Ten-Year Summary of the Monterey Peninsula Water Management District's Bioassessment Program on the Carmel River

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SUMMARY

The Monterey Peninsula Water Management District (District) initiated a monitoring program in the fall of 2000 to help evaluate the water quality and physical habitat conditions of the Carmel River and to establish baseline information that may be used in conjunction with other water quality programs to assess potential effects of future land and water use activities. District staff recognized that monitoring of aquatic benthic macroinvertebrates (BMI) could supplement and complement their ongoing surface water quality sampling program and fisheries management efforts.

The monitoring was conducted using protocols outlined in the California Stream Bioassessment Procedure (CSBP), which is a standardized procedure for characterizing BMI assemblages inhabiting riffle habitat in wadeable streams. Because of BMI abundance, taxonomic diversity and range of response to changes in their aquatic environment, they are commonly used to monitor the quality of surface water resources.

In the fall of 2000, four monitoring sites were established on the Carmel River between Mid-Carmel Valley and below Los Padres Dam. Sampling was continued twice per year in the spring and fall seasons through fall of 2003. In 2002, an additional site was established at the Russell Wells to better evaluate effects of future sediment releases from San Clemente Reservoir. This site was later dropped. In 2004, sampling was restricted to the fall season and a reference site was established above Los Padres Reservoir. An alternative site, Scarlett Well, was sampled on two occasions when low flow conditions prevented sampling at the Red Rock site.

From 2000 to 2003, benthic samples collected from the sites were processed in the laboratory by identifying a random subsample of 300 BMIs from the three samples collected at each site. From 2004 to 2009 the three samples collected at each site were composited and 500 organisms were subsampled. Subsampled organisms were identified to a standard taxonomic level. BMI data prior to 2004 were standardized to 500 organism subsamples and current standard taxonomic effort so that exploratory data analyses could be conducted on the 10-year data set. Biological metrics were used to describe characteristics of the BMI assemblages and a composite of seven metrics was used to generate a regional index of biotic integrity (IBI) to assess site quality as a function of the BMI assemblages that inhabited the sites. In addition, ordination was used to evaluate relative sample similarity as a function of BMI taxonomic composition and to identify relationships between biological and environmental variables.

Carmel River BMI monitoring over the 10-year program period indicated strong and consistent effects of the dam/reservoir systems on downstream BMI assemblage quality as depicted by IBI values with some improvement with increasing distance downstream of the reservoirs. Published literature sources list multiple effects of dam/reservoir systems on downstream benthic fauna, which include altering fluvial processes, allochthonous material transport, flow, water temperature and food supplies. While inconclusive, several factors assessed during the Carmel River Bioassessment Program likely contributed to lowered BMI assemblage quality downstream of the reservoirs. These factors included elevated water temperature downstream of the reservoirs when compared to the upstream reference site and slightly higher average substrate size at sites immediately downstream of the reservoirs. Annual hydrographic data indicated a mostly seasonal pattern of flow through the sites, indicating that the dams do not appreciably alter seasonal flow patterns. Other

causative factors identified in the literature were either not assessed or not adequately quantified due to the constraints of the monitoring procedure. Consequently, alternative monitoring approaches or targeted studies would need to be adopted to gain a clearer understanding of all the factors contributing to compromised BMI assemblages downstream of the reservoirs.

Urbanization effects on Carmel River BMI assemblage quality were of less magnitude when compared to reservoir effects. While periodic accumulations of both natural and anthropogenic organic material have been documented at the lowest elevation Carmel River monitoring site, the level of organic material did not preclude the presence of sensitive BMI taxa, nor did it compromise abundance. Conversely, the lowest elevation monitoring site had the highest BMI abundance and biovolume of all sites probably because of seasonal accumulations of organic matter. Reservoir systems sequester allochthonous organic matter, which may be one factor compromising BMI assemblage quality at sites immediately downstream of the project reservoirs. But reservoir systems can also augment downstream BMI food supplies with plankton as appeared to be the case downstream of Los Padres Reservoir where BMI abundance and biovolume were higher than the upstream reference site.

There were downward trends in BMI assemblage quality over the 10-year monitoring period at two successive sites downstream of San Clemente Reservoir, possibly in response to annual drawdowns of the reservoir. There were no upward or downward trends in BMI assemblage quality at the other sites throughout the monitoring period. However, there was a large magnitude decline in BMI assemblage quality at the reference site in 2007 during a critically dry water year. Full recovery occurred the following years despite the Basin Complex Fire in the Los Padres Wilderness, which occurred in the summer of 2008. The Sleepy Hollow Steelhead Rearing Facility's rearing channel had similar BMI assemblage quality compared to the two sites immediately downstream of the reservoirs. While there were seasonal influences on BMI taxonomic composition, index of biotic integrity values were minimally affected by season. This result is important with regard to future program planning because it allows some flexibility in the sampling window. A late spring or early summer sampling window is being recommended for central coast bioassessment projects.

A published literature source indicated that the dominant BMI taxa sampled from the Carmel River provide readily available food resources for salmonid populations. These taxa include baetid mayflies, black flies, and midges.

Instream and riparian habitat quality at the monitoring sites were generally good as determined by qualitative assessments outlined in the monitoring procedure. Instantaneous water quality constituents (temperature, pH, dissolved oxygen and specific conductance) measured during the monitoring period fell within ranges typical for the region.

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1.0 INTRODUCTION

1.1 District Background

In 1977, the Monterey Peninsula Water Management District (District) was created by the California State Legislature. A major finding of the Legislature was that water problems in the area required integrated management. The Legislature concluded that there was a need for conserving and augmenting ground and surface water supplies, for control and conservation of storm and waste water, and for the promotion of reuse and reclamation of water. In addition, it was mandated that the District would promote endeavors to conserve and foster scenic values, environmental quality, native vegetation, fish and wildlife.

The District and its contractors have produced numerous studies of water supply alternatives and their effects on stream flow and steelhead (Kelly, D.W. & D.H. Dettman, 1981, 1982, 1983). In 1989, the District hired a full-time fisheries biologist to help manage water resources to maintain and improve conditions for steelhead (*Oncorhynchus mykiss*). Subsequently, two additional full-time fisheries positions were created, and seasonal aids were hired to assist with fisheries-related tasks. Among other responsibilities, fishery personnel regularly monitor surface water quality parameters that affect steelhead (i.e., dissolved oxygen, carbon dioxide and temperature) at stations along the Carmel River. Other staff and contractors monitor the effects of water production on the status of riparian and wetland vegetation along the river. However, other than an investigation of the feeding requirements of steelhead on the Carmel River (Fields, 1984), there was limited information available about the aquatic invertebrates until the District implemented a Carmel River Bioassessment Program (CRBP) in the year 2000.

1.2 Physical Setting

The Carmel River is approximately 36 miles long, originating in the Santa Lucia Range between 4,500 and 5,000 feet above sea level and discharging into Carmel Bay just south of the City of Carmel-by-the-Sea. The river and its tributaries drain a watershed of approximately 255 square miles (**Figure 1**). According to the United States Forest Service, most of the watershed is located within ecological unit and subsection 261Aj, referred to as the North Coastal Santa Lucia Range, with a small portion of the upper watershed in subsection M262Ae, the interior Santa Lucia Range. Physical and biological characteristics of these subsections are described in detail at (http://www.fs.fed.us/r5/projects/ecoregions/261aj.htm). All of the bioassessment sites on the Carmel River that are discussed in this report are located in subsection 261Aj. The highest elevation site is near the boundary of the two ecological subsections.

California American Water (CAW) has been maintaining rainfall records at San Clemente Reservoir, located at River Mile 18.6 (measured upstream from the mouth of the river at Carmel Bay), since 1922. Based on CAW's records, District staff calculated the mean annual rainfall (measured from October 1 through September 30) to be 21.37 inches, with a maximum of 46.29 inches in 1998 and a minimum of 8.87 inches in 1924. A mean of 69,001 acre-feet of unimpaired flow in the Carmel River at the same site has been calculated from records of the United States Geological Survey and CAW going back to 1902, with a maximum of 318,987 acre-feet in 1983, and a minimum of 2,855 acre-feet in 1977.

CAW owns and operates two dams on the river, at River Mile 24.8 and 18.6. CAW also operates 16 wells that draw water from the alluvial deposits of the river below River Mile 18. There are also more than 288 private wells that drew approximately 2,300 acre-feet from the Carmel Valley alluvial aquifer in Water Year 2009 (October 1, 2008 through September 30, 2009). The river and alluvial aquifer are the primary source of water for cities on the Monterey Peninsula (Carmel, Del Rey Oaks, Monterey, Pacific Grove, Sand City, Seaside and unincorporated areas within Monterey County such as Pebble Beach and Carmel Valley Village). An Order from the State Water Resources Control Board has directed CAW to reduce production from its Carmel River system sources and rely more heavily on water from the Seaside Coastal Basin since 1995. In Water Year 2009, CAW reported over 10,400 acre-feet of water was produced from its wells in the alluvial aquifer. Carmel Valley itself is relatively developed, in recent years moving toward a more suburban than rural character, especially downstream of River Mile 15.

1.3 Implementation of the District's Bioassessment Program

In 1997, the United States Environmental Protection Agency (EPA) developed a Rapid Bioassessment Protocol that used benthic macroinvertebrates (BMI) as indicators of stream health. In 1999, the California Department of Fish and Game (CDFG) approved the California Stream Bioassessment Procedure (CSBP) based on the EPA protocol (Harrington 1999). CDFG has recommended the use of bioassessment techniques for determining the condition of streams. Further, monitoring of BMI using the CSBP has been required by the State Water Resources Control Board - Division of Water Quality, and Regional Water Quality Boards for NPDES (National Pollutant Discharge Elimination System) discharge permits, enforcement cases, storm water discharge, and for Agricultural and Timber Harvest Waivers.

District staff recognized that monitoring of BMI could supplement and complement their ongoing surface water quality sampling. Reasons cited to implement a BMI monitoring program (Peckarsky 1997) include:

- BMI are relatively easy to collect and identify
- BMI have cosmopolitan distribution (are present in a wide variety of habitats).
- BMI have a diversity of species that are responsive to conditions ranging from healthy to degraded
- BMI are abundant enough that reasonable sampling does not deplete the overall population
- Many BMI have well-documented natural histories and tolerances to environmental conditions
- Many BMI have limited mobility, so they do not move in and out of habitats seasonally, or in response to degradation
- Some BMI are relatively long-lived, so chronic degradation can be detected.

Conventional water quality programs focus on chemical contamination, but degradation often stems from other factors, such as sedimentation. In some cases, BMI provide a more effective analytical tool. District staff also recognized that they had primarily been managing the watershed for a single species (i.e., steelhead), but individual species do not thrive outside of a sustaining biological context. In June 2004 a three-year bioassessment report was prepared with the following objectives:

- Document biological integrity of the Carmel River using BMI assemblages at selected stream locations;
- Consolidate existing BMI data and associated information for the Carmel River;
- Establish a baseline data set using a standardized procedure from which future biological assessments may be compared;
- Contribute data to a Monterey region-wide data set intended to characterize watershed health and development of an Index of Biological Integrity.

This bioassessment report includes 10 years of bioassessment data from years 2000 to 2009 and supplements the previous 2004 bioassessment report with several new components:

1. a reference site was established in 2004 upstream of Los Padres Reservoir, which provided needed perspective for evaluating biotic integrity across monitoring sites,
2. an index of biotic integrity (IBI) was published by Ode et al. in 2005, which was applied to all BMI data collected for each sampling event for the CRBP. The IBI provided an empirical assessment of CRBP sites and produces a single biotic variable that facilitates the assessment of monitoring site quality through time and space,
3. an ordination technique was applied to the 10-year data set to gain further insight into taxonomic composition potentially influenced by sample type, season (spring and fall), and environmental variables, and
4. an estimate of BMI biovolume was added in 2005 to supplement BMI abundance estimates.

1.4 Historical Information

A literature review of historical information regarding BMI assemblages in the Carmel River and nearby drainages was conducted, and the results are summarized below.

<u>Spatial Distribution of Invertebrates in Carmel Lagoon, Carmel, California</u>
Thomas Evan De Lay prepared a paper as part of a Bachelor of Science Degree through the CSU, Monterey Bay that described substrate complex preferences for a variety of invertebrates in the Carmel Lagoon. Several of the invertebrates are known to be important food resources for the federally threatened Central-California Coast Steelhead (*Oncorhynchus mykiss*). De Lay found that *Neomysis* (mysid shrimp) was more abundant among sandy substrates with grass; *Eogammarus* (amphipod or scud) was more abundant among fine sand with mud, coarse particulate organic matter (CPOM) with mud and sand substrate with grass. *Corophium* (amphipod or scud) was more abundant among CPOM with mud and sandy substrate with grass. De Lay emphasized that identifying spatial patterns of epibenthic invertebrates among the different substrate types will allow for more efficient management to commence and therefore provide optimal habitat conditions for the food sources of steelhead.

<u>The Life History Demographics of *Corophium spinicorne* in the Carmel River Lagoon</u>
Jessica Watson prepared a paper as part of a Bachelor of Science Degree through the CSU, Monterey Bay that described life history demographics of the amphipod *Corophium spinicorne* in the Carmel Lagoon in 2007. The importance of this species as a food resource for the federally threatened

Central-California Coast Steelhead (*Oncorhynchus mykiss*) was previously established. Significant changes in length or abundance of *C. spincorne* were not evident during the four month duration of the study. There was evidence of a synchronous reproductive cycle perhaps associated with the lunar cycle and that there was higher *C. spinicorne* abundance in sandy substrates when compared to other substrate types. *C. spinicorne* abundance did not appear to be related to variation in basic water quality constituents. Watson suggested that subtle changes in bottom habitat may have the strongest effect on *C. spinicorne* populations, which confounded the focus of the life history emphasis of the study. A follow-up study described above supports Watson's observation that sandy bottomed substrate is preferred habitat for *C. spinicorne*.

<u>Central Coast Ambient Water Quality Monitoring Program, Carmel River</u>
The Central Coast Regional Water Quality Control Board (RWQCB) collected and processed benthic samples using the CSBP from two sites on the Carmel River in the spring season from 2001 to 2004 as part of its Central Coast Ambient Water Quality Monitoring Program (CCAMP). In 2005 CCAMP used the Surface Water Ambient Monitoring Program (SWAMP) sampling method but not the targeted riffle component. In 2007 CCAMP used the SWAMP sampling method including the targeted riffle component. Samples were collected from sites located from the Carmel River at the Highway 1 road crossing and at river mile 14.5 at Esquiline Road. BMI data from riffle habitat from the CCAMP Carmel River sites were compared with BMI data compiled for the District's Bioassessment Program, results of which are described in Section 3.4.

<u>Coastal Lagoons Biomonitoring Project</u>
As part of its ambient water quality monitoring program, the RWQCB developed its CCAMP to assess the water quality at the confluence of freshwater streams within the central California coast region. In September 2001, the CDFG's Aquatic Bioassessment Laboratory participated in this effort by conducting a pilot study to evaluate the utility of BMI bioassessment for monitoring water quality in these coastal lagoon environments. The objectives of the pilot study were to determine a chemical contaminant gradient for fourteen coastal lagoons; collect BMI samples using a standardized procedure to determine a biological gradient; assess whether the biological gradient correlated with the contaminant gradient; and provide recommendation for incorporating biological assessment data into the Coastal Confluence Monitoring and Assessment Program.

For each of the fourteen lagoon sites, biological metrics (numerical attributes of BMI assemblages) were integrated into a site score, which provided a relative assessment of site quality as a function of BMI assemblage quality. Also, organic chemical constituents (pesticides and PCBs) extracted from sampled sediments at the fourteen lagoon sites were analyzed. Resultant organic chemical values were integrated into a mean Sediment Quality Guideline Quotient (SQGQ). Results of the biological and chemical integrative indices were plotted to explore possible relationships.

One of the fourteen sites was located at the mouth of the Carmel River. The BMI metric site score for the Carmel River lagoon site was above average when compared to the other sites; five sites ranked higher and eight sites ranked lower than the Carmel River lagoon site. The SQGQ determined for the Carmel River lagoon site was lowest when compared to the SQGQs determined for the other lagoon sediment samples. This indicates that the Carmel River lagoon site had the lowest levels of pesticide and PCB values associated with sediment when compared to the other sites. Because there was not a strong relationship determined for biological metric scores and SQGQs, the authors of the study suggested that factors associated with local habitat condition may have had a stronger influence on biological metric scores.

Numerically dominant BMI taxa sampled from the Carmel River lagoon included (in order of decreasing numerical dominance): *Corophium* (amphipod or scud), Gnorimosphaeroma (intertidal pill bug), Cyprididae (ostracod or seep shrimp), *Gammarus* (amphipod or scud) and Oligochaeta (segmented worm).

Pajaro River Biological/Physical Habitat Assessment

The Pajaro River watershed drains approximately 1,270 square miles and discharges into Monterey Bay approximately 25 miles north of the outlet of the Carmel River. In 1997, the RWQCB, with assistance from the Association of Monterey Bay Area Governments initiated an ambient water quality monitoring program in the Pajaro River watershed. The objective of the program is to evaluate the chemical, biological and physical habitat in surface waters in seven tributaries and the Pajaro River mainstem. To date, one compiled report was available for review, which provided information on the biological assessment component of the program (CDFG, unpublished). Biological and habitat assessments were conducted by the CDFG's Aquatic Bioassessment Laboratory using the CSBP in April 1998 and results compiled into a report (unpublished).

Results of the biological assessment indicated substantial variability in site quality based on the BMI assemblages. Two tributary sites with high-ranking habitat quality also had the highest quality BMI assemblages as determined by integrating several biological metrics. BMI assemblages at all other sites ranked average or below average when compared to the two high quality tributary sites. One factor, which may have contributed to the dissimilar quality of BMI assemblages was the wide range of substrate composition at the sites; notably the sandy, transitory substrate in the larger river system sites including the Pajaro River and San Benito River.

Invertebrate Fauna of the Carmel River System

As part of an assessment of the Carmel River steelhead resource, a report by Hydrozoology (Fields 1984) was prepared for the District. Fields' report on the Carmel River comprised elements associated with BMI including:

1. benthic sampling (March and May) and diel drift on the lower river,
2. terrestrial drift in open versus canopied stream reaches,
3. benthic sampling on the river reach and tributaries between the San Clemente and Los Padres reservoirs,
4. food habits of trout in San Clemente and Los Padres Reservoirs, and
5. food habits of steelhead for various river reaches including the lagoon.

For element 1 above, black fly and midge larvae were the most numerically dominant BMI groups for both months but the benthic fauna was less diverse with fewer individuals in March than benthic fauna sampled in May. Although the mayfly *Baetis tricaudatus* was common in March, their abundance in May was much greater. In March, average BMI density at the sites was 1,800 BMI per m^2 (range 510 to 3,000); in May, average BMI density was 3,300 (range 620 to 5,500). There were fewer differences in abundance and composition of benthic fauna in March and May samples at sites where the substrate was relatively stable. Diel drift was highest in areas where substrate consisted of gravel and cobble and was considerably lower in areas dominated by sand substrate. Chironomids, simuliids, baetid mayflies and oligochaetes comprised over 93 percent of drifting organisms.

For element 2 above, contribution of terrestrial organisms to drift as a food resource for steelhead was considerably higher (numerical abundance and biovolume) in canopied river reaches when compared to river reaches with no or little canopy cover.

For element 3 above, Fields reported the BMI assemblages of Pine Creek to be the most diverse and attributed the high diversity to the "unperturbed" condition of the site where samples were collected. Fields also found that while there was ample BMI drift downstream of San Clemente Reservoir, species diversity was low and almost all the food available as drift to steelhead consisted of black fly larvae.

For element 4 above, Fields found that trout inhabiting both San Clemente and Los Padres Reservoirs fed on invertebrates from three sources, in order of decreasing relative importance: riverine, lucustrine and terrestrial. By far, the terrestrial component was the least important food source to trout. Of the lucustrine food source, benthic invertebrates were more important than planktonic invertebrates.

2.0 METHODS

2.1 Monitoring Sites

To optimize time and budget constraints, originally only four sites were established by District staff. In fall of 2000, four monitoring sites on the Carmel River were chosen to conduct the CRBP. An additional site at the Sleepy Hollow Steelhead Rearing Facility's (SHSRF) rearing channel (SHRC) was sampled three times during the monitoring period. In 2004 a site was added upstream of Los Padres Reservoir (CRLP) and a site (CRSW) approximately one river mile upstream of site CRRR was added as an alternative to site CRRR during conditions of inadequate flow for sampling. A summary of all BMI sites monitored by the District is provided in **Table 1** where "B" indicates that benthic samples were collected and "H" indicates that a site scale habitat assessment was performed using the parameters shown in **Appendix A**. Site CRDD was sampled using a point-source design as part of a separate project, which precludes a site scale habitat assessment.

The sites are shown in **Figure 1**, along with the approximate locations of three of the District's streamflow gaging stations. Flow data for those stations, Below Los Padres (BLP), Sleepy Hollow Weir (SHW) and Don Juan Bridge (DJB) are provided in **Appendix I** along with continuous water temperature data monitored at three sites, upstream of Los Padres Reservoir, and downstream of Los Padres and San Clemente reservoirs. The four original invertebrate sampling sites were selected because they corresponded to established juvenile steelhead population survey sites and they were representative of most reaches of the Carmel River. Reaches farther downstream have lower gradients, a higher percentage of sand and fines, and frequently dry up during the dry season in response to pumping and low flows. The CRRW site was added in 2002 to determine if detrimental effects were occurring as a result of the operation of the District's SHSRF, and to better detect effects of sedimentation from Tularcitos Creek. This site may also provide information on the effects of sedimentation and turbidity associated with the annual lowering of the water surface elevation of San Clemente Reservoir, which began in June 2003, in response to an order from the California Department of Water Resources, Division of Safety of Dams.

Site locations are summarized below:

- Los Padres – CRLP: upstream of Los Padres Reservoir;
- Cachagua - CRCA: between Los Padres Dam and Cachagua Creek;
- Sleepy Hollow - CRSH: about one mile downstream from San Clemente Dam, immediately above the SHSRF intake pumps;
- Sleepy Hollow Rearing Channel - SHRC: artificial off-channel steelhead rearing facility (sampled three times);
- Russell Wells - CRRW: added in 2002, between Sleepy Hollow and Stonepine;
- Stonepine - CRSP: just below confluence with Tularcitos Creek;
- DeDampierre - CRDD: sampled once in Spring 2001, prior to a restoration project that installed large-woody debris in channel;
- Scarlett Well – CRSW: alternate site sampled twice when the CRRR site was dry; and
- Red Rock - CRRR: Mid-Valley, below the Narrows; channel dries up here some years.

Table 1. Carmel River monitoring locations including year of sampling for benthic macroinvertebrates (B) and habitat assessment (H). Fall season unless indicated otherwise.

	Monitoring Sites							Other Sites	
Site Name	Los Padres	Cachagua	Sleepy Hollow	Russell Wells	Stonepine	Scarlett Well	Red Rock	DeDampierre	Sleepy Hollow Rearing Channel
Site Code	CRLP	CRCA	CRSH	CRRW	CRSP	CRSW	CRRR	CRDD	SHRC
River Mile	26.0	23.5	17.6	16.2	15.7	8.9	7.7	13.9	17.5
Site Elev. (ft)	1,100	820	380	360	280	200	110	250	400
2000		BH	BH		BH		BH		BH
2001 spring		BH	BH		BH		BH	B	
2001		BH	BH		BH		BH		
2002 spring		BH	BH		BH		BH		
2002		BH	BH	BH	BH		BH		
2003 spring		BH	BH	BH	BH		BH		
2003		BH	BH	BH	BH		BH		
2004	BH	BH	BH		BH		BH		BH
2005	BH	BH	BH		BH		BH		
2006	BH	BH	BH		BH		BH		
2007	BH	BH	BH		BH	BH			
2008	BH	BH	BH		BH	BH			BH
2009	BH	BH	BH		BH		BH		

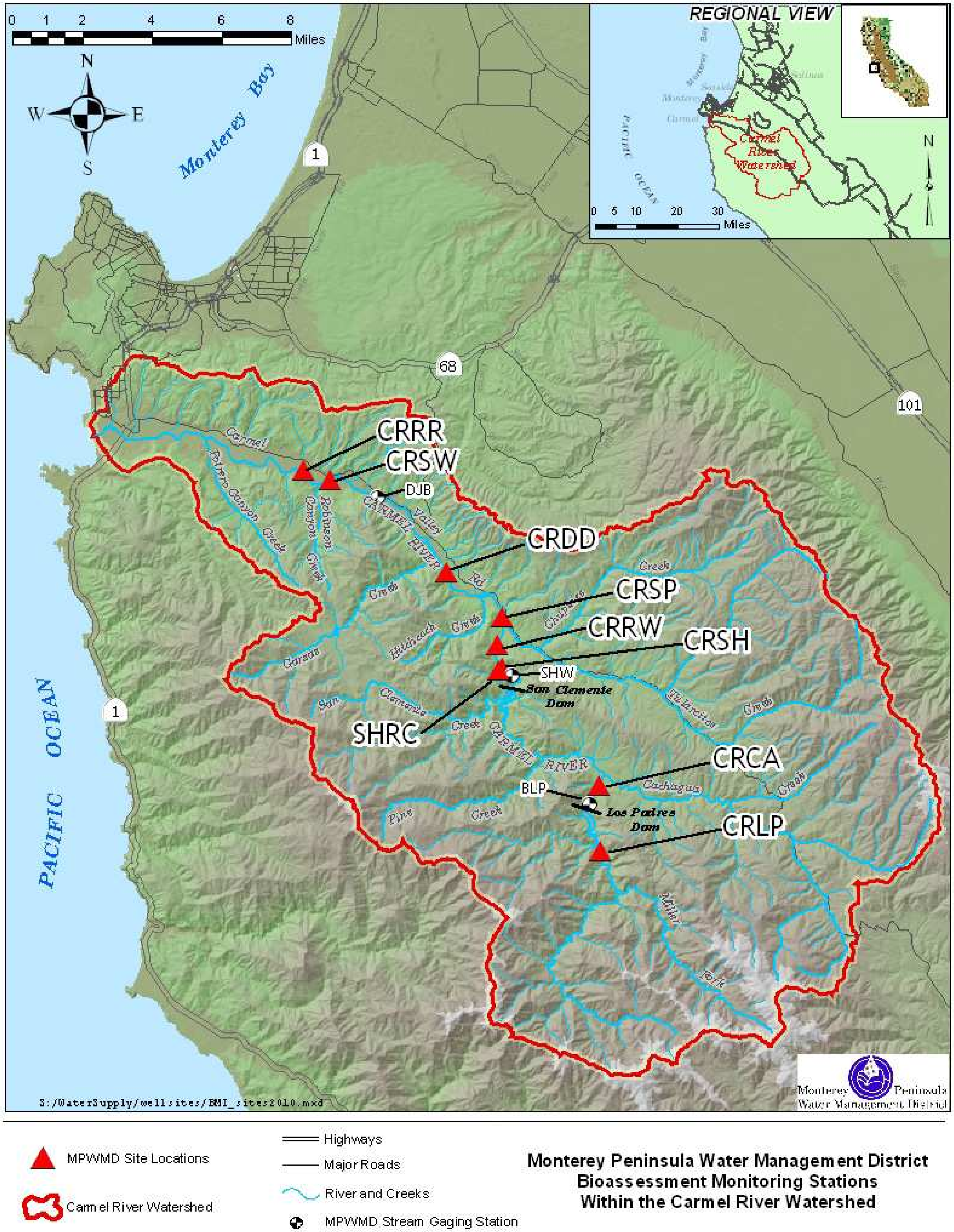

Figure 1. Benthic macroinvertebrate sampling stations in the Carmel River system.

2.2 Benthic Sampling

The non-point source portion of the CSBP was applied to this monitoring effort for documenting and describing BMI assemblages and physical habitat within the selected sites. The non-point sampling strategy is used to monitor general conditions along a stream segment or watershed where potential perturbations are diffuse and of variable magnitude. In contrast, the point source sampling strategy is used to assess changes in BMI assemblages upstream and downstream of a specific location where a potential perturbation, such as a storm drain, could affect water quality condition of the receiving stream. For both sampling strategies, a targeted riffle approach is used as specified in the CSBP.

The sampling strategy used for the CRBP is described as follows. Each sample reach consisted of riffle habitat units of varying number. Three riffles were randomly chosen for sampling when possible but for some sites with fewer than three riffles, samples were collected from different sections of the same riffle. Three subsamples were collected along a transect established perpendicular to the current, one near each bank, and a third near the thalweg. Samples collected from the three distinct riffles or riffle areas comprised the total samples for each site during each monitoring event.

Benthic samples were collected by rubbing cobble and boulder substrates and disturbing finer substrates for 90 seconds within a 2 square foot (sq. ft.) area upstream of a D-frame kicknet fitted with a 0.5 mm mesh net. The total area sampled per transect was 6 sq. ft. Each sample was transferred to a plastic jar, preserved with 95 percent ethanol and labeled. At each transect, where benthic samples were collected, several local habitat parameters were assessed including substrate composition, percent canopy, average stream velocity, average water depth and riffle gradient (**Appendix A**). A substrate index was developed where each composite benthic sample was collected from riffle habitat. The substrate index was calculated as a weighted mean midpoint substrate size as described by Quinn and Hickey (1990). The following categories were used to classify substrate: sand/fines (<2 mm) gravel (2-64 mm), cobble (64-256 mm), boulder (256-330 mm) and bedrock. Bedrock was assigned a nominal size of 400 mm (Quinn and Hickey 1990).

2.3 Habitat and Water Quality Assessment

At each site, physical characteristics of the riparian zone were documented using the CDFG's Aquatic Biological Laboratory's Physical/Habitat field Data Sheet (May 1999 revision), which in turn is based on the US EPA's Rapid Bioassessment Protocols for high gradient streams (Barbour et al. 1999). Criteria for scoring the habitat parameters are shown in **Appendix A**. In addition, sites were photographed and water quality measurements recorded. Dissolved oxygen, pH and temperature were measured using either a Hach test kit or YSI 85 multi-meter. Specific conductance was measured with a calibrated Cole-Parmer TDSTestr, model 20, and YSI 85 multi-meter, which were calibrated prior to the sampling trip and checked daily.

2.4 Sample Processing and Data Analysis

Samples were processed according to a standard level of analysis as per the California Stream Bioassessment Procedure. At the laboratory, each sample was rinsed in a standard no. 35 sieve (0.5 mm) and transferred to a tray with twenty, 4 in.^{2} (25 cm^2) grids for subsampling. Benthic material in the subsampling tray was transferred from randomly selected grids (or half grids if BMI densities were high) to Petri dishes where the BMIs were removed systematically with the aid of a stereomicroscope and placed in vials containing 70 percent ethanol and 30 percent water. From 2000 to 2003, at least 300 BMIs were subsampled from a minimum of three grids. If there were more BMIs remaining in the last grid after 300 were archived, then the remaining BMIs were tallied and archived in a separate vial. This was done to assure a reasonably accurate estimate of BMI abundance based on the portion of benthos in the tray that was subsampled. These "extra" BMIs were not included in the taxonomic lists and metric calculations. From 2004 to 2009 the three samples collected at each site were composited at the laboratory and 500 (±5%) organisms were subsampled. This latter procedure change was consistent with the methods outlined in the 2003 version of the CSBP.

Starting in 2005, the subsampling procedure was supplemented to accommodate an estimate of BMI biovolume. Biovolume measurements were made by calculating the volume of liquid displaced by the subsampled BMIs from each sample prior to sorting by taxon. Subsampled BMIs were transferred to a 35% ethanol solution prior to volumetric displacement measurements. Surface liquid was removed from the BMIs using blotting paper after the BMIs were transferred to a 5.0 ml graduated cylinder. The blotting paper was rolled into a cylinder of suitable diameter to facilitate insertion into the graduated cylinder to the level of the BMIs. The graduated cylinder was then inverted to facilitate the wicking effect of the blotting paper. The endpoint of removing surface liquid from the BMIs occurred when the wicking action of the blotting paper ceased. A 35% ethanol solution was dispensed from a 10 ml capacity burette to the graduated cylinder to the 5.0 ml mark. The volume of organisms was determined by subtracting the volume of liquid/organism mixture contained in the graduated cylinder (5.0 mls) from the volume of liquid dispensed from the burette. For example, if 3.2 mls of ethanol solution were dispensed from the burette to fill the 5.0 ml graduated cylinder, then the volume of the BMIs was 1.8 mls. After biovolume measurements, the BMIs were preserved in an 80% ethanol, and 20% water solution. BMI volume of the sample was then estimated and reported as mls per m^2 of benthos sampled.

Subsampled BMIs were identified using taxonomic keys (Merritt and Cummins 1996; Stewart and Stark 1993; Thorp and Covich 2001 and Wiggins 1996) and unpublished references. A standard level of taxonomic effort was used as specified in the California Aquatic Macroinvertebrate Laboratory Network (CAMLnet, http://www.nps.gov/yose/naturescience/upload/Macroinvertebrates.2003.pdf) short list of taxonomic effort, January 2003 revision and the Southwest Association of Freshwater Invertebrate Taxonomists (SAFIT, http://www.safit.org/). Exceptions were made for some early instar organisms and organisms in poor condition. Other exceptions included the identification of midges to subfamily/tribe. The subsampled BMIs identified from each sample were archived in labeled vials with a mixture of 70 percent ethanol and 30 percent water.

2.4.1 Macroinvertebrate Metrics

BMI taxa and the number of BMIs comprising each taxonomic group were entered into a Microsoft Access® database. Database queries generated taxonomic lists which were transferred to a spreadsheet program where a suite of biological metrics was calculated. Data sets from year 2000 to year 2003 consisted of three samples of 300 organisms each, resulting in a 900 organism subsample for each site. Since the current protocol yields a 500 organism subsample for each site, the 900 organism subsamples were reduced to 500 organisms for the purpose of equalizing processing effort. Two methods were used to standardize the data set consisting of 900 organism subsamples. First, for presentation of taxonomic lists, 900 organism subsamples were reduced to 500 organisms by proportion to avoid loss of taxa. The second method was applied to the original taxonomic list for metric calculations and consisted of converting 900 organism subsamples to 500 organisms using software that resampled the data without replacement. This latter resampling technique resulted in the probability of lost taxa but was necessary so that metrics associated with richness could be compared for all years using the same subsample size of 500 organisms. Richness metrics are influenced by subsample size and are part of the suite of metrics used in the application of indices of biotic integrity (Section 2.4.2). It is therefore necessary to apply an equal subsampling effort across all sample units when indices of biotic integrity are used.

Biological metrics provide numerical attributes of biotic assemblages and are described in **Appendix B**. Tolerance values and functional feeding group designations were obtained from the California Macroinvertebrate Laboratory network (CAMLnet) short list of taxonomic effort, January 2003 revision. The SAFIT, which replaced CAMLnet in 2006, is a network of professional taxonomists that conducts taxonomic workshops and establishes standard taxonomic effort guidelines. Where possible, all taxa identified for the CRBP were standardized to the SAFIT level 1 standard taxonomic effort. Biological metric values were tabulated by sample and summarized at the project scale and sample scale.

The various metrics can be categorized into five main types:

- Richness Measures (reflects one component of diversity);
- Composition Measures (reflects the distribution of individuals among the taxonomic groups);
- Tolerance/Intolerance Measures (reflects the relative sensitivity of the assemblage to disturbance);
- Functional Feeding Groups (shows the balance of feeding strategies in the aquatic assemblage);
- Abundance and biovolume (estimate of total number and volumetric displacement of organisms in a sample based on the area sampled)

2.4.2 Index of Biotic Integrity

To assess the biological integrity of the sites, the coastal southern California index of biotic integrity (IBI) (Ode et al. 2005) was applied to the 10-year data set. Development of the IBI included the screening and testing of 61 possible metrics from 275 sites exhibiting a wide range of condition, from reference sites to severely impaired sites. Seven metrics were selected and were scored and combined into a composite index. The objectives of a regional IBI are to incorporate metrics that measure distinct attributes of the BMI assemblage, and are responsive to stressor gradients while maintaining a high signal-to-noise ratio. The spatial extent of the coastal southern California IBI includes the Carmel River watershed (Ode et al. 2005).

The seven metrics used to develop the IBI are:

1. Coleoptera (beetle) taxa
2. EPT [Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly)] taxa

3. Predator taxa
4. Percent collector individuals
5. Percent intolerant individuals
6. Percent non-insect taxa
7. Percent tolerant taxa

The product of the IBI yields scores and narrative descriptions of biotic integrity as follows: 0 to 19 (very poor), 20 to 39 (poor), 40 to 59 (fair), 60 to 79 (good), and 80 to 100 (very good). The IBI values generated for the CRBP were used as a primary biological signal to assess site quality and to explore interactions with other variables relating to physical habitat and other factors such as seasonal differences.

2.4.3 Ordination

Nonmetric multidimensional scaling (NMS) ordination was used to evaluate relative similarity of samples based on BMI taxonomic composition. Unlike other ordination methods that require normal data distributions, NMS ordination is based on ranked distances, which make it suitable for ecological data that are often not normally distributed nor measured on continuous scales (McCune and Grace 2002). The output of NMS is a plot, which shows sample units oriented in relative space along one or more ordination axes where the distance between the samples increases with increasing taxonomic dissimilarity. In addition, quantitative environmental variables can be included as an overlay of lines (termed 'joint plot') radiating from the center of the graph, with each line indicating both the direction and strength of correlation with the graph axes. The graph axes represent the unit-less numeric 'scores' generated during the 12-step ordination procedure that orients the sample units along the graph axes based on relative taxonomic dissimilarity. The numeric 'scores' are used for correlation with quantitative environmental variables (section 2.4.4). In addition, the application of categorical variables can be used to identify ecologically meaningful site groupings. While NMS consists of many steps involving complex mathematical algorithms, the output is visually straightforward and is useful for screening multiple variables for relationships, identifying patterns in ecological data and summarizing results in graphical formats. For additional information on NMS applications and procedures see McCune and Grace (2002), Clarke (1993), and Mather (1976).

PC-ORD® version 5 software (McCune and Mefford 2006) was used to perform NMS in "autopilot mode", utilizing the "slow and thorough" setting (500 iterations) and the Sorensen (Bray-Curtis) distance measure. Plots of stress versus iteration (scree plots) were evaluated to assure that improvement in fit was achieved with added dimensions and exceeded a cumulative coefficient of determination of 0.6.

2.4.4 Analyses

Data analyses were primarily exploratory, utilizing graphics and tables of pertinent summary information, with the objective of revealing patterns in biological data across sites and their relationships with environmental variables. Hypothesis testing was used in some cases to detect significant differences but these analyses should be considered with caution because a priori hypotheses were not developed as part of the CRBP and budget constraints limited sample sizes. Sample size limitations were partially overcome by combining samples from sites in close proximity:

samples from site CRRW were combined with samples from CRSP and samples from CRSW were combined with samples from CRRR.

Statistical analyses included the application of the non-parametric Wilcoxon paired sample test to evaluate significant seasonal effects on IBI, EPT taxa, and Predator taxa values for the time period between 2001 and 2003 when both spring and fall samples were collected. One-factor analysis of variance (ANOVA) was used to test for significant differences in log transformed abundance and biovolume data across sites. The non-parametric alternative to ANOVA, Kruskal-Wallis, was applied when assumptions of normal data distributions and homogeneity of variance were not met. Pearson correlations were used to test for significant increases or decreases in IBI values at the monitoring sites through the 10-year monitoring period.

NMS ordination was applied to the CRBP data set for examining potential effects of categorical and quantitative environmental variables on taxonomic composition. Categorical variables included seasonality of sampling (spring and fall), sample type (reference and non-reference), year of sampling, and water-year type. Quantitative variables included elevation, total habitat score, gradient, canopy, substrate index, substrate classes, water temperature and specific conductance. The IBI values were included as a quantitative biological variable. A threshold coefficient of determination of 0.20 was used to screen quantitative variables for the joint plot; coefficient of determination values less than 0.20 were excluded from the joint plot. Numbers of organisms comprising each taxon and quantitative environmental variables were log transformed prior to running ordination.

The RWQCB, in association with the CDFG, collected and processed benthic samples using the CSBP from sites on the Carmel River from 2001 to 2004, and again in 2007. The sites were located near the mouth of the Carmel River at the Highway 1 crossing and at river mile 14.5 at Esquiline Road. BMI data were obtained through the CCAMP. IBIs were calculated for the CCAMP sites after standardizing subsample size to 500 organisms when necessary.

Methods employed by Fields (1984) in the spring season of 1982 for characterizing BMI fauna of the Carmel River were evaluated for applicability to methods used for this current monitoring program. Factors considered for data set compatibility included sampling sites, sampling method and sample processing method including standard taxonomic level.

3.0 RESULTS

3.1 Benthic Macroinvertebrates

The ten-year CRBP yielded a total of 133 samples from which 46,378 BMIs were processed. After site compositing and standardization of subsample size, 66 composite samples were generated comprising 111 total taxa, 42 EPT taxa, 13 mayfly taxa, six stonefly taxa, 23 caddisfly taxa, and 14 beetle taxa (**Table 2**). Tolerance and Shannon Diversity for the pooled samples were 5.1 and 2.7, respectively. Median sample taxa richness was 21 (range 13 - 41), median EPT richness was 7 (range 4 – 22), median mayfly richness was 2 (range 1 – 9), median stonefly richness was 0 (range 0 – 6), median caddisfly richness was 5 (range 2 – 12), and median beetle richness was 1 (range 0 – 5).

Median tolerance of the samples was 5.4 (range 2.0 – 6.3) and median sample Shannon Diversity was 2.0 (range 1.1 – 2.9).

A project taxa list indicating California Tolerance Values (CTV) and Functional Feeding Group designations is shown in **Appendix C**; annual taxonomic lists are shown in **Appendix D**. Biological metric values are presented by sample in **Appendix E**.

Table 2. Commonly reported biological metric values including cumulative project totals and sample statistics for the Carmel River Bioassessment Program.

Metric*	Project Totals	Project Statistics (n=66 samples) Median	Minimum	Maximum
Taxa Richness	111	21	13	41
EPT Taxa	42	7	4	22
Ephemeroptera (mayfly) Taxa	13	2	1	9
Plecoptera (stonefly) Taxa	6	0	0	6
Trichoptera (caddisfly) Taxa	23	5	2	12
Coleoptera (beetle) Taxa	14	1	0	5
Tolerance Value	5.1	5.4	2.0	6.3
Shannon Diversity	2.7	2.0	1.1	2.9

*Based on site composites from riffle habitat, 500 organism subsamples, and SAFIT level 1 standard taxonomic effort.

3.1.1 Index of Biotic Integrity

The index of biotic integrity (IBI) values for the monitoring sites and for the Sleepy Hollow Rearing Channel are shown in **Figure 2**. IBI values for all sample units downstream of the CRLP reference site fell below the average reference site IBI value. Reference site IBI values ranged from 51 (fair) to 92 (very good) and averaged 78 (good). The reference site IBI value that fell within the fair category was likely due to a critically dry condition in 2007, when river flow was low (**Appendix I**) and black flies comprised 58 percent of the BMIs sampled. Also noteworthy was the relatively high IBI value (89) documented in 2009 despite the Basin Complex Fire in the Los Padres Wilderness, which occurred in the summer of 2008.

The lowest average IBI value (29) occurred at site CRRW and the second lowest average IBI value (31) occurred at sites immediately downstream of the reservoir systems. One sample collected from site CRCA fell within the very poor range of the IBI, and all other values for site CRCA fell within the poor range of the IBI. There was more variability in IBI values at site CRSH when compared to site CRCA, with two values in the fair range of the IBI and two values within the very poor range of the IBI. The average IBI value for the Sleepy Hollow Rearing Channel site was 34, which is within the poor range of the IBI. Site SHRC is a manufactured channel augmented with gravel for the purpose of rearing steelhead but the IBI values were not appreciably different from the sites upstream (CRCA) and downstream (CRSH).

If reservoir/dam effects were contributing to poor IBI values for sites CRCA, CRSH, and CRRW, these effects may have been attenuated at the two sites furthest downstream where average IBI values were higher. IBI values for sites CRSP and CRSW/CRRR averaged 37 and 49, respectively, values approaching and falling within the fair range of the IBI. Note that sites CRSW and CRRR were combined due to their close proximity to each other. IBI values for site CRSP were highly variable ranging from 17 (very poor) in the fall of 2005 to 60 (good) in one sample collected in the spring of 2001. IBI values for the CRSW/CRRR site complex were less variable, nearly all values falling within the fair range of the IBI.

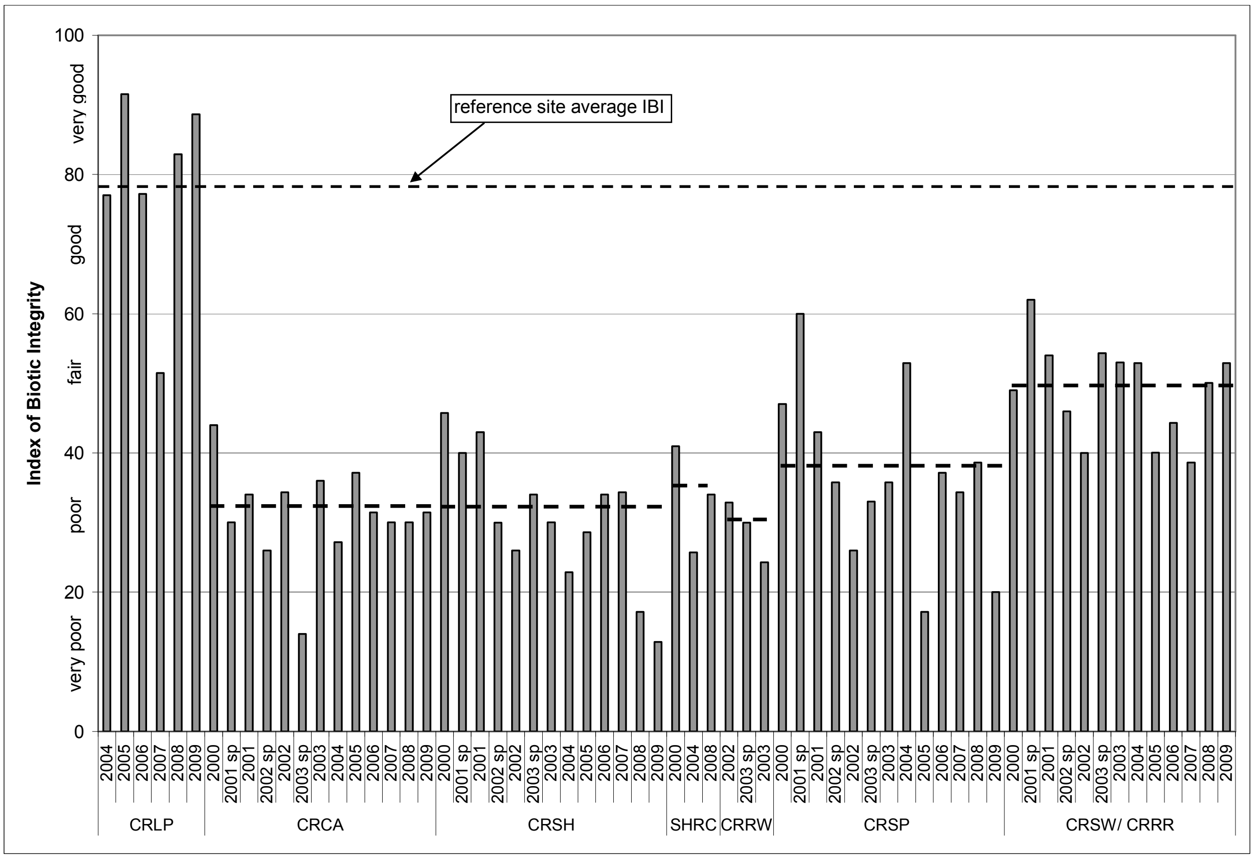

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Figure 2. Indices of biotic integrity for benthic macroinvertebrates sampled from monitoring sites within the Carmel River. IBI values are for the fall season unless noted otherwise with a "sp", which denotes spring season samples. Site average IBI values are shown as horizontal dashed lines.

The difference in sample IBI values between the reference site and the other sites is supported by differences in taxonomic composition as shown by NMS ordination (**Figure 3**). The two site groups were clearly partitioned along axis 1 of the ordination plot.

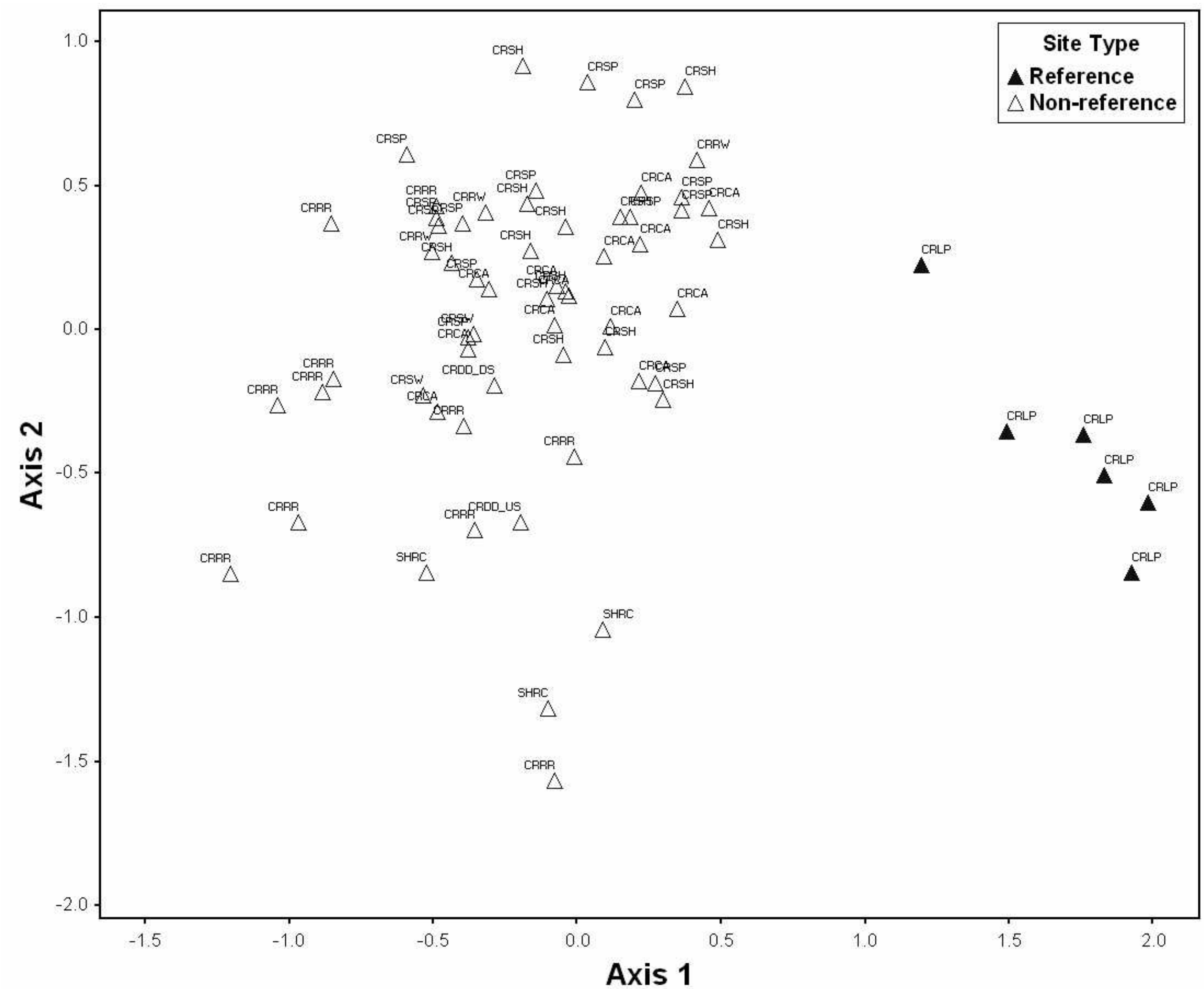

Figure 3. Nonmetric multidimensional scaling ordination of relative sample similarity as a function of BMI taxonomic composition showing samples (triangles) grouped by site type. Increasing variation in taxonomic composition corresponds to increasing distance in ordination space between samples. Sample units are labeled with the site code and grouped by sample type: reference and non-reference sites.

3.1.2 Annual Trends and Seasonal Differences

<u>Annual Trends</u>

Sites CRSH and CRSP had increasingly lower IBI values through the monitoring period (**Figure 4**). There were no detectable upward or downward trends in IBI values for the other sites. One factor that may have influenced the downward trend in IBI values at two sites downstream of San Clemente Reservoir is the annual San Clemente Reservoir drawdown project, which was initiated in 2003 (Entrix 2009).

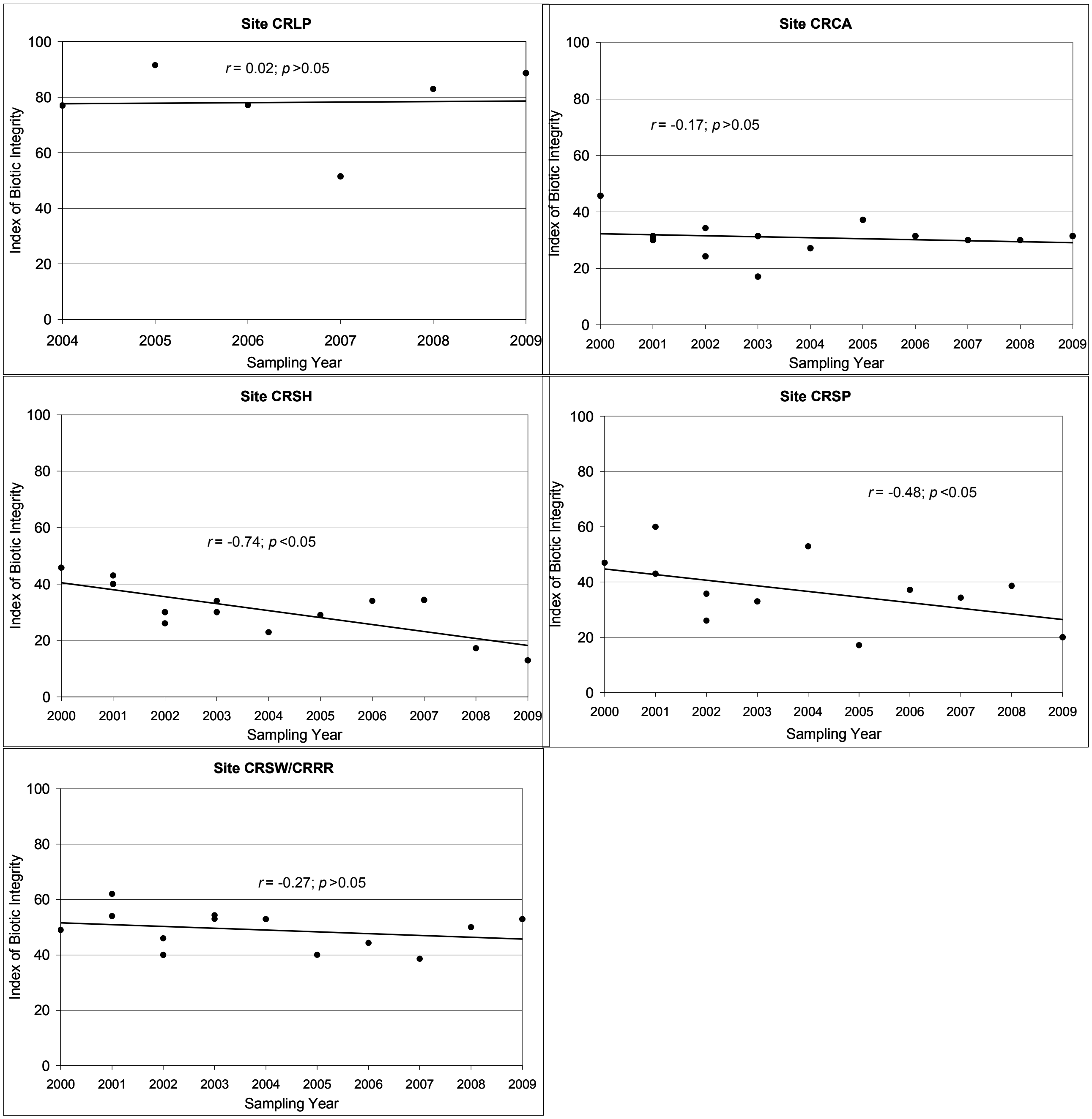

Figure 4. Plots showing annual trend of IBI values for Carmel River monitoring sites. Pearson correlation (*r*) coefficients and probability values (*p*) are shown. Sites with significant change in IBI values have *p* values less than 0.05.

Seasonal Differences

Distinct seasonal differences in BMI taxonomic composition were evident by ordination, and by the numerically dominant taxa. Ordination shows a clear seasonal partitioning of sample units along axis 3 (**Figure 5**). Numerically dominant BMI taxa sampled at the monitoring sites in the spring and fall seasons are presented in **Table 3** and photomicrographs of the dominant taxa are shown in **Appendix F**. Black flies (*Simulium*) were by far the most numerically dominant at all sites for both seasons, but with somewhat inconsistent seasonal representation. Percentages of black flies at sites CRSH, CRRW and CRSP were similar for both seasons but their percentages were seasonally variable at sites CRCA and CRRR. The mayfly *Baetis* was consistently dominant at all sites during both seasons. Other taxa were either more seasonal or site specific. Seasonal taxa included the hydroptilid caddisfly *Leucotrichia pictipes*, which was dominant only in fall samples at all sites except site CRRR. The fixed-retreatmaking caddisfly, *Wormaldia*, was dominant at the three middle sites (CRSH, CRRW and CRSP), but only in the spring.

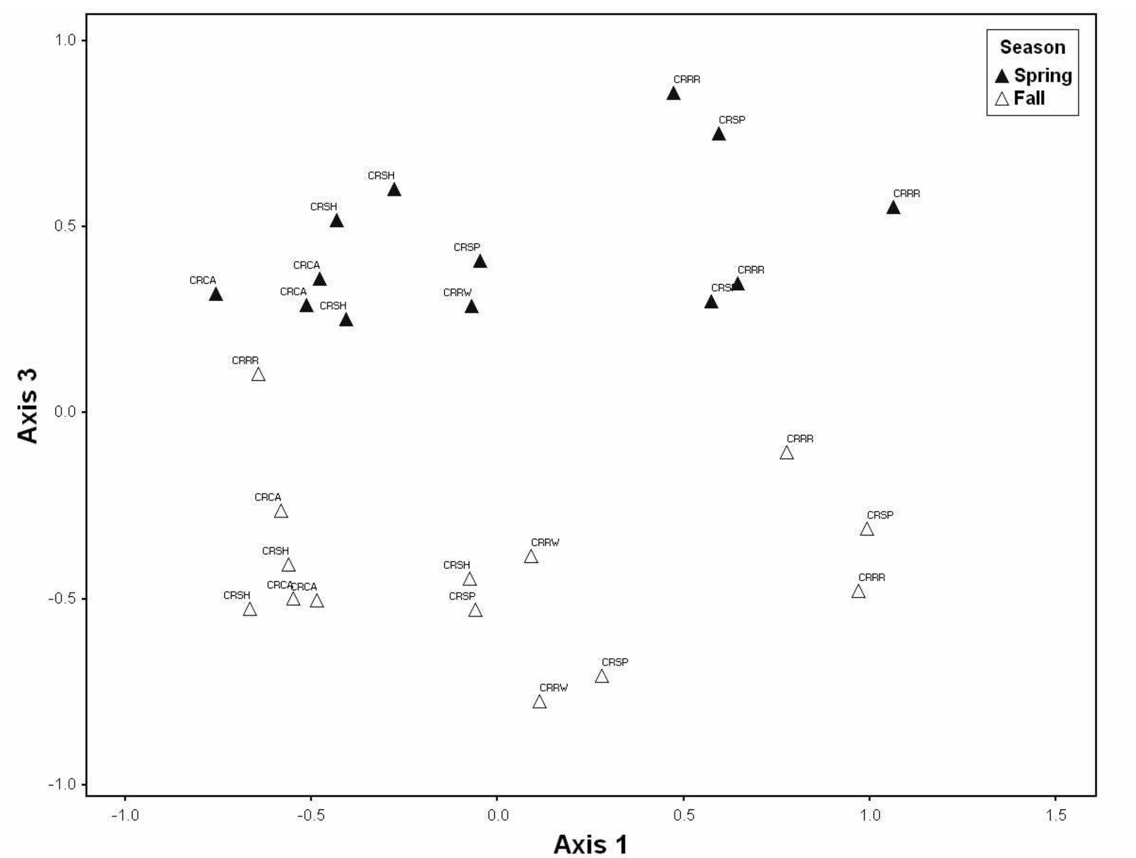

Figure 5. Nonmetric multidimensional scaling ordination of relative sample similarity as a function of BMI taxonomic composition showing samples (triangles) grouped by season of sampling. Increasing variation in taxonomic composition corresponds to increasing distance in ordination space between samples. Sample units are labeled with site code.

Several taxa were site specific or specific to groups of sites. The amphipod *Hyalella*, was sampled only from spring season samples at site CRCA, the mayfly *Tricorythodes*, was dominant only at site CRRR, and the caddisfly *Cheumatopsyche* was dominant in fall samples at site CRSP. The portable case-making caddisfly *Micrasema*, was most abundant at the two lowermost sites, CRSP and CRRR. *Micrasema* was the most dominant taxon in spring samples at the lowermost site (CRRR). Midges within the subfamily Orthocladiinae and tribe Tanytarsini were consistently more abundant at the three upper sites (CRCA, CRSH and CRRW) when compared to the two lowermost sites (CRSP and CRRR).

In contrast to clear effects of season on taxonomic composition, seasonal differences in metric values were variable. For example, the Wilcoxon paired sample test indicated significantly higher EPT taxa values in spring compared to fall ($p<0.05$) but no significant seasonal difference in predator taxa values ($p>0.05$). The disparity in response of metrics comprising the IBI dampened its seasonal response to the extent that there was no significant seasonal difference in IBI values according to the Wilcoxon paired sample test ($p>0.05$). This result is consistent with the objectives of IBI development in that composite metrics of the index are more responsive to anthropogenic stressor gradients than to natural gradients such as season, and metrics were empirically selected to measure different attributes of the BMI assemblage (Ode et al. 2005).

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Table 3. **Numerically dominant benthic macroinvertebrate taxa sampled from the Carmel River in the fall and spring seasons (years 2001 to 2003). Also shown is the percentage of individuals subsampled that comprised the seven most dominant taxa.**

		Dominant Taxa							
Site	Season	1	2	3	4	5	6	7	Total
CRCA	Spring	*Simulium* 30%	*Baetis* 22%	Orthocladiinae 12%	*Hyalella* 11%	Tanytarsini 6%	*Hydropsyche* 4%	Oligochaeta 4%	89%
	Fall	*Baetis* 20%	*Leucotrichia pictipes* 17%	*Hydropsyche* 14%	Orthocladiinae 10%	Tanytarsini 10%	*Argia* 6%	*Simulium* 5%	82%
CRSH	Spring	*Simulium* 32%	*Baetis* 30%	Orthocladiinae 14%	Oligochaeta 5%	*Antocha* 4%	Tanytarsini 2%	*Wormaldia* 2%	89%
	Fall	*Simulium* 31%	*Baetis* 26%	*Leucotrichia pictipes* 14%	Orthocladiinae 8%	*Hydropsyche* 3%	*Argia* 3%	*Antocha* 3%	71%
CRRW	Spring	*Baetis* 35%	*Simulium* 33%	Orthocladiinae 12%	*Wormaldia* 4%	*Antocha* 4%	*Micrasema* 3%	*Hydropsyche* 3%	94%
	Fall	*Simulium* 23%	*Baetis* 21%	Orthocladiinae 18%	Ostracoda 14%	*Leucotrichia pictipes* 5%	*Hydropsyche* 4%	*Ochrotrichia* 3%	67%
CRSP	Spring	*Baetis* 40%	*Simulium* 19%	*Hydropsyche* 12%	*Micrasema* 6%	*Wormaldia* 6%	Orthocladiinae 5%	*Antocha* 2%	89%
	Fall	*Hydropsyche* 26%	*Baetis* 22%	*Simulium* 13%	*Cheumatopsyche* 6%	*Micrasema* 6%	*Leucotrichia pictipes* 4%	Oligochaeta 3%	72%
CRRR	Spring	*Micrasema* 22%	*Baetis* 15%	*Hydropsyche* 11%	Tanytarsini 8%	*Simulium* 5%	Ostracoda 5%	*Tricorythodes* 5%	72%
	Fall	*Simulium* 20%	*Tricorythodes* 12%	*Hydropsyche* 10%	*Baetis* 8%	*Micrasema* 8%	Tanytarsini 5%	Orthocladiinae 4%	66%

3.1.3 Intolerant Taxa

Tolerance values were originally developed by Hilsenhoff (1982) for evaluating effects of organic enrichment on stream dwelling invertebrates. While the scale of tolerance values has remained consistent (0 for highly intolerant to 10 for highly tolerant), values have since been refined and regionally adjusted. The most recent and locally relevant refinements to tolerance values were those made by Robert Wisseman (Aquatic Biology Associates, Inc, Corvalis, Oregon) for BMIs of the Pacific Northwest. The CDFG's Aquatic Bioassessment Laboratory incorporates tolerance values assigned by Aquatic Biology Associates, Inc. for most taxa but uses values reported by the EPA in cases where values are missing (CAMLnet, unpublished document). The refinement of tolerance values is an iterative process: as more information is gained through documentation of BMI assemblages across various pollutant and/or habitat quality gradients, values will be refined accordingly. Generally, BMIs that require well oxygenated, cool, flowing water are assigned low values while BMIs that are less sensitive to low dissolved oxygen and elevated temperature are assigned higher tolerance values. The assignment of tolerance values is complicated by potential variation in tolerance of the life stages of any given BMI taxon and by potential variation exhibited at the species level.

BMI taxa with tolerance values less than three are shown for the monitoring sites in **Table 4**. There were four intolerant taxa within the Diptera (true flies) insect order but most taxa were within the more sensitive EPT insect orders, Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). There were seven intolerant mayfly taxa, five of which were sampled from site CRLP, and three of these were unique to site CRLP: *Drunella*, *Epeorus* and *Rhithrogena*. Heptageniid scrapers, *Epeorus*, and *Rhithrogena*, were abundant at the reference site but absent from all sites downstream of the reservoirs. Site CRLP also contained the most intolerant stonefly individuals and taxa; the number of stonefly taxa and abundance of stonefly individuals were low in the Carmel River monitoring sites downstream of the reservoirs.

An intolerant baetid mayfly, *Centroptilum* (one individual) was sampled from site CRSP. Sites CRLP and CRSP contained the most intolerant caddisfly taxa. Site CRRR contained the most caddisfly individuals, which were locally abundant populations of *Micrasema*. As described in section 3.1.1, there appears to be an attenuating effect on BMI assemblages downstream of the reservoirs: average intolerant organism values generally increase with distance downstream of the reservoirs.

Table 4. Intolerant benthic macroinvertebrate taxa and individuals sampled from Carmel River monitoring sites. CTV: California Tolerance Value.

Taxa	CTV	n=6 CRLP	n=13 CRCA	n=13 CRSH	n=3 SHRC	n=2 CRRW	n=13 CRSP	n=2 CRSW	n=11 CRRR
Diptera (true flies)									
Dixa	2	5	1	2			1		
Meringodixa chalonensis	2	1							
Maruina lanceolata	2	1	6		6		4		
Hexatoma	2	4							
Ephemeroptera (mayflies)									
Ameletus	0	17	1						
Centroptilum	2						1		
Drunella	0	1							
Ephemerella	1	69				1	2		28
Serratella	2		1	1			7		42
Epeorus	0	230							
Rhithrogena	0	148							
Plecoptera (stoneflies)									
Capniidae	1	47					2		
Sweltsa	1	61					1		
Malenka	2	34	2	13	38	1	35	6	2
Calineuria californica	1	8							
Cultus	2	20							
Isoperla	2	21					2		
Trichoptera (caddisflies)									
Micrasema	1	176	169	21		21	348	176	1117
Agapetus	0						5		
Glossosoma	1	1					1		
Glossosomatidae	1								2
Lepidostoma	1	9	1		11		5	1	8
Cryptochia	0	1							
Tinodes	2				1		2	2	36
Rhyacophila	0	48	4	12		1	28		
Farula	0	1							
Total intolerant individuals:		903	183	48	55	24	442	185	1235
Average intolerant individuals:		150	14	4	18	12	34	92	112
Intolerant taxa:		21	8	5	4	4	15	4	7
Intolerant EPT taxa:		17	5	3	3	3	12	4	6
Intolerant Ephemeroptera taxa:		5	1	0	0	0	2	0	1
Intolerant Plecoptera taxa:		6	1	1	1	1	4	1	1
Intolerant Trichoptera taxa:		6	3	2	2	2	6	3	4

3.1.4 Functional Feeding Groups

The functional feeding group (FFG) designations for each taxon are shown in **Appendix C**. Site CRLP had the most balanced distribution of FFGs when compared to the other monitoring sites (**Figure 6**). The primary difference in the distribution of FFGs across sites was the low relative abundance of shredders at sites downstream of the reservoirs with the exception of site SHRC. Shredders were well represented at the CRLP site and consisted of several taxa including crane flies, riffle beetles, winter stoneflies, and lepidostomatid caddisflies, while the predominant shredders at site SHRC included nemourid stoneflies and lepidostomatid caddisflies.

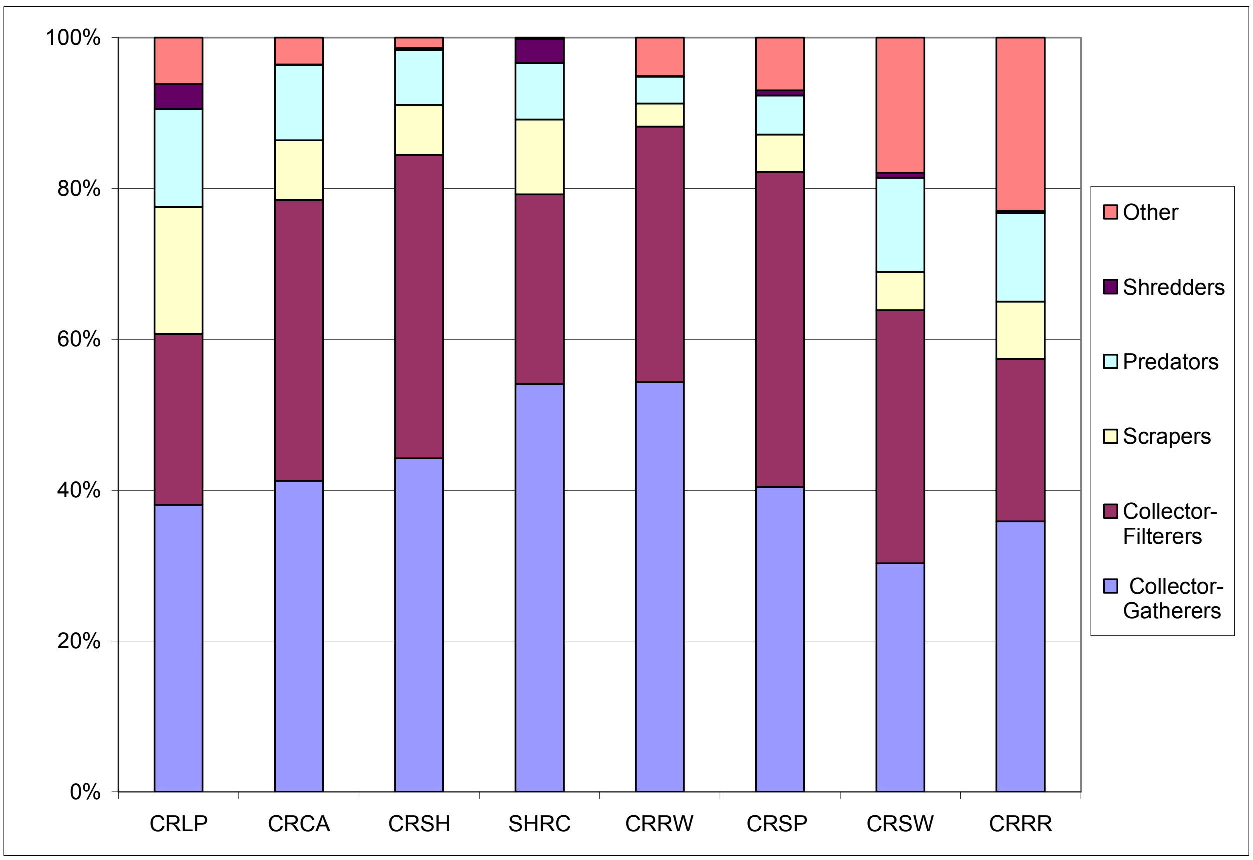

Figure 6. Relative abundances of benthic macroinvertebrate functional feeding groups sampled from Carmel River monitoring sites.

FFGs listed as "other" are less common and include omnivore, xylophage, parasite, macrophyte-herbivore and piercer-herbivore. The caddisfly omnivore *Micrasema*, was most dominant at site CRRR, and contributed to the relatively high percentage of the "other" FFG category. Piercer-herbivore hydroptilid caddisflies also contributed to the "other" category at most sites.

Orthoclad midges and *Baetis* mayflies were the most abundant collector-gatherers at most sites. Non-insect taxa including amphipods and ostracods contributed to the collector-gatherer FFG at sites immediately downstream of the reservoirs. Black flies and hydropsychid caddisflies were the most abundant collector-filterers. When compared to the reference site (CRLP), collector-filterers were more prevalent at sites downstream of the reservoirs with the exception of the site CRRR, which had a similar relative abundance of collector-filterers as the reference site. The distribution of collector-filterers across the sites is consistent with the findings of investigators who reported higher relative abundances of filter-feeding invertebrates downstream of epilimnial-release reservoirs (Petts 1984).

Heptageniid mayflies were the dominant scrapers present at the CRLP site and were lacking at sites downstream of the reservoirs. Reduced populations of heptageniid scrapers downstream of reservoirs were also documented by Rehn et al. (2007). The caddisfly *Leucotrichia pictipes* was the dominant scraper at sites immediately downstream of the reservoirs while riffle beetles and snails were the dominant scrapers at the lowermost sites. There were numerous taxa that contributed to the predator FFG at site CRLP including dance flies, chloroperlid and perlodid stoneflies, free-living caddisflies and mites. Overall, dance flies, damselflies, and mites were dominant predators downstream of the reservoirs.

3.1.5 Abundance and Biovolume

Estimated BMI abundance and biovolume values for the Carmel River monitoring sites are shown in **Figure 7**. One biovolume value from site CRCA in 2009 was an outlier and was not included in the statistical analysis. The outlier sample contained one large tipulid larva, which accounted for most of the biovolume resulting in an estimated value of 54 ml/m^2.

One-way ANOVA performed on log transformed abundance values for years 2004 to 2009 from the five CRBP monitoring site groups was inconclusive due to excessive heterogeneity of variance and non-normal distribution. The non-parametric Kruskal-Wallis test indicated a marginally significant difference in abundance across monitoring site groups (p=0.052). One-way ANOVA performed on log transformed biovolume values indicated a significant difference across monitoring site groups [$F(4, 19) = 16.4, p<0.05$)]. The Tukey multiple comparison test indicated the following biovolume differences across monitoring site groups: CRLP and CRSH < CRSP and CRCA < CRSW/CRRR. The reference site (CRLP) and site CRSH had the lowest biovolume values while the lowermost monitoring site group (CRSW/CRRR) had the highest biovolume.

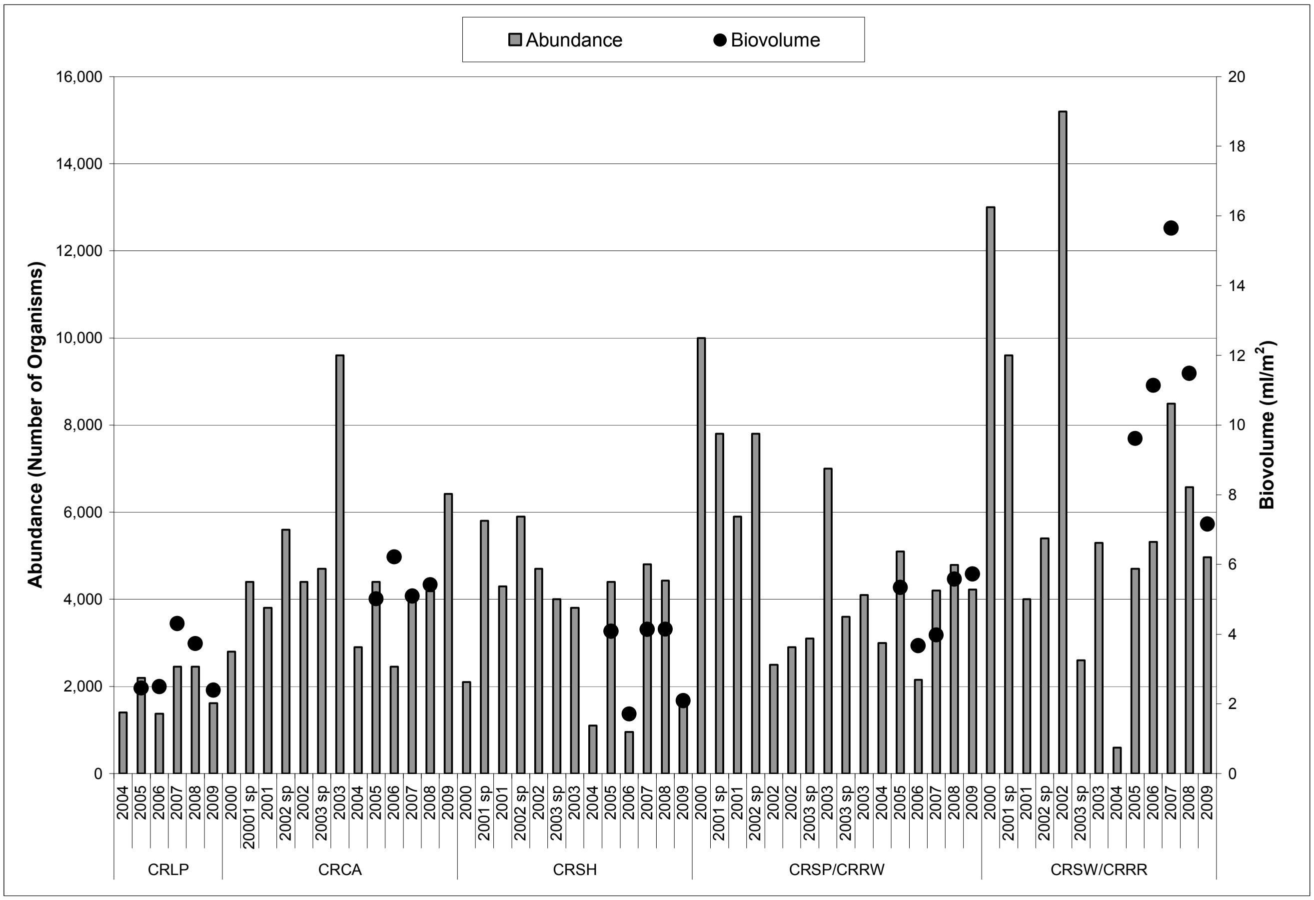

Figure 7. Benthic macroinvertebrate abundance and biovolume from benthic samples collected at Carmel River monitoring sites.

3.2 Habitat and Water Quality Assessment

Complete data sets for the habitat and water quality assessments are presented in **Appendices G and H,** respectively. **Appendix I** includes average daily flow and temperature plots for most of the monitoring period.

Streamflow estimated at the BMI monitoring sites during the sampling events ranged from 2.0 cubic feet per second (cfs) at site CRRR in the fall of 2002 to 60 cfs at CRRR in the spring of 2003. The rearing channel site (SHRC) flow was 1.5 cfs when measured in the fall of 2002 (**Appendix G**). Carmel River flow measured as daily averages through the sites had a seasonal component during the monitoring period when peak winter/spring season flows were approximately two orders of magnitude higher than fall season flows (**Appendix I**). Peak discharge during winter and spring ranged from 1,000 to 2,000 cfs except during the critically dry years of 2002 and 2007 when peak discharge ranged from 100 to 400 cfs.

Daily water temperature fluctuated by season at monitoring stations both upstream and downstream of the reservoirs (Appendix I). However, reference site water temperature was cooler than water temperature downstream of the reservoirs, particularly in summer and fall. Water temperature differences between the reference site and the site downstream of Los Padres Reservoir were more pronounced than water temperature differences between the reference site and the site downstream of San Clemente Reservoir.

Habitat scores were calculated using the 10 habitat parameters shown on the field sheets in **Appendix A**. Average site habitat quality scores ranged from 135 at site CRRR to 177 at site CRCA. Using the criteria outlined by Barbour et al. (1999), all of the sites had average habitat scores in the optimal category (>150) except sites CRRR, CRSW and SHRC, which had average habitat scores in the suboptimal category (>100 to 150). No site scored in the poor (0 to 50) or marginal (>50 to 100) categories.

Substrate index (weighted mean substrate size) values increased with increasing site elevation to approximately 400 feet elevation and remained fairly constant in the large cobble class at sites immediately downstream of the reservoirs. The reference site above Los Padres Reservoir had generally lower substrate index values than the sites immediately downstream of the reservoirs (**Figure 8**). However, boulder was dominant during several site assessments at the reference site and there was some overlap in substrate index values between the reference site and the sites downstream of the reservoirs. Despite the overlap of substrate index values for the reference site and sites immediately downstream of the reservoirs there was a large magnitude difference in IBI values indicating that factors other than mean substrate size were influencing BMI assemblages. Site CRRR had the lowest substrate index values (**Figure 8**). Generally, boulder and cobble were the dominant substrate size classes at sites CRLP, CRCA and CRSH while cobble and gravel were the dominant substrate size classes assessed at the lowest elevation site (CRRR). Substrate size classes were variable at site CRSP, ranging from gravel to boulder dominant.

Average canopy cover for the sites ranged from 87 percent at site CRLP to 48 percent at site CRRR/CRSW. Average riffle gradient ranged from 2.1 percent at sites CRLP and CRRR to 3.3 percent at site CRCA.

Instantaneous measurements of water temperature, dissolved oxygen, specific conductance and pH values were within expected ranges (**Appendix G**). Water temperature averaged 14 °C (range 8.3 to 21), specific conductance averaged 324 µS/cm at 25 °C (range 183 to 498), pH averaged 7.9 (range 7.0 to 8.4) and dissolved oxygen averaged 10.4 mg/l (range 8.0 to 13.6) (**Appendix H**).

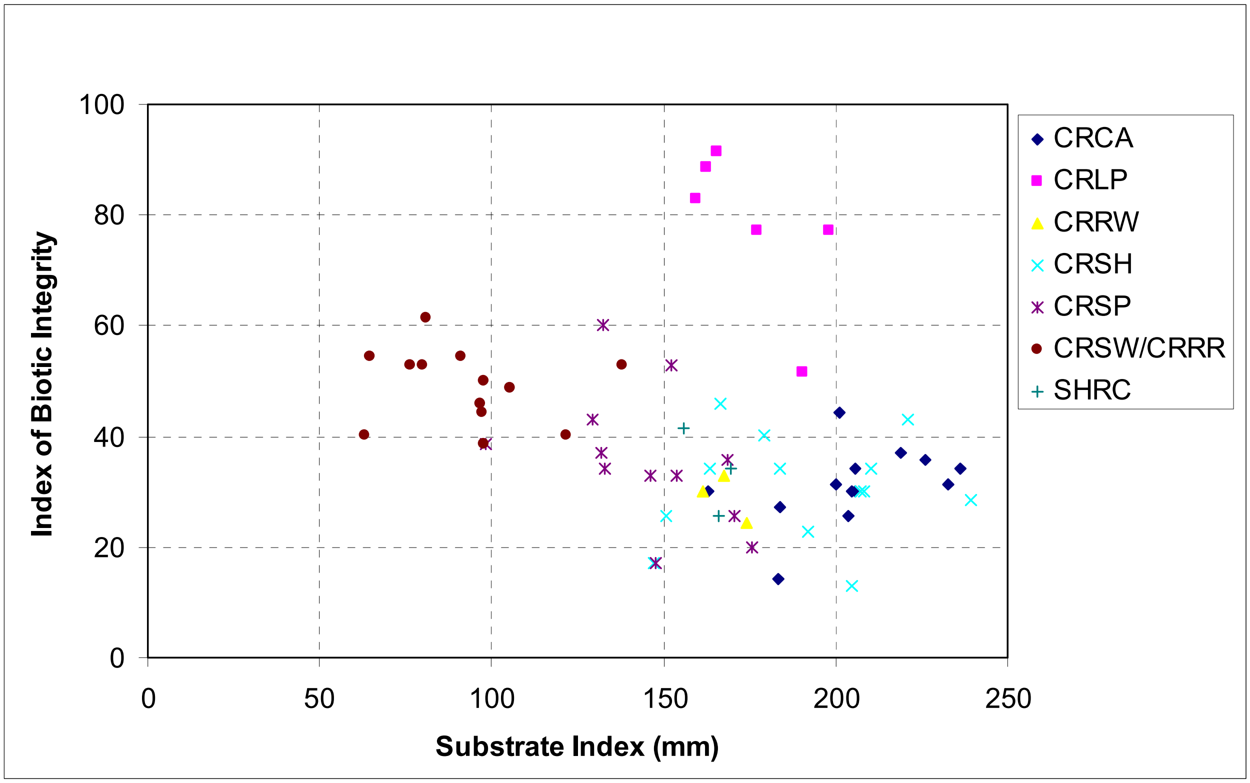

Figure 8. Benthic macroinvertebrate index of biotic integrity vs. substrate index (weighted mean midpoint substratum size) for Carmel River samples collected at indicated sites.

3.3 Habitat Influence on Macroinvertebrates

There was a weak relationship (R^2=0.14) between substrate index and IBI values (**Figure 9**). Within the middle range of the large cobble size class (150 – 200 mm) there was a large range (up to four-fold) of IBI values between reference site sample units and sample units immediately downstream of the reservoirs. This large range of IBI values within the same substrate size class indicates that factors other the mean substrate size was influencing IBI values. This result is consistent with one of the objectives of IBIs whereby metrics tested for the development of IBIs were selected for response to anthropogenic stressor gradients and not natural gradients such as natural variation in substrate composition (Ode et al. 2005). **Figure 9** suggests that the IBI may respond somewhat to the lower and upper range of substrate size; however this hypothesis would need to be tested with samples collected from multiple reference sites with a range of substrate size classes.

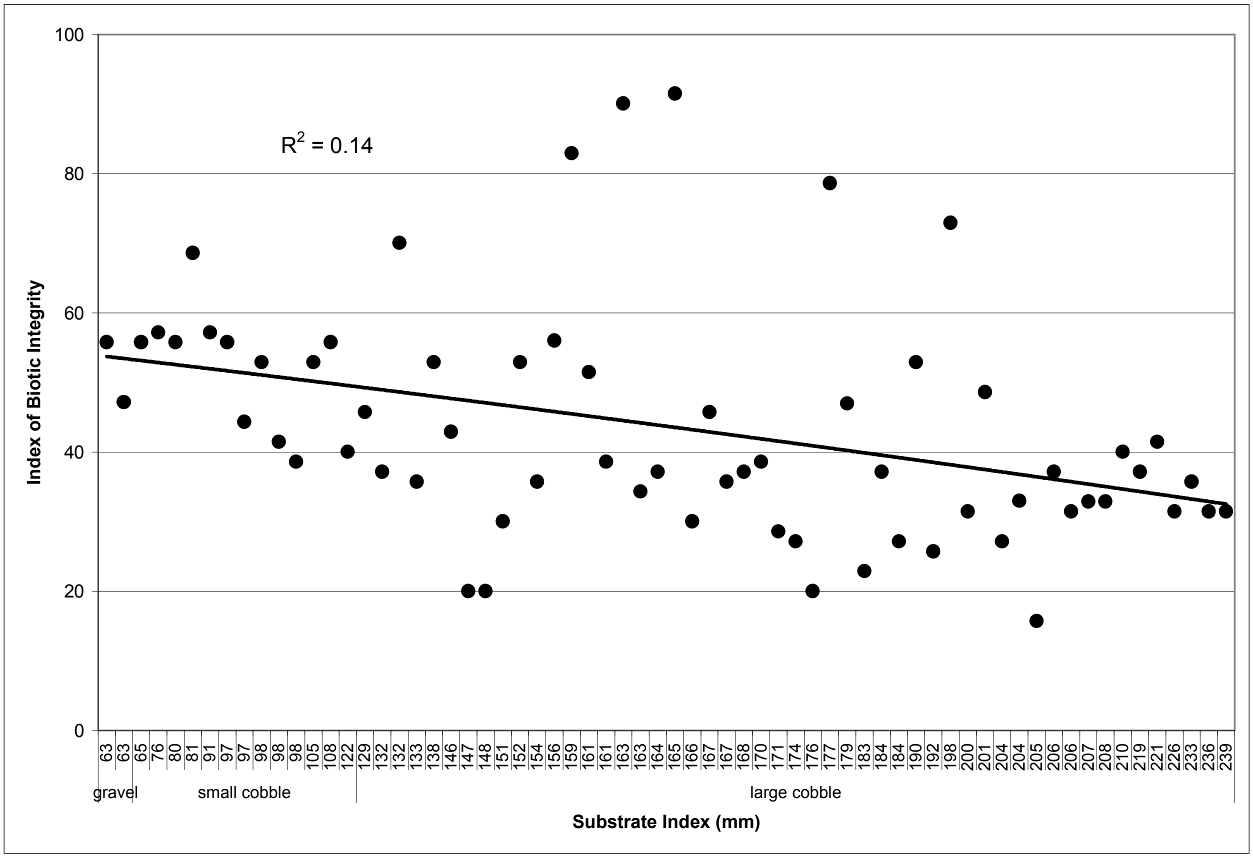

Figure 9. Benthic macroinvertebrate index of biotic integrity vs. substrate index (weighted mean midpoint substratum size) for Carmel River samples showing regression line and coefficient of determination.

Taxonomic composition changed substantially along several environmental gradients (**Figure 10**). Environmental variables that increased positively with changes in taxonomic composition along axis one included elevation, habitat score, percent boulder, and substrate index; percent gravel increased with decreasing elevation primarily along axis one. These variables explained at least 20 percent of the variation in taxonomic composition along axis one. Samples from the lowest elevation site group CRRR/CRSW were clearly partitioned on the left side of the ordination plot while the highest elevation samples from site CRLP were grouped on the right side of the ordination plot.

Sample taxonomic composition changes along axis three were not directly associated with corresponding changes in environmental variables except for some weak effects of substrate (substrate index and gravel). However, the IBI was strongly correlated with axis three suggesting that axis three represents the stressor gradient, which includes factors not directly assessed as part of the monitoring program, or factors not amenable to direct quantitative analysis. Sites downstream of the reservoirs with IBI values averaging in the poor range included CRCA, CRSH, and CRSP and were grouped within the middle and upper areas of the plot while CRLP reference samples with higher IBI values grouped in the lower half of the plot along axis three. CRRR samples were grouped more or less together in an intermediate range along axis three, which was consistent with their IBI values that fell within an intermediate range of IBI values for the CRBP.

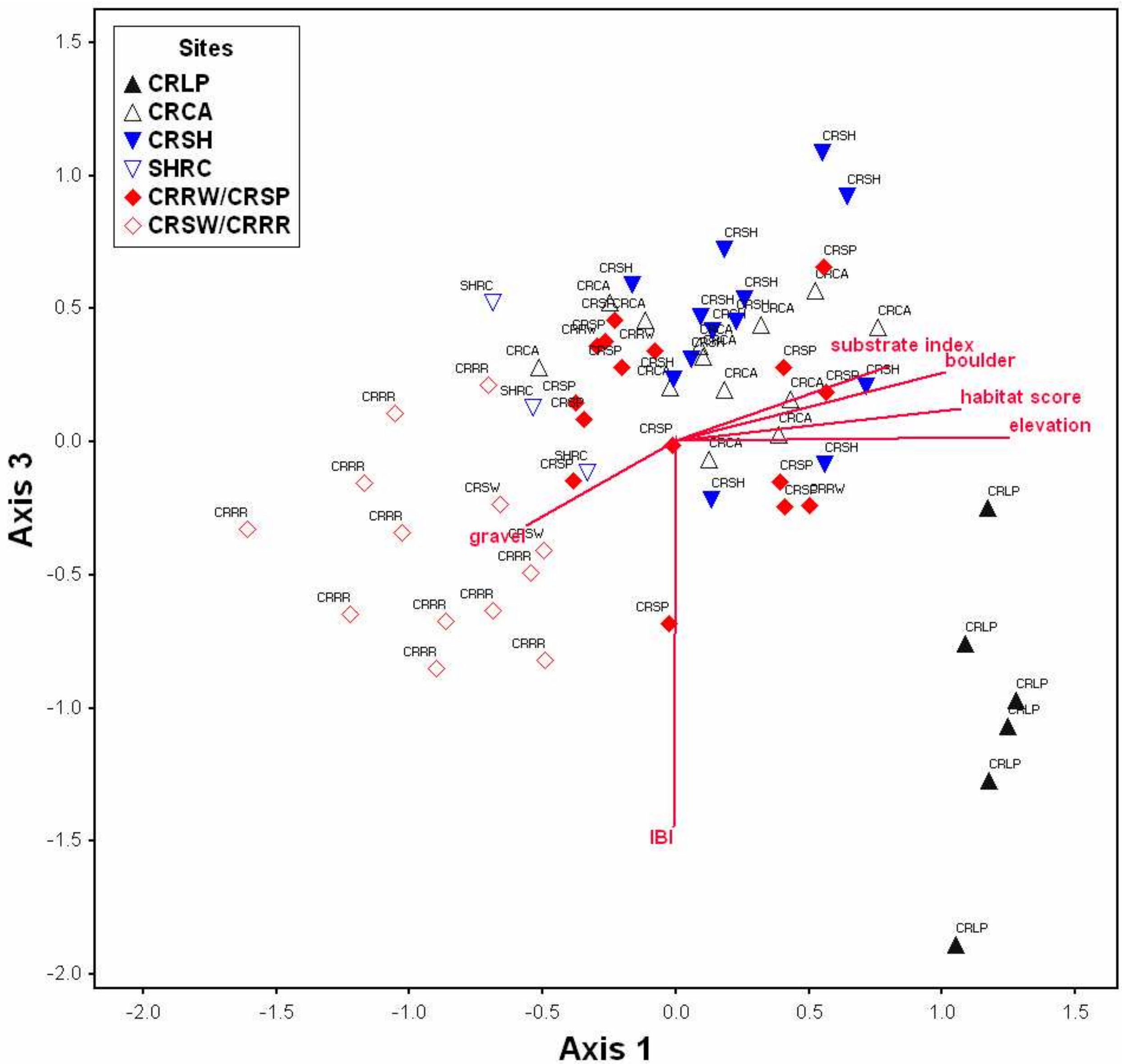

Figure 10. **Nonmetric multidimensional scaling ordination of relative sample similarity as a function of BMI taxonomic composition showing samples (geometric symbols) grouped by site. Increasing variation in taxonomic composition corresponds to increasing distance in ordination space between samples. Joint plot of environmental variables and one biotic variable (IBI) are shown as radiating from the center of the sample cluster, with each line indicating both the direction and strength (R^2>0.2) of correlation with the graph axes.**

3.4 Inter-program Data Comparisons

IBI values from the CCAMP are shown in **Table 5** for Carmel River sites sampled in the spring season of 2002 and 2003 from the Esquiline Road crossing and 2001 to 2004 and 2007 from the Highway 1 crossing. IBI values for Carmel River at the Esquiline Road crossing were 27 in 2002 and 17 in 2003, which fall within the lower range of IBI values of site CRSP. CCAMP IBI values from the Carmel River at the Highway 1 crossing were generally higher than the Esquiline Road site and were consistent with IBI values for the CRBP's CRRR site where IBI values were higher when compared to site CRSP.

Table 5. Index of biotic integrity values for CCAMP sites for the spring season from riffle habitat.

Year	Carmel R. at Esquiline Rd	Carmel R. at Highway 1
2001		37
2002	27	37
2003	17	47
2004		17
2007		33

BMI taxa sampled from the Carmel River since the fall season of 2000 were compared with BMI taxa sampled by Fields (1984) during BMI surveys in the spring season (March and May) of 1982. Fields' taxa lists are presented in **Appendix J**. Quantitative comparisons of Fields' data with the data collected for the current monitoring program are inappropriate for several reasons, which include differences in:

- sampling net (Surber [Fields] vs. D-frame kick-net [CSBP])
- net mesh size (0.59 mm mesh [Fields] vs. 0.50 mm mesh [CSBP])
- sampling area (3 square feet [Fields] vs. 6 square feet [CSBP])
- subsampling procedure (total count [Fields] vs. 500 fixed count [CSBP])
- taxonomic resolution (usually species [Fields] vs. genus/family [CSBP])

Although Fields' sampling sites were established at different locations, four of the sites fell within the same range of sites established for the current monitoring program. These sites included Garland Park, Boronda Road, Paso Hondo and the Filter Plant.

Despite the different methodologies and site locations, some qualitative comparisons are noteworthy. In May 1982, Fields reported a similar numerical dominance of black flies (*Simulium*), baetid mayflies (*Baetis*) and midges (Orthocladiinae and Tanytarsini) that were documented for the current monitoring program reported in **Table 3** and **Appendix C**. Fields reported few stonefly taxa: *Amphinemura* (family Nemouridae) and *Kogotus* (family Perlodidae). Similar stonefly taxa (same families) were sampled during the current monitoring program (**Table 4**).

Fields reported a winter stonefly taxon, Taeniopterygidae, which was absent from samples collected during the current monitoring program. However, spring samples collected for the current monitoring program were collected in May, which was likely too late in the season for collecting Taeniopterygidae stonefly nymphs. Fields reported five blephariceridae fly larvae, which are intolerant BMI usually found in cool, unpolluted flowing water (Erman 1996). No blephariceridae were found in samples collected during the current monitoring program.

Some taxonomic groups were lacking from Fields' data set when compared to taxa sampled during the current monitoring program. *Leucotrichia pictipes* was absent from Fields' data set probably because it is more commonly encountered in the fall season (**Table 3**). The most conspicuous taxonomic group missing from Fields' data set was the insect order Coleoptera, particularly riffle beetle larvae and adults (family Elmidae) and water pennies (family Psephenidae). Although these taxa were not numerically dominant in samples collected during the current monitoring program, they were commonly encountered in samples collected for the two lower elevation sites (CRSP and CRRR) and the reference site (CRLP). Coleopteran richness is one of seven biological metrics used in the IBI and is thus an important indicator of biotic integrity within wadeable streams of the central coast region. While Fields reported the caddisfly *Micrasema*, the number of individuals was low when compared to the abundant but localized populations of *Micrasema* collected at sites CRRR and CRSP during the current monitoring program. Finally, snails were not reported by Fields but were commonly encountered, though not numerically dominant, in samples collected during the current monitoring program. It is important to note that the introduced invasive New Zealand mudsnail (*Potamopyrgus antipodarum*) and the Asiatic clam (*Corbicula*) were absent from Fields' data set and were not encountered in any sample processed for the duration of the 10-yr CRBP.

4.0 DISCUSSION

The primary difference between this 10-year CRBP report and the interim three-year report prepared in 2004 was the application of the coastal southern California index of biotic integrity (IBI), which was developed by Ode et al. in 2005. The IBI provided a more empirical assessment of biotic integrity of sites than the composite metric scores reported in the 2004 report and provided more clarity to the stressor gradients within the watershed. Furthermore, the reference site added to the CRBP in 2004 validated the IBI and provided much needed perspective as a focal point from which to compare the quality of other sites within the watershed. Other differences included the integration of more data through time and a BMI biovolume measurement to supplement abundance values. Finally, in addition to the IBI, ordination was applied to the bioassessment data to provide further insight into seasonal differences and influence of environmental variables on BMI taxonomic composition.

4.1 Potential Stressor Gradients: Urbanization and Reservoirs

Factors contributing to streams with productive and diverse benthic fauna include mixtures of loosely consolidated substrate, a natural hydrograph, allochthonous (organic material of terrestrial origin) inputs with retention and good water quality (Allan and Castillo 2007). These conditions become altered in urban areas where upstream impervious landscape surfaces alter the natural hydrograph and

interfere with the production, transport and retention of allochthonous material (Williams and Feltmate 1992, Schueler 1995, and Karr and Chu 1999). While bank sloughing is a natural phenomenon of stream systems, urban streams are characterized as having higher peak discharges, which contribute to increases in bank instability, increasing channel cross-sectional area and sediment discharge (Trimble 1997). Excessive sediment input occludes interstitial space and thereby decreases the variation of area within the substrate for colonization of benthic fauna (Allan and Castillo 2007). Often, a shift in benthic fauna occurs with increases in sedimentation resulting in increases in burrowing forms such as segmented worms and clams and potentially contributes to lower richness and diversity. Benthic fauna of urban streams may also be affected by constituents from storm water runoff such as petroleum hydrocarbons, fine sediment, organic enrichment, pesticides, fertilizers and detergents (Schueler 1987).
In addition to urbanization of watersheds, reservoir characteristics including operations, depth of release point, level of primary production and effects on fluvial processes influence BMI assemblages downstream by affecting flow and temperature regimes, food resources and substrate composition (Allan and Castillo 2007, Camargo and Voelz 1998, Mount 1995, Petts 1984, Ward and Stanford 1979). BMI assemblages often recover with distance downstream of reservoir systems with sufficient inputs from unregulated tributaries (Rehn et al. 2007, Stanford and Ward 2001, Camargo and Voelz 1998, Armitage 1989). Recovery of BMI assemblage quality was also observed for the CRBP with increased IBI values documented at the two sites furthest downstream of the reservoirs.

Another reservoir effect potentially compromising BMI assemblages during the CRBP is the annual San Clemente Reservoir drawdown project, which has been occurring since 2003 (Entrix 2009). In years 2008 and 2009, IBI values for the site immediately downstream of San Clemente Reservoir were considerably lower than IBI values at the site immediately downstream of Los Padres Reservoir (**Figure 2**). In addition, the two successive sites downstream of San Clemente Reservoir had significant decreases in IBI values during the monitoring period suggesting a possible cumulative effect of the annual drawdown of the reservoir.

Evaluating the effects of Carmel River reservoir/dam systems on downstream substrate composition was compromised because the CSBP uses a targeted riffle sampling approach where substrate composition is assessed where benthic samples are collected. Consequently, depositional habitats such as pool and glide were not characterized, which precluded a more thorough site-scale substrate analysis. A site-scale substrate assessment would provide more insight into substrate characteristics (see Recommendations, Section 6.0).

The District implemented gravel augmentation downstream of the dams between 1993 and 2003, where 3,400 tons of 1.5-4 inch gravel was placed below the two dams for salmonid spawning habitat enhancement (B. Chaney, District staff, personal communication). Without the gravel enhancement, substrate index values would have been higher at sites downstream of the dams, which would likely have contributed to even lower IBI values if gravel augmentation had not occurred.

Without the potential stressor effects imposed by reservoirs and urbanization, the upstream reference site CRLP had the highest average IBI value, the most balanced distribution of functional feeding groups, and the highest average abundance of intolerant organisms and taxa. Site CRLP receives natural flow and temperature regimes, its substrate composition is unaltered by upstream impoundments, and there are minimal upstream impervious landscape surfaces. Reference site IBI values were more affected by water-year type as shown during the critically dry period in 2007 when the IBI value was considerably lower than average. There was full recovery of the IBI values in subsequent years however, despite the Basin Complex Fire in the Los Padres Wilderness, which occurred in the summer of 2008.

Reference site BMI abundance and biovolume were comparatively low compared to most of the other sites. The ecological significance of relatively low abundance and biovolume at the reference site is not clear except in the context of potential reservoir effects on the other sites and an aspect of the river continuum concept. Petts (1984) summarized the results of investigators who documented increases of planktonic organisms released from epilimnial-release dams that could serve as a food resource for downstream BMI. This was suggested for the CRBP by increased BMI abundance and biovolume downstream of Los Padres Reservoir when compared to abundance and biovolume values from samples upstream of the reservoir. If a planktonic food source contributed to increases in BMI biovolume downstream of Los Padres Reservoir, this phenomenon was not observed downstream of San Clemente Reservoir where BMI biovolume was similar to the upstream reference site (**Figure 7**). The disparity in BMI biovolume at the two sites immediately downstream of the reservoirs could be due to the annual San Clemente Reservoir drawdown and the reservoir's diminished capacity, both of which could reduce plankton production.

BMI abundance and biovolume values at the lowest elevation site (CRRR) were the highest among the monitoring sites, which is consistent with the river continuum concept (Vannote et al. 1980). One aspect of the river continuum concept is an increase in secondary production with increasing stream order due to warmer temperatures and accumulations of organic detritus and nutrients. Additionally, site CRRR receives anthropogenic sources of organic constituents (B. Chaney, District staff, personal communication), which may also have contributed to the site's high BMI abundance and biovolume values. Despite periodic anthropogenic organic enrichment, site CRRR maintained higher IBI values and higher average intolerant BMI individuals compared to sites immediately downstream of the reservoirs.

Lower BMI taxonomic richness and diversity downstream of the reservoirs would suggest an effect of altered temperature regime that could affect the cyclic thermal cues necessary for many BMI taxa to complete their life cycles (Allan and Castillo 2007). Altered temperature regimes downstream of reservoirs may explain the lack of longer-lived taxa such as stoneflies as they may be particularly sensitive to thermal cues for life cycle regulation.

Continuous temperature monitoring data indicated generally lower water temperature at the site upstream of Los Padres Reservoir when compared to sites downstream of the reservoirs, particularly in summer and fall (**Appendix I**). Water temperature difference nearing 8° F during the fall between the reference site and the site downstream of Los Padres Reservoir may have been sufficient to influence BMI assemblages. Lessard and Hayes (2003) documented declines in BMI richness downstream of relatively small reservoirs that discharged water with elevated temperature when compared to upstream control sites. The disparity in water temperature between the site downstream of San Clemente Reservoir and the reference site was of less magnitude than the disparity in water temperature between the site downstream of Los Padres Reservoir and the reference site. However, average IBI values for both sites downstream of the reservoirs were identical despite differences in the disparity in water temperature. This suggests that in addition to potential water temperature effects, other factors were influencing BMI assemblages downstream of the reservoirs. While continuous temperature data indicated a more or less seasonal change in temperature at sites downstream of the reservoirs, there were abrupt temperature decreases downstream of the Los Padres Reservoir in late summer documented for several years (**Appendix I**). These abrupt decreases in water temperature were a result of water releases from Los Padres Reservoir, which were made to lower the risk of thermal stress on salmonid populations (B. Chaney, District staff, personal communication). These abrupt temperature changes could influence BMI assemblages.

The two stressor gradients described above, urbanization and reservoir systems, were likely the primary influences on BMI assemblage quality as depicted by the IBI. The IBI either did not respond to or responded weakly to natural gradients including elevation, substrate size, canopy, stream width, water velocity, gradient, and relative percentages of substrate classes. Consequently, other factors were more important influences on low IBI values downstream of the reservoirs. Based on the literature and supporting data compiled for the CRBP, other factors would include water temperature and flow regime, substrate characteristics not assessed, planktonic food resources discharged from the reservoirs, and sequestration of allochthonous material in the reservoirs. Of these factors, water temperature differences between the reference site and the sites downstream of the reservoirs could be one important factor. Annual Carmel River flow follows a more or less seasonal pattern through the sites downstream of the reservoirs precluding altered flow regime as a major factor contributing to low IBI values. The loss of allochthonous organic material in the reservoirs could be important but would be difficult to mitigate.

4.2 Salmonid Food Sources

Despite relatively low IBI values documented downstream of the reservoirs, the numerically dominant taxa sampled from the sites may provide adequate food resources for salmonids according to Rader (1997). Rader developed a classification system to rank aquatic invertebrates on their propensity to drift and importance as a food resource for salmonids. The four highest ranking BMI taxa according to Rader, in order of decreasing rank were: 1) *Baetis*, 2) Simuliidae, 3) *Acentrella*, and 4) Chironomidae. For the CRBP, the most abundant individuals were black flies (Simuliidae), baetid mayflies (*Baetis*), and chironomids (Chironomidae). *Acentrella* is a baetid mayfly that was not encountered during the sampling events for the CRBP. Fields (1984) also documented black flies and *Baetis* mayflies as the most numerically dominant taxa across several sites of the Carmel River during a 1982 sampling event. According to Rader, heptageniid mayflies also rank high as a food resource for salmonids but they were restricted to the reference site upstream of the reservoirs during the CRBP monitoring period.

4.3 Seasonal and Annual Trends

While there were seasonal differences in BMI taxonomic composition, the effect of season on the IBI was minimal. This result is important with regard to future CRBP planning because IBIs are being emphasized for use as primary biological signals for characterizing water and habitat quality. Consequently, the IBI's stability with regard to season provides some flexibility in the timing of sampling; a late spring or early summer sampling window is being recommended for central coast bioassessment projects (P. Ode, personal communication).

Two sites, both sequentially downstream of San Clemente Reservoir, had downward trends in IBI values through the monitoring period. IBI values for 2008 and 2009 were particularly low at the site immediately downstream of San Clemente Reservoir, possibly as a result of reservoir drawdown initiated in 2003. All other sites had no detectable upward or downward trends in IBI values through the monitoring period.

4.4 Regional Integration of Bioassessment Data

The State Water Resources Control Board has developed standardized procedures for the collection, storage and dissemination of ambient water quality data including BMI-based bioassessment. The State Board program is being implemented through the Surface Water Ambient Monitoring Program (SWAMP), which is the current statewide standard for the collection of BMI, algal, habitat, and water quality data. For bioassessment data to be compatible with SWAMP standards, a quality assurance project plan is required, which describes the processes and data quality standards to be maintained through all stages of data acquisition. Database modules are in various stages of development for storing SWAMP compatible data and dissemination of information can be achieved through the California Environmental Data Exchange Network.

The Central Coast Ambient Monitoring Program (CCAMP) is the Central Coast's regional component of the SWAMP. CCAMP plays a key role in assessing Central Coast regional goals and has a number of program objectives including collaborating with other monitoring programs to promote effective and efficient monitoring. The CRBP is in a good position to supplement CCAMP efforts through the sharing of historic Carmel River bioassessment data (data collected to date) and by transitioning to the SWAMP data collection methods and implementing data quality standards.

5.0 CONCLUSIONS

Carmel River macroinvertebrate monitoring over the 10-year program period indicated strong and consistent effects of the dam/reservoir systems on downstream macroinvertebrate assemblage quality as depicted by an index of biotic integrity with some improvement with increasing distance downstream of the reservoirs. Published literature sources list multiple effects of dam/reservoir systems on downstream benthic fauna, which include altering fluvial processes, allochthonous material transport, flow, water temperature and food supplies. While inconclusive, several factors assessed during the Carmel River Bioassessment Program likely contributed to lowered macroinvertebrate assemblage quality downstream of the reservoirs. These factors included elevated water temperature downstream of the reservoirs when compared to the upstream reference site and slightly higher average substrate size at sites immediately downstream of the reservoirs. Annual hydrographic data indicated a mostly seasonal pattern of flow through the sites, indicating that the dams do not appreciably alter seasonal flow patterns. Other causative factors identified in the literature were either not assessed or not adequately quantified due to the constraints of the monitoring procedure. Consequently, alternative monitoring approaches or targeted studies would need to be adopted to gain a clearer understanding of all the factors contributing to compromised BMI assemblages downstream of the reservoirs.

Urbanization effects on Carmel River macroinvertebrate assemblage quality were of less magnitude when compared to reservoir effects. While periodic accumulations of both natural and anthropogenic organic material have been documented at the lowest elevation Carmel River monitoring site, the level of organic material did not preclude the presence of sensitive macroinvertebrate taxa, nor did it compromise abundance. Conversely, the lowest elevation monitoring site had the highest macroinvertebrate abundance and biovolume of all sites probably because of seasonal accumulations of organic matter. Reservoir systems sequester allochthonous organic matter, which may be one factor compromising macroinvertebrate assemblage quality at sites immediately downstream of the reservoirs. But reservoir systems can also augment downstream macroinvertebrate food supplies with plankton as appeared to be the case downstream of Los Padres Reservoir where macroinvertebrate abundance and biovolume were higher than the upstream reference site.

There were downward trends in macroinvertebrate assemblage quality over the 10-year monitoring period at two successive sites downstream of San Clemente Reservoir, possibly in response to annual drawdowns of the reservoir. There were no upward or downward trends in macroinvertebrate assemblage quality at the other sites throughout the monitoring period. However, there was a large magnitude decline in macroinvertebrate assemblage quality at the reference site in 2007 during a critically dry water-year. Full recovery occurred the following years despite the Basin Complex Fire in the Los Padres Wilderness, which occurred in the summer of 2008. The Sleepy Hollow rearing channel had similar macroinvertebrate assemblage quality compared to the two sites immediately downstream of the reservoirs. While there were seasonal influences on macroinvertebrate taxonomic composition, index of biotic integrity values were minimally affected by season. This result is important with regard to future program planning because it allows some flexibility in the sampling window. A late spring or early summer sampling window is being recommended for central coast bioassessment projects.

A published literature source indicated that the dominant macroinvertebrate taxa sampled from the Carmel River provide readily available food resources for salmonid populations. These taxa include baetid mayflies, black flies, and midges.

Instream and riparian habitat quality at the monitoring sites were generally good as determined by qualitative assessments outlined in the monitoring procedure. Instantaneous water quality constituents (temperature, pH, dissolved oxygen and specific conductance) measured during the monitoring period fell within ranges typical for the region.

6.0 RECOMMENDATIONS

1. Change the bioassessment procedure from the CSBP to the SWAMP. Unlike the CSBP, the SWAMP's reachwide benthic sampling procedure is not restricted to sampling of riffle habitat. Instead, one benthic sample and habitat data are collected from each of 11 equidistant transects established along a 150 m monitoring reach; the benthic samples collected at each of

the 11 transects are composited. Consequently, characteristics of the entire site are assessed instead of only riffles as specified in the CSBP. Quantitative characterization of substrate of the entire site using SWAMP would provide more robust data for determining effects of gravel enhancement downstream of Los Padres Reservoir as well as documenting amounts of fine sediment and particulate organic matter at the sites. In addition, one component of the recently drafted SWAMP stream algae procedure could be added to assess amounts of algae along site transects. For data compatibility with the SWAMP, a quality assurance project plan would need to be developed.

2. Establish at least one additional reference site, minimally affected by reservoirs and urbanization. Potential sites could include Cachagua Creek downstream of James Creek, and Pine Creek upstream of the confluence of the Carmel River. The Pine Creek site would represent a lower elevation reference site. Additional reference sites would provide more of a range of conditions (e.g. substrate characteristics) from which to compare sites that are affected by reservoirs, urbanization, and management activities such as water releases and gravel augmentation.

3. Conduct a special study to reduce or eliminate effects of variation in substrate composition on BMI assemblages upstream and downstream of the reservoir systems. This could be achieved with the deployment of substrate baskets, which would contain known amounts and proportions of substrate, typically mixtures of gravel and cobble. Substrate baskets could be deployed upstream and downstream of the reservoirs after peak flow in summer and processed in late fall. By evaluating the BMI assemblages that colonized the baskets, more insight could be made into reservoir effects by factoring out variation in substrate composition.

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8.0 ABBREVIATIONS/GLOSSARY

BMI Benthic macroinvertebrates: invertebrates that live in streambeds and are large enough to be detected with the naked eye (>0.5 mm).

CAMLnet California Aquatic Macroinvertebrate Laboratory Network: a network of professionals that reviews current taxonomic advancements, laboratory techniques for processing samples, and methods of laboratories to ensure quality control and recommend standards. CAMLnet was replaced by SAFIT.

CCAMP Coastal Confluence Monitoring and Assessment Program: program of the RWQCB for assessing water quality on a regional basis.

RWQCB Central Coast Regional Water Quality Control Board

CDFG California Department of Fish and Game

CRBP Carmel River Bioassessment Program

CRCA Carmel River at Cachagua – District bioassessment site

CRDD Carmel River at DeDampierre - District bioassessment site

CRLP Carmel River upstream of Los Padres Reservoir – District bioassessment site

CRRR Carmel River at Red Rock- District bioassessment site

CRRW Carmel River at Russell Wells - District bioassessment site

CRSP Carmel River at Stonepine - District bioassessment site

CSBP California Stream Bioassessment Procedure: standardized procedure for characterizing macroinvertebrate assemblages in riffle habitat of wadeable streams

EPA Environmental Protection Agency

IBI Index of Biological Integrity: a tool to evaluate stream conditions based on a biotic assemblage such as algae, macroinvertebtates or fishes.

Metrics In the context of biological assessment, metrics refer to numerical attributes of biotic assemblages. Metrics provide a tool for comparing one site to another, or samples from the same site taken at different times.

NMS Nonmetric multidimensional scaling: ordination procedure that orients samples in ordination space as a function of taxonomic composition. Space between sample units increases with increasing taxonomic dissimilarity.

NPDES National Pollutant Discharge Elimination System: program administered by Regional Water Quality Control Boards

SAFIT Southwest Association of Freshwater Invertebrate Taxonomists: a professional organization that reviews current taxonomic advancements, maintains master invertebrate taxonomic list, and holds taxonomic workshops.

SWAMP The State Board's Surface Water Ambient Monitoring Program. Includes quantitative procedure for assessing habitat and sampling benthic macroinvertebrates from multiple habitats.

sq. ft. Square feet

SQGQ Sediment Quality Guideline Quotient

APPENDIX A

Field data sheets used for recording habitat quality during biological assessment surveys

CALIFORNIA BIOASSESSMENT WORKSHEET

WATERSHED/ STREAM: ____________________ DATE/ TIME: ____________________

COMPANY/ AGENCY: ____________________ SAMPLE ID #: ____________________

SITE DESCRIPTION: ____

SAMPLING CREW

____

____

____

SITE INFORMATION

GPS Coordinates

Latitude: ____________________

Longitude: ____________________

Elevation: ____________________

Ecoregion: ____________________

COMMENTS:

____

____

____

____

____

CHEMICAL CHARACTERISTICS

Water Temperature: __________

Specific Conductance: __________

pH: __________

Dissolved Oxygen: __________

Bioassessment Laboratory Information:

____

____

____

____

____

SEND A COPY OF THIS FORM TO:
DFG/ WPCL
2005 Nimbus Road
Rancho Cordova, CA 95670
(916) 358-2858
website: www.dfg.ca.gov/cabw/cabwhome.html

RIFFLE/ REACH CHARACTERISTICS

Point Source Sampling Design

Riffle Length: ____

Transect 1: ____

Transect 2: ____

Transect 3: ____

(record Physical/ Habitat Characteristics in Riffle 1 column)

Non-Point Source Sampling Design

Reach Length: _____

Physical Habitat Quality Score: _____

Physical/ Habitat Characteristics

	Riffle 1	Riffle 2	Riffle 3
Riffle Length:			
Transect Location:			
Avg. Riffle Width:			
Avg. Riffle Depth:			
Riffle Velocity:			
% Canopy Cover:			
Substrate Complexity:			
Embeddedness:			
Substrate Composition:			
Fines (<0.1"):			
Gravel (0.1-2"):			
Cobble (2-10"):			
Boulder (>10"):			
Bedrock (solid):			
Substrate Consolidation:			
Percent Gradient:			

PHYSICAL HABITAT QUALITY
(California Stream Bioassessment Procedure)

WATERSHED/ STREAM: ____________________

DATE/ TIME: ____________________

COMPANY/ AGENCY: ____________________

SAMPLE ID NUMBER: ____________________

SITE DESCRIPTION: ____________________

Circle the appropriate score for all 20 habitat parameters. Record the total score on the front page of the CBW.

Parameters to be evaluated within the sampling reach

HABITAT PARAMETER	CONDITION CATEGORY			
	OPTIMAL	**SUBOPTIMAL**	**MARGINAL**	**POOR**
1. Epifaunal Substrate/ Available Cover	Greater than 70% (50% for low gradient streams) of substrate favorable for epifaunal colonization and fish cover; most favorable is a mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% (30-50% for low gradient streams) mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% (10-30% for low gradient streams) mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% (10% for low gradient streams) stable habitat; lack of habitat is obvious; substrate unstable or lacking.
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% 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 more than 75% surrounded by fine sediment.
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/ Depth Regimes *(deep<0.5 m, slow<0.3 m/s)*	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow).	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-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	Little or no enlargement of islands or point bars and less than 5% (<20% for low-gradient streams) of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% (20-50% for low-gradient) of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% (50-80% for low-gradient) of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% (80% for low-gradient) of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
	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	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water 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

Parameters to be evaluated in an area longer than the sampling reach

HABITAT PARAMETER	CONDITION CATEGORY			
	OPTIMAL	**SUBOPTIMAL**	**MARGINAL**	**POOR**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of 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 width 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 (score each bank) Note: determine left of right side by facing downstream	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
	Left Bank 10 9	8 7 6	5 4 3	2 1 0
	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immediate riparian zones covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank 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 centimeters or less in average stubble height.
	Left Bank 10 9	8 7 6	5 4 3	2 1 0
	Right Bank 10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities haveimpacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
	Left Bank 10 9	8 7 6	5 4 3	2 1 0
	Right Bank 10 9	8 7 6	5 4 3	2 1 0

APPENDIX B

Metrics used to describe characteristics of benthic macroinvertebrate assemblages including those used for the coastal southern California index of biotic integrity

BMI Metric	Description	Response to Impairment [1]
Richness Measures		
1. Taxonomic	Total number of individual taxa.	Decrease
2. EPT [2]	Number of taxa in the orders Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly)	Decrease
3. Ephemeroptera	Number of mayfly taxa	Decrease
4. Plecoptera	Number of stonefly taxa	Decrease
5. Trichoptera	Number of caddisfly taxa	Decrease
6. Coleoptera [2]	Number of beetle taxa	Decrease
7. Predator [2]	Number of predator taxa	Decrease
Composition Measures		
8. EPT Index (%)	Percent composition of mayfly, stonefly and caddisfly larvae	Decrease
9. Sensitive EPT Index (%)	Percent composition of mayfly, stonefly and caddisfly larvae with CTVs less than 4.	Decrease
10. Shannon Diversity Index	General measure of sample diversity that incorporates richness and evenness.	Decrease
11. Non-insect Taxa (%) [2]	Percentage of taxa not within the class Insecta	Increase
Tolerance/Intolerance Measures		
12. California Tolerance Value (CTV)	CTVs between 0 and 10 weighted for abundance of individuals designated as pollution tolerant (higher values) and intolerant (lower values).	Increase
13. Intolerant Organisms (%) [2]	Percentage of organisms that are highly intolerant to water and/ or habitat quality impairment as indicated by CTVs of 0, 1 or 2.	Decrease
14. Tolerant Taxa (%) [2]	Percentage of taxa that are highly tolerant to water and/ or habitat quality impairment as indicated by CTVs of 8, 9 or 10.	Increase
Functional Feeding Groups (FFG)		
15. % Collector-gatherers (cg)	Percentage of macroinvertebrates that collect or gather material.	Increase
16. % Collector-filterers (cf)	Percentage of macroinvertebrates that filter suspended material from the water column.	Increase
17. % Collectors [2]	Percentage of macroinvertebrates that collect and filter suspended material from the water column.	Increase
18. % Scrapers (sc)	Percentage of macroinvertebrates that graze upon periphyton.	Variable
19. % Predators (p)	Percentage of macroinvertebrates that prey on living organisms.	Decrease
20. % Shredders (sh)	Percentage of macroinvertebrates that shred leaf litter.	Decrease
21. % Others (ot)	Percentage of macroinvertebrates that occupy an FFG not described above.	Variable
Other		
22. Abundance	Estimate of the number of organisms in a sample based on the proportion of organisms subsampled.	Variable
23. Biovolume (ml)	Volumetric displacement of organisms subsampled.	Variable

[1] The responses indicated are generalized and can follow natural gradients associated with elevation, water temperature and substrate composition.
[2] Metrics used for index of biotic integrity.

APPENDIX C

Cumulative taxonomic list of benthic macroinvertebrates sampled from the Carmel River including California Tolerance Values (CTV) and Functional Feeding Group (FFG) designations

Phylum / Class / Order / Family / Final ID	CTV*	FFG**	Total Individuals
Arthropoda			
Insecta			
Coleoptera			
Dryopidae			
Helichus	5	sh	1
Postelichus	5	sh	2
Dytiscidae			
Agabus	8	p	7
Elmidae			
Ampumixis dispar	4	cg	28
Cleptelmis addenda	4	cg	30
Narpus	4	sc	1
Optioservus	4	sc	231
Ordobrevia nubifera	4	sc	59
Zaitzevia	4	sc	33
Gyrinidae			
Gyrinus	5	p	1
Hydraenidae			
Hydraena	5	sc	2
Hydrophilidae			
Hydrophilidae	5	cg	1
Psephenidae			
Eubrianax edwardsii	4	sc	76
Psephenus falli	4	sc	139
Diptera			
Cyclorrhaphous/Brachycera	6		1
Ceratopogonidae			
Atrichopogon	6	cg	13
Bezzia/ Palpomyia	6	p	14
Dasyhelea	6	cg	21
Chaoboridae			
Chaoborus	7	p	4
Chironomidae			
Chironomini	6	cg	271
Orthocladiinae	5	cg	3425
Tanypodinae	7	p	94
Tanytarsini	6	cg	2094
Dixidae			
Dixa	2	cg	12
Meringodixa chalonensis	2	cg	1
Dolichopodidae			
Dolichopodidae	4	p	2
Empididae			
Clinocera	6	p	1
Empididae	6	p	8
Hemerodromia	6	p	354
Neoplasta	6	p	53
Trichoclinocera	6	p	6
Wiedemannia	6	p	24
Ephydridae			
Ephydridae	6		1
Psychodidae			
Maruina lanceolata	2	sc	22
Psychodidae		cg	1
Sciomyzidae			
Sciomyzidae	6	p	4
Simuliidae			
Simulium	6	cf	10606
Stratiomyidae			
Caloparyphus/Euparyphus	8	cg	43
Hedriodiscus/Odontomyia	8	cg	1
Tabanidae			
Tabanidae	8	p	4
Tipulidae			
Antocha	3	cg	708
Cryptolabis	3	sh	11
Dicranota	3	p	15
Hexatoma	2	p	4
Limnophila	4	p	1
Limonia	6	sh	10
Tipula	4	om	17
Tipulidae	3		3
Ephemeroptera			
Ameletidae			
Ameletus	0	cg	18
Baetidae			
Baetis	5	cg	9114
Centroptilum	2	cg	1
Diphetor hageni	5	cg	22
Fallceon quilleri	4	cg	33
Ephemerellidae			
Drunella	0	cg	1
Ephemerella	1	cg	125
Serratella	2	cg	157
Heptageniidae			
Epeorus	0	sc	230
Heptageniidae	4	sc	12
Ironodes	4	sc	5
Rhithrogena	0	sc	148
Leptohyphidae			
Tricorythodes	4	cg	828
Paraleptophlebia	4	cg	34
Hemiptera			
Naucoridae			
Ambrysus	5	p	5
Megaloptera			
Sialidae			
Sialis	4	p	1
Odonata			
Calopterygidae			
Hetaerina americana	6	p	40
Coenagrionidae			
Argia	7	p	770
Coenagrionidae		p	2
Cordulegastridae			
Cordulegaster dorsalis	3	p	1
Plecoptera			
Capniidae			
Capnia	1	sh	24
Capniidae	1	sh	25
Chloroperlidae			
Sweltsa	1	p	62
Nemouridae			
Malenka	2	sh	140
Perlidae			
Calineuria californica	1	p	8
Perlodidae			
Cultus	2	p	20
Isoperla	2	p	24
Trichoptera			
Brachycentridae			
Amiocentrus aspilus	3	cg	5
Brachycentridae			
Micrasema	1	mh	3072
Glossosomatidae			
Agapetus	0	sc	10
Glossosoma	1	sc	4
Glossosomatidae	0	sc	3
Hydropsychidae			
Cheumatopsyche	5	cf	427
Hydropsyche	4	cf	3938
Hydroptilidae			
Hydroptila	6	ph	16
Leucotrichia pictipes	6	sc	1872

Phylum	Class	Order	Family	Final ID	CTV*	FFG**	Total Individuals
				Ochrotrichia	4	ph	664
				Oxyethira	3	ph	9
			Lepidostomatidae				
				Lepidostoma	1	sh	47
			Leptoceridae				
				Mystacides	4	om	2
				Nectopsyche	3	om	1
				Oecetis	8	p	17
				Triaenodes frontalis	6	sh	1
			Limnephilidae				
				Cryptochia	0	sh	1
			Philopotamidae				
				Wormaldia	3	cf	275
			Polycentropodidae				
				Polycentropus	6	p	81
			Psychomyiidae				
				Psychomyia	2	cg	1
				Tinodes	2	sc	73
			Rhyacophilidae				
				Rhyacophila	0	p	116
			Sericostomatidae				
				Gumaga	3	sh	6
			Uenoidae				
				Farula	0	cg	1
	Arachnoidea						
		Acari					
			Hydryphantidae				
				Protzia	8	p	15
			Hygrobatidae				
				Atractides	8	p	7
				Hygrobates	8	p	8
				Hygrobatidae	8	p	26
			Lebertiidae				
				Lebertia	8	p	105
			Sperchontidae				
				Sperchon	8	p	1071
				Sperchonopsis	8	p	52
			Torrenticolidae				
				Torrenticola	5	p	2
	Crustacea						
		Decapoda					
				Astacidea	8	om	3
	Malacostraca						
		Amphipoda					
			Hyalellidae				
				Hyalella	8	cg	634
	Ostracoda						
				Ostracoda	8	cg	1432
Annelida							
	Hirudinea						
		Arhynchobdellida					
			Erpobdellidae				
				Erpobdellidae	8	p	1
	Oligochaeta						
				Oligochaeta	5	cg	588
Mollusca							
	Bivalvia						
		Veneroida					
			Sphaeriidae				
				Pisidium	8	cf	10
	Gastropoda						
		Basommatophora					
			Ancylidae				
				Ferrissia	6	sc	18
			Lymnaeidae				
				Lymnaeidae	6	sc	138
			Physidae				
				Physa	8	sc	307
			Planorbidae				
				Gyraulus	8	sc	70
				Menetus	7	sc	2
				Planorbidae	6	sc	29
Nemertea							
	Enopa						
			Tertastemmatidae				
				Prostoma	8	p	288
Platyhelminthes							
	Turbellaria						
				Turbellaria	4	p	620

* CTV: California Tolerance Value

**FFG: Functional Feeding Group

- cg: collector-gatherer
- cf: collector-filterer
- sc: scraper
- p: predator
- sh: shredder
- om: omnivore
- mh: macrophyte herbivore
- ph: piercer herbivore

Note: FFGs om, mh and ph were combined into "other" (ot) catogory for metric calculations

APPENDIX D

Carmel River benthic macroinvertebrate individuals organized by taxonomic group and year of sampling

	Fall 2000					Spring 2001						Fall 2001				Spring 2002				Fall 2002				
Taxa	CRCA	CRSH	SHRC	CRSP	CRRR	CRCA	CRSH	CRSP	CRDD US	CRDD DS	CRRR	CRCA	CRSH	CRSP	CRRR	CRCA	CRSH	CRSP	CRRR	CRCA	CRSH	CRRW	CRSP	CRRR
Agabus																								1
Agapetus								1	1									4						
Ambrysus											2								1					
Ameletus																								
Amiocentrus aspilus																								
Ampumixis dispar																								
Antocha	8	17	7	15	2	9	11	6	9	7	3	10	18	12	5	12	32	12	2	6	6	13	7	
Argia	13	27	8		1	2	3	1	1		1	44	10	1	4	14	3	2	1	37	10	2		3
Astacidea																1		1						
Atractides																								
Atrichopogon							1	1																
Baetis	112	185	54	100	55	54	63	148	34	68	32	108	121	110	64	156	216	216	62	85	106	103	118	3
Bezzia/ Palpomyia								1																
Calineuria californica																								
Caloparyphus/Euparyphus									1	1		1	1											1
Capniidae																								
Centroptilum				1																				
Chaoborus																								
Cheumatopsyche		3	6	3	9			5	2	22	15	1	11	63	33			11			1	5	22	
Chironomini			5			7	4	3	7	2	16					2			2	1				2
Cleptelmis addenda																								
Clinocera	1																							
Coenagrionidae																								1
Cordulegaster dorsalis																								
Cryptochia																								
Cryptolabis																								
Cultus																								
Cyclorrhaphous/Brachycera																								
Dasyhelea												1										2		2
Dicranota							1	1									1							
Diphetor hageni							1		1										1					
Dixa								1								1	1							
Dolichopodidae																								
Drunella																								
Empididae																								
Epeorus																								
Ephemerella																		2	14					
Ephydridae								1																
Erpobdellidae																								
Eubrianax edwardsii																								
Fallceon quilleri			1		16																			1
Farula																								
Ferrissia			5																			1		
Glossosoma								1	1															
Glossosomatidae																								
Gumaga					2																			
Gyraulus			31																					
Gyrinus																			1					
Hedriodiscus/Odontomyia																								
Helichus			1																					
Hemerodromia	13	7	1	2	4		3	1	4	1	10	11	2	1	1					6	6	2	3	
Heptageniidae																								

Taxa	Fall 2000					Spring 2001						Fall 2001				Spring 2002				Fall 2002				
	CRCA	CRSH	SHRC	CRSP	CRRR	CRCA	CRSH	CRSP	CRDD US	CRDD DS	CRRR	CRCA	CRSH	CRSP	CRRR	CRCA	CRSH	CRSP	CRRR	CRCA	CRSH	CRRW	CRSP	CRRR
Hetaerina americana	1	1			2						1		1		2							1		
Hexatoma																								
Hyalella						18	2		13	1	1	16		4	3	116	1		19	20	1	7		1
Hydraena																								
Hydropsyche	65	13	68	185	88	32	3	118	94	91	85	132	33	167	59	18	6	50	68	8	2	21	42	5
Hydroptila		1					1	2		1				2					2					
Hygrobates																								
Hygrobatidae							1	1	6	3	3								1					
Ironodes																								
Isoperla				2																				
Lebertia	1	1			1	1		1	1		1	1	1							1				1
Lepidostoma			1	3		1			2		2													
Leucotrichia pictipes	84	142	18	6	1	2	13	1				70	38	22	12	1	1			95	49	23	31	6
Limnophila																								
Limonia																								
Lymnaeidae	1	3	42	11						1		1										3	6	2
Malenka			2	1		1		3									1	2						
Maruina lanceolata			5							1								1						
Menetus																								
Meringodixa chalonensis																								
Micrasema	36	1		44	10	17	4	61	99	80	126	10	3	36	56	12	2	4	49	17	1	5	7	49
Mystacides											1													
Narpus												1												
Nectopsyche				1																				
Neoplasta	1		2			2	11		1															
Ochrotrichia	13	14	1	3		1	12	5	3	18	7	3	18	10	21	6	5	10	2	5	5	17	21	23
Oecetis			2		3				3	1	1													
Oligochaeta		3	1	1		54	75	12	23	7	9	2	1	1		1	1	1	1		3	2	42	
Optioservus		2		1	39		1	1	4	2	4		2						1					11
Ordobrevia nubifera													1	9	21									
Orthocladiinae	33	25	14	3	6	78	119	39	20	18	27	28	20	2	4	20	29	9	21	95	76	91	28	48
Ostracoda		2		9			2	2	7	5	5	2		9	21	1		1	46			69	18	28
Oxyethira															1				2			1	1	
Paraleptophlebia							1																	
Physa			23	1	3				1															54
Pisidium							2		1														1	
Planorbidae	1		5			1	2															1		3
Polycentropus			30	1				1										1						
Postelichus				1	1																			
Prostoma																				9	13	12	42	3
Protzia																								
Psephenus falli				1	8			1		4	4			2	42			2	12					
Psychodidae																								
Psychomyia										1														
Rhithrogena																								
Rhyacophila		1					4	10						1		1	3	3				1	1	
Sciomyzidae																								
Serratella						1	1	4	20	16	19							2	24					
Sialis																								
Simulium	1	18	23	72	22	163	121	13	14	65	6	2	206	27	104	120	184	117	54	76	198	114	96	167
Sperchon	9	25	7	8	32	7	12	11	13	30	15	29	11	8	17	1	2	1	5	19	6	3	11	1
Sperchonopsis																								
Sweltsa																								

Taxa	Fall 2000					Spring 2001						Fall 2001				Spring 2002				Fall 2002				
	CRCA	CRSH	SHRC	CRSP	CRRR	CRCA	CRSH	CRSP	CRDD US	CRDD DS	CRRR	CRCA	CRSH	CRSP	CRRR	CRCA	CRSH	CRSP	CRRR	CRCA	CRSH	CRRW	CRSP	CRRR
Tabanidae																								
Tanypodinae	1		3		1	1	3	2	7	1	2					1			1		1	2		3
Tanytarsini	99	10	130	1		48	18	10	23	7	22	29	3		1	13	2	5	92	20	15	1	3	77
Tinodes			1		6				2	1	3			2	9				2					
Tipula									1	1		1				1	1			1				
Tipulidae																								
Torrenticola																								
Triaenodes frontalis								1																
Trichoclinocera						1	2	1																
Tricorythodes	1			28	155		4	2	68	25	53			6	18				4					1
Tropisternus																								1
Turbellaria	6		3		32		1	1	14	18	23			1	4			1	13		2	1		2
Wiedemannia																								
Wormaldia							2	27	2	2				4		2	11	44				1		
Zaitzevia																								

Taxa	Spring 2003					Fall 2003					Fall 2004						Fall 2005					Fall 2006				
	CRCA	CRSH	CRRW	CRSP	CRRR	CRCA	CRSH	CRRW	CRSP	CRRR	CRLP	CRCA	CRSH	SHRC	CRSP	CRRR	CRLP	CRCA	CRSH	CRSP	CRRR	CRLP	CRCA	CRSH	CRSP	CRRR
Agabus																6										
Agapetus																										
Ambrysus																										
Ameletus											14															
Amiocentrus aspilus																										
Ampumixis dispar											5						3					9				
Antocha	10	18	19	8	5	7	7	8	5			4	8	12	5		2	18	19	13	6	10	4	8	3	7
Argia	16	4		1	1	13	4		15	9	5	11	28		7			14	41		4		24	32		
Astacidea																										
Atractides																3							1			
Atrichopogon							1					1			3		1							1		
Baetis	124	174	176	231	129	58	136	141	140	4	13	78	84	10	124	15	56	157	67	195	40	106	133	84	233	46
Bezzia/ Palpomyia					1						6						3					1				
Calineuria californica																	3					1				
Caloparyphus/Euparyphus						1	1				4	1	4			2	4					4				
Capniidae											24						13					1			1	
Centroptilum																										
Chaoborus																										
Cheumatopsyche						3	1	3						1				10	1						4	
Chironomini	3	1	1				1				10	2	1	61		4			2			2	1	4		
Cleptelmis addenda		1						2	1				1			1	3		1			4		3		
Clinocera																										
Coenagrionidae																										
Cordulegaster dorsalis																										
Cryptochia																						1				
Cryptolabis											1						6					2				
Cultus											2						5					3				
Cyclorrhaphous/Brachycera											1															
Dasyhelea					2	1										7										
Dicranota	2		1								3						2					2				
Diphetor hageni	1	1															5					3	1			
Dixa		1									3															
Dolichopodidae											1					1										
Drunella																										
Empididae		1		2																						
Epeorus											12						79					39				
Ephemerella			1	1	14						2						21					4				
Ephydridae																										
Erpobdellidae												1														
Eubrianax edwardsii											11						13					14				
Fallceon quilleri										1																
Farula																										
Ferrissia			1			1					3		4													
Glossosoma																										
Glossosomatidae					2																					
Gumaga										1																
Gyraulus	2	1			2							1	1			2										3
Gyrinus																										
Hedriodiscus/Odontomyia		1																								
Helichus																										
Hemerodromia						13	1	2	3		26	9	6	7	4		14	12	6	2		8	13	3	2	1
Heptageniidae																	12									

Taxa	Spring 2003					Fall 2003					Fall 2004						Fall 2005					Fall 2006				
	CRCA	CRSH	CRRW	CRSP	CRRR	CRCA	CRSH	CRRW	CRSP	CRRR	CRLP	CRCA	CRSH	SHRC	CRSP	CRRR	CRLP	CRCA	CRSH	CRSP	CRRR	CRLP	CRCA	CRSH	CRSP	CRRR
Hetaerina americana								1	1	2	1								2		6					8
Hexatoma											2						2									
Hyalella	26	4			3	10		4	1	1		7	2		2			2	11	1	3		48	1	3	
Hydraena																	1									
Hydropsyche	14	3	14	7	16	11	5	32	56	34		5	4	151	15		3	38	7	57	120	1	15	18	68	127
Hydroptila		1																								
Hygrobates				1	4																					
Hygrobatidae																										
Ironodes			1																			1				
Isoperla											3						3					1				
Lebertia	1	1	1	1	3	2	2	1	1	1	5	1		1	2	2	2	3	1		7		2	2	4	4
Lepidostoma	1				5						2			4							1	5				
Leucotrichia pictipes						61	80	32	90			27	24	8	44	1	1	79	15	27			51	38	32	1
Limnophila											1															
Limonia		1				1			1							1								2		
Lymnaeidae			1										2			1										
Malenka			1	1		1					5		1	14			9		3	2		8		4	14	2
Maruina lanceolata						1									3			1								
Menetus																										
Meringodixa chalonensis																										
Micrasema	5	8	16	23	161	5		6	16	121	4	36	1		118	134	22	2			56	4	19		15	99
Mystacides																										
Narpus																										
Nectopsyche																										
Neoplasta		1	2	1	1						1		1			1	1	1								
Ochrotrichia	2	2	13	7	4	4	3	10	16	6		1		1	6	5		12	4	10	19		4	3	8	57
Oecetis																										
Oligochaeta		2		1	1					25	3	7	12	21	18	15	2			9			5	5		1
Optioservus				1	1					6					2	21					9					12
Ordobrevia nubifera																										
Orthocladiinae	81	70	58	28	12	35	25	10	16	27	116	40	71	39	30	142	53	35	22	13	11	95	27	63	5	4
Ostracoda	2				29	1		170	49	16	23	2	2		39	4			2	11	57			6	3	6
Oxyethira																					1					
Paraleptophlebia		1									11						3					3				
Physa	1				18					44				7	14	6					9					1
Pisidium																							2			
Planorbidae								3	1																	
Polycentropus														15												
Postelichus																										
Prostoma						13	4	7	5	14			1	2	2	8	1	18	2	4	2	1	5	4		4
Protzia										2						2	1				2	2				
Psephenus falli										1																
Psychodidae			1																							
Psychomyia																										
Rhithrogena											9						44					10				
Rhyacophila		1	1	3			2				8				1		15					8		1	4	
Sciomyzidae																1										
Serratella																										
Sialis																										
Simulium	167	179	163	161	22	218	199	49	64		93	254	176		70	8	56	41	256	133	4	60	107	176	95	16
Sperchon	6	5	10	8	30	12	11	10	15	27	3	5	2	3	9	2	8	21	9	4	64	14	13	12	10	18
Sperchonopsis	1					2	1	2	2									3	1		5	1	3			4
Sweltsa											21						7					6				

Taxa	Spring 2003					Fall 2003					Fall 2004						Fall 2005					Fall 2006				
	CRCA	CRSH	CRRW	CRSP	CRRR	CRCA	CRSH	CRRW	CRSP	CRRR	CRLP	CRCA	CRSH	SHRC	CRSP	CRRR	CRLP	CRCA	CRSH	CRSP	CRRR	CRLP	CRCA	CRSH	CRSP	CRRR
Tabanidae											2															
Tanypodinae	4	1	1	1	1					1	21			1		1	2					1	1			
Tanytarsini	33	5			2	29	18	4	4	8	22	14	73	172		119	19	26	16	2	1	61	4	17		
Tinodes					2					10																3
Tipula												1			1	1						2	2			
Tipulidae																						3				
Torrenticola																	1									
Triaenodes frontalis																										
Trichoclinocera																										
Tricorythodes		1			18					15						2					40			1	1	59
Tropisternus																										
Turbellaria				1	13	1	1	3	2	125			1		1			1	8	8	35		7	8	2	27
Wiedemannia		1		2							3	2			1		2	1					1			
Wormaldia	2	12	21	14	1						1						1					6			3	
Zaitzevia											8						3					5				

Taxa	Fall 2007					Fall 2008						Fall 2009				
	CRLP	CRCA	CRSH	CRSP	CRSW	CRLP	CRCA	CRSH	SHRC	CRSP	CRSW	CRLP	CRCA	CRSH	CRSP	CRRR
Agabus																
Agapetus																
Ambrysus																
Ameletus						2						1	1			
Amiocentrus aspilus	1											2				2
Ampumixis dispar	4					4						3				
Antocha	2		3	2	1	3	5		5		3		1	1	1	4
Argia	2	20	30	17	3	1	14	20		26	3		10	23	8	
Astacidea																
Atractides									1		1	1				
Atrichopogon	1	1			1											
Baetis	71	73	115	124	61	90	72	33	34	100	77	21	33	82	92	78
Bezzia/ Palpomyia						2										
Calineuria californica						3						1				
Caloparyphus/Euparyphus	10	1				2	1			1						
Capniidae	5											4			1	
Centroptilum																
Chaoborus													4			
Cheumatopsyche		2					2			2	4					10
Chironomini	1					3	1	4	71	1		1	1	1		
Cleptelmis addenda	1		2	2			1	1	1	1		2				
Clinocera																
Coenagrionidae																
Cordulegaster dorsalis	1															
Cryptochia																
Cryptolabis						1						1				
Cultus						4						6				
Cyclorrhaphous/Brachycera																
Dasyhelea																
Dicranota													1			
Diphetor hageni											3	1		1		2
Dixa	1					1										
Dolichopodidae																
Drunella												1				
Empididae	3															
Epeorus						38						62				
Ephemerella						4						38				
Ephydridae																
Erpobdellidae																
Eubrianax edwardsii	11					15						12				
Fallceon quilleri																
Farula												1				
Ferrissia																
Glossosoma												1				
Glossosomatidae																
Gumaga																
Gyraulus																2
Gyrinus																
Hedriodiscus/Odontomyia																
Helichus																
Hemerodromia	13	23	6	1		13	5	3	5	1			4			
Heptageniidae																

Taxa	Fall 2007					Fall 2008						Fall 2009				
	CRLP	CRCA	CRSH	CRSP	CRSW	CRLP	CRCA	CRSH	SHRC	CRSP	CRSW	CRLP	CRCA	CRSH	CRSP	CRRR
Hetaerina americana			1		3											
Hexatoma																
Hyalella		3	3	7	3		11	10		3			4	2	17	
Hydraena						1										
Hydropsyche		3	9	11	52	4	8	1	88	17	68	27	6	1	10	75
Hydroptila																
Hygrobates																
Hygrobatidae																
Ironodes												3				
Isoperla						3						11				
Lebertia	1	1		4	3	3	2	1		1	12	1			1	
Lepidostoma						1			6	2	1	1				
Leucotrichia pictipes		5	12	4			23	1	2	1				1	3	
Limnophila																
Limonia			2	1												
Lymnaeidae					2		1						1			7
Malenka	3		3	3	1	1		1	22	9	5	8			1	
Maruina lanceolata		1				1	2		1				1			
Menetus							1						1			
Meringodixa chalonensis	1															
Micrasema	5	4		7	46	1	1			14	130	140	4		3	255
Mystacides																
Narpus																
Nectopsyche																
Neoplasta		3	1	1	1	2			1	1		2				
Ochrotrichia	5		1	2	8	1	1			1	2		1			2
Oecetis																
Oligochaeta					3	1	2	1		1	1	2		1		
Optioservus					37						5					13
Ordobrevia nubifera						1						1				
Orthocladiinae	40	71	51	25	11	73	26	31	25	15	15	37	40	19	20	4
Ostracoda	1		73	2	101			76	3	1	23			88	14	4
Oxyethira																
Paraleptophlebia				1		4						9				
Physa					6				6		1					1
Pisidium												1				
Planorbidae																
Polycentropus									11							
Postelichus																
Prostoma	2	2		2		2	3			2	1			1		
Protzia	1					3						1				
Psephenus falli																
Psychodidae																
Psychomyia																
Rhithrogena						30						55				
Rhyacophila	1			3		6	2			2		10	1		1	
Sciomyzidae				3												
Serratella																
Sialis												1				
Simulium	294	248	166	266	127	127	276	311	46	280	98	16	362	290	316	45
Sperchon	7	20	1	5	4	11	24		4	5	47	3	5	1	2	2
Sperchonopsis		2				2	6	1		1	5		2	2	1	
Sweltsa	2					18				1		7				

Taxa	Fall 2007					Fall 2008						Fall 2009				
	CRLP	CRCA	CRSH	CRSP	CRSW	CRLP	CRCA	CRSH	SHRC	CRSP	CRSW	CRLP	CRCA	CRSH	CRSP	CRRR
Tabanidae	1											1				
Tanypodinae					1	1	1		2							
Tanytarsini	4	8	23	5	6	16	3	9	164	1	1	1	10	2		
Tinodes					2											2
Tipula	2	1											1			
Tipulidae																
Torrenticola												1				
Triaenodes frontalis																
Trichoclinocera																
Tricorythodes					2						3			3		1
Tropisternus																
Turbellaria			1		28				6		18					
Wiedemannia		2				6										
Wormaldia									1	1						
Zaitzevia	13					1						3				

APPENDIX E

Biological metric values for benthic macroinvertebrates sampled from the Carmel River

Biological metric values for Carmel River monitoring sites, years 2000 to 2009.

	Fall 2000					Spring 2001						Fall 2001			
	CRCA	CRSH	SHRC	CRSP	CRRR	CRCA	CRSH	CRSP	CRDD US	CRDD DS	CRRR	CRCA	CRSH	CRSP	CRRR
Richness:															
Taxonomic	17	20	24	22	21	17	28	32	28	26	26	20	16	20	20
EPT*	5	8	9	13	9	7	11	16	12	12	11	6	6	10	9
Ephemeroptera	1	1	2	3	3	1	4	3	4	3	3	1	1	2	2
Plecoptera	0	0	1	2	0	1	0	1	0	0	0	0	0	0	0
Trichoptera	4	7	6	8	6	5	7	12	8	9	8	5	5	8	7
Coleoptera*	0	1	1	1	2	0	1	2	1	2	2	1	2	2	2
Predator*	7	6	6	4	7	5	8	9	6	5	8	4	4	2	4
Composition:															
EPT Index (%)	61	72	37	74	68	21	22	79	65	66	66	64	42	86	53
Sensitive EPT Index (%)	7.0	0.3	0.6	11	2.8	3.6	2.2	21	25	19	28	1.2	0.6	8.4	15
Shannon Diversity	2.0	1.9	2.4	2.0	2.2	1.9	2.2	2.1	2.5	2.5	2.4	2.1	1.8	2.1	2.5
Dominant Taxon (%)	27	37	31	35	32	31	26	30	19	18	23	25	44	34	23
Non-insect Taxa (%)*	29	25	33	18	19	24	29	19	32	27	27	30	13	20	20
Tolerance:															
Tolerance Value	5.1	5.5	5.7	4.4	4.5	5.6	5.6	4.2	4.1	4.4	4.0	5.4	5.5	4.5	4.6
Intolerant Organisms (%)*	7.0	0.3	1.4	11	2.6	3.6	1.6	17	25	19	28	1.2	0.6	7.4	14
Intolerant Taxa (%)	5.9	10	13	23	9.5	18	11	22	18	19	15	5.0	6.3	10	10
Tolerant Taxa (%)*	12	15	17	9.1	19	18	18	13	32	19	23	20	6	15	15
Functional Feeding Groups:															
Collector-Gatherers (%)	52	48	44	32	48	58	59	45	48	31	41	39	31	30	23
Collector-Filterers (%)	13	6.8	20	51	23	35	27	33	22	37	23	25	52	51	38
Collectors (%)*	65	55	64	83	71	93	86	78	70	68	63	65	82	81	61
Scrapers (%)	16	29	26	3.0	10	0.6	4.0	1.0	1.8	2.0	1.8	16	8.6	7.4	16
Predators (%)	9.4	12	9.4	3.4	17	2.8	7.4	6.8	8.2	11	10	18	5.8	1.8	5.8
Shredders (%)	0.0	0.0	0.8	0.8	0.2	0.6	0.0	0.8	0.4	0.0	0.2	0.0	0.0	0.0	0.0
Other (%)	9.2	3.0	0.0	10	1.8	3.4	2.8	13	20	20	25	1.6	3.2	10	18
Abundance/Biovolume:															
Organisms per m^2	2800	2100	3200	10000	13000	4400	5800	7800	5900	9100	9600	3800	4300	5900	4000
Organisms (ml per m^2)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

* metrics used for index of biotic integrity

Biological metric values for Carmel River monitoring sites, years 2000 to 2009.

	Spring 2002				Fall 2002					Spring 2003					Fall 2003				
	CRCA	CRSH	CRSP	CRRR	CRCA	CRSH	CRRW	CRSP	CRRR	CRCA	CRSH	CRRW	CRSP	CRRR	CRCA	CRSH	CRRW	CRSP	CRRR
Richness:																			
Taxonomic	13	15	21	21	14	15	21	17	22	16	22	16	14	27	21	16	19	20	21
EPT*	5	7	11	10	5	5	8	7	5	5	9	8	6	10	7	6	6	5	8
Ephemeroptera	1	1	3	4	1	1	1	1	1	2	3	3	1	3	1	1	1	1	3
Plecoptera	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Trichoptera	4	5	7	6	4	4	7	6	4	3	6	5	5	7	5	5	5	4	5
Coleoptera*	0	0	1	2	0	0	0	0	3	0	1	0	1	1	0	0	1	1	2
Predator*	2	3	3	4	5	5	7	4	6	5	6	4	4	7	6	7	6	8	6
Composition:																			
EPT Index (%)	39	50	71	45	42	32	37	49	18	30	40	49	58	71	30	45	46	64	38
Sensitive EPT Index (%)	2.2	3.4	13	18	3.8	0.2	1.6	1.8	11	1.6	4.0	6.6	8.6	38	1.8	0.6	1.0	3.4	25
Shannon Diversity	1.7	1.4	1.8	2.3	2.1	1.7	2.1	2.4	1.9	1.7	1.7	1.7	1.5	2.2	1.9	1.6	2.0	2.2	2.3
Dominant Taxon (%)	33	44	42	24	24	41	23	24	33	33	35	36	47	33	45	40	33	27	24
Non-insect Taxa (%)*	23	13	19	24	29	33	29	35	36	38	23	25	14	33	29	25	42	40	38
Tolerance:																			
Tolerance Value	5.9	5.2	4.7	4.9	5.8	5.8	5.8	5.5	5.7	5.7	5.4	5.2	5.1	3.9	5.9	5.7	6.2	5.5	4.4
Intolerant Organisms (%)*	2.0	1.6	3.2	18	3.8	0.2	1.4	1.8	11	1.4	1.6	2.6	5.8	38	2.0	0.6	1.0	3.4	25
Intolerant Taxa (%)	15	27	33	19	7.1	6.7	9.5	12	4.5	6.3	14	19	14	19	14	6.3	5.3	5.0	9.5
Tolerant Taxa (%)*	15	13	10	19	29	20	19	24	32	38	18	13	7	26	24	31	32	30	29
Functional Feeding Groups:																			
Collector-Gatherers (%)	67	58	48	58	46	41	59	45	33	56	56	52	53	42	27	37	68	42	19
Collector-Filterers (%)	28	39	46	26	17	41	28	31	33	37	38	39	36	7.8	48	41	16	25	7.2
Collectors (%)*	95	96	94	84	63	83	86	76	66	93	95	92	90	50	74	78	84	67	26
Scrapers (%)	0.0	0.0	1.4	2.8	19	8.8	4.8	8.2	15	0.2	0.2	0.8	0.2	4.8	13	16	6.8	18	13
Predators (%)	2.8	1.2	1.2	4.0	14	7.6	4.2	10	2.2	5.8	3.0	3.0	3.2	11	10	5.6	5.4	8.2	36
Shredders (%)	0.0	0.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.6	0.0	0.0	0.0	0.4
Other (%)	2.4	2.2	2.6	9.6	4.6	0.8	4.8	5.8	16	1.4	2.2	4.6	7.0	33	2.0	0.4	3.6	7.2	24
Abundance/Biovolume:																			
Organisms per m^2	5600	5900	7800	5400	4400	4700	2900	2500	15200	4700	4000	3100	3600	2600	9600	3800	7000	4100	5300
Organisms (ml per m^2)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

* metrics used for index of biotic integrity

Biological metric values for Carmel River monitoring sites, years 2000 to 2009.

	Fall 2004						Fall 2005					Fall 2006				
	CRLP	CRCA	CRSH	SHRC	CRSP	CRRR	CRLP	CRCA	CRSH	CRSP	CRRR	CRLP	CRCA	CRSH	CRSP	CRRR
Richness:																
Taxonomic	39	21	22	16	24	27	41	20	20	15	22	37	22	22	20	23
EPT*	15	5	5	8	6	5	18	6	6	5	7	19	6	7	11	8
Ephemeroptera	6	1	1	1	1	2	7	1	1	1	2	7	2	2	2	2
Plecoptera	5	0	1	1	0	0	6	0	1	1	0	6	0	1	2	1
Trichoptera	4	4	3	6	5	3	5	5	4	3	5	6	4	4	7	5
Coleoptera*	3	0	1	0	1	3	5	0	1	0	1	4	0	1	0	1
Predator*	17	6	6	5	8	9	16	9	8	4	8	12	9	7	5	7
Composition:																
EPT Index (%)	25	29	22	38	59	30	60	60	20	59	55	41	45	30	75	77
Sensitive EPT Index (%)	21	7.1	0.4	3.4	23	26	44	0.4	0.6	0.4	12	19	3.9	1.0	7.3	20
Shannon Diversity	2.6	1.7	1.8	1.5	2.3	1.7	2.9	2.2	1.8	1.8	2.4	2.4	2.3	2.1	1.8	2.3
Dominant Taxon (%)	33	50	35	52	24	51	16	32	52	40	24	31	27	35	46	25
Non-insect Taxa (%)*	13	33	41	31	33	37	15	30	35	40	41	11	41	32	25	39
Tolerance:																
Tolerance Value	4.8	5.5	5.8	5.2	4.7	4.7	3.3	5.5	5.8	5.3	5.0	4.6	5.7	5.8	5.0	3.9
Intolerant Organisms (%)*	22	7.1	0.4	3.4	23	26	44	0.6	0.6	0.4	11	18	3.9	1.0	6.7	20
Intolerant Taxa (%)	36	4.8	9.1	13	13	3.7	29	10	5.0	6.7	9.1	35	4.5	9.1	20	13
Tolerant Taxa (%)*	13	33	27	25	25	37	12	25	30	27	36	14	32	23	20	30
Functional Feeding Groups:																
Collector-Gatherers (%)	48	31	51	60	42	60	34	48	28	50	31	59	45	39	49	24
Collector-Filterers (%)	18	51	35	29	16	2	12	18	53	39	25	13	25	39	33	28
Collectors (%)*	66	81	86	88	59	62	46	66	81	88	56	72	71	78	82	52
Scrapers (%)	8.4	5.5	6.1	2.8	12	6.0	30	16	3.0	5.5	3.6	13	10	7.7	6.3	3.9
Predators (%)	18	5.7	7.6	5.3	5.2	5.0	14	15	14	3.7	25	9.4	14	13	4.3	13
Shredders (%)	6.2	0.0	0.2	3.4	0.0	0.2	5.5	0.0	0.6	0.4	0.2	3.3	0.0	1.2	2.9	0.4
Other (%)	0.8	7.5	0.2	0.2	24	27	4.3	2.8	0.8	2.0	15	1.2	5.1	0.6	4.5	31
Abundance/Biovolume:																
Organisms per m^2	1400	2900	1100	6500	3000	600	2200	4400	4400	5100	4700	1376	2452	957	2153	5323
Organisms (ml per m^2)	ND	ND	ND	ND	ND	ND	2.5	5.0	4.1	5.3	9.6	2.5	6.2	1.7	3.7	11.1

* metrics used for index of biotic integrity

Biological metric values for Carmel River monitoring sites, years 2000 to 2009.

	Fall 2007					Fall 2008						Fall 2009				
	CRLP	CRCA	CRSH	CRSP	CRSW	CRLP	CRCA	CRSH	SHRC	CRSP	CRSW	CRLP	CRCA	CRSH	CRSP	CRRR
Richness:																
Taxonomic	30	20	18	22	23	39	23	14	19	25	23	40	20	15	16	18
EPT*	8	5	5	8	7	16	7	4	7	11	9	22	6	5	7	9
Ephemeroptera	1	1	1	2	2	6	1	1	1	1	3	9	2	3	1	3
Plecoptera	3	0	1	1	1	5	0	1	1	2	1	6	0	0	2	0
Trichoptera	4	4	3	5	4	5	6	2	5	8	5	7	4	2	4	6
Coleoptera*	4	0	1	1	1	5	1	1	1	1	1	5	0	0	0	1
Predator*	11	8	6	8	6	15	7	4	6	9	7	13	7	4	5	1
Composition:																
EPT Index (%)	18	18	28	31	34	42	22	7	32	31	56	82	9	17	23	84
Sensitive EPT Index (%)	3.3	0.8	0.6	2.6	9.6	22	0.6	0.2	5.7	5.9	26	70	1.2	0.0	1.2	51
Shannon Diversity	1.7	1.7	1.8	1.5	2.3	2.5	1.7	1.3	1.7	1.5	2.2	2.6	1.1	1.3	1.3	1.6
Dominant Taxon (%)	58	50	33	53	25	25	56	62	52	57	25	28	73	56	64	50
Non-insect Taxa (%)*	17	25	22	23	35	15	35	36	26	28	39	18	25	40	31	28
Tolerance:																
Tolerance Value	5.6	5.9	6.0	5.7	5.4	4.5	5.9	6.3	5.3	5.5	4.5	2.0	5.9	6.2	5.9	2.9
Intolerant Organisms (%)*	3.5	1.0	0.6	2.6	9.6	22	1.0	0.2	5.7	5.7	26	69	1.4	0.0	1.2	50
Intolerant Taxa (%)	23	10	5.6	14	13	36	13	7.1	16	20	13	40	20	0.0	25	11
Tolerant Taxa (%)*	23	30	17	23	22	15	26	29	21	28	30	15	15	33	31	22
Functional Feeding Groups:																
Collector-Gatherers (%)	27	32	54	34	37	40	25	33	60	25	24	24	18	39	29	19
Collector-Filterers (%)	58	51	35	56	35	26	58	62	27	61	32	9	74	56	66	26
Collectors (%)*	85	83	88	89	72	66	83	95	87	86	56	33	93	95	96	44
Scrapers (%)	4.7	1.2	2.4	0.8	9.2	17	5.5	0.2	1.8	0.2	1.1	27	0.6	0.2	0.6	4.9
Predators (%)	6.7	15	8.0	7.2	8.2	16	11.3	5.0	5.5	8.1	17	9.2	5.5	5.2	2.6	0.4
Shredders (%)	1.6	0.0	1.0	0.8	0.2	0.6	0.0	0.2	5.5	2.2	1.1	2.8	0.0	0.0	0.4	0.0
Other (%)	2.4	1.0	0.2	1.8	11	0.4	0.4	0.0	0.0	3.1	25	28	1.2	0.0	0.6	50
Abundance/Biovolume:																
Organisms per m^2	2452	4163	4809	4205	8494	2452	4187	4426	4187	4785	6580	1615	6418	1579	4223	4965
Organisms (ml per m^2)	4.3	5.1	4.1	4.0	15.7	3.7	5.4	4.1	7.0	5.6	11.5	2.4	53.6	2.1	5.7	7.2

* metrics used for index of biotic integrity

APPENDIX F

Selected photographs of benthic macroinvertebrate taxa sampled from the Carmel River (magnification 15-25x)

Baetis sp. (mayfly); Carmel R.; spring 2003

Rhithrogena sp. (mayfly); Carmel R.; fall 2009

Tricorythodes sp. (mayfly); Carmel R.; spring 2003

Ephemerella sp. (mayfly); Carmel R.; fall 2009

Epeorus sp. (mayfly); Carmel R.; fall 2009

Serratella sp. (mayfly); Merced R.; genus also found in Carmel R.

Isoperla sp. (stonefly); Carmel R.; fall 2009

Calineuria californica (stonefly); Carmel R.; fall 2009

Malenka sp. (stonefly); Carmel R.; fall 2009

Leucotrichia pictipes (caddisfly); Carmel R fall 2002

Rhyacophila sp. (caddisfly); Carmel R.; fall 2009

Ochrotrichia sp. (caddisfly); Carmel R.; fa 2002

Wormaldia sp. (caddisfly); Carmel R.; fall 2002

Hydropsyche sp. (caddisfly); Carmel R.; fall 2002

Cheumatopsyche sp. (caddisfly); Carmel R.; fall 2002

Lepidostoma (caddisfly); Carmel R.; fall 2002

Micrasema sp. (caddisfly); Carmel R.; spring 2003

Hydraena sp. (beetle); Carmel R.; fall 2009

Optioservis sp. (riffle beetle); Carmel R.; fall 2002

Ampumixus sp. (riffle beetle); Carmel R.; fall 2009

Orthocladiinae (midge); Carmel R.; fall 2002

Tanytarsini (midge); Carmel R.; fall 2002

Antocha sp. (crane fly); Carmel R.; fall 2002

Simulium sp. (black fly); Carmel R.; fall 2002

Argia sp. (damselfly); Carmel R.; spring 2003

Ostracoda (seed shrimp); Carmel R.; spring 2002

Sperchon sp. (water mite); Carmel R.; spring 2003

Naididae (segmented worm); Carmel R.; fall 2002

Hyalella sp. (scud); Carmel R.; fall 2002

APPENDIX G

Physical habitat constituents assessed during benthic macroinvertebrate surveys of the Carmel River

Year	Season	Site	Flow (cfs)	Site Habitat Score (0-200)	Ave. Canopy (%)	Ave. Width (ft)	Ave. Depth (ft)	Ave. Velocity (ft/s)	Ave. Riffle Gradient (%)	Substrate Index (mm)	Dominant Substrate Class	Subdominant Substrate Class	Sand (%)	Gravel (%)	Cobble (%)	Boulder (%)	Bedrock (%)
2000	Fall	CRCA	20	179	68	25	1.0	1.9	2.7	201	boulder	cobble	4	13	36	47	1
		CRSH	20	166	57	22	1.0	0.7	1.9	167	cobble	boulder	5	13	59	23	0
		SHRC	1.5	139	60	6.6	0.6	0.8	0.5	156	cobble	gravel	0	18	67	14	0
		CRSP	20	142	43	23	0.7	2.3	3.0	161	cobble	boulder	8	13	55	23	0
		CRRR	20	109	22	21	0.9	2.4	1.4	105	cobble	gravel	10	33	53	3	0
2001	Spring	CRCA	25	173	71	32	0.8	2.1	2.8	204	boulder	cobble	4	14	33	50	0
		CRSH	25	184	64	21	0.9	1.7	2.1	179	cobble	boulder	5	13	48	33	0
		CRSP	25	162	55	25	0.8	2.4	2.7	132	cobble	gravel	6	22	66	7	0
		CRDD_US	ND	point source design	24	23	0.8	2.1	1.0	63	sand	gravel	45	25	25	5	0
		CRDD_DS	ND		5	24	0.6	3.0	3.0	108	cobble	gravel	15	25	35	15	0
		CRRR	20	110	29	25	0.7	2.9	1.9	81	gravel	cobble	13	46	40	1	0
	Fall	CRCA	7.5	185	68	25	0.7	1.3	4.1	236	boulder	cobble	1	11	18	69	0
		CRSH	7.0	169	67	13	0.8	1.8	7.0	221	boulder	cobble	2	7	36	33	23
		CRSP	6.0	164	62	19	0.5	2.2	2.9	129	cobble	gravel	8	28	49	14	0
		CRRR	12	140	42	20	0.6	2.3	2.4	65	gravel	cobble	29	43	25	1	2
2002	Spring	CRCA	25	179	71	22	1.2	2.8	3.0	204	boulder	cobble	1	11	40	47	0
		CRSH	20	173	51	15	0.8	2.6	3.0	207	boulder	cobble	2	8	44	46	0
		CRSP	35	167	49	24	0.9	2.9	3.4	168	cobble	boulder	2	17	41	33	0
		CRRR	25	142	24	22	0.8	3.3	2.4	97	cobble	gravel	4	47	48	1	0
	Fall	CRCA	6.5	179	62	27	0.6	1.5	4.1	206	boulder	cobble	3	14	31	52	0
		CRSH	6.5	170	53	15	0.6	1.9	6.5	151	cobble	boulder	7	13	43	27	0
		CRRW	6.5	157	40	15	0.7	2.3	3.7	167	cobble	boulder	5	15	53	26	0
		CRSP	6.0	159	41	22	0.5	2.8	3.2	171	cobble	boulder	5	13	55	27	0
		CRRR	2.0	119	54	14	0.4	1.6	3.3	63	cobble	gravel	13	60	26	0	0
2003	Spring	CRCA	40	188	59	37	1.2	2.4	3.3	183	boulder	cobble	4	20	34	42	0
		CRSH	50	177	51	26	1.5	3.0	4.2	210	boulder	cobble	6	13	25	57	0
		CRRW	53	158	43	30	1.1	3.3	2.3	161	cobble	boulder	8	20	42	30	0
		CRSP	53	168	47	26	1.4	3.3	2.2	146	cobble	boulder	12	20	38	27	0
		CRRR	60	155	32	31	1.1	2.6	1.6	91	gravel	cobble	13	43	40	2	2
	Fall	CRCA	7.5	176	59	25	0.9	1.8	3.0	226	boulder	cobble	2	9	29	58	2
		CRSH	8	165	54	13	0.5	1.8	2.2	208	boulder	cobble	1	12	38	49	0
		CRRW	9	166	43	17	0.6	2.6	2.8	174	cobble	boulder	5	12	55	28	0
		CRSP	9	174	71	21	0.6	1.9	2.3	154	boulder	cobble	15	23	28	30	3.3
		CRRR	6	146	59	19	0.4	2.4	1.8	80	gravel	cobble	12	51	36	1.7	0

Year	Season	Site	Flow (cfs)	Site Habitat Score (0-200)	Ave. Canopy (%)	Ave. Width (ft)	Ave. Depth (ft)	Ave. Velocity (ft/s)	Ave. Riffle Gradient (%)	Substrate Index (mm)	Dominant Substrate Class	Subdominant Substrate Class	Sand (%)	Gravel (%)	Cobble (%)	Boulder (%)	Bedrock (%)
2004	Fall	CRLP	ND	160	75	27	1.1	2.7	2.0	198	boulder	cobble	19	6	18	57	0
		CRCA	ND	178	60	27	0.7	2.7	3.9	184	boulder	cobble	5	20	32	43	0
		CRSH	ND	154	75	21	1.8	1.7	2.3	192	cobble	boulder	8.3	12	35	45	0
		SHRC	ND	154	75	4	0.6	1.3	0.5	166	cobble	boulder	0.3	12	72	16	0
		CRSP	ND	161	41	17	0.7	2.3	3.7	152	cobble	gravel	5	23	50	22	0
		CRRR	ND	138	37	21	0.5	1.9	1.6	76	gravel	cobble	13	60	17	10	0
2005	Fall	CRLP	ND	180	85	28	0.8	1.7	2.5	165	cobble	boulder	10	20	35	35	0
		CRCA	11	174	60	30	0.7	1.6	3.0	219	boulder	cobble	5	10	25	60	0
		CRSH	9	162	77	14	0.7	2.1	2.0	239	boulder	cobble	1	7.3	41	51	0
		CRSP	9	155	60	18	0.6	3	4.2	147	cobble	gravel	8.3	23	47	22	0
		CRRR	7	130	76	16	0.5	0.9	2.0	122	cobble	gravel	13	35	40	2	10
2006	Fall	CRLP	ND	179	91	35	0.8	2.2	2.0	177	boulder	cobble	10	20	30	35	5
		CRCA	ND	165	67	39	0.5	1.8	6.0	233	boulder	cobble	3	7	25	65	0
		CRSH	ND	159	72	14	0.6	2.5	2.5	164	cobble	boulder	10	15	50	20	5
		CRSP	ND	168	94	14	0.6	3.2	2.0	132	cobble	gravel	10	20	60	10	0
		CRRR	ND	135	57	17	0.5	1.9	1.0	97	cobble	gravel	20	35	35	10	0
2007	Fall	CRLP	3.5	173	94	20	0.5	1.2	2.5	190	boulder	cobble	7	15	35	40	3
		CRCA	3.5	169	84	18	0.6	1.4	3.0	206	boulder	cobble	5	10	35	50	0
		CRSH	3.5	160	89	12	0.7	0.8	2.5	184	cobble	boulder	7	15	40	35	3
		CRSP	3.5	159	82	9	0.4	0.6	2.0	133	cobble	gravel	15	25	40	18	2
		CRSW	ND	130	66	8	0.5	1.5	3.0	98	cobble	gravel	5	45	48	2	0
2008	Fall	CRLP	10	171	93	24	0.8	1.3	2.0	159	cobble	boulder	10	25	32	30	3
		CRCA	6.2	178	74	26	0.7	1.8	2.5	163	boulder	cobble	10	22	33	35	0
		CRSH	ND	168	84	15	0.6	1.6	3.0	147	cobble	boulder	5	17	40	30	3
		SHRC	ND	137	65	6	0.5	1.3	0.5	170	cobble	gravel	2	13	80	5	0
		CRSP	5.5	154	88	14	0.5	1.2	2.5	98	cobble	gravel	15	35	45	5	0
		CRSW	ND	145	56	10	0.5	1.8	3.0	98	cobble	gravel	13	35	50	2	0
2009	Fall	CRLP	25	175	85	26	0.8	1.5	1.7	163	cobble	boulder	15	20	30	30	5
		CRCA	25	182	50	26	0.7	2.5	2.0	200	boulder	cobble	3	17	30	50	0
		CRSH	25	176	90	14	1.1	2.0	1.5	205	cobble	boulder	5	10	40	40	5
		CRSP	25	171	74	15	1.2	2.8	2.5	176	boulder	cobble	5	25	30	38	2
		CRRR	28	158	76	15	1.1	3	1.5	138	cobble	gravel	2	20	73	5	0

APPENDIX H

Instantaneous water quality constituents assessed during benthic macroinvertebrate surveys of the Carmel River

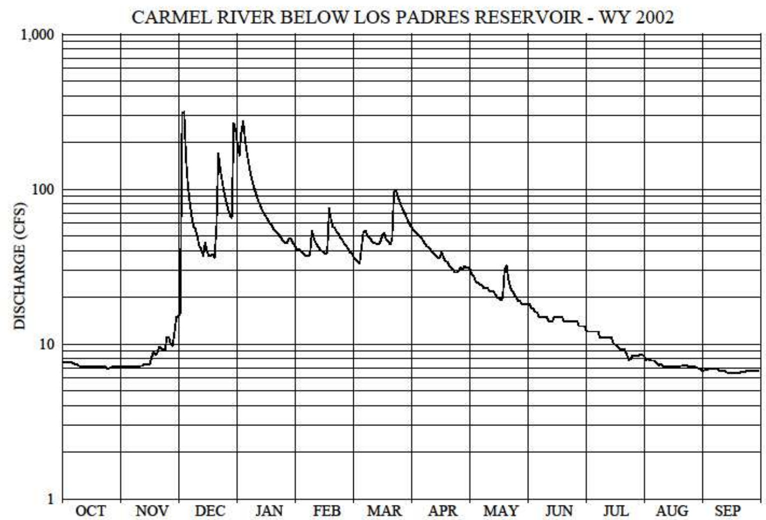
Site Code	Date	Water Temp. (°F)	Water Temp. (°C)	pH	Specific Conductance (µS/cm at 25 °C)	Dissolved Oxygen (mg/l)
CRCA	11/6/00	57	14	8.0	272	11
CRSH	11/7/00	54	12	8.0	297	11
CRSP	11/8/00	54	12	8.0	441	11
CRRR	11/3/00	59	15	7.5	498	10
CRCA	6/7/01	63	17	7.5	183	10
CRSH	6/6/01	70	21	8.0	206	11
CRSP	5/30/01	63	17	7.5	261	9.0
CRRR	6/6/01	63	17	8.0	ND	9.0
CRCA	11/7/01	64	18	7.5	291	10
CRSH	11/5/01	61	16	8.0	300	11
CRSP	10/19/01	59	15	8.0	462	11
CRRR	11/13/01	61	16	7.5	435	12
CRCA	5/24/02	61	16	8.0	209	11
CRSH	5/29/02	64	18	8.0	226	11
CRSP	5/17/02	63	17	7.5	364	12
CRRR	5/17/02	61	16	7.5	315	11
CRCA	11/5/02	55	13	7.5	291	10
CRSH	11/4/02	54	12	8.0	319	11
CRRW	11/6/02	54	12	8.0	308	11
CRSP	11/4/02	55	13	7.5	324	10
CRRR	11/6/02	55	13	7.5	479	11
CRCA	6/6/03	66	19	8.0	230	9.0
CRSH	6/4/03	66	19	8.0	231	10
CRRW	6/2/03	66	19	8.0	235	10
CRSP	6/2/03	64	18	8.0	254	9.0
CRRR	5/28/03	64	18	8.0	281	9.0
CRCA	11/12/03	51	11	ND	ND	ND
CRSH	11/3/03	54	12	8.0	358	11
CRRW	11/5/03	51	11	8.0	350	11
CRSP	11/5/03	57	14	8.0	367	11
CRRR	11/4/03	57	14	8.0	435	11
CRLP	11/4/04	48	9	8.0	311	9.0
CRCA	11/2/04	49	9	7.5	300	10
CRSH	11/1/04	53	12	8.0	337	10
SHRC	10/29/04	55	13	8.0	353	11
CRSP	11/1/04	55	13	7.5	320	10
CRRR	11/2/04	50	10	7.0	322	8.0
CRLP	11/9/05	55	13	8.0	253	10
CRCA	11/7/05	58	15	8.0	326	9.3
CRSH	11/8/05	56	14	8.0	356	10
CRSP	11/4/05	ND	ND	ND	ND	ND
CRRR	11/4/05	58	15	8.0	450	9.0
CRLP	11/1/06	49	9	8.0	311	14
CRCA	10/31/06	57	14	8.0	324	12
CRSH	10/31/06	55	13	8.0	353	13
CRSP	10/30/06	56	13	8.0	333	12
CRRR	10/30/06	55	13	8.0	353	13
CRLP	11/7/07	50	10	8.4	322	10

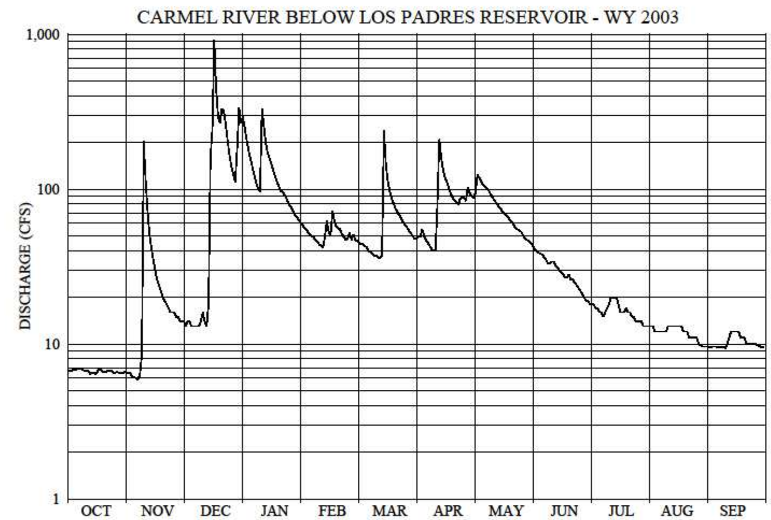
Site Code	Date	Water Temp. (°F)		pH	Specific Conductance (µS/cm at 25 °C)	Dissolved Oxygen (mg/l)
CRCA	11/7/07	55	13	8.2	327	10
CRSH	11/8/07	54	12	8.3	361	10
CRSP	11/9/07	55	13	8.0	430	8.0
CRSW	11/9/07	56	13	8.2	422	9.0
CRLP	11/6/08	50	10	8.0	248	9.0
CRCA	11/5/08	56	14	7.5	265	12
CRSH	11/3/08	56	14	8.0	284	11
SHRC	11/3/08	57	14	8.0	287	10
CRSP	11/5/08	55	13	8.0	289	9.0
CRSW	11/4/08	57	14	8.0	362	13
CRLP	11/10/09	47	8	ND	ND	ND
CRCA	11/12/09	51	11	ND	ND	ND
CRSH	11/9/09	51	11	ND	ND	ND
CRSP	11/9/09	50	10	ND	ND	ND
CRRR	11/6/09	57	14	ND	ND	ND

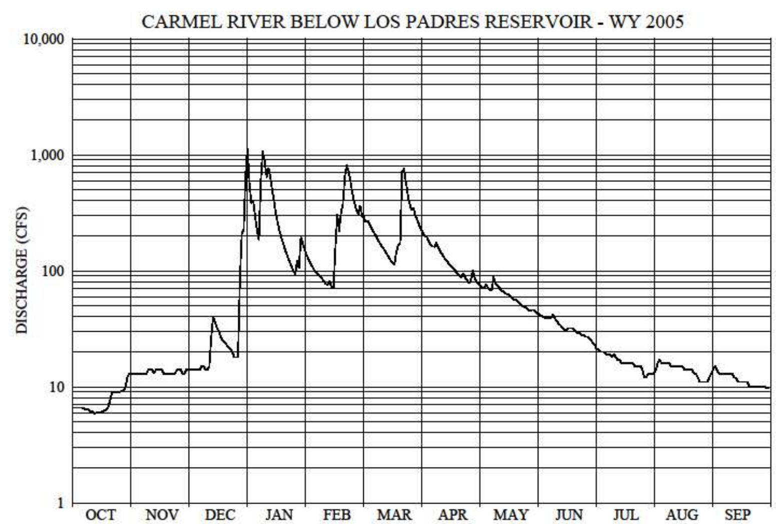
APPENDIX I

Carmel River daily flow and water temperature

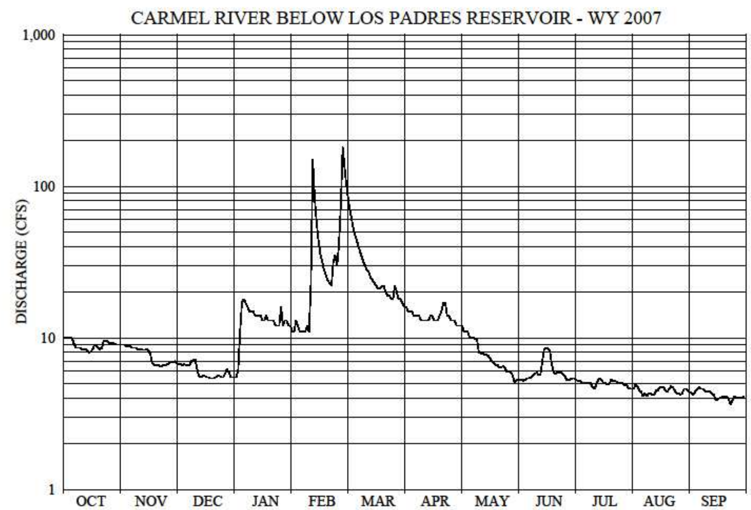
Average daily Carmel River flow below Los Padres Reservoir

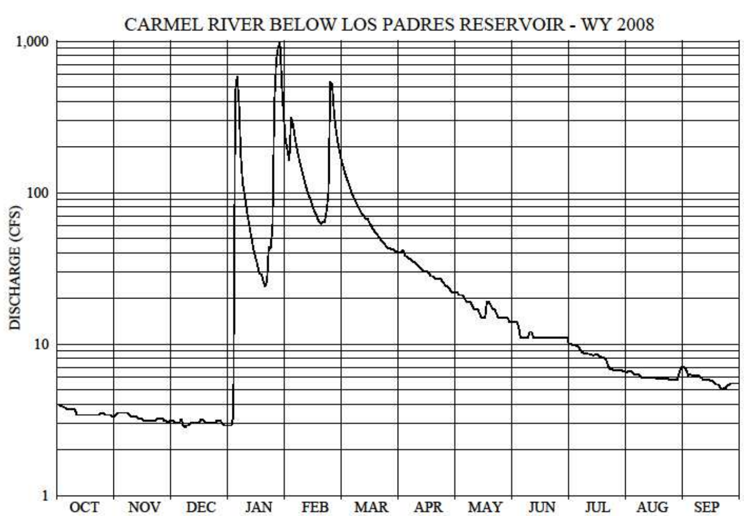




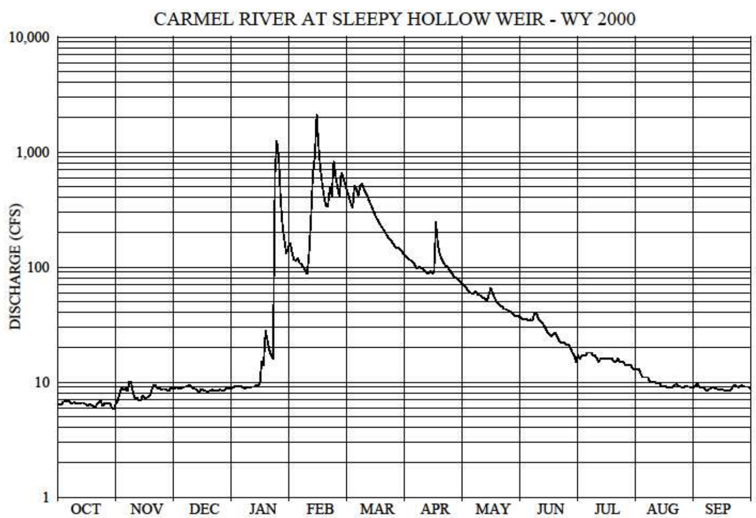


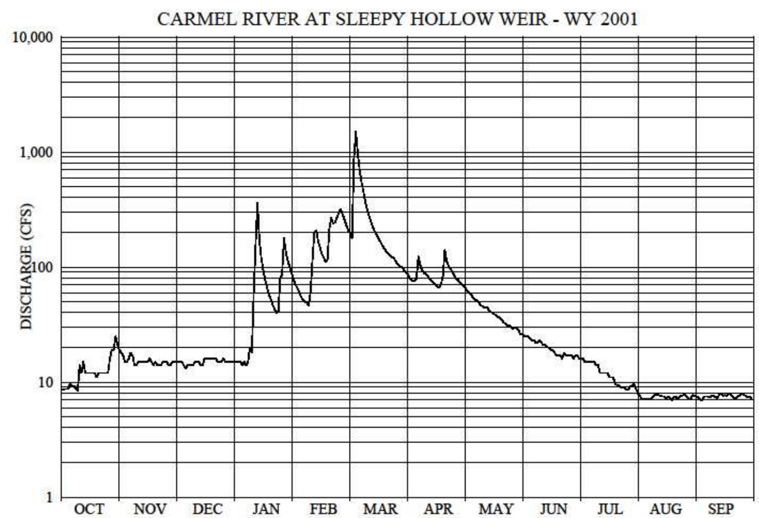
Average daily Carmel River flow below Los Padres Reservoir

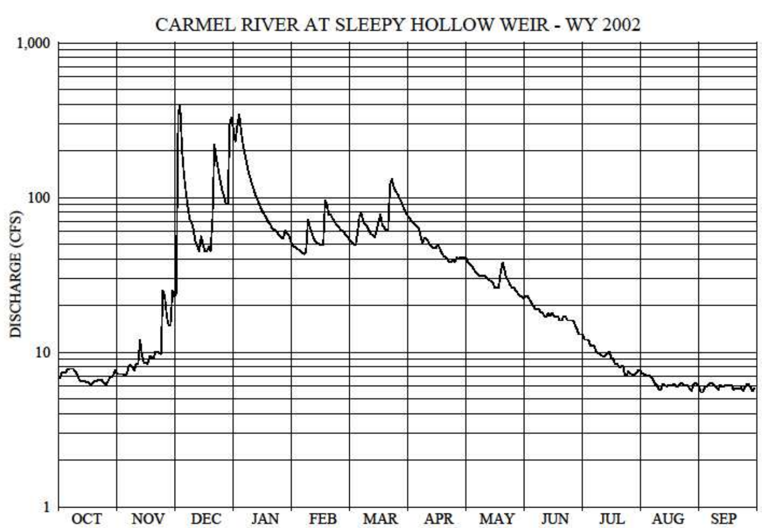


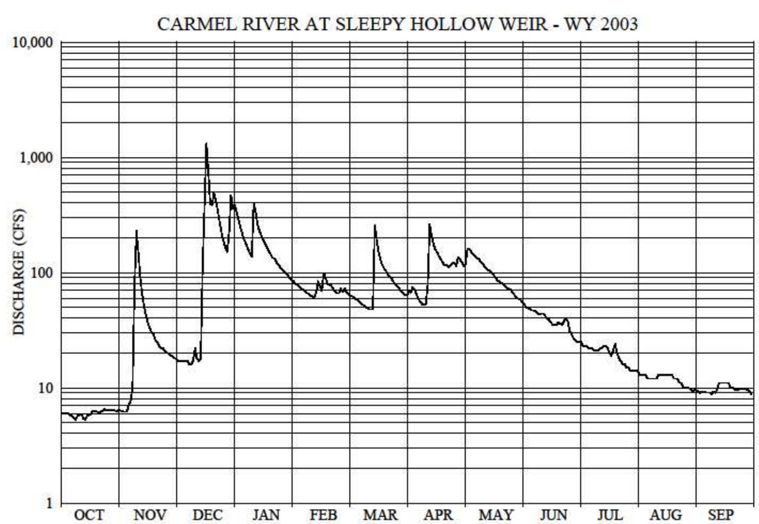


Average daily Carmel River flow below San Clemente Reservoir

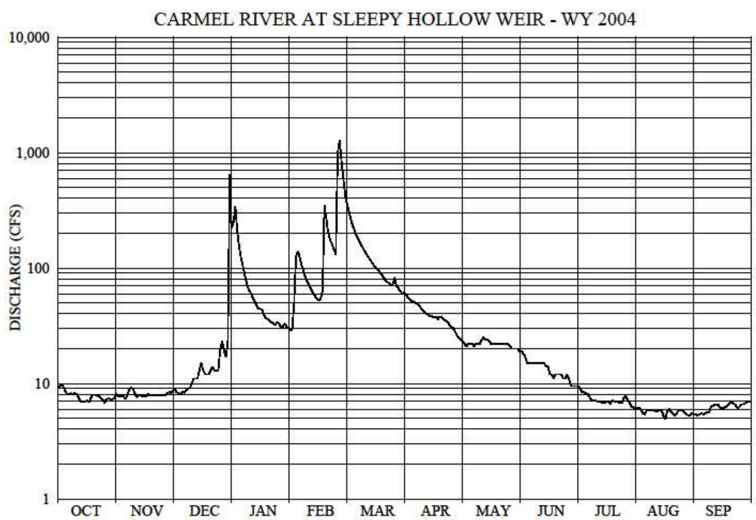


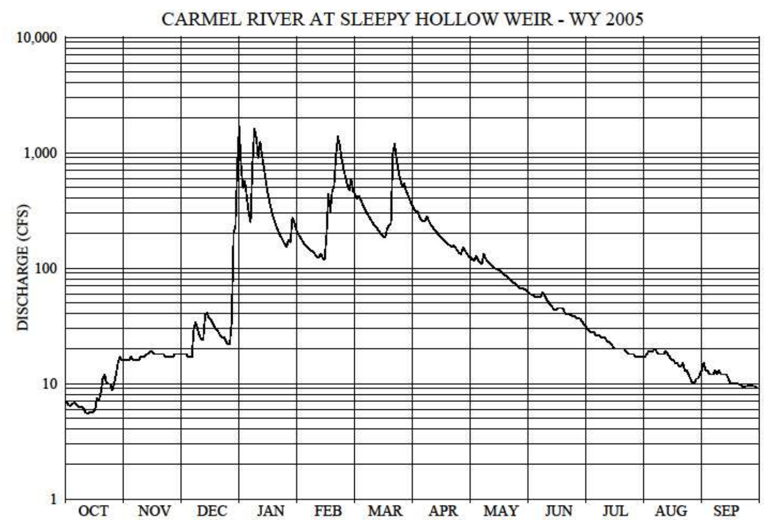


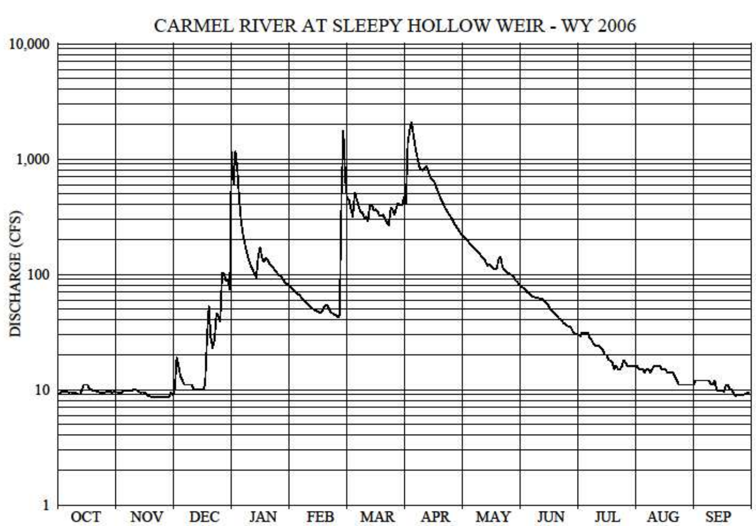


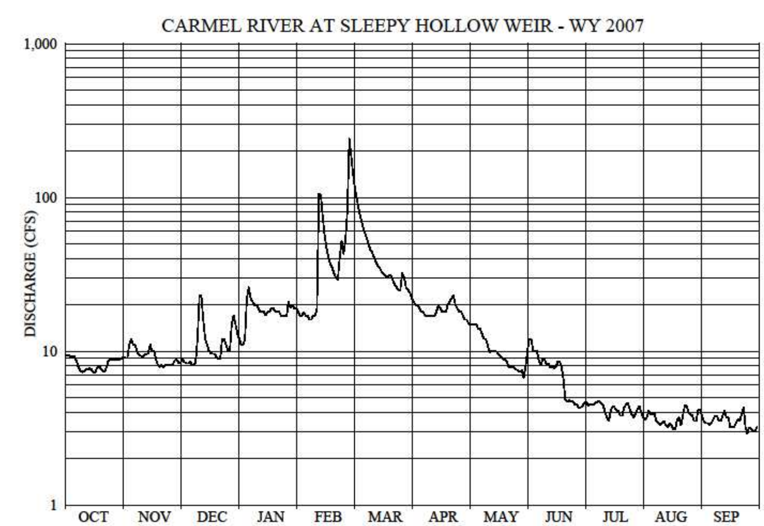


Average daily Carmel River flow below San Clemente Reservoir

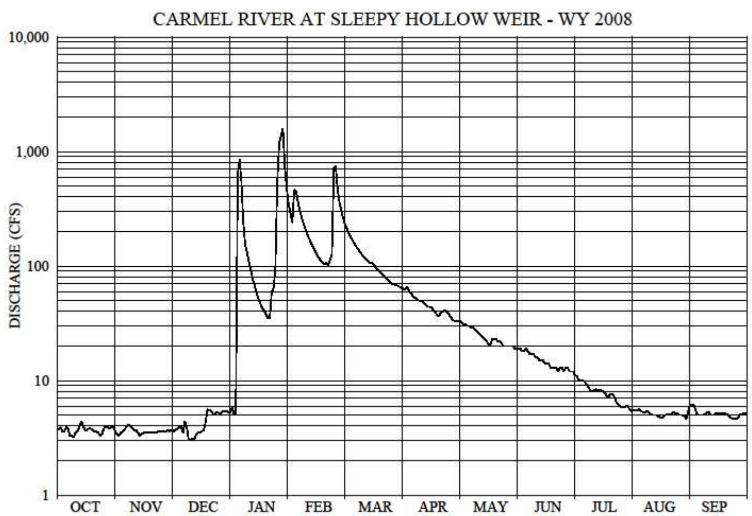


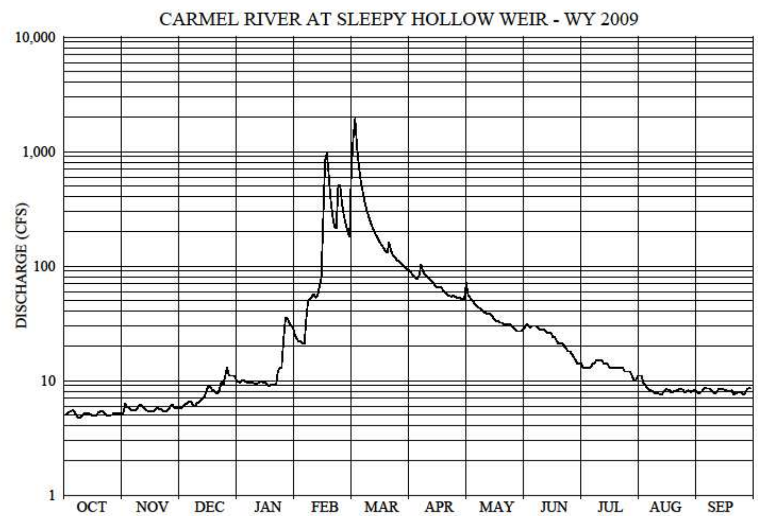




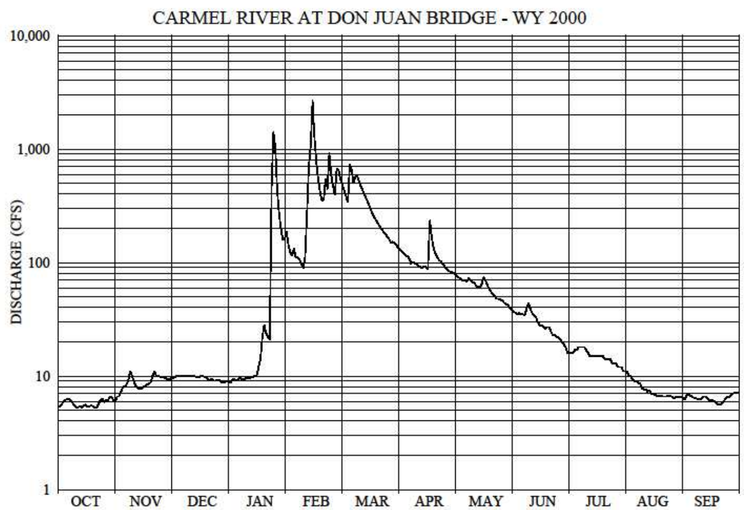


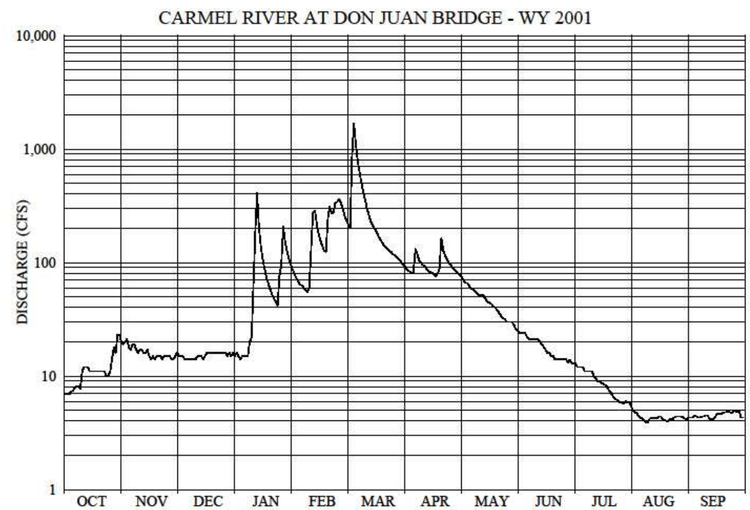
Average daily Carmel River flow below San Clemente Reservoir

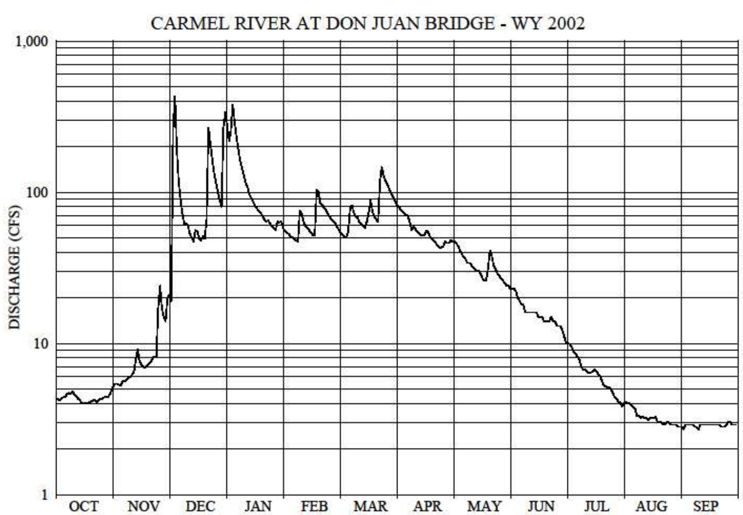


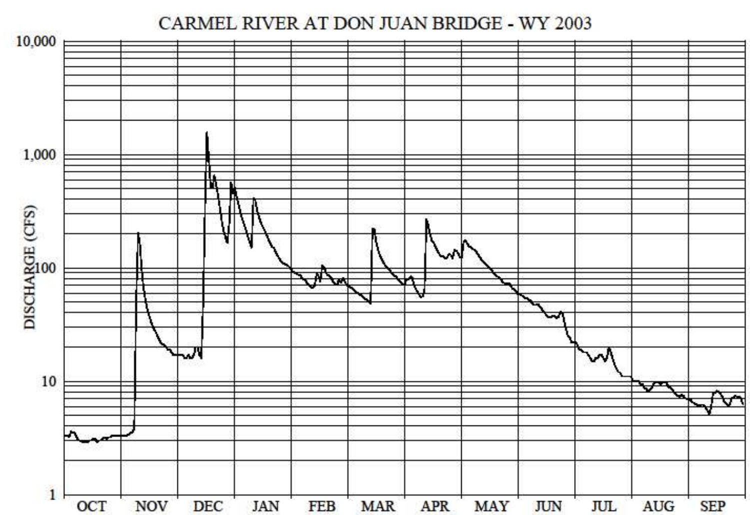


Average daily Carmel River flow at Don Juan Bridge

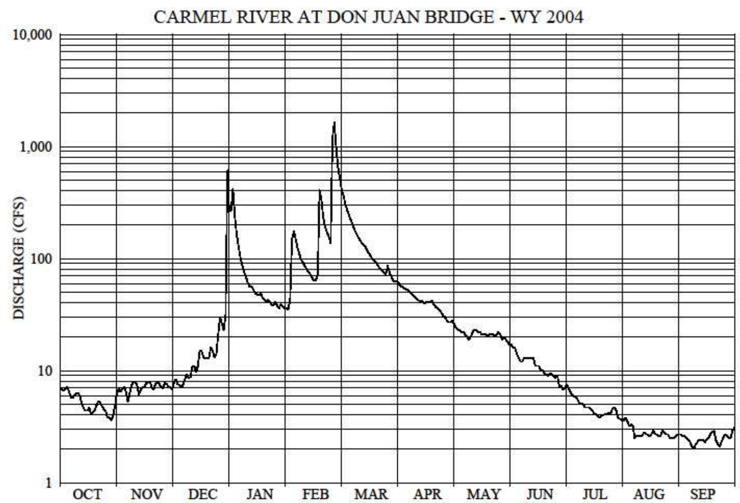


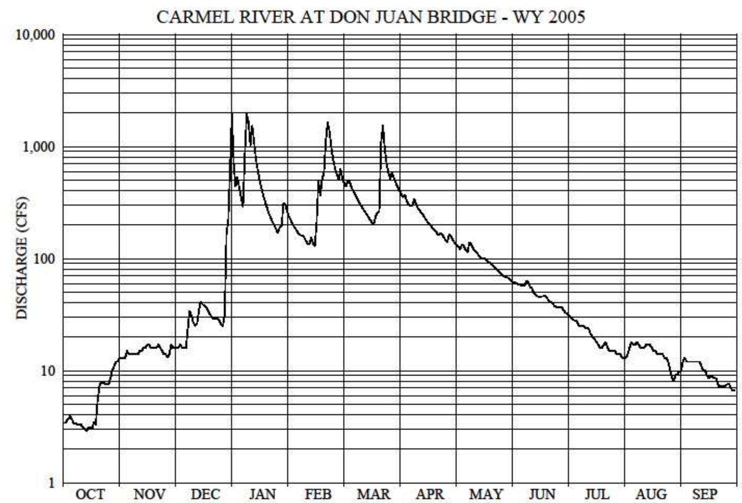


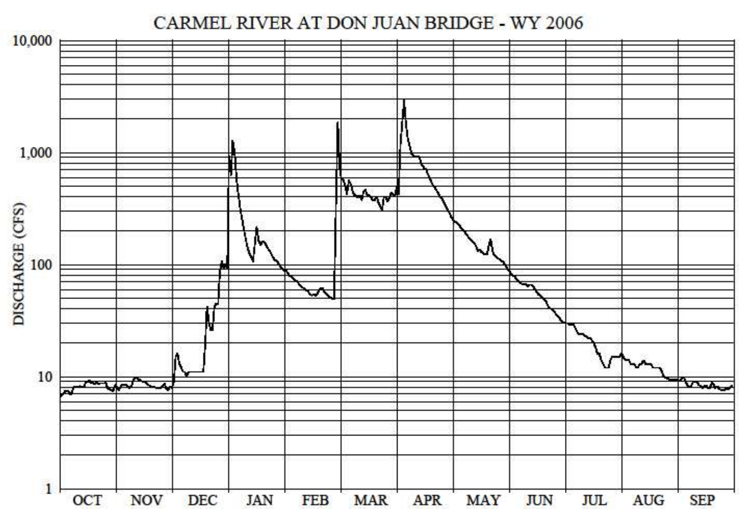


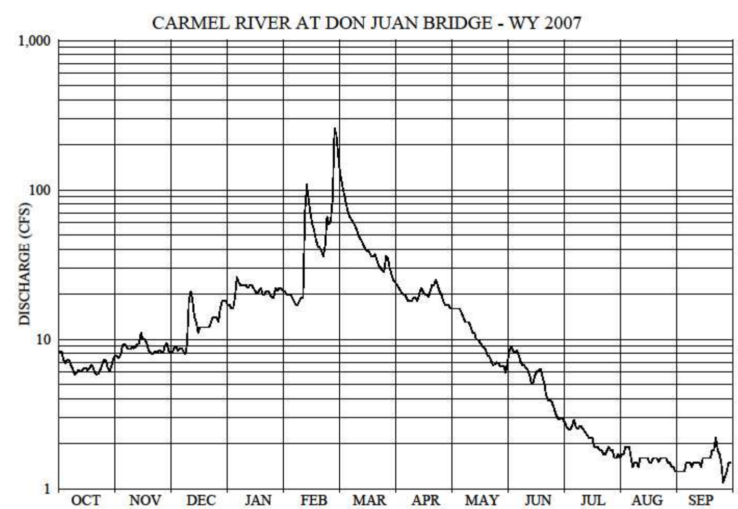


Average daily Carmel River flow at Don Juan Bridge

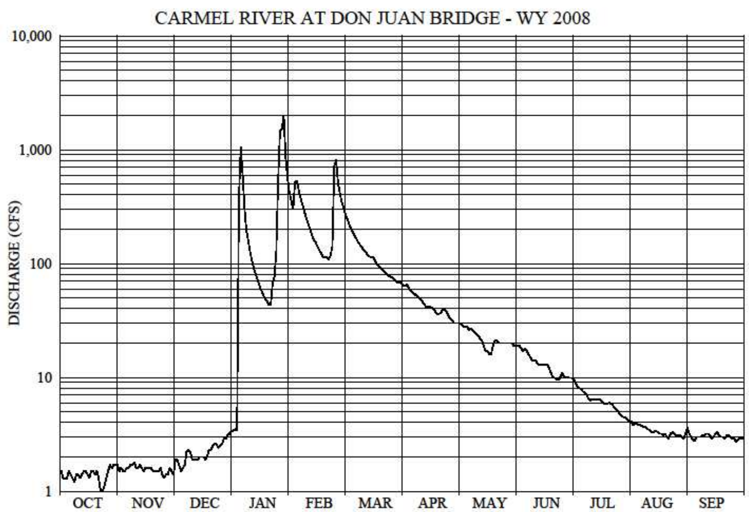


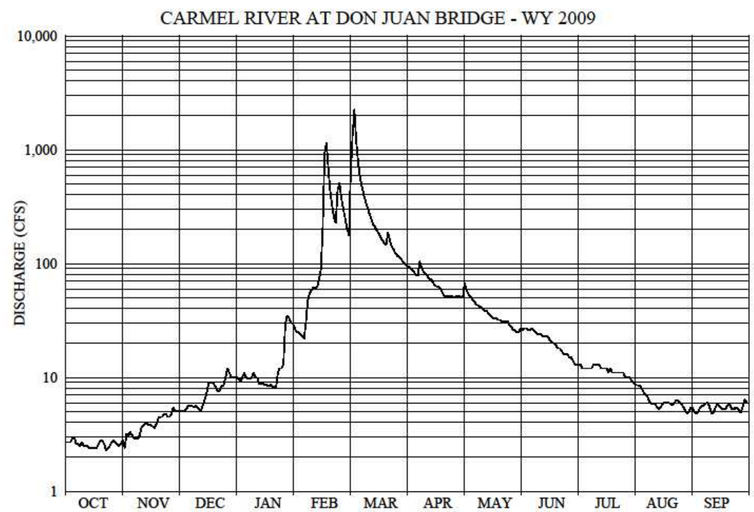




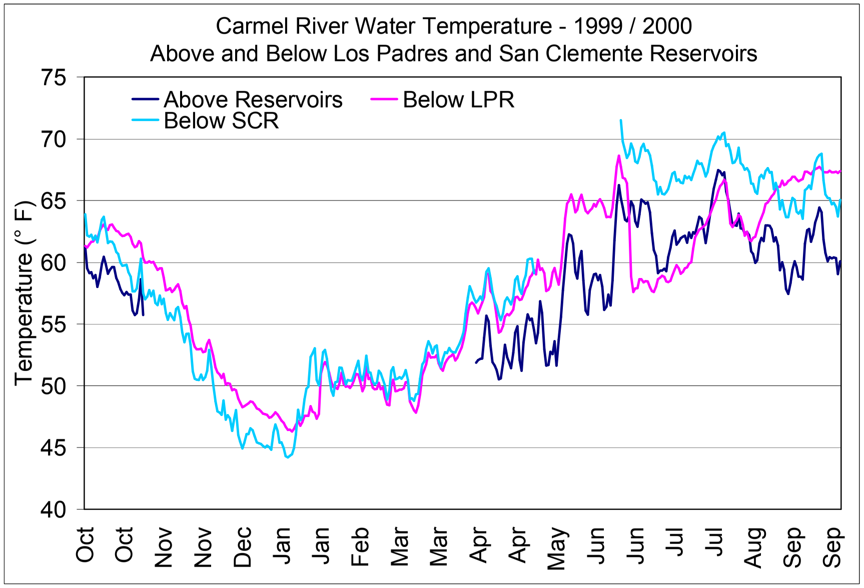


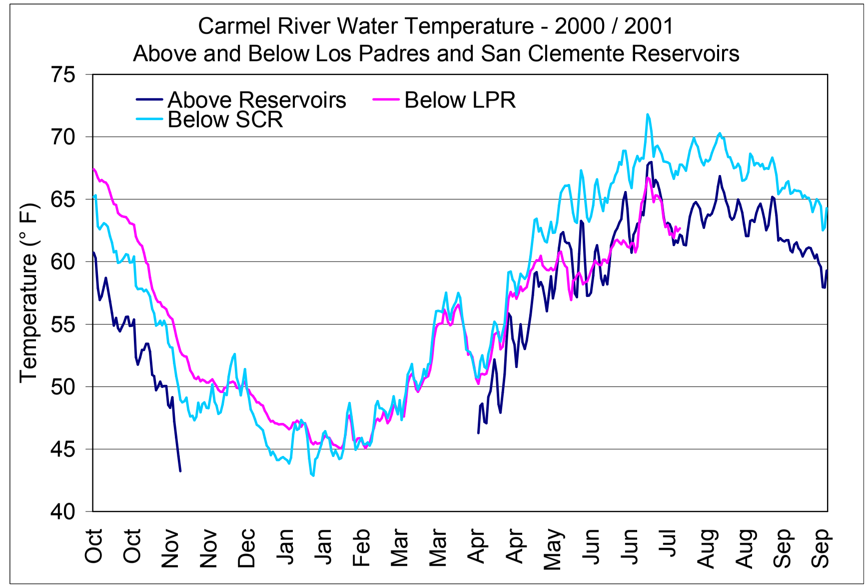
Average daily Carmel River flow at Don Juan Bridge

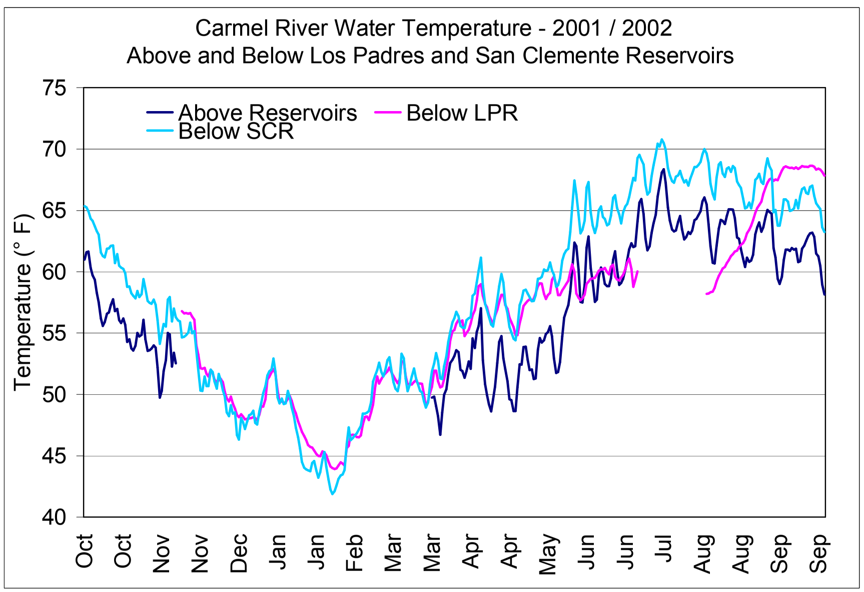


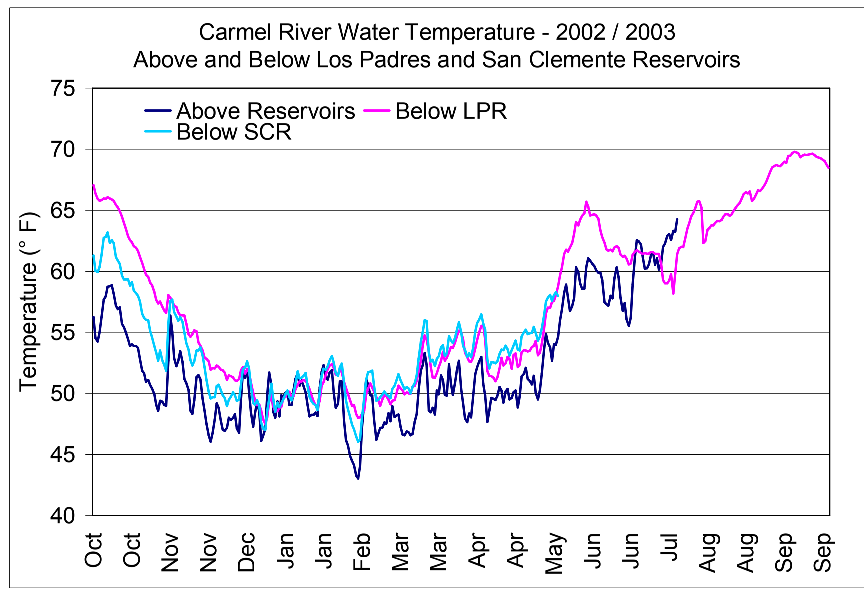


Average daily water temperature upstream and downstream of the reservoirs

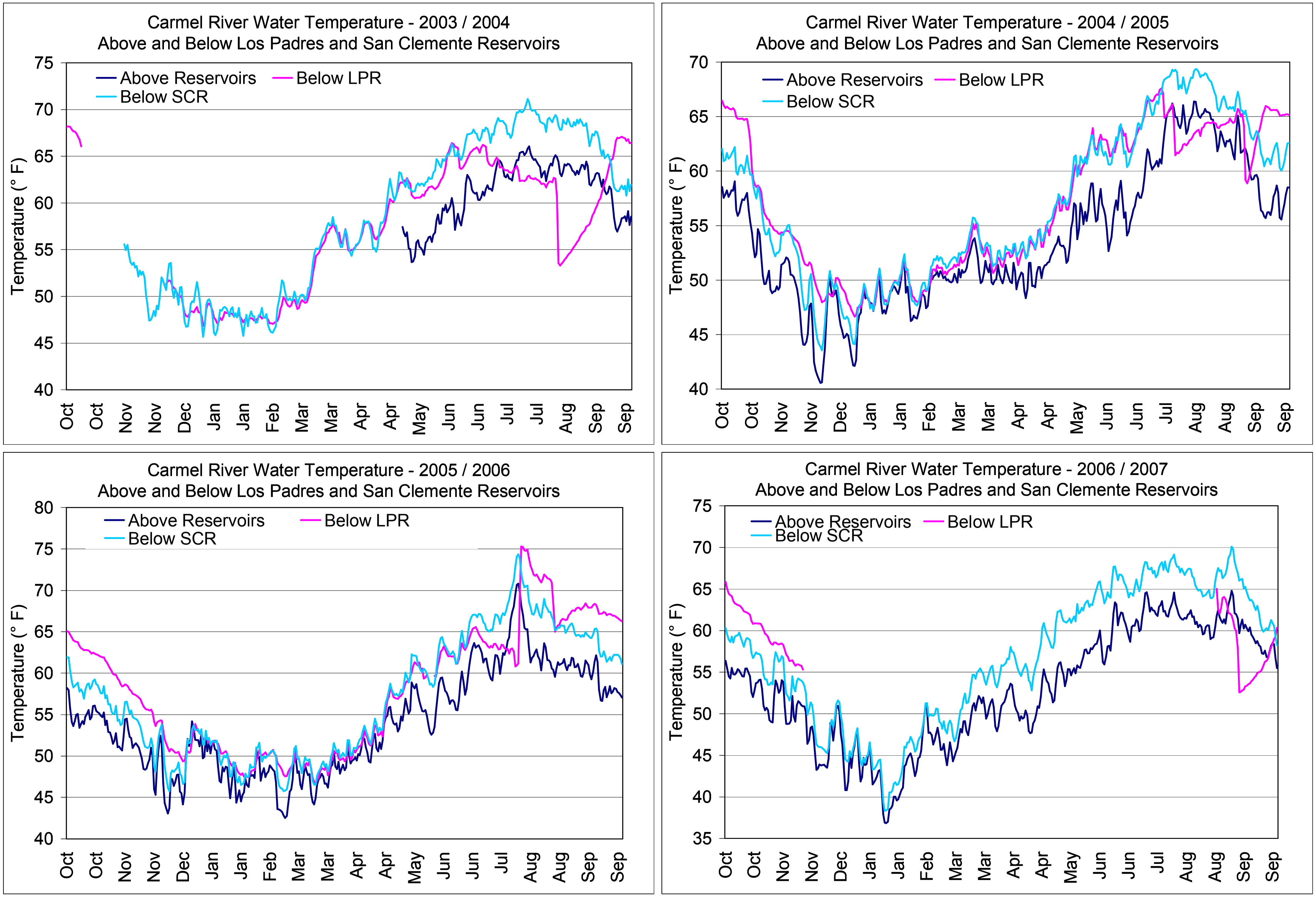




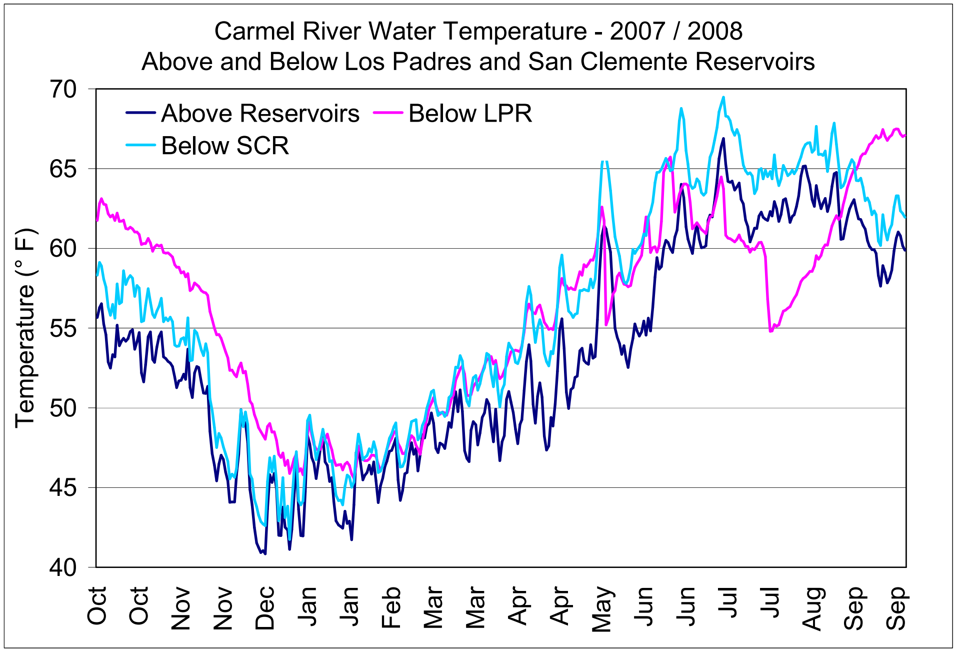




Average daily water temperature upstream and downstream of the reservoirs



Average daily water temperature upstream and downstream of the reservoirs



APPENDIX J

Carmel River benthic macroinvertebrate taxa lists from samples collected in March and May 1982 (Fields 1984)

Benthic Insect Samples from the Carmel River, March 10-12, 1982.
Source: Fields, W.C. 1986.

INSECTS:			Sampling Sites (three Surber samples/site)*								
Order	Family	Genus & Species	San Clemente Road	Filter Plant	Paso Hondo Road	Boronda Road	Garland Park	Riverside Park	San Carlos Road	Total Number	Percent by Number
Ephemeroptera	Heptageniidae	Epeorus longimanus		1						1	0.03%
	Baetidae	Baetus tricaudatus	50	37	20	27	25	4	2	165	4.98%
	Leptophlebiidae	Paraleptophlebia sp.	2							2	0.06%
	Tircorthyidae	Triorthythodes sp.			1		2		5	8	0.24%
Plecoptera	Nemouridae	Amphinemura sp.			1					1	0.03%
	Taeniopterygidae	Taenionema pacificum		1	3	1	13			18	0.54%
	Capniidae	Capnia umpqua	1	2	52	90	87	3	6	241	7.27%
	Perlodidae	Isoperla pinta				1				1	0.03%
		Cultus sp.	2				1			3	0.09%
		Kogotus sp.	1							1	0.03%
		Unidentified	1							1	0.03%
Megaloptera	Corydalidae	Neohermes sp.		1						1	0.03%
Trichoptera	Brachycentridae	Micrasema sp.				8	2			10	0.30%
	Glossosomatidae	Agapetus marlo		1		9	66		2	78	2.35%
		Glossosoma sp.					1			1	0.03%
	Hydropsychidae	Cheumatopsyche mickeli			4	6	14			24	0.72%
		Hydropsyche californica			2	3	8	5		18	0.54%
		Symphitopsyche sp.			2					2	0.06%
	Lepidostomatidae	Lepidostoma sp.					1			1	0.03%
	Leptoceridae	Oecetis avara				1				1	0.03%
	Philopotamidae	Wormaldia gabriella		3						3	0.09%
	Psychomyiidae	Tinodes sp.					1			1	0.03%
	Rhyacophilidae	Rhyacophila argelita		4						4	0.12%
	Sericostomatidae	Gumaga griseola							1	1	0.03%

Diptera	Tipulidae	Antocha sp.			2		1			3	0.09%
	Blephariceridae	Agathon doanei				2				2	0.06%
		Agathon comstocki	1							1	0.03%
	Simulidae	Prosimulium dicum	285	115	230	132	1	5	2	770	23.24%
		Simuliun arcticum	181	19	6	9	1			216	6.52%
		Simuliun aureum	67	11	16	30	3	4		131	3.95%
		Simulium canadense	3							3	0.09%
		Simulium sp. A	98	79	308	194	114	70	34	897	27.08%
		Simulium argus	3	2	1					6	0.18%
	Chironomidae	Thienemannimyla Group							1	1	0.03%
		Micropsectra sp.				1				1	0.03%
		Paratanytarsus sp. A				1				1	0.03%
		Rheotanytarsus sp.	2							2	0.06%
		Microtendipes sp.	1	1						2	0.06%
		Polypedilium sp. A	5	2	1		5		2	15	0.45%
		Phaenopsectra sp.				1	2			3	0.09%
		Brillia sp.			1	8				9	0.27%
		Cricotopus (laricomalis gp.)	4		1		5		1	11	0.33%
		Cricotopus (trifascia gp.)					1			1	0.03%
		Eukiefferiella (discoloripes g	3	1		2	1			7	0.21%
		Heterotrissocladius latilaminus		1						1	0.03%
		Orthocladius obumbraus	4	1		10	11		4	30	0.91%
		Orthocladius euorthocladius	21	6	155	86	244	48	33	593	17.90%
		Parakeifferiella sp.					4	1	1	6	0.18%
		Thienemanniella sp.						1		1	0.03%
		Cricotopus (intersectus gp.)	1	2		2	2			7	0.21%
		nid Diamesine pupa					1			1	0.03%
	Ceratopogonidae	Bezzia/Probezzia sp.			1					1	0.03%
	Stratiomyidae	Euparyphus sp.							1	1	0.03%
	Empididae	Chelifera					1			1	0.03%
		Hemerodromia					1			1	0.03%
		Wiedemannia					1			1	0.03%
											0.00%
Overall Total			736	290	807	624	620	141	95	3,313	100.0%
Average										473.29	

Benthic Insect Samples from the Carmel River, May 24-25, 1982.
Source: Fields, W.C. 1986.

INSECTS:			Sampling Sites (three Surber samples/site)*								
Order	Family	Genus & Species	San Clemente Road	Filter Plant	Paso Hondo Road	Boronda Road	Garland Park	Riverside Park	San Carlos Road	Total Number	Percent by Number
Ephemeroptera	Siphlonuridae	Ameletus sp.				1				1	0.02%
	Heptageniidae	Epeorus longimanus		1						1	0.02%
		Unidentified Species	2	1						3	0.05%
	Baetidae	Baetus tricaudatus	48	149	401	306	272	59	22	1257	22.08%
	Leptophlebiidae	Paraleptophlebia sp.	2	1						3	0.05%
	Ephemerellidae	Drunella flavilinea							1	1	0.02%
		Serratella teresa		1	1	5		6	1	14	0.25%
	Tircorthyidae	Triorthythodes sp.					4			4	0.07%
Plecoptera	Nemouridae	Amphinemura sp.	5							5	0.09%
	Perlodidae	Kogotus sp.							1	1	0.02%
Megaloptera	Corydalidae	Neohermes sp.			1					1	0.02%
Trichoptera	Glossosomatidae	Agapetus marlo		2	4	3	65	1		75	1.32%
	Hydropsychidae	Cheumatopsyche mickeli			5	3		8	6	22	0.39%
		Hydropsyche californica			21	4	3	19	7	54	0.95%
	Hydroptilidae	Hydroptila sp.	9							9	0.16%
		Ochrotrichia sp.			1	1	1			3	0.05%
	Philopotamidae	Wormaldia gabriella	22	36	2	2				62	1.09%
	Rhyacophilidae	Rhyacophila argelita		1						1	0.02%
Coleoptera	Hydrophilidae	Tropisternus ellipticus						1		1	0.02%

Diptera	Tipulidae	Antocha sp.	7	10	1		1			19	0.33%
		Tipula sp.			1					1	0.02%
	Blephariceridae	Blepharicera micheneri			2					2	0.04%
	Simulidae	Simuliun arcticum	406	84	826		264	33	24	1637	28.75%
		Simulium argus			9	1	77	138	41	266	4.67%
		Simuliun aureum	4	11	5					20	0.35%
		Simulium piperi					2			2	0.04%
		Simulium canadense	2	3						5	0.09%
		Simulium species A.	52	1	102	4	67	8	7	241	4.23%
	Chironomidae	Larsia sp.					1			1	0.02%
		Pentanerua sp.						2		2	0.04%
		Thienemannimyla Group	3							3	0.05%
		Constempellina sp.				1				1	0.02%
		Micropsectra sp.	17	5	4	22	23	13	1	85	1.49%
		Rheotanytarsus sp.	3	3	1	19	6	7		39	0.69%
		Tanytarsine Pupa B		1			2			3	0.05%
		Tanytarsine Pupa C					1	1		2	0.04%
		Microtendipes sp.	17	2			1			20	0.35%
		Cryptochironomus sp B.					1			1	0.02%
		Phaenopsectra sp.					4	9	2	15	0.26%
		Polypedilium sp. A	21	17	6	21	12	4	4	85	1.49%
		Corynoneura sp.		1	1	1				3	0.05%
		Cricotopus (intersectus) A	67	17		17	59	46	1	207	3.64%
		Cricotopus (intersectus) B	8		1				3	12	0.21%
		Cricotopus (laricomalis gp.)	48	6	4	17	41	2	1	119	2.09%
		Cricotopus (trifascia gp.)	77	32	23	78	69	6	1	286	5.02%
		Eukiefferiella (bavarica) sp.	1	5			3			9	0.16%
		Eukiefferiella (claripennis) sp.	3	2				1		6	0.11%
		Eukiefferiella (discoloripes gp.)					1			1	0.02%
		Eukiefferiella sp. A	1	3	1	3	2	2		12	0.21%
		Eukiefferiella sp. B	19	5		4	3	2		33	0.58%
		Eurycnemus sp.				1				1	0.02%
		Heterotrissocladius latilaminus	5	3	2	3	5	3		21	0.37%
		Nanoladius rectinervis	1			1		1		3	0.05%
		Orthocladius obumbraus		1			7	57	3	68	1.19%
		Orthocladius euorthocladius) A			20	63	381	239	34	737	12.95%
		Orthocladius euorthocladius) B	1				14	82	1	98	1.72%
		Parakeifferiella sp.						5	7	12	0.21%
		Thienemanniella sp.	2			5	9	27	5	48	0.84%
		Unidentified Orthoclad pupa A				1				1	0.02%
		Unidentified Orthoclad pupa B		2	1	1	5		1	10	0.18%
		Potthastia sp.				1				1	0.02%
		Psuedodiamesa sp.	1							1	0.02%
		Und. Diamesine pupa A				1				1	0.02%
	Heleidae	Palpomyia sp.				1	12	13	2	28	0.49%
	Ceratopogonidae	Bezzia/Probezzia sp.				8				8	0.14%
Overall Total			854	406	1,446	598	1,418	795	176	5,693	100.0%
Average										1,423	

*
San Clemente Rd: RM ~ 18.0
Filter Plant: RM 16.2
Paso Hondo Rd: RM 13.5
Boronda Rd: RM 12.7
Garland Park: RM 0.8
Riverside RV Park: RM 5.7
San Carlos Rd: RM 3.9