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 blephariceri d fly larvae, which are intolerant BMI usually found in cool, unpolluted flowing water (Erman 1996). No blephariceri ds 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.

7.0 LITERATURE CITED

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