 to 30), EPT Taxa (2 to 18), Ephemeroptera Taxa (2 to 9), Plecoptera Taxa (0 to 3), Trichoptera Taxa (0 to 5), EPT Index (2 to 64), Sensitive EPT Index (1 to 31), Shannon Diversity (1.0 to 2.6), Tolerance Value (5.4 to 3.7), Percent Intolerant Organisms (1 to 32), Percent Tolerant Organisms (13 to 3), and Percent Dominant Taxon (74 to 23). Generally, macroinvertebrate abundance was lower (680 to 1,100) for the more diverse, high elevation stations (CM3b, 7b, 10), than for the less diverse, low elevation stations (840 to 5,700). Dominant taxa during spring 2000 were chironomid midges, simulid black flies, *Baetis* mayflies, chloroperlid stoneflies, *Lepidostoma* caddisflies, water mites, and oligochaete worms.

Most low-elevation stations (CM1-7) of the Corte Madera Creek watershed had a poor rating of the Index of Biological Integrity, while high-elevation stations were rated fair (CM 7b, 8, 9) or good (CM 3b, 10). These results were consistent with the other biological metric values. Stations rated good were especially rich in intolerant taxa and EPT taxa requiring coarse stream substrates.

When the macroinvertebrate fauna was subdivided into Functional Feeding Groups, the results were mixed for the fall 1999 sampling period, but much more consistent for the spring 2000 period. In fall 1999, only the Shredder group increased somewhat with elevation, while other functional groups changed erratically or opposite to that predicted by the River Continuum Concept. In spring 2000, Collectors and Filterers generally decreased with elevation, while Grazers and Shredders increased, as expected by theory.

In general, the macroinvertebrate fauna of the Corte Madera Creek watershed was very similar to the three other Marin County watersheds studied by the California Stream Bioassessment Procedure in 1999 and 2000. All four watersheds were impacted by varying degrees of urbanization in their lower reaches, while their upper reaches approached natural conditions. All four watershed experienced similar Mediterranean-type climates, with hot dry summers and cool wet winters, causing streamflows to be distinctly seasonal. Most small streams in Marin County have very low flows in late summer and autumn, often becoming intermittent. Intermittent flow conditions were strongly indicated at CM 7 and CM7b by the presence of the perlodid stonefly *Baumannella,* which is adapted for seasonal stream drying. Because of the distinct seasonality of water temperatures and streamflows, the macroinvertebrate fauna of small streams in Marin County often exhibited similar growth and development. As for the other watersheds, Corte Madera Creek watershed had much greater abundance and diversity of ameletid, ephemerellid, and heptageniid mayflies in spring 2000 than was present in fall 1999.

Station CM3 on Ross Creek was located downstream of Phoenix Lake, and the macroinvertebrate fauna may have been influenced by lake discharges of organic particles and plankton. In particular, the occurrence of Hydridae at CM3 in spring 2000 may be caused by lake discharges.

As was typical of other Marin County streams, snails tended to be concentrated in the lower reaches of the Corte Madera watershed. This was true of the Lymnaeidae, Physidae, and Planorbidae for both fall 1999 and spring 2000 samplings. However, during spring 2000, hydrobiid snails were only found at the high elevation station CM3b. Hydrobiidae are often referred to as "spring snails" since they often inhabit the headwater spring sources of small streams.

The high elevation station CM3b contained several macroinvertebrate taxa not found elsewhere in the Corte Madera watershed. Most notable was the amphipod *Stygobromus,* which lives in small water-filled pore spaces of coarse stream substrates. When fine sediments are present, pore spaces become filled, completely excluding this subterranean amphipod. Thus, it is very unlikely that this amphipod would occur at lower elevation stations which often have finer sediments. Other macroinvertebrate taxa requiring coarse substrates for feeding, hiding, and clinging occurred exclusively or most commonly at CM3b and CM10. These included the perlid stonefly *Calineuria,* peltoperlid stonefly *Soliperla,* and caddisflies *Glossosoma, Rhyacophila, Neophylax, and Dolophilodes.* Their claws are adapted for clinging and moving on coarse substrates, not the fine sediments more common at lower stations. Although elmid and psephenid beetles and heptageniid mayflies were found at several stations in the Corte Madera Creek watershed, their claws also allow them to cling to and prefer coarse substrates, not fine sediments. Such preferences at least partly explain their abundance at CM3b and CM10. Another group requiring coarse substrates were the chloroperlid stoneflies *Suwallia* and *Sweltsa.* These elongated stoneflies inhabit the small pore spaces in the upper hyporheic zone of streams. These taxa were especially abundant at upper elevation stations (CM3b, 7b, 9, 10).

Miller Creek

Taxa lists for MC Fall and Spring sampling are presented in **Appendix E** and **F** respectively. The five dominant taxa for each season are listed in **table 15.** IBI for ACM are listed in **table 16.** Physical habitat quality scores for each season are listed in **table 17.** Taxonomic metrics means for the Fall are listed in **table 18,** and Spring in **table 19.**

Table 15. Dominant macroinvertebrate taxa and their percent contribution () by reach from samples collected April 1999 and September 2000 within the Miller Creek watershed.

Reach	Dominant Taxa				
	1	2	3	4	5
MC1 F 99	Orthocladiinae 57 (19%)	Chironomini 56 (18%)	Oligochaeta 46 (15%)	Hydracarina 21 (7%)	*Baetis sp.* 21 (7%)
Sp 00	Orthocladiinae 116 (39%)	*Baetis sp.* 82 (27%)	Oligochaeta 37 (12%)	Tanytarsini 30 (10%)	Simuliidae 26 (9%)
MC2 F 99	Chironomini 84 (28%)	Orthocladiinae 37 (12%)	Oligochaeta 37 (12%)	Tanypodinae 14 (5%)	*Baetis sp.* 14 (5%)
Sp 00	Orthocladiinae 163 (54%)	*Baetis sp.* 44 (15%)	Tanytarsini 39 (13%)	Oligochaeta 26 (9%)	Psychoda sp 18 (6%)
MC3 F 99	Chironomini 62 (21%)	Simuliidae 43 (14%)	Orthocladiinae 40 (13%)	Planariidae 13 (4%)	Argia sp. 12 (4%)
Sp 00	*Baetis sp.* 96 (327%)	Orthocladiinae 63 (21%)	Simuliidae 18 (6%)	Tanytarsini 18 (6%)	Acari 8 (3%)
MC4 F 99	Chironomini 53 (17%)	Orthocladiinae 53 (17%)	Argia 29 (10%)	Tanypodinae 27 (9%)	Oligochaeta 23 (8%)
Sp 00	*Baetis sp.* 83 (28%)	Orthocladiinae 81 (27%)	Tanytarsini 34 (11%)	*Serratella sp. 32 (11%)*	Simuliidae 21 (7%)
MC5 F 99	-	-	-	-	-
Sp 00	rthocladiinae 169 (56%)	*Serratella sp. 44 (15%)*	Tanytarsini 16 (5%)	Tanypodinae 15 (5%)	*Baetis sp.* 14 (5%)
MC6 F 99	-	-	-	-	-
SP 00	*Baetis sp.* 107 (36%)	*Serratella sp. 62 (21%)*	Orthocladiinae 32 (11%)	Drunella sp. 15 (5%)	Tanypodinae 13 (4%)

Table 16. IBI scores by reach from samples collected September 1999 and April 2000 within the Miller Creek watershed.

Reach		IBI						
		taxa richness	% dominance	EPT taxa	Modified EPT	Shannon	Tolerance value	SCORE
MC1	F 99	(19) 1	(28) 3	(5) 1	(15) 1	(2.2) 1	(5.2) 1	8, poor
	Sp 00	(9) 1	(42) 1	(2) 1	(1) 1	(1.5) 1	(5.6) 1	6, poor
MC2	F 99	(19) 1	(29) 3	(4) 1	(19) 3	(2.1) 1	(5.0) 1	10, poor
	Sp 00	(9) 1	(53) 1	(2) 1	(0) 1	(1.3) 1	(5.0) 1	6, poor
MC3	F 99	(19) 1	(30) 3	(5) 1	(16) 1	(2.3) 3	(5.0) 1	10, poor
	Sp 00	(15) 1	(53) 1	(5) 1	(3) 1	(1.5) 1	(5.1) 1	6, poor
MC4	F 99	(23) 1	(27) 3	(8) 1	(11) 1	(2.5) 3	(5.4) 1	10, poor
	Sp 00	(20) 1	(36) 3	(12) 3	(19) 3	(2.0) 1	(4.7) 1	12, fair
MC5	F 99	-	-	-	-	-	-	-
	Sp 00	(19) 1	(56) 1	(10) 1	(25) 3	(1.6) 1	(4.4) 3	10, poor
MC6	F 99	-	-	-	-	-	-	-
	Sp 00	(23) 1	(37) 3	(15) 3	(44) 3	(2.1) 1	(3.6) 3	14, fair

Table 17. Habitat assessment results for reaches within Miller Creek, September 1999 and April 2000. Numbers in parentheses are ranges of ranks. (see Table 1 for a description of habitat parameters and ranking criteria)

Ranked Habitat Parameter	MC1 F 99	MC1 SP00	MC2 F 99	MC2 SP00	MC3 F99	MC3 SP00	MC4 F99	MC4 SP00	MC5 F99	MC5 SP00	MC6 F99	MC7 SP00
1. Instream Cover (0 - 20)	12	13	14	18	13	15	17	19	dry	13	dry	13
2. Embeddedness (0 - 20)	14	14	13	15	14	11	16	14		12		17
3. Velocity/Depth Regime (0 - 20)	14	11	15	16	14	15	16	17		14		14
4. Sediment Deposition (0 - 20)	12	16	11	10	14	13	13	13		12		12
5. Channel Flow (0 - 20)	5	9	7	9	8	11	7	10		7		7
6. Channel Alteration (0 - 20)	19	17	18	18	18	18	20	19		19		18
7. Riffle Frequency (0 - 20)	15	16	15	17	15	12	17	18		16		18
8. Bank Stability (LB: 0 - 10/RB: 0-10)	9/9	15	7/8	14	14	14	9/9	18		18		5
9. Vegetative Protection (LB: 0 - 10/RB: 0-10)	8/8	13	8/8	14	7/7	14	9/10	20		14		8
10. Riparian Vegetative Zone Width (LB: 0 - 10/RB: 0-10)	6/8	15	8/6	14	8/7	16	8/10	18		16		14
Reach Total	139	139	138	145	139	139	161	166		141		126
condition	sub optimal	sub optimal	sub optimal	suoptimal	sub optimal	sub optimal	optimal	optimal		sub optimal		sub optimal
Other Reach Descriptions												
Vegetative Canopy Cover Estimate (%)	70	65	70	80	85	70	50	47		17		20
Water Temperature (˚ F)	62	13 c	62	14c	61	14c	60	15c		17c		13c
Specific Conductance (µS/cm at 25°C)	354	360	332	340	294	310	273	280		220		210
Comments	Storm drain between riffle 1 and 2; residence on left bank; minimal flow for sampling	stormdain r-2	Bridge abutments, residences and school within or near riparian zone; minimal flow for sampling	school nearby. stormdrain d/s r-1	Storm drain on right bank upstream of riffle 1; trails within riparian zone	stormdrain u/s r-5	Overall good quality site but minimal flow for samplimg; samples collected under blackberry vines; recommend frog surveys for this site			stormdrain @ upper end reach		yoy trout. stream dry u/s of bridge @ top of riffle

Table 19. Cumulative total, mean and coefficient of variation values of biological metrics by reach for benthic macroinvertebrates sampled from the Miller Creek drainage in Fall 1999, Marin County.

	MC1			MC2			MC3			MC4		
	CRT	mean	CV	CRT	mean	CV	CRT	mean	CV	CRT	mean	CV
Taxonomic Richness	25	19	5	23	19	3	26	19	11	31	23	17
EPT Taxa	7	5	39	5	4	13	5	5	12	11	8	25
Ephemeroptera Taxa	3	2	50	1	1	0	1	1	0	5	3	33
Plecoptera Taxa	1	1	87	1	0	173	1	1	87	1	1	0
Trichoptera Taxa	3	3	22	3	3	0	3	3	0	5	4	27
EPT Index	24	24	65	26	26	40	29	29	39	23	23	52
Sensitive EPT Index	15	15	90	18	18	57	11	11	44	8.5	9	56
Shannon Diversity	2.4	2.2	6	2.3	2.1	5	2.4	2.3	6	2.7	2.5	18
Tolerance Value	5.2	5.2	15	5.0	5.0	14	5.0	5.0	7	5.4	5.4	4
Percent Intolerant Organisms	15	15	90	18	18	57	12	12	42	7	7	45
Percent Tolerant Organisms	16	16	75	13	13	104	5	5	46	11	11	78
Percent Hydropsychidae*	2	2	159	2	2	123	9	9	53	5	5	60
Percent Baetidae*	7	7	40	5	5	43	4	4	58	7	7	55
Percent Dominant Taxon	19	28	4	28	29	10	21	30	32	17	27	47
Percent Collectors*		54	33		54	20		39	45		43	46
Percent Filterers*		4	81		6	44		25	84		14	56
Percent Grazers*		11	35		7	35		10	56		10	78
Percent Predators		16	22		14	10		14	16		24	21
Percent Shredders*		15	85		18	55		12	40		10	45
Abundance* (X1000)		4.4	46		4	36		2	29		2	35

Table 19. Cumulative total, mean and coefficient of variation values of biological metrics by reach for benthic macroinvertebrates sampled from the Miller Creek drainage in Spring 2000, Marin County.

	MC1			MC2			MC3			MC4			MC5			MC6		
	CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV
Taxonomic Richness	15	9	16	14	9	11	20	15	10	26	20	14	26	19	9	32	23	3
EPT Taxa	4	2	50	4	2	49	9	5	11	16	12	13	12	10	20	18	15	7
Ephemeroptera Taxa	1	1	0	2	1	43	4	3	33	7	6	0	8	6	24	9	8	13
Plecoptera Taxa	1	0		0	0		2	1	173	7	4	43	3	3	22	7	6	10
Trichoptera Taxa	2	1	173	2	1	100	3	2	69	2	2	35	1	1	0	2	1	43
EPT Index	28	28	33	15	15	78	46	46	53	47	47	21	30	30	29	80	80	8
Sensitive EPT Index (TV<4)	0	0	173	0	0	88	3	3	54	17	17	8	22	23	38	42	41	33
Shannon Diversity	1.6	1.5	2	1.5	1.3	14	1.7	1.5	15	2.1	2.0	2	1.7	1.6	6	2.2	2.1	19
Tolerance Value	5.6	5.6	1	5.4	5	5	5.1	5.1	2	4.7	4.7	2	4.4	4.4	7	3.6	3.6	14
Percent Intolerant Organisms	0	0	173	0	0	88	3	3	54	17	17	7	23	23	38	43	43	30
Percent Tolerant Organisms	12	12	18	9	8	132	2	2	24	2	2	71	1	1	69	0	0	100
Percent Hydropsychidae	0	0		0	0		1	1	26	0	0		0	0		0	0	
Percent Baetidae	27	27	34	15	15	81	42	42	61	28	28	37	5	5	43	36	36	47
Percent Dominant Taxon	39	42	8	53	53	21	42	53	21	28	36	9	56	56	6	36	37	39
Percent Collectors	52	52	21	62	61	27	38	38	42	42	42	29	74	74	8	34	34	11
Percent Filterers	19	19	20	19	20	33	13	13	67	18	18	35	5	5	54	1	1	173
Percent Grazers	27	27	33	15	15	81	43	43	60	30	30	33	8	8	51	45	45	24
Percent Predators	2	2	71	4	4	78	6	6	27	8	8	35	12	12	37	15	15	24
Percent Shredders	0	0		0	0	88	0	0		1	1	17	1	1	107	6	6	128
Abundance																		
(organisms per sample X 1000)		2.8	66		1.9	22		1.8	40		1.9	6		3.1	66		0.87	63

Six stations were sampled for macroinvertebrates along the continuum of Miller Creek (MC1-6). Changes in macroinvertebrate taxonomic composition and biological metrics along this continuum were generally subtle. Dramatic changes in the macroinvertebrate fauna were uncommon. Nevertheless, significantly better habitats occurred at upstream stations, especially during the spring 2000 sampling.

In evaluating the habitat quality of Miller Creek stations, the fall 1999 results were especially ambiguous. Only the first four stations (MC1-4) were sampled because the upper two stations (MC5-6) were dry. Most biological metrics in fall 1999 showed little or no change for the four stations MC1-4. Possibly, slight increases were noted in Taxonomic Richness (19 to 23), EPT Taxa (5 to 8), and Shannon Diversity (2.2 to 2.5), but natural data variability questions if these were significant differences. Macroinvertebrate abundance's varied from 4,400 at MC1 to 2,000 at MC4. Dominant taxa included chironimid midges, *Baetis* mayflies, *Lepidostoma* caddisflies, and oligochaete worms.

In spring 2000, all six stations of Miller Creek had flowing water and were sampled (MC1-6). In contrast with the fall 1999 results, many biological metrics demonstrated significant changes. For example, distinct improvements were found between MC1 and MC6 in Taxonomic Richness (9 to 23), EPT Taxa (2 to 15), Ephemeroptera Taxa (1 to 8), Plecoptera Taxa (0 to 6), EPT Index (28 to 80), Sensitive EPT Index (0 to 41), Shannon Diversity (1.5 to 2.1), Tolerance Value (5.6 to 3.6), Percent Tolerant Organisms (12 to 0), and Percent Intolerant Organisms (0 to 43). Macroinvertebrate abundances varied from 2,800 at MC1 to 870 at MC6. Dominant taxa included chironimid midges, *Baetis* mayflies, simulid black flies, and oligochaete worms.

Habitat improvement at MC4-6 during spring 2000 was apparent in the general taxonomic composition of macroinvertebrates. In comparison with the lower three stations (MC1-3), several faunal groups were much more abundant at the upstream stations (MC4-6), including all Plecoptera, most Ephemeroptera, all Megaloptera, *Lepidostoma* and *Rhyacophila* caddisflies, most tipulids, and all dytiscid beetles. An increased diversity of mayflies and stoneflies was noticeable. Some of these differences were also detected at MC4 in fall 1999. A counter trend of decreasing abundance with distance upstream was observed for some dominant taxa, such as chironomid midges, simulid black flies, and oligochaete worms.

The subtle improvement in habitat quality along the continuum of Miller Creek was also noted by the Index of Biological Integrity. The first three stations (MC1-3) were rated as poor habitat (IBI Values 6-10), while MC4 was slightly improved (12, fair) in spring 2000. The upper two stations were only sampled in spring 2000, but MC5 was rated poor (10), while MC6 rated fair (14). Thus, the macroinvertebrate habitat of Miller Creek only had slight improvements at upstream stations, while the downstream stations with greater urban exposure rated poorly. As indicated by the abundance of chironmids, baetids, and oligochaetes, the lower habitats likely had fine sediments, warmer waters, and little riparian vegetation.

It was difficult to find consistent trends in the Functional Feeding Groups of Miller Creek. Most groups exhibited few or irregular changes along the continuum. Possibly during spring, filterers may have increased and shredders decreased between upper and lower stations, in agreement with the River Continuum Concept.

During fall 1999, the upper two stations (MC5-6) of Miller Creek were dry, but flow had resumed by spring 2000. By spring, these two stations had been recolonized primarily by macroinvertebrate taxa typical of perennial streams. However, Miller Creek's flow may frequently be intermittent in late-summer and autumn as indicated by the perlodid stonefly *Baumannella,* which is adapted for the summer-autumn drying conditions of Coast Range small streams. Possibly, the fall 1999 drying of stations MC5-6 and complete loss of the macroinvertebrate fauna was partially responsible for the ambiguous results for Miller Creek. Faunal recovery may have been incomplete by spring 2000, negatively affecting the biological metrics, Index of Biological Integrity, and Functional Feeding Groups.

Three other macroinvertebrate taxa of Miller Creek were of special interest. The mayfly *Tricorythodes* found at MC1 and MC4 commonly inhabits streams with fine sediments. It possesses a special thick gill plate which covers and protects the remaining fragile gill plates from abrasion by silt and sand. The caddisfly *Gumaga* is of environmental interest because of its ability to inhabit very warm streams. As found in the other Marin County watersheds, the chloroperlid stoneflies *Suwallia* and *Sweltsa* found in Miller Creek primarily occurred at upstream stations where coarser substrates allowed them to inhabit the upper hyporheic zone.

Seasonal differences in the macroinvertebrate composition of Miller Creek were similar to that found in the other Marin County watersheds and were primarily caused by natural cycles of growth and development in individual taxa. Higher abundances and diversities of ameletid, ephemerellid, and heptageniid mayflies occurred in spring 2000 in most Marin creeks. The caddisfly *Lepidostoma* was notable in being very common in Miller Creek during the fall 1999 sampling, but scarce in spring 2000.

Novato Creek

Taxa lists for NC Fall and Spring sampling are presented in **Appendix G** and **H** respectively. The five dominant taxa for each season are listed in **table 20.** IBI for ACM are listed in **table 21.** Physical habitat quality scores are listed in **table 22.** Taxonomic metrics means for the Fall are listed in **table 23,** and Spring in **table 24.**

Table 20. Dominant macroinvertebrate taxa and their percent contribution () by reach from samples collected September 1999 and April 2000 within the Novato Creek watershed.

Reach		Dominant Taxa				
		1	2	3	4	5
NC1	F 99	*Hydropsyche sp.* 81 (27%)	Tricorythodes 53 (18%)	*Baetis sp.* 41 (14%)	Hydroptilidae 16 (5%)	Chironomini 13 (4%)
	Sp 00	Orthocladiinae 203 (67%)	Oligochaeta 42 (14%)	Diphetor sp. 19 (6%)	Tanytarsini 13 (4%)	Drunella sp. 4 (1%)
NC2	F 99	*Hydropsyche sp.* 92 (31%)	Tricorythodes 26 (9%)	Orthocladiinae 26 (9%)	Hydroptilidae 19 (6%)	*Baetis sp.* 16 (5%)
	Sp 00	Orthocladiinae 114 (38%)	Oligochaeta 68 (23%)	*Baetis sp.* 38 (13%)	Tanytarsini 25 (8%)	*Drunella sp.* 20 (7%)
NC3	F 99	-	-	-	-	-
	Sp 00	*Baetis sp.* 78 (26%)	Orthocladiinae 51 (17%)	Oligochaeta 51(17%)	*Serratella sp 29 (10%)*	Tanytarsini 20 (7%)
NC4	F 99	*Hydropsyche sp.* 68 (22%)	*Baetis sp.* 37 (12%)	Orthocladiinae 33 (11%)	Planariidae 31 (10%)	Diphetor sp. 19 (6%)
	Sp 00	*Baetis sp.* 121 (40%)	Orthocladiinae 33 (11%)	Tanytarsini 20 (7%)	*Tanypodidae 18 (6%)*	*Serratella sp 17 (6%)*
NC5	F 99	*Hydropsyche sp.* 66 22%)	*Baetis sp.* 39 (13%)	*Amphinemura sp. 23 (8%)*	Orthocladiinae 21 (7%)	Tanypodinae 18 (6%)
	Sp 00	Orthocladiinae 65 (22%)	*Baetis sp.* 54 (18%)	*Simuliidae 45 (15%)*	Oligochaeta 42 (14%)	Tanytarsini 26 (9%)
NC6	F 99	-	-	-	-	-
	Sp 00	Suwallia sp. 83 (28%))	*Baetis sp.* 66 (22%)	Orthocladiinae 58 (19%)	Agapetus sp. 15 (5%))	Tanytarsini 12 (4%)
NC7	F 99	-	-	-	-	-
	Sp 00	Oligochaeta 68 (23%)	Tanypodinae 60 (20%)	Orthocladiinae 40 (13%)	Ameletus sp. 14 (5%)	Simuliidae 13 (4%)
NC8	F 99	Orthocladiinae 49 (16%)	hyaletta azteca 47 (15%)	*Baetis sp.* 32 (10%)	*Hydropsyche sp.* 30 (10%)	Simuliidae 26 (9%)
	Sp 00	Oligochaeta 91 (30%)	Simuliidae 90 (30%)	Orthocladiinae 78 (26%)	Tanytarsini 29 (10%)	*Baetis sp.* 6 (2%)

Table 21. IBI scores by reach from samples collected September 1999 and April 2000 within the Novato Creek watershed.

Reach		IBI						
		taxa richness	% dominance	EPT taxa	Modified EPT	Shannon	Tolerance value	SCORE
NC1	F 99	(22) 1	(31) 3	(67) 1	(25) 3	(2.3) 3	(4.9) 1	12, poor
	Sp 00	(10) 1	(67) 1	(4) 1	(2) 1	(1.1) 1	(5.4) 1	6, poor
NC2	F 99	(23) 1	(33) 3	(6) 1	(20) 3	(2.4) 3	(4.9) 1	12, fair
	Sp 00	(16) 1	(38) 3	(6) 1	(9) 1	(1.8) 1	(5.4) 1	8, poor
NC3	F 99	-	-	-	-	-	-	-
	Sp 00	(20) 1	(30) 3	(9) 1	(17) 3	(2.2) 1	(5.1) 1	10, poor
NC4	F 99	(21) 1	(24) 3	(8) 1	(21) 3	(2.4) 3	(4.5) 3	14, fair
	Sp 00	(23) 1	(41) 1	(10) 1	(14) 1	(2.1) 1	(4.9) 1	6, poor
NC5	F 99	(24) 1	(22) 3	(10) 1	(20) 3	(2.5) 3	(4.6) 3	14, fair
	Sp 00	(22) 1	(24) 3	(9) 1	(7) 1	(2.2) 1	(5.5) 1	8, poor
NC6	F 99	-	-	-	-	-	-	-
	Sp 00	(17) 1	(29) 3	(9) 1	(39) 3	(2.0) 1	(3.6) 3	12, fair
NC7	F 99	-	-	-	-	-	-	
	Sp 00	(13) 1	(39) 3	(4) 1	(6) 1	(1.7) 1	(5.7) 1	8,poor
NC8	F 99	(19) 1	(28) 3	(4) 1	(6) 1	(2.1) 1	(5.8) 1	8, poor
	Sp 00	(10) 1	(39) 3	(2) 1	(0) 1	(1.4) 1	(6.3) 1	8, poor

Table 22. Habitat assessment results for reaches withNovato Creek, September 1999 and April 2000. Numbers in parentheses are ranges of ranks. (see Table 1 for a description of habitat parameters and ranking criteria)

Ranked Habitat Parameter	NC1 F 99	NC1 SP00	NC2 F 99	NC2 SP00	NC3 F99	NC3 SP00	NC4 F99	NC4 SP00	NC5 F99	NC5 SP00	NC6 F99	NC6 SP00	NC7 F99	NC7 SP00	NC8 F99
1. Instream Cover (0 - 20)	12	12	8	12	dry		15	13	13	11		14		11	10
2. Embeddedness (0 - 20)	12	15	12	12		12	14	14	12	11		14		12	6
3. Velocity/Depth Regime (0 - 20)	15	15	9	12		16	17	15	15	13		15		14	8
4. *Sediment Deposition* (0 - 20)	16	12	11	12		10	13	13	12	9		14		15	12
5. Channel Flow (0 - 20)	7	10	7	10		9	7	8	5	6		6		6	6
6. Channel Alteration (0 - 20)	20	16	20	16		18	20	20	20	20		20		17	7
7. Riffle Frequency (0 - 20)	15	14	12	16		12	18	18	16	16		16		17	10
8. Bank Stability (LB: 0 - 10/RB: 0-10)	9/9	14	8/8	15		12	9/8	12	6/5	10		18		14	8/8 (see comm ent)
9. Vegetative Protection (LB: 0 - 10/RB: 0-10)	8/8	17	8/7	16		14	8/8	16	6/6	12		18		14	6/6
10. Riparian Vegetative Zone Width (LB: 0 - 10/RB: 0-10)	6/8	14	8/7	14		14	10/10	18	9/10	18		20		9	3/3
Reach Total	145	139	125	135			157	147	135	126		155		129	93
condition	sub opti mal	sub opti mal	sub opti mal	subo ptim al			opti mal	sub opti mal	subo ptim al	sub opti mal		opti mal		subop timal	margi nal
Vegetative Canopy Cover Estimate (%)	50	64	70	77		62	60	75	70	72		33		57	30

Ranked Habitat Parameter	NC1 F 99	NC1 SP00	NC2 F 99	NC2 SP00	NC3 F99	NC3 SP00	NC4 F99	NC4 SP00	NC5 F99	NC5 SP00	NC6 F99	NC6 SP00	NC7 F99	NC7 SP00	NC8 F99
Water Temperature (F)	57	12	57	13		14	59	14	64	15		16		15	63
Specific Conductance (µS/cm at 25°C)	440	440	420	460		420	330	410	290	520		350		490	580
Comments	Storm drain upstream of riffle 6. Low flow in reach	sheen on water surface. petroleum smell. storm drain u/s r-2	Sinols Environmental Club was doing a stream cleanup during our sampling. Low flow in reach	outfall between r-1 & 2		stormdrain in u/s of t-3 & d/s t-2. fish in pool.	Mitten crab found in reach; overall good quality reach except for low flow conditions		Low flow in reach	overall poor riffle habitat		SF garter snake on path		stormdrain u/s r-8	Substrate mostly hardpan clay; banks stabilized w/ concrete bags

Table 23. **Cumulative total, mean and coefficient of variation values of biological metrics by reach for benthic macroinvertebrates sampled from the Novato Creek drainage in Fall 1999, Marin County.**

	Novato Creek			Novato Creek			Novato Creek			Novato Creek			Warner Creek		
	NC1			NC2			NC4			NC5			NC8		
	CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV
Taxonomic Richness	28	22	1	27	23	1	27	21	3	34	24	4	26	19	2
EPT Taxa	7	6	1	7	6	1	9	8	1	12	10	2	7	4	1
Ephemeroptera Taxa	3	3	0	3	3	0	4	4	0	4	4	0	3	2	1
Plecoptera Taxa	1	0	1	1	0	1	1	1	0	1	1	0	0	0	0
Trichoptera Taxa	3	3	1	3	3	0	4	3	1	7	5	2	4	2	2
EPT Index	67	67	6	57	57	12	61	61	13	58	58	20	26	26	23
Sensitive EPT Index (TV<4)	1	1	1	5	5	2	7	7	5	10	10	3	0	0	0
Shannon Diversity	2.4	2.3	0.1	2.5	2.4	0.3	2.6	2.4	0.2	2.7	2.5	0.3	2.6	2.1	0.3
Tolerance Value	4.9	4.9	0.2	4.9	4.9	0.3	4.5	4.5	0.2	4.6	4.6	0.4	5.8	5.8	0.6
Percent Intolerant Organisms	1	1	1	5	5	2	8	8	6	12	12	3	0	0	1
Percent Tolerant Organisms	5	5	1	9	9	5	1	1	1	7	7	11	24	24	19
Percent Hydropsychidae	27	27	8	31	31	16	22	22	2	22	22	7	10	10	8
Percent Baetidae	15	15	5	6	6	4	17	18	16	16	16	11	10	10	14
Percent Dominant Taxon	27	31	4	31	33	12	22	24	1	22	22	7	16	28	13
Percent Collectors	32	32	9	27	27	16	25	25	4	23	23	14	46	46	26
Percent Filterers	30	30	9	34	34	17	28	28	4	28	28	7	22	22	16
Percent Grazers	25	25	3	21	21	9	19	19	11	18	18	10	13	13	14
Percent Predators	10	10	4	11	11	7	16	16	4	19	19	7	19	19	16
Percent Shredders	3	3	1	6	6	3	13	13	1	12	12	4	0	0	0
Abundance (organisms per sample X 1000)		2.6	0.5		2.0	0.7		3.4	0.9		3.1	0.8		2.7	1.4

Table 24. Cumulative total, mean and coefficient of variation values of biological metrics by reach for benthic macroinvertebrates sampled from the Novato Creek drainage in Spring 2000, Marin County.

	Novato Creek NC1			Novato Creek NC2			Novato Creek NC3			Novato Creek NC4		
	CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV
Taxonomic Richness	13	10	10	23	16	13	27	20	0	31	23	13
EPT Taxa	5	4	16	9	6	24	14	10	12	13	10	10
Ephemeroptera Taxa	5	4	16	6	5	25	8	6	9	7	6	9
Plecoptera Taxa	0	0		1	1	87	1	1	0	2	2	35
Trichoptera Taxa	0	0		2	1	100	5	2	65	4	2	50
EPT Index	9	9	47	22	22	10	45	45	12	60	60	18
Sensitive EPT Index (TV<4)	2	2	52	9	9	20	15	15	58	11	11	27
Shannon Diversity	1.2	1.1	29	1.9	1.8	1	2.3	2.2	5	2.3	2.1	19
Tolerance Value	5.4	5.4	5	5.4	5.4	7	5.1	5.1	12	4.8	4.8	1
Percent Intolerant Organisms	2	2	52	9	9	20	14	14	55	12	12	28
Percent Tolerant Organisms	14	14	66	23	23	46	17	17	76	4	4	77
Percent Hydropsychidae	0	0		0	0		0	0		1	1	101
Percent Baetidae	7	7	45	13	13	13	28	28	32	45	45	34
Percent Dominant Taxon	67	67	19	38	38	20	26	30	25	41	41	46
Percent Collectors	82	82	9	63	63	3	46	46	23	25	25	32
Percent Filterers	9	9	44	11	11	9	11	11	39	11	11	14
Percent Grazers	8	8	42	20	20	6	33	32	26	46	46	37
Percent Predators	1	1	50	5	5	36	8	8	9	12	12	69
Percent Shredders	0	0		0	0		2	2	101	5	5	72
Abundance (organisms per sample X 1000)		1.8	53		0.42	43		1.9	54		0.8	39

Table 24. (cont.

	Novato Creek			Novato Creek			Warner Creek			Warner Creek		
	NC5			NC6			NC7			NC8		
	CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV	CRT	Mean	CV
Taxonomic Richness	29	10	10	30	16	13	21	20	0	15	23	13
EPT Taxa	12	4	16	15	6	24	7	10	12	3	10	10
Ephemeroptera Taxa	4	4	16	5	5	25	3	6	9	2	6	9
Plecoptera Taxa	4	0	####	4	1	87	2	1	0	0	2	
Trichoptera Taxa	4	0	####	5	1	100	2	2	65	1	2	50
EPT Index	27	9	47	63	22	10	8	45	12	2	60	18
Sensitive EPT Index (TV<4)	6	2	52	39	9	20	6	15	58	0	11	
Shannon Diversity	2.3	1.1	29	2.1	1.8	1	1.7	2.2	5	1.5	2.1	19
Tolerance Value	5.5	5.4	5	3.5	5.4	7	5.7	5.1	12	6.3	4.8	1
Percent Intolerant Organisms	5	2	52	39	9	20	6	14	55	0	12	
Percent Tolerant Organisms	15	14	66	1	23	46	23	17	76	30	4	77
Percent Hydropsychidae	0	0		0	0		0	0		0	1	
Percent Baetidae	20	7	45	22	13	13	2	28	32	2	45	34
Percent Dominant Taxon	22	67	19	28	38	20	39	30	25	30	41	46
Percent Collectors	39	82	9	21	63	3	62	46	23	57	25	32
Percent Filterers	28	9	44	13	11	9	24	11	39	39	11	14
Percent Grazers	21	8	42	30	20	6	7	32	26	2	46	37
Percent Predators	9	1	50	36	5	36	6	8	9	2	12	69
Percent Shredders	3	0	100	1	0		0	2		0	5	
Abundance												
(organisms per sample X 1000)		1.8	53		0.4	43		1.9	54		0.8	39

Six stations were sampled for macroinvertebrates along the continuum of Novato Creek (NC1-6) and two stations were sampled along Warner Creek (NC7-8), an urban tributary of Novato Creek. Sampling results were somewhat ambiguous within the Novato watershed, with most stations being rated as poor or fair stream habitats. The small streams in this watershed were influenced by intermittent flow conditions in fall 1999, stations NC3, NC6, and NC7 being dry.

Along the Novato Creek continuum from low elevation (NC1, 25') to higher elevation (NC5, 122'), habitat quality as measured by the biological metrics showed only slight improvements during fall 1999. Taxonomic Richness remained above 20, but there were few changes along the continuum. Only slight improvements occurred in EPT Taxa (6 to 10), Trichoptera Taxa (3 to 5), Shannon Diversity (2.3 to 2.5), Tolerance Value (4.9 to 4.6), and Percent Dominant Taxon (31 to 22). Two metrics were distinctly improved, Sensitive EPT Index (1 to 10) and Percent Intolerant Organisms (1 to 12). Other biological metrics showed erratic or no change along this continuum. Macroinvertebrate abundance's varied within a narrow range from 2,000 to 3,400, without a consistent trend along the continuum. These ambiguous results may have been impacted by intermittent flow conditions in fall 1999. Dominant taxa in fall 1999 were chironomid midges, *Baetis* mayflies, *Tricorythodes* mayflies, hydropsychid caddisflies, planarian flatworms, and oligochaete worms.

During spring 2000, habitat quality as measured by the biological metrics showed distinct improvements along the Novato Creek continuum (NC1-6), including Taxonomic Richness (10 to 19), EPT Taxa (4 to 11), Plecoptera Taxa (0 to 3), Trichoptera Taxa (0 to 3), EPT Index (9 to 63), Sensitive EPT Index (2 to 39), Shannon Diversity (1.1 to 2.1), Tolerance Value (5.4 to 3.5), Percent Intolerant Organisms (2 to 39), Percent Tolerant Organisms (14 to 1), and Percent Dominant Taxon (67 to 29). Some of these trends had irregularities at certain stations, especially at NC5 which was located downstream of a reservoir. No consistent trends were found in macroinvertebrate abundance's, these narrowly ranging from 420 to 1,900. During spring 2000, all stations had good streamflows and none were dry. Dominant taxa in fall 1999 were chironomid midges, *Baetis* mayflies, *Drunella* mayflies, simulid black flies, and oligochaete worms.

During spring 2000, habitat quality showed slight improvements between the two stations sampled on Warner Creek, the higher station NC7 (elevation 101') being better than the lower station NC8 (elevation 44'). These improvements were found in almost all biological metrics, giving confidence that the observed improvements reflected true changes.

Conclusions based upon the macroinvertebrate taxonomic composition and biological metrics were consistent with the results shown by the Index of Biological Integrity. While seasonal differences occurred in the IBI between fall 1999 and spring 2000, all eight stations in the Novato Creek watershed were rated as poor or fair aquatic habitats. The five stations sampled in fall 1999 were rated as fair, except for NC8 on lower Warner Creek, which was rated as poor. During spring 2000, all eight stations were rated as poor, except NC6 on upper Novato Creek, which was rated as fair. Although NC6 was only sampled in one season, apparently it had the best habitat quality of the eight stations.

The results for Functional Feeding Groups were mixed. Clearly, the proportion of Collectors significantly decreased from NC1 to NC6, in agreement with that predicted by the River Continuum Concept. Also in agreement, Grazers and Shredders apparently increased along the continuum, though both trends had irregularities and unexpected differences between fall and spring.

While macroinvertebrate distributions within the Novato Creek watershed had similarities with other Marin County small streams, several were especially interesting. In particular, the macroinvertebrate fauna at station NC5 may have been influenced by discharges from an upstream reservoir. Three filter feeders, simulid blackfly larvae, *Wormaldia* caddisfly larvae, and the coelenterate *Hydra,* were especially abundant at NC5 in spring 2000. It is a well-known fact of stream ecology that filter-feeding organisms can be very abundant downstream of reservoirs releasing large quantities of organic particles and plankton. This fine organic matter is filtered from the flowing water and consumed by these macroinvertebrates. It is also of interest that the two ephemerellid mayflies *Drunella* and *Serratella* were abundant at the lower stations NC1-4, but absent from NC5-6.

The mayfly *Tricorythodes* found at NC1-5 commonly inhabits streams with fine sediments. It possesses a special thick gill plate which covers and protects the remaining fragile gill plates from abrasion by silt and sand. Interestingly, *Tricorythodes* continuously decreased in abundance along the Novato Creek continuum from the lowest station NC1 (abundance = 160) to the higher station NC5 (abundance = 19). This change in abundance was especially noticeable during the fall 1999 sampling. The pronounced decrease in abundance may be caused by less fine sediments at higher stations.

In contrast, a group of macroinvertebrate taxa requiring clean, coarser substrates were the chloroperlid stonefly nymphs *Suwallia* and *Sweltsa,* and the psychodid *Maruina.* These taxa were only collected at the upstream stations of NC5-6.

It was also of interest that large crustaceans such as crangonyctid amphipods and isopods were only found at the lower stations (NC1-2, 8), though the reasons for this distribution were unknown.

Discussion

The information in this report provides a baseline from which future bioassessment data sets for the same sites may be compared. This BMI data set can also contribute to the development of a regional Index of Biological Integrity (IBI) which could be used for evaluating the biological condition of these and other regional stream reaches. Efforts at developing regional IBIs are on-going in various areas of California (DFG 1998) using a modification of the approaches outlined in the EPA's conceptual model for implementation of biological criteria (EPA 1990), the Rapid Bioassessment Protocols (Barbour et al. 1997) and Karr and Chu (1999). Specific elements for developing an IBI are to 1) determine the best time of year or index period for sampling BMIs, 2) determine site classification for streams within the region based on a variety of proven biological metrics, 3) evaluate the biological metrics for their sensitivity to water quality impairment, and 4) incorporate the most appropriate set of biological metrics into a workable IBI. The results of this bioassessment will be discussed in relation to these elements.

Best sampling period
Role of Macroinvertebrate survey in stromwater pollution prevention program
Role of volunteers

Conclusions and Recommendations

Literature Cited

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