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Bioassessment of Tahoe Keys Marina South Lake Tahoe, CA

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INTRODUCTION

The Tahoe Keys Resort and associated marina is located on the south side of Lake Tahoe near the city of South Lake Tahoe. The Tahoe Keys area was once the largest and most important wetland area associated with Lake Tahoe. In its natural state, it acted like a filter removing sediment and nutrients from streams draining into the Lake. When the lagoons and waterways were constructed within the original wetland to create the Resort and marina, much of the filtering properties and flushing abilities were lost. As a result, the Tahoe Keys Property Owners Association had to construct a water circulation and filtering facility to prevent the excessive buildup of algae and vascular plant material. In August and September 1998, aluminum concentration from the water treatment facility exceeded the allowable discharge requirement of a four-day average concentration of 87 µg/L. This initiated a report from the Lahontan Regional Water Quality Control Board asking the Association to fund a program to investigate the effects of excessive aluminum on the biological integrity of Tahoe Keys Marina.

In July 2000, the California Department of Fish and Game's Aquatic Bioassessment Laboratory (ABL) was contracted by the Tahoe Keys Property Owner's Association to initiate an assessment of the biological condition in Tahoe Keys Marina as part of their NPDES permit requirements. The assessment was designed to measure water column chemistry and the benthic macroinvertebrate (BMI) communities at four areas within the Marina every two years.

Water resource monitoring using BMIs is by far the most popular biological assessment method used throughout the world. BMIs are ubiquitous, relatively stationary, and their large species diversity provides a spectrum of responses to environmental stresses (Rosenberg and Resh 1993). Individual species of BMIs reside in the aquatic environment for a period of months to several years and are sensitive, in varying degrees, to temperature, dissolved oxygen, sedimentation, scouring, nutrient enrichment and chemical and organic pollution (Resh and Jackson 1993). Finally, BMIs represent a significant food source for aquatic and terrestrial animals and provide a wealth of evolutionary, ecological and biogeographical information (Erman 1996).

This report presents results from BMI and water chemistry samples collected on July 22, 2004. There are also some comparisons of the 2004 result with the results of an identical sampling event conducted July 13, 2000 and July 12, 2002.

MATERIALS AND METHODS

Monitoring Site Descriptions

The locations of the four sampling sites, the sample depth and the substrate composition within the Tahoe Keys Marina are presented in Table 1. We tried to sample the exact location for all three sampling events (2002, 2002 and 2004). The depth of each site was fairly consistent with the exception of site TKL003 where there was close to a 3 meter difference in depth during the 2000 sampling event.

Table 1. Location description, depth of the benthic samples, substrate type within which the samples were taken and the GPS coordinates for areas of Tahoe Keys Marina sampled during July 2000, 2002 and 2004 for biological and chemical analysis, South Lake Tahoe, California.

Site ID	Location Description	Depth	Substrate	Latitude/Longitude
TKL001	Lagoon between Kokanee Way and Wedeln Court	2.3-3.5 meters	clay/sand	N38° 55.729' W120° 00.541'
TKL002	Lagoon between Genevieve Court and Lido Drive	2.2-2.9 meters	clay/sand	N38° 55.923' W120° 01.314'
TKL003	Lagoon 300 feet west of Spinnaker Cove near West Channel	3.4-7.3 meters	Fine clay/ sand	N38° 56.097' W120° 01.069'
TKL004	Sailing Lagoon 55 feet east of East Channel	1.3-2.7 meters	clay/sand	N38° 56.399' W120° 00.194'

Benthic Macroinvertebrate Sampling

BMI communities were collected using a modified Van Veen grab sampler. The sampler is box shaped (30 cm X 30 cm) with closing clam-shell doors on the bottom and a screen/ rubber flap on the top to prevent sample washout. The sampler was modified by adding a stabilizing structure, which allows the sampler to be used in moving water situations. The sampler is used by lowering the device to the bottom of the Marina using a boom from the deck of a specially equipped Boston Whaler boat. The clam-shell doors were closed upon impact with the bottom and retrieved using the boom. Once the sampler was retrieved, the contents of the corer was removed and washed through a 0.5 mm mesh sieve. The organisms were then removed and placed in a jar with 70% ethanol. This procedure was repeated three times to produce three replicate samples at each sampling location.

Water Chemistry Sampling

Water chemistry grab samples were collected in appropriate sample jars at each sampling location just below the surface of water surface. All samples were kept on ice at 4° C and submitted to the Water Pollution Control Laboratory in Rancho Cordova on the day of collection.

Sediment Chemistry and Toxicity Sampling

Separate sediment grab samples were collected for chemistry and toxicity testing in appropriate sample jars from the sediment contained in the Van Veen grab sampler. All samples were kept on ice at 4° C and submitted to the Water Pollution Control Laboratory in Rancho Cordova on the day of collection. Water column and sediment samples for metal analysis were delivered to the DFG Moss Landing Marine Laboratory. Sediment samples for toxicity testing were delivered to ToxScan Inc. in Watsonville, California on July 23, 2004.

BMI Laboratory Analysis

At the laboratory, each sample was rinsed through a No. 35 standard testing sieve (0.5 mm brass mesh) and transferred into a tray marked with twenty, 25 cm^2 grids. All detritus was removed from one randomly selected grid at a time and placed in a petri dish for inspection under a stereomicroscope. All invertebrates from the grid were separated from the surrounding detritus and

transferred to vials containing 70% ethanol and 5% glycerol. This process was continued until 300 organisms were removed from each sample. The material left from the processed grids was transferred into a jar with 70% ethanol and labeled as "remnant" material. Any remaining unprocessed sample from the tray was transferred back to the original sample container with 70% ethanol and archived. Macroinvertebrates were then identified to a standard taxonomic level, typically genus level for insects and family or genus for non-insects using standard taxonomic keys (Brown 1972, Edmunds et al. 1976, Klemm 1985, Merritt and Cummins 1995, Pennak 1989, Stewart and Stark 1993, Surdick 1985, Thorp and Covich 1991, Usinger 1963, Wiederholm 1983, 1986, Wiggins 1996, Wold 1974).

Chemical Laboratory Analyses

All water chemistry analyses were performed in accordance with standard EPA procedures for laboratory analysis.

- Volatile organic compounds were tested for following EPA Method 8260
- Semi-Volatile compounds were tested for following EPA Method 8270
- Chlorpyifos and Diazinon were tested for following EPA Method
- Metals (Aluminum, Boron and Copper) were tested for following EPA Methods 200.7, 200.7 and 220.2 respectively
- Hardness was measured following Standard Methods 1992

Other ambient chemical characteristics (specific conductivity, dissolved oxygen and water temperature) were measures using a Yellow Springs Instruments Model 85 meter while the biological and chemical samples were collected.

Toxicity Testing

The sediment samples were set up for initial testing on August 6, 2004 using EPA Method 100.1 from Methods for measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates (EPA 600/R-94/024: June 1994). The test organism used was *Hyalella azteca*, the number of organism was 10 amphipods per replicate and the test duration was 10 days. The initial bioassays did not meet the test acceptability criterion (TAC) of 80% survival in the control sediment exposures, and were subsequently re-tested beginning September 7, 2004. The retest bioassays met all method test acceptability criteria and were within protocol QA/QC limits.

Data Analysis

A taxonomic list of BMIs identified from the samples was entered into a Microsoft Excel® spreadsheet program. MS Excel® was used to calculate and summarize macroinvertebrate community based metric values. A description of the metric values used to describe the community is shown in Table 2.

RESULTS

Dominant BMI Taxa/ General Taxonomic Notes

The five dominant taxa observed at the four monitoring reaches are presented in Table 3 for the 2000, Table 4 for the 2002 and Table 5 for the 2004 sampling event. A complete list of BMIs identified Table 2. Metrics used to describe characteristics of the benthic macroinvertebrate (BMI) community

at sampling areas within the Tahoe Keys Marina, South Lake Tahoe, California.

BMI Metric	Description	Response to Impairment
Richness Measures		
Taxa Richness	Number of individual taxa collected from each replicate sample	decrease
Cumulative Taxa	Total number of individual taxa collected from each site	decrease
EPT Taxa	Number of taxa in the Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) insect orders collected from each replicate sample	decrease
Cumulative EPT Taxa	Total number of taxa in the Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) insect orders collected at each site	decrease
Composition Measures		
EPT Index	Percent composition of mayfly, stonefly and caddisfly larvae	decrease
Sensitive EPT Index	Percent composition of mayfly, stonefly and caddisfly larvae with tolerance values between 0 and 3	decrease
Percent Dominant Taxa	Percent composition of the single most abundant taxon	increase
Shannon Diversity Index	General measure of sample diversity that incorporates richness and evenness (Shannon and Weaver 1963)	decrease
Tolerance/Intolerance Measures		
Tolerance Value	Value between 0 and 10 weighted for abundance of individuals designated as pollution tolerant (higher values) or intolerant (lower values)	increase
Percent Intolerant Organisms	Percent of organisms in sample that are highly intolerant to impairment as indicated by a tolerance value of 0, 1 or 2	decrease
Percent Tolerant Organisms	Percent of organisms in sample that are highly tolerant to impairment as indicated by a tolerance value of 8, 9 or 10	increase
Functional Feeding Groups (FFG)		
Percent Collectors	Percent of macrobenthos that collect or gather fine particulate matter	increase
Percent Filterers	Percent of macrobenthos that filter fine particulate matter	increase
Percent Grazers	Percent of macrobenthos that graze upon periphyton	variable
Percent Predators	Percent of macrobenthos that feed on other organisms	variable
Percent Shredders	Percent of macrobenthos that shreds coarse particulate matter	decrease
Abundance		
Estimated Abundance	Estimated number of macroinvertebrates in sample calculated by extrapolating from the proportion of organisms in each sample	variable

from the samples collected in 2002 is presented in Appendix 1.

where's Appendix 1?

Although the dominant taxa were different for each sampling event, the BMI community for both events were dominated by disturbance tolerant non-insect fauna (primarily worm taxa, copepods and a few snail species) in addition to several chironomid midge taxa (Diptera: Chironomidae). The 2004 sampling event had an exceptionally depopulate BMI community with no more than 4 taxa found in samples and with no organisms found at the TKL-002 site.

Table 3. Dominant macroinvertebrate taxa (and their percent contribution) for samples collected July 2000 from four sites within the Tahoe Keys Marina, South Lake Tahoe, California.

Site Number	Dominant Taxa				
	1	2	3	4	5
TKL-001	Tubificidae (44)	Harpacticoida (16)	Nematoda (8)	Cyclopidae (7)	Chirnomini (6)
TKL-002	*Helisoma* (39)	Planorbiidae (26)	Cyclopidae (21)	*Hyallela azteca* (3)	Daphniidae/ Cypridiidae (2)
TKL-003	Harpacticoida (80)	Planorbiidae (6)	*Hyallela azteca* (3)	Cyclopidae (3)	*Physa/ Physella* (2)
TKL-004	Cyclopidae (34)	Tubificidae (30)	Chironomini (9)	Valvata (4)	Naididae (3)

Table 4. Dominant macroinvertebrate taxa (and their percent contribution) for samples collected July 2002 from four sites within the Tahoe Keys Marina, South Lake Tahoe, California.

Site Number	Dominant Taxa				
	1	2	3	4	5
TKL-001	Chirnomini (45)	Tanypdinae (19)	Cyclopidae (8)	*Hyallela azteca* (8)	Tanyderidae (6)
TKL-002	Gyraulus sp. (82)	Tanypdinae (11)	Acri (2)	*Physa/Physella* (2)	Cyclopidae (3)
TKL-003	*Hyallela azteca* (35)	Cyclopidae (22)	Chirnomini (8)	Planorbiidae (8)	Tubificidae (6)
TKL-004	Chironomini (31)	Gyraulus sp. (19)	Planorbiidae (10)	Valvata (10)	Cyclopidae (8)

Benthic Macroinvertebrate Community Metrics

Bioassessment metrics values (described in Table 2) based on the BMIs identified for samples collected in 2002 are listed in Appendix 2. The values are means of the three samples collected at each site along with the associated coefficient of variation.

Table 5. Dominant macroinvertebrate taxa (and their percent contribution) for samples collected July

2004 from four sites within the Tahoe Keys Marina, South Lake Tahoe, California.

Site Number	Dominant Taxa				
	1	2	3	4	5
TKL-001	Oligochaeta (85)	*Physa/Physella* (7)	Gyraulus sp (4)	*Chironomini* (4)	N/A
TKL-002	N/A	N/A	N/A	N/A	N/A
TKL-003	*Pisidium sp.* (67)	Gyraulus sp. (33)	N/A	N/A	N/A
TKL-004	Oligochaeta (78)	Chironomini (22)	N/A	N/A	N/A

Richness Measures

Mean Taxonomic Richness (Figure 1) was higher at most sites in 2000 than in 2002, especially at site TKL004. In general, taxonomic richness was higher in sites TKL001 and TKL004 than in sites TKL002 and TKL003, for both years. Taxonomic richness at all sites was lower in 2004. The number of mayfly (Order: Ephemeroptera), stonefly (Order: Plecoptera) and caddisfly (Order: Trichoptera) taxa present at the four sites were extremely low (Figure 2). Cumulative EPT Taxa (Figure 2) was higher in sites TKL001 and TKL004 in 2000. Since then, EPT taxa was 1 or 0 at all sites with 0 taxa being found at all sites in 2004.

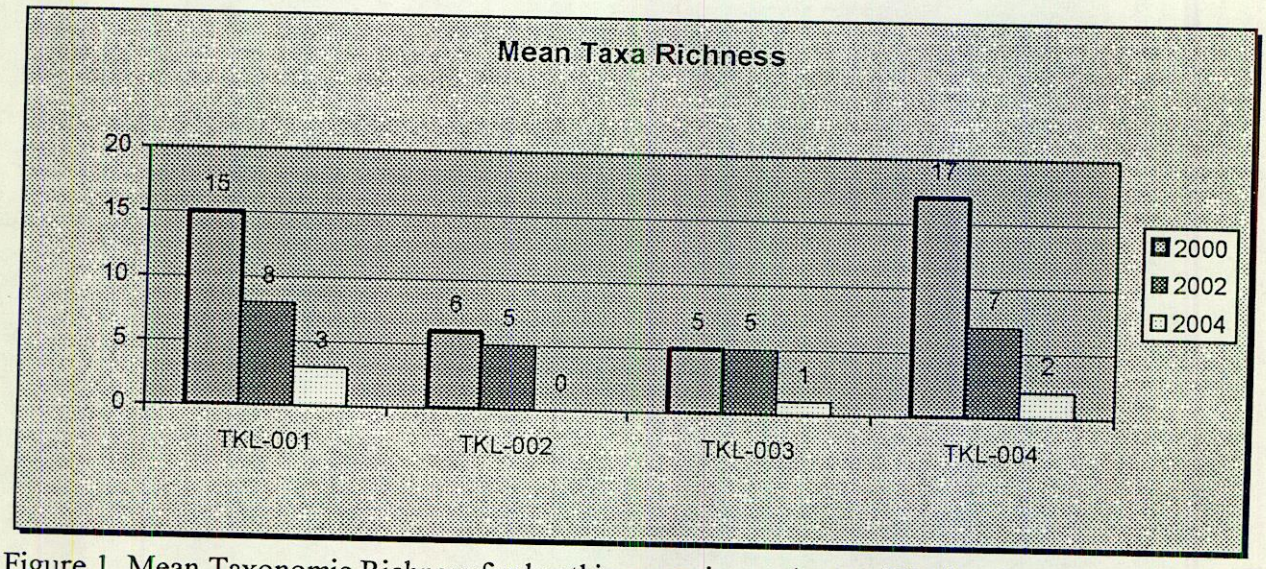


Figure 1. Mean Taxonomic Richness for benthic macroinvertebrates (BMI) collected on July 13, 2000, July 12, 2002 and July 2004 at four areas of the Tahoe Keys Marina, South Lake Tahoe, California.

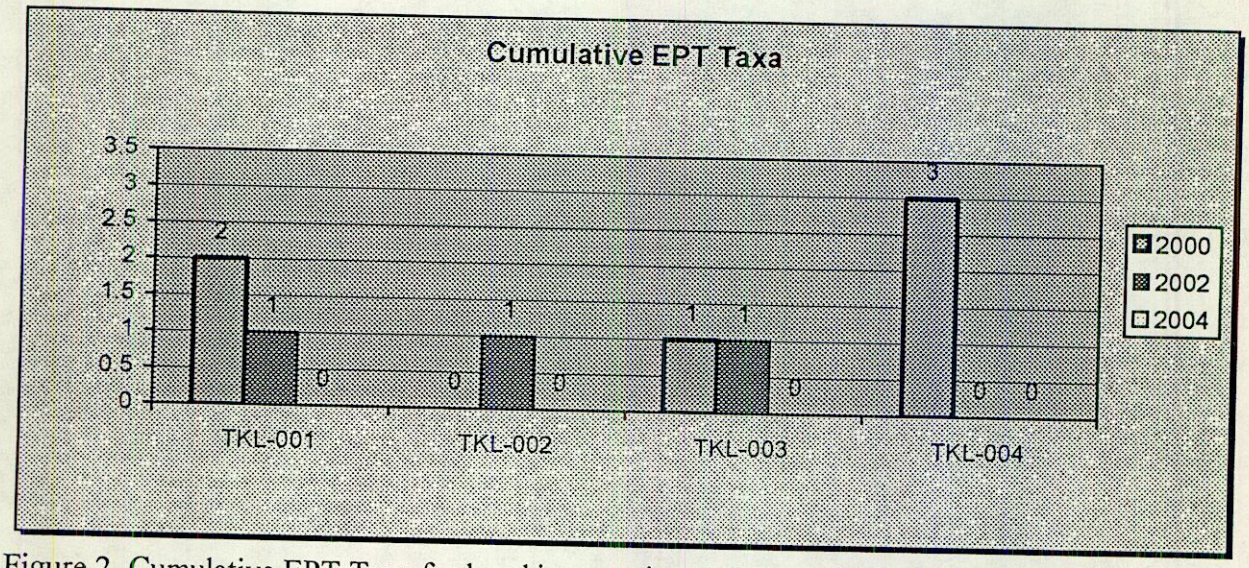


Figure 2. Cumulative EPT Taxa for benthic macroinvertebrates (BMI) collected on July 13, 2000, July 12, 2002 and July 2004at four areas of the Tahoe Keys Marina, South Lake Tahoe, California.

Composition Measures

The number of mayflies (Order: Ephemeroptera), stoneflies (Order: Plecoptera) and caddisflies (Order: Trichoptera) ranged from 0 to only 3% at each of the four sites for all three sampling events. None of these EPT organisms were in the sensitive taxa category. Shannon Diversity values (Figure 3) were extremely low at all sites for all three sampling events, especially for 2004 where values were lower at all sites. The Percent Dominant Taxon metric (Figure 4) indicates that the most abundant taxon comprised between 37 and 73 percent of the total BMI community in 2000, between 33 and 80 percent in 2002 and between 85 and 67 in 2004.

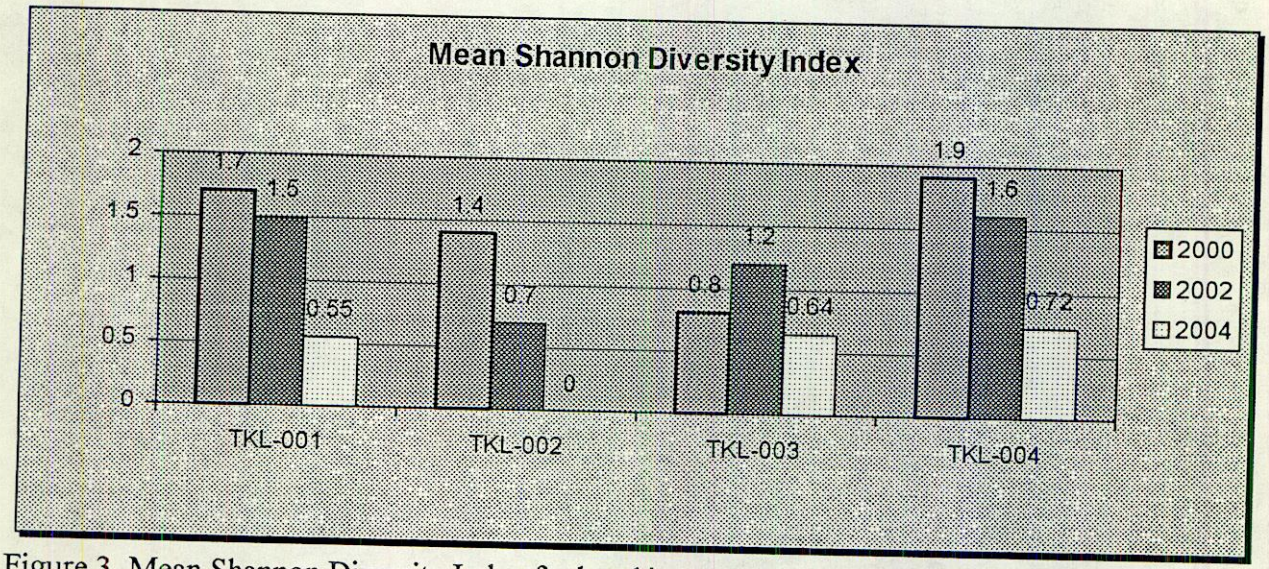


Figure 3. Mean Shannon Diversity Index for benthic macroinvertebrates (BMI) collected on July 13, 2000, July 12, 2002 and July 2004 at four areas of the Tahoe Keys Marina, South Lake Tahoe, California.

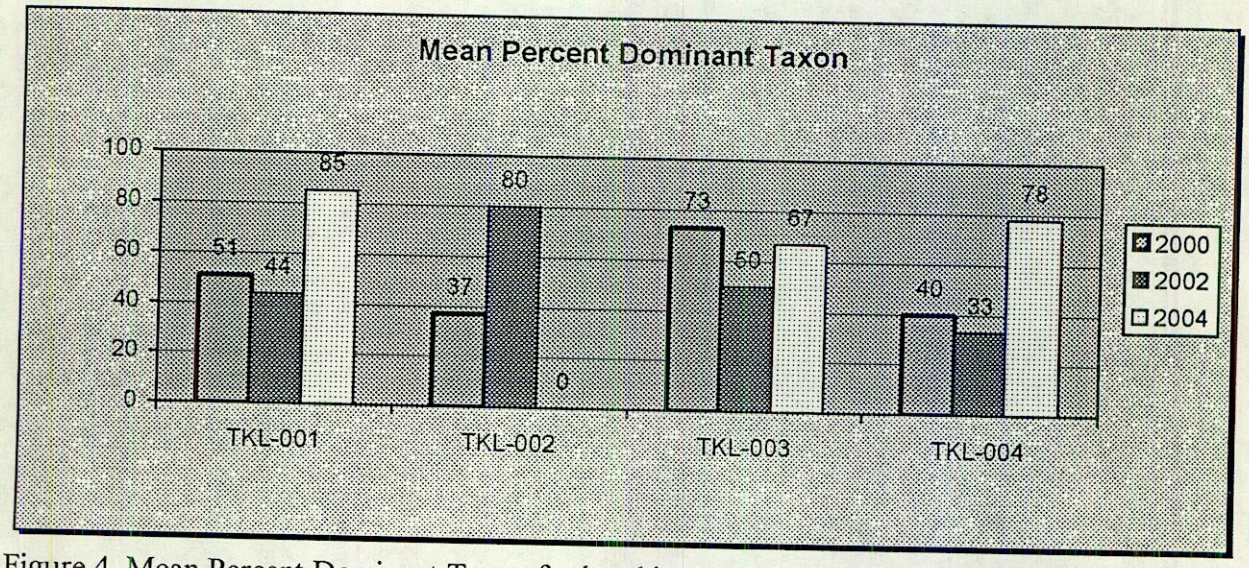


Figure 4. Mean Percent Dominant Taxon for benthic macroinvertebrates (BMI) collected on July 13, 2000, July 12, 2002 and July 2004 at four areas of the Tahoe Keys Marina, South Lake Tahoe, California.

Tolerance Measures

All tolerance measures indicated communities that were very tolerant to disturbance or extremely tolerant to disturbance. The mean Tolerance Values (Figure 5) ranged between 7.4 and 7.9 in 2000 and slightly lower (6.4 - 7.7) in 2002. The mean Tolerance Values at TKL-001 and TKL-004 for 2004 were the lower than any other sampling event. However, since there were so few organisms, these values are probably not reliable.

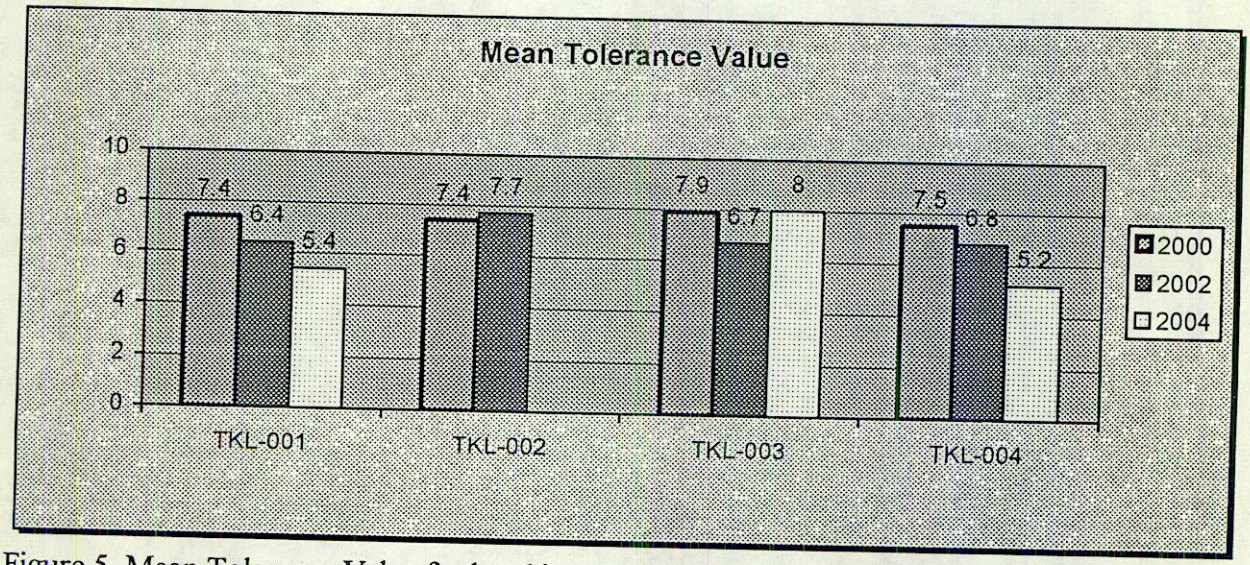


Figure 5. Mean Tolerance Value for benthic macroinvertebrates (BMI) collected on July 13, 2000, July 12, 2002 and July 2004 at four areas of the Tahoe Keys Marina, South Lake Tahoe, California.

Functional Feeding Groups (FFG)

All of the FFGs were present within the Tahoe Keys Marina except shredders (Figure 6). Most organisms in this watershed were either collector-gatherers, which feed on fine particulate organic matter (FPOM) or grazers that feed on algae or vascular plant material. The community of BMIs seemed to be in balance with freshwater lotic (stillwater) environment and fairly consistent for the two sampling events. Only the BMI community at site TKL-002 in 2002 was different having more herbivorous grazing snails than the other site.

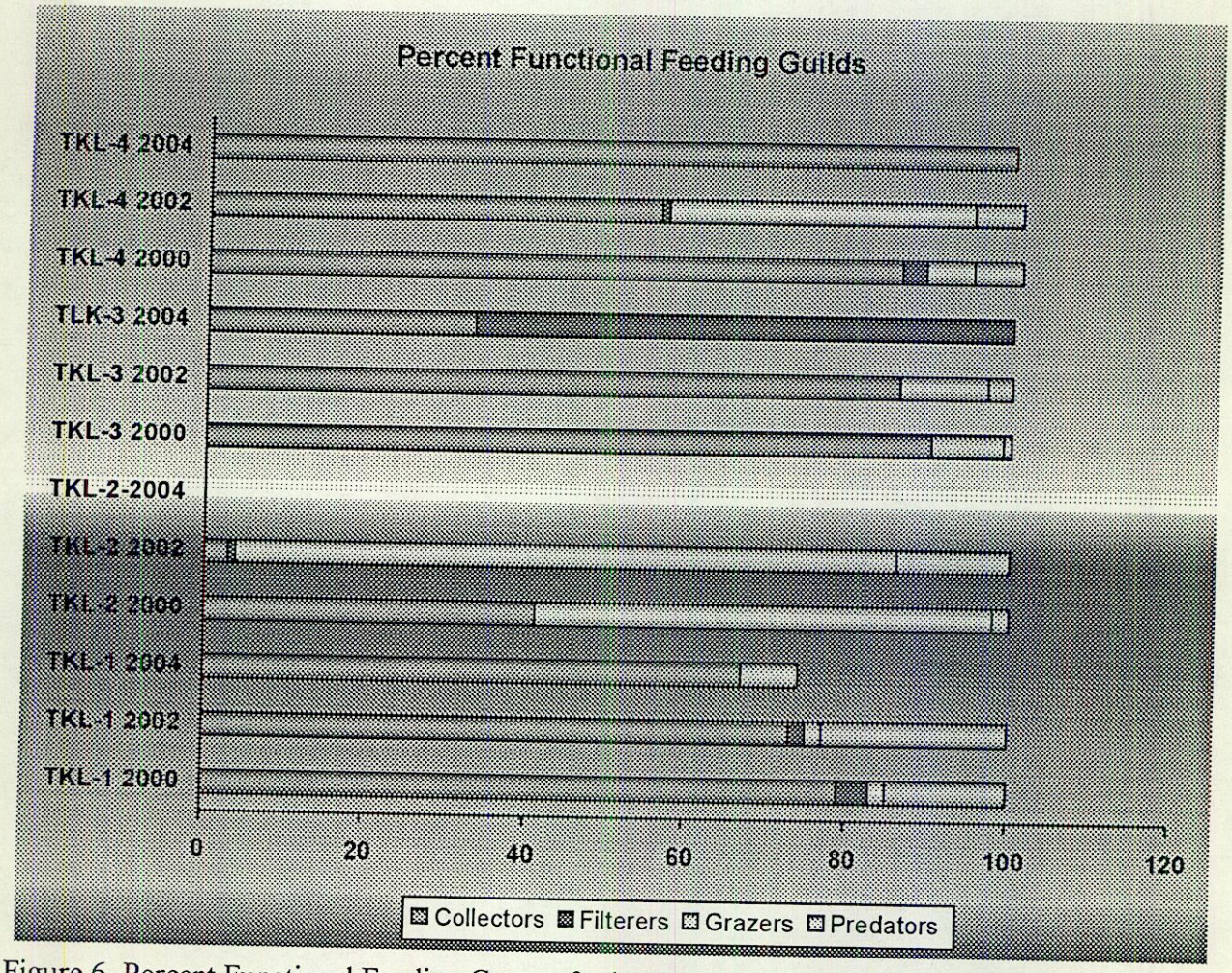


Figure 6. Percent Functional Feeding Groups for benthic macroinvertebrates (BMI) collected on July 13, 2000, July 12, 2002 and July 2004 at four areas of the Tahoe Keys Marina, South Lake Tahoe, California.

Abundance

The number of organisms was higher in 2000 than in 2002 and was higher at sites TKL-001 and TKL-004 and lower at sites TKL-002 and TKL-003. The number of organisms in 2004 was extremely low at all the sites with no organisms being found in TKL-002.

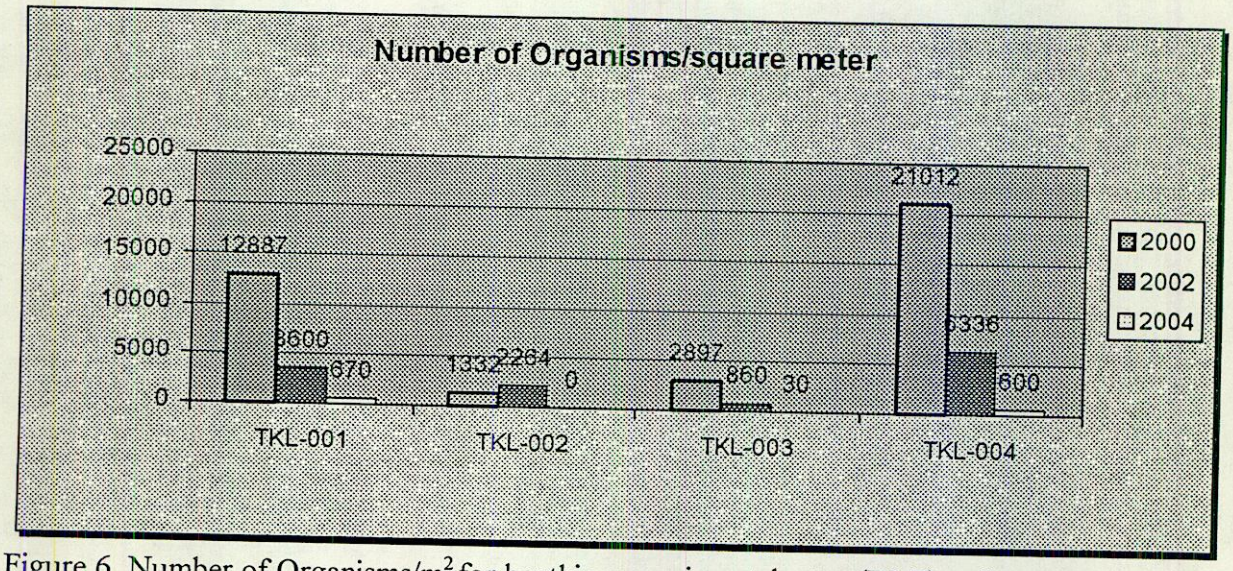


Figure 6. Number of Organisms/m^2 for benthic macroinvertebrates (BMI) collected on July 13, 2000, July 12, 2002 and July 2004 at four areas of the Tahoe Keys Marina, South Lake Tahoe, California.

Water Chemistry Results

Results of water chemistry testing are presented in Table 6. All chemical contaminates were below reporting limits (BRL) or in relatively low concentrations in the water column of the four sites sampled in the Tahoe Keys Marina on July 22, 2004.

Sediment Chemistry Results

Results of sediment chemistry testing are presented in Table 7. Copper and Aluminum concentrations in sediment were high at all sitesAll chemical contaminates were below reporting limits (BRL) or in relatively low concentrations in the bottom sediments of the four sites sampled in the Tahoe Keys Marina on July 22, 2004.

Sediment Toxicity Test Results

Results of the toxicity testing are presented in Table 8. The bottom sediments at the four sites sampled in the Tahoe Keys Marina on July 22, 2004 exhibited no toxicity, except for site TKL-003 which exhibited only slight toxicity.

Table 6. Ambient chemistry, total metals, herbicide, base/neutral semivoatile compounds and volatile organic compounds determined for water samples collected on July 22, 2004 at four areas of the Tahoe Keys Marina, South Lake Tahoe, California.

Chemical Constituent	TKL001	TKL002	TKL003	TKL004
Ambient Chemistry				
Hardness (mg/L CaCO3)	39.8	39.8	37.3	41.8
pH @ 22 °C	8.0	8.2	7.8	8.6
Dissolved Metals				
Copper (ug/L)	0.51	0.61	0.54	1.09
Aluminum (ug/L)	<0.10	<0.10	0.16	6.21

Boron (ug/L)	23.6	23.6	24.1	22.6
Herbicide				
Diazinon (ug/L)	<0.05	<0.05	<0.05	<0.05
Chlorpyrifos (ug/L)	<0.05	<0.05	<0.05	<0.05
Base/Neutral Semivoatile Compounds				
All 41 compounds	<5.0	<5.0	<5.0	<5.0
Volatile Organic Compounds				
Benzene	0.2	<0.2	0.4	<0.2
Toluene	0.4	0.3	0.3	<0.2
All other 43 compounds	BRL	BRL	BRL	BRL

Table 7. Total metals, herbicide, base/neutral semivoatile compounds and volatile organic compounds determined for sediment samples collected on July 22, 2004 at four areas of the Tahoe Keys Marina, South Lake Tahoe, California.

Chemical Constituent	**TKL001**	**TKL002**	**TKL003**	**TKL004**
Total Metals				
Copper (mg/kg; dry weight)	46.6	55.6	65.8	64.1
Aluminum (mg/kg; dry weight)	36,977	50,305	66,846	41,700
Boron (mg/kg; dry weight)	N/A	N/A	N/A	N/A
Herbicide				
Diazinon (ng/g)	<1.00	<1.00	<1.00	<1.00
Chlorpyrifos (ng/g)	<2.00	<2.00	<2.00	<2.00
Base/Neutral Semivoatile Compounds	BRL	BRL	BRL	BRL
All 41 compounds				
Volatile Organic Compounds	BRL	BRL	BRL	BRL
All other 45 compounds	BRL	BRL	BRL	BRL

Table 8. Summary of sediment acute bioassays with Hyalella azteca for samples collected on July 22, 2004 at four areas of the Tahoe Keys Marina, South Lake Tahoe, California.

	Initial Test (August 6, 2004)		Re-Test (September 7, 2004)	
Sample Number	Mean % Survival	Standard Deviation	Mean % Survival	Standard Deviation
Control	70	2.00	98	0.54
TKL-001	69	2.42	84*	0.74
TKL-002	61	2.42	90	1.20
TKL-003	60	1.93	94	1.06
TKL-004	68	1.58	96	0.74
* significantly diminished from control exposure (ANOVA/Bonferroni t-test: p=0.05				

DISCUSSION

The Tahoe Keys area was once the largest and most important wetland area associated with Lake Tahoe. In its natural state, it acted like a filter removing sediment and nutrients from streams draining into the Lake. It also provided habitat for many species of wildlife including important rearing and

spawning grounds for endemic Lake Tahoe fishes such as the Lahontan cutthroat trout. Undoubtedly, the benthic macroinvertebrate fauna was quite diverse and abundant in the area that is now Tahoe Keys marina. Surveys of the edge of Lake Tahoe in the 1960's (Frantz and Cordone 1996) found 95 different BMI taxa with ten of those being endemic to the Lake. Using equipment similar to that used in this present day study, Frantz and Cordone calculated an average standing crop of 2500 organisms/m^2 along the edge of the lake in water up to 30 meters deep.

The Tahoe Keys wetland in its natural state probably had more types of BMIs and at higher densities than were found by Frantz and Cordone (1996) along the Lake's edges. However, in the altered condition that exists today in the Tahoe Keys, its BMI community would be more similar to the edge of the lake than a wetland. The BMI structure at the four areas within the Marina were in somewhat similar proportion with what Frantz and Cordone (1996) found; numerically, they found oligochaets, amphipods, ostacods and dipertan larvae (in that order) dominated the community. Other insects such as the mayflies (Order: Ephemeroptera), stoneflies (Order: Plecoptera) and caddisflies (Order: Trichoptera) were present, but in less numbers. We observed similar proportions, but instead of 95 different taxa, we found 27 taxa in 2000, 19 in 2002 and only 5 taxa in 2004.

Besides low richness of BMI taxa, the biological metrics indicated that the BMI community had low diversity, was dominated by high numbers of particular types of BMIs that were tolerant to low dissolved oxygen and general human disturbance. The biological metrics also indicated that sites TLK002 and TLK003 were in more degraded condition than sites TLK001 and TKL004 and that in general, BMI communities were more degraded in 2004 than in 2002 or 2000. The 2004 sampling event showed a significant decrease in the number of organisms, number of taxa and in the biological metric values. This significant decrease was in all sites including the control site outside the marina area.

In the 2002 report, we concluded that the overall degraded condition of the BMI communities in Tahoe Keys Marina and the more degraded condition of the TLK002 and TLK003 sites may be more a product of habitat degradation than chemical contamination. Of all the chemical constituents measured in 2002, high pH and low dissolved oxygen values were of most concern. All the areas sampled for dissolved oxygen except TLK003, had values below that considered safe for most aquatic organisms (5.0 mg/L). Furthermore, all the areas had pH values above 9.0 which are out of the range (6.7 and 8.6) of most inland waters containing healthy fish populations (McKee and Wolf 1971).

In the 2002 report, we also observed that dissolved copper and aluminum were present in the water column, but probably at low enough concentration not to harm aquatic life. Water quality criteria goals for copper to freshwater aquatic life is 4.8 ug/L (maximum concentration) for waters with hardness <25 mg/L $CaCo_3$ (Marshack 1993). The US EPA recommends that to protect most aquatic organisms, the concentration of aluminum in water with pH of 6.5 to 9.0 should not exceed 87 µg/l (US EPA 1988). For our measurements in July 2002, copper never exceeded 0.89 ug/L and aluminum never exceeded 6.12 ug/L. Diazinon was present at the two sites that were closest to homes and further from the open water (TLK001 and TLK002), but in very low concentrations (0.040 and 0.035 ug/L).

To determine whether the degraded biotic condition was due to habitat alteration or chemical contamination, we measured sediment chemistry and sediment toxicity in 2004. In 2004, water column chemistry at the four sites was lower than or as low as in 2000 and 2002. Benzene and toluene was detected at very low levels in the water column for the first time in 2004. This was probably due to contamination of the sample water and not human disturbance. The only contaminates that were found in the sediment chemistry was copper and aluminum. Those values were extremely high and probably have some effect on the biota. However, since we did not find significant sediment toxicity (except for TKL-001), the effect is probably not acute. The site with toxicity was extremely slight with an 84% survival in the test sediment compared to 98% in the control.

Conclusions and Recommendations

For the 2000 and 2002 sampling period, the BMI community at the four sites within the Tahoe Keys Marina was somewhat similar in composition to that found from historic surveys along the edge of the Lake. However, compared to those surveys, the BMI community within the Marina was lower in taxonomic richness, lower in community diversity and was dominated by high numbers of BMIs that were tolerant to low dissolved oxygen and general human disturbance. The data also indicated that sites TLK002 and TLK003 were in more degraded condition than sites TLK001 and TKL004 and that in general, BMI communities were more degraded in 2002 than 2000. For the 2004 sampling period, the BMI community at the four sites within the Tahoe Keys Marina were extremely depopulate with no organisms being found at the TLK-002 site.

For the 2000 and 2002 sampling period, the chemical data indicated that the overall degraded condition of the BMI communities in Tahoe Keys Marina and the more degraded condition of the TLK002 and TLK003 sites was probably not a product of water column contamination. Furthermore, since there was no acute toxicity at the sites, the high concentrations of copper and aluminum in the sediment samples collected in 2004 was probably not the sole cause of the depopulate community of benthic macroinvertebrates. The poor biotic condition at the four Tahoe Keys Marina sites is probably a result of several factors. The primary factors could be: 1) the levels of copper and aluminum in the sediment probably produce a chronic toxicity effect; 2) the lack of good quality habitat within the Marina prevents colonization of diverse invertebrate populations and; 3) the buildup of dead vegetation on the benthos probably produces the low dissolved oxygen and pH imbalance.

Literature Cited

Brown, H.P. 1972. Aquatic Dryopoid Beetles (Coleoptera) of the United States. U.S. Environmental Protection Agency Project, # 18050 ELD. Washington D.C.

Erman, N.A. 1996. Status of Aquatic Invertebrates. in: Sierra Nevada Ecosystem Project: Final Report to Congress, Vol II, Assessments and Scientific Basis for Management Options. University of California Davis, Centers for Water and Wildland Resources.

Frantz, T.C. and A.J. Cordone. 1996. Observations on the macrobenthos of Lake Tahoe, California – Nevada. California Fish and Game Vol. 82 No. 1. Sacramento, CA.

Gibson, G. R. 1996. Biological Criteria: Technical guidance for streams and small rivers. EPA 822-B-96-001. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

Harrington, J. M. 1999. California stream bioassessment procedures. California Department of Fish and Game, Water Pollution Control Laboratory. Rancho Cordova, CA.

Klemm, D.J. 1985. A guide to the freshwater Annelida (Polychaeta, Naidid and Tubificid Oligochaeta, and Hirudinea of North America. Kendall/ Hunt Publishing Co., Dubuque, Iowa.

Leivestad, H.G., H.I. Muniz and E. Snekvik. 1976. Effects of acid precipitation on freshwater organisms. In F.H. Braekke (Ed.) SNSF Research Report 6/76.

Marshack J.B. 1993. A Compilation of Water Quality Goals. California Regional Water Quality Control Board - Central Valley Region. Sacramento, Ca.

McKee J.E. and H.W. Wolf. 1971. Water Quality Criteria. Publication 3-A. California State Water Resources Control Board. Sacramento, Ca.

Merritt, R. W. and K. W. Cummins. 1995. An introduction to the aquatic insects of North America. Second Edition. Kendall/Hunt Publishing Co., Dubuque, Iowa

Pennak, R. W. 1989. Freshwater invertebrates of the United States, 3rd Ed. John Wiley and Sons, Inc., New York.

Resh, V.H. and J.K. Jackson. 1993. Rapid assessment approaches to biomonitoring using benthic macroinvertebrates. In: D.M. Rosenberg and V.H. Resh, eds., Chapman and Hall, New York.

Rosenberg, D. M. and V. H. Resh (editors). 1993. Freshwater Biomonitoring and Benthic Macroinvertebrates, Chapman and Hall, New York, NY.

Sorensen E.M. 1991. Metal Poisoning in Fish. CRC Press. Boca Raton, Fl.

Stewart, K. W. and B. P. Stark. 1993. Nymphs of North American stonefly genera (Plecoptera). University of North Texas Press, Denton, Texas.

Surdick, R.F. 1985. Nearctic Genera of Chloroperlinae (Plecoptera: Chloroperlidae). University of Illinois Press. Chicago, IL.

Thorp, J. H. and A. P. Covich (eds.). 1991. Ecology and classification of North American invertebrates. Academic Press, San Diego, CA.

U. S. Environmental Protection Agency. 1998. Ambient Aquatic Life Water Quality Criteria for Aluminum. US EPA Publication No. 440/5-86-008. Dulut, Mn

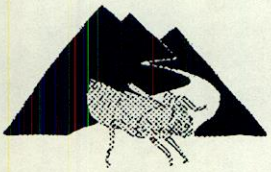
Usinger, R. L. Aquatic Insects of California. University of California Press. Berkeley, Ca.

Wiederholm, T. 1983. Chironomidae of the Holarctic region - Part 1. Larvae. Entomologica Scandinavica, Supplement No. 19. Sandby, Sweden.

_____. 1986. Chironomidae of the Holarctic region - Part 2. Pupae. Entomologica Scandinavica, Supplement No.28. Sandby, Sweden.

Wiggins, G. B. 1996. Larva of North American caddisfly genera (Trichoptera), 2nd ed. University of Toronto Press, Toronto.

Wold, J. L. 1974. Systematics of the genus *Rhyacophila* (Trichoptera: Rhyacophilidae) in western North America with special reference to the immature stages. Master of Science Thesis. Oregon State University, Corvallis, OR.



WATER QUALITY INVENTORY SERIES
BIOLOGICAL AND PHYSICAL/
HABITATASSESSMENT OF CALIFORNIA
WATER BODIES

Bioassessment of Tahoe Keys Marina South Lake Tahoe, CA

December 2002

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INTRODUCTION

The Tahoe Keys Resort and associated marina is located on the south side of Lake Tahoe near the city of South Lake Tahoe. The Tahoe Keys area was once the largest and most important wetland area associated with Lake Tahoe. In its natural state, it acted like a filter removing sediment and nutrients from streams draining into the Lake. When the lagoons and waterways were constructed within the original wetland to create the Resort and marina, much of the filtering properties and flushing abilities were lost. As a result, the Tahoe Keys Property Owners Association had to construct a water circulation and filtering facility to prevent the excessive buildup of algae and vascular plant material. In August and September 1998, aluminum concentration from the water treatment facility exceeded the allowable discharge requirement of a four-day average concentration of 87 □g/L. This initiated a report from the Lahontan Regional Water Quality Control Board asking the Association to fund a program to investigate the effects of excessive aluminum on the biological integrity of Tahoe Keys Marina.

In July 2000, the California Department of Fish and Game's Aquatic Bioassessment Laboratory (ABL) was contracted by the Tahoe Keys Property Owner's Association to initiate an assessment of the biological condition in Tahoe Keys Marina as part of their NPDES permit requirements. The assessment was designed to measure water column chemistry and the benthic macroinvertebrate (BMI) communities at four areas within the Marina every two years.

Water resource monitoring using BMIs is by far the most popular biological assessment method used throughout the world. BMIs are ubiquitous, relatively stationary, and their large species diversity provides a spectrum of responses to environmental stresses (Rosenberg and Resh 1993). Individual species of BMIs reside in the aquatic environment for a period of months to several years and are sensitive, in varying degrees, to temperature, dissolved oxygen, sedimentation, scouring, nutrient enrichment and chemical and organic pollution (Resh and Jackson 1993). Finally, BMIs represent a significant food source for aquatic and terrestrial animals and provide a wealth of evolutionary, ecological and biogeographical information (Erman 1996).

This report presents results from BMI and water chemistry samples collected on July 12, 2002. There are also some comparisons of the 2002 result with the results of an identical sampling event conducted July 13, 2000.

MATERIALS AND METHODS

Monitoring Site Descriptions

The locations of the four sampling sites within the Tahoe Keys Marina are presented in Table 1 for the 2000 sampling event and in Table 2 for the 2002 sampling event. Although there are slight differences in GPS coordinates, we tried to sample the exact location for both sampling events. The depth of the site was fairly consistent with the exception of site TKL003 where there was close to a 3 meter difference in depth.

BMI Laboratory Analysis

At the laboratory, each sample was rinsed through a No. 35 standard testing sieve (0.5 mm brass mesh) and transferred into a tray marked with twenty, 25 cm^2 grids. All detritus was removed from one randomly selected grid at a time and placed in a petri dish for inspection under a stereomicroscope. All invertebrates from the grid were separated from the surrounding detritus and transferred to vials containing 70% ethanol and 5% glycerol. This process was continued until 300 organisms were removed from each sample. The material left from the processed grids was transferred into a jar with 70% ethanol and labeled as "remnant" material. Any remaining unprocessed sample from the tray was transferred back to the original sample container with 70% ethanol and archived. Macroinvertebrates were then identified to a standard taxonomic level, typically genus level for insects and family or genus for non-insects using standard taxonomic keys (Brown 1972, Edmunds et al. 1976, Klemm 1985, Merritt and Cummins 1995, Pennak 1989, Stewart and Stark 1993, Surdick 1985, Thorp and Covich 1991, Usinger 1963, Wiederholm 1983, 1986, Wiggins 1996, Wold 1974).

Chemical Laboratory Analyses

All water chemistry analyses were performed in accordance with standard EPA procedures for laboratory analysis.

- Volatile organic compounds were tested for following EPA Method 8260
- Semi-Volatile compounds were tested for following EPA Method 8270
- Chlorpyifos and Diazinon were tested for following EPA Method
- Metals (Aluminum, Boron and Copper) were tested for following EPA Methods 200.7, 200.7 and 220.2 respectively
- Hardness was measured following Standard Methods 1992

Other ambient chemical characteristics (specific conductivity, dissolved oxygen and water temperature) were measures using a Yellow Springs Instruments Model 85 meter while the biological and chemical samples were collected.

Data Analysis

A taxonomic list of BMIs identified from the samples was entered into a Microsoft Excel® spreadsheet program. MS Excel® was used to calculate and summarize macroinvertebrate community based metric values. A description of the metric values used to describe the community is shown in Table 3.

RESULTS

Dominant BMI Taxa/ General Taxonomic Notes

The five dominant taxa observed at the four monitoring reaches are presented in Table 4 for the 2000 sampling event and in Table 5 for the 2002 sampling event. A complete list of BMIs identified from the samples collected in 2002 is presented in Appendix 1.

Table 3. Metrics used to describe characteristics of the benthic macroinvertebrate (BMI) community

at sampling areas within the Tahoe Keys Marina, South Lake Tahoe, California.

BMI Metric	Description	Response to Impairment
Richness Measures		
Taxa Richness	Number of individual taxa collected from each replicate sample	decrease
Cumulative Taxa	Total number of individual taxa collected from each site	decrease
EPT Taxa	Number of taxa in the Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) insect orders collected from each replicate sample	decrease
Cumulative EPT Taxa	Total number of taxa in the Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) insect orders collected at each site	decrease
Composition Measures		
EPT Index	Percent composition of mayfly, stonefly and caddisfly larvae	decrease
Sensitive EPT Index	Percent composition of mayfly, stonefly and caddisfly larvae with tolerance values between 0 and 3	decrease
Percent Dominant Taxa	Percent composition of the single most abundant taxon	increase
Shannon Diversity Index	General measure of sample diversity that incorporates richness and evenness (Shannon and Weaver 1963)	decrease
Tolerance/Intolerance Measures		
Tolerance Value	Value between 0 and 10 weighted for abundance of individuals designated as pollution tolerant (higher values) or intolerant (lower values)	increase
Percent Intolerant Organisms	Percent of organisms in sample that are highly intolerant to impairment as indicated by a tolerance value of 0, 1 or 2	decrease
Percent Tolerant Organisms	Percent of organisms in sample that are highly tolerant to impairment as indicated by a tolerance value of 8, 9 or 10	increase
Functional Feeding Groups (FFG)		
Percent Collectors	Percent of macrobenthos that collect or gather fine particulate matter	increase
Percent Filterers	Percent of macrobenthos that filter fine particulate matter	increase
Percent Grazers	Percent of macrobenthos that graze upon periphyton	variable
Percent Predators	Percent of macrobenthos that feed on other organisms	variable
Percent Shredders	Percent of macrobenthos that shreds coarse particulate matter	decrease
Abundance		
Estimated Abundance	Estimated number of macroinvertebrates in sample calculated by extrapolating from the proportion of organisms in each sample	variable

Although the dominant taxa were different for each sampling event, the BMI community for both

events were dominated by disturbance tolerant non-insect fauna (primarily worm taxa, copepods and a few snail species) in addition to several chironomid midge taxa (Diptera: Chironomidae).

Table 4. Dominant macroinvertebrate taxa (and their percent contribution) for samples collected July 2000 from four sites within the Tahoe Keys Marina, South Lake Tahoe, California.

Site Number	Dominant Taxa				
	1	2	3	4	5
TKL-001	Tubificidae (44)	Harpacticoida (16)	Nematoda (8)	Cyclopidae (7)	Chirnomini (6)
TKL-002	*Helisoma* (39)	Planorbiidae (26)	Cyclopidae (21)	*Hyallela azteca* (3)	Daphniidae/ Cypridiidae (2)
TKL-003	Harpacticoida (80)	Planorbiidae (6)	*Hyallela azteca* (3)	Cyclopidae (3)	*Physa/ Physella* (2)
TKL-004	Cyclopidae (34)	Tubificidae (30)	Chironomini (9)	Valvata (4)	Naididae (3)

Table 5. Dominant macroinvertebrate taxa (and their percent contribution) for samples collected July 2002 from four sites within the Tahoe Keys Marina, South Lake Tahoe, California.

Site Number	Dominant Taxa				
	1	2	3	4	5
TKL-001	Chirnomini (45)	Tanypdinae (19)	Cyclopidae (8)	*Hyallela azteca* (8)	Tanyderidae (6)
TKL-002	Gyraulus sp. (82)	Tanypdinae (11)	Acri (2)	*Physa/Physella* (2)	Cyclopidae (3)
TKL-003	*Hyallela azteca* (35)	Cyclopidae (22)	Chirnomini (8)	Planorbiidae (8)	Tubificidae (6)
TKL-004	Chironomini (31)	Gyraulus sp. (19)	Planorbiidae (10)	Valvata (10)	Cyclopidae (8)

Benthic Macroinvertebrate Community Metrics

Bioassessment metrics values (described in Table 2) based on the BMIs identified for samples collected in 2002 are listed in Appendix 2. The values are means of the three samples collected at each site along with the associated coefficient of variation.

Richness Measures

Mean Taxonomic Richness (Figure 1) was higher at most sites in 2000 than in 2002, especially at site TKL004. In general, taxonomic richness was higher in sites TKL001 and TKL004 than in sites TKL002 and TKL003, for both years. The number of mayfly (Order: Ephemeroptera), stonefly (Order: Plecoptera) and caddisfly (Order: Trichoptera) taxa present at the four sites were extremely

low (Figure 2). Cumulative EPT Taxa (Figure 2) was higher in sites TKL001 and TKL004 than in sites TKL002 and TKL003, for both years. However, Site TKL004 had a more significant change between the two sampling events going from 3 in 2000 to 0 in 2002.

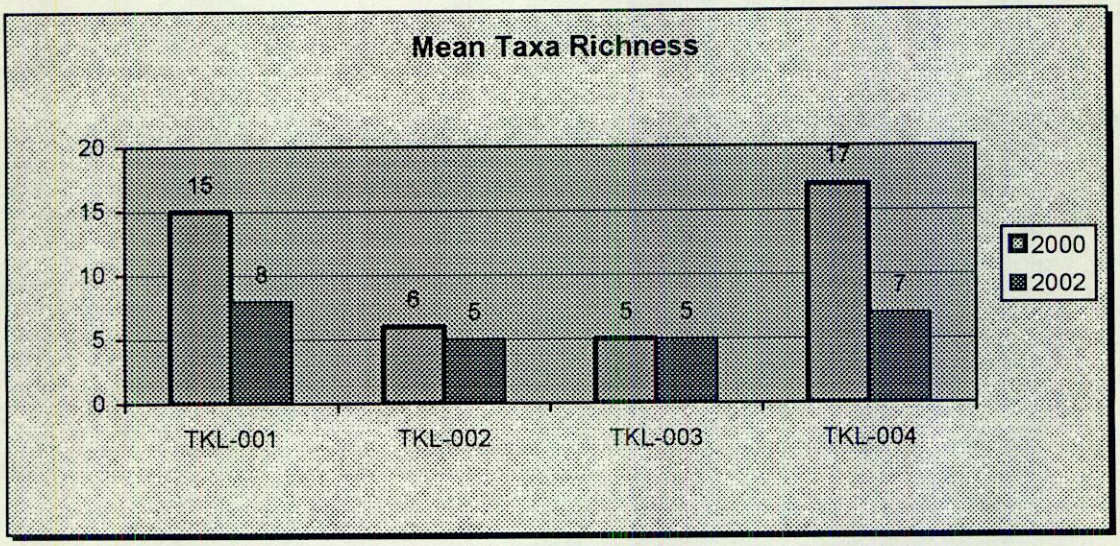


Figure 1. Mean Taxonomic Richness for benthic macroinvertebrates (BMI) collected on July 13, 2000 and July 12, 2002 at four areas of the Tahoe Keys Marina, South Lake Tahoe, California.

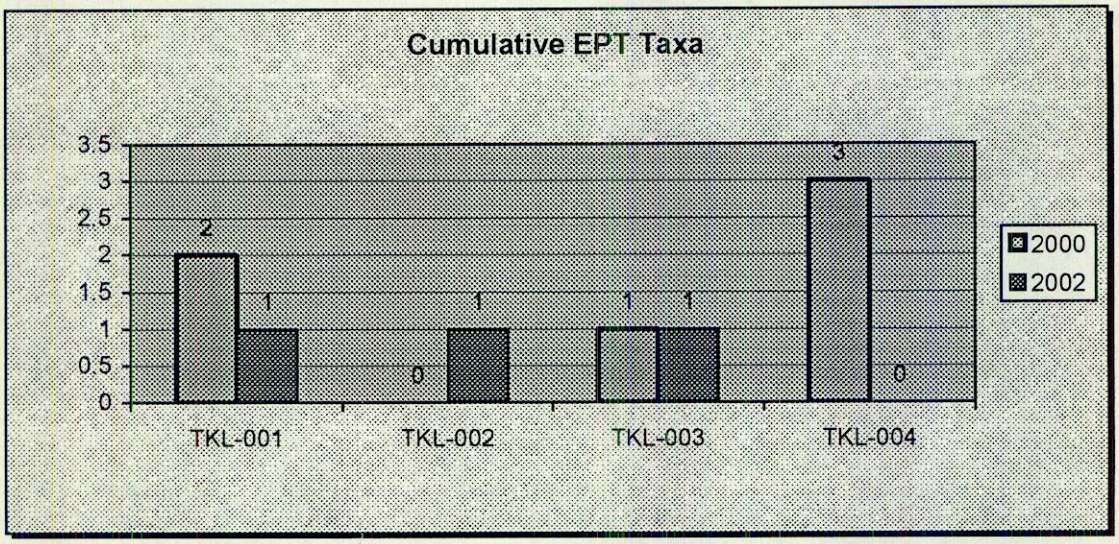


Figure 2. Cumulative EPT Taxa for benthic macroinvertebrates (BMI) collected on July 13, 2000 and July 12, 2002 at four areas of the Tahoe Keys Marina, South Lake Tahoe, California.

Composition Measures

The number of mayflies (Order: Ephemeroptera), stoneflies (Order: Plecoptera) and caddisflies (Order: Trichoptera) ranged from 0 to only 3% at each of the four sites for both sampling events. None of these EPT organisms were in the sensitive taxa category. Shannon Diversity values (Figure 3) were extremely low at all sites for both sampling events and except for TKL003, values were lower in 2002 than in 2000. The Percent Dominant Taxon metric (Figure 4) indicates that the most abundant taxon comprised between 37 and 73 percent of the total BMI community in 2000 and between 33 and 80

percent in 2002. In general when the Shannon Diversity Index values are low the Percent Dominant Taxon values are high. This tendency was present for both years and indicated that sites TKL001 and TKL004 had better biological integrity than sites TKL002 and TKL003.

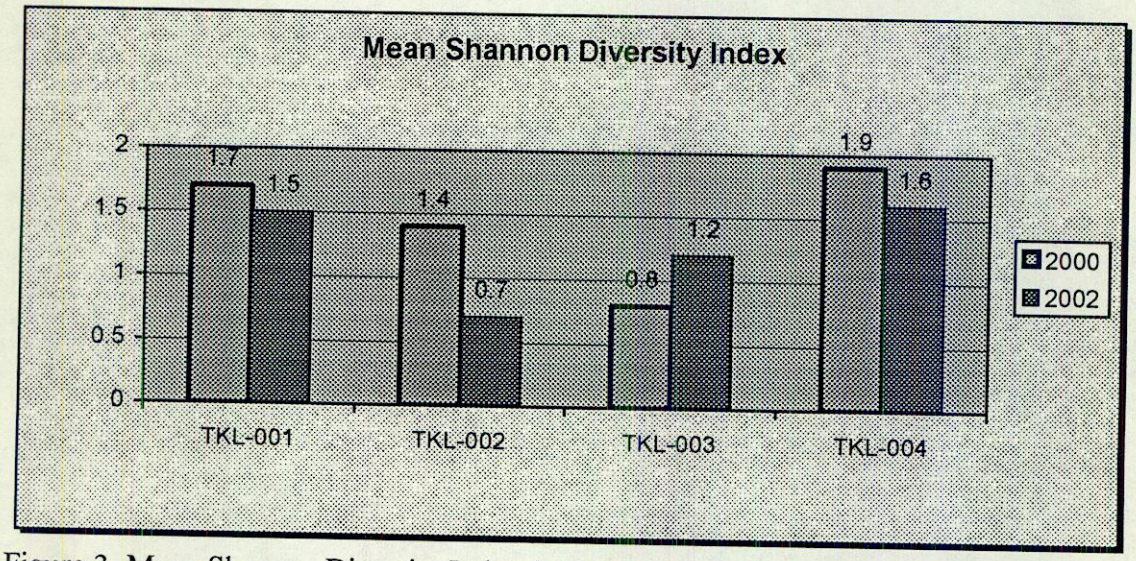


Figure 3. Mean Shannon Diversity Index for benthic macroinvertebrates (BMI) collected on July 13, 2000 and July 12, 2002 at four areas of the Tahoe Keys Marina, South Lake Tahoe, California.

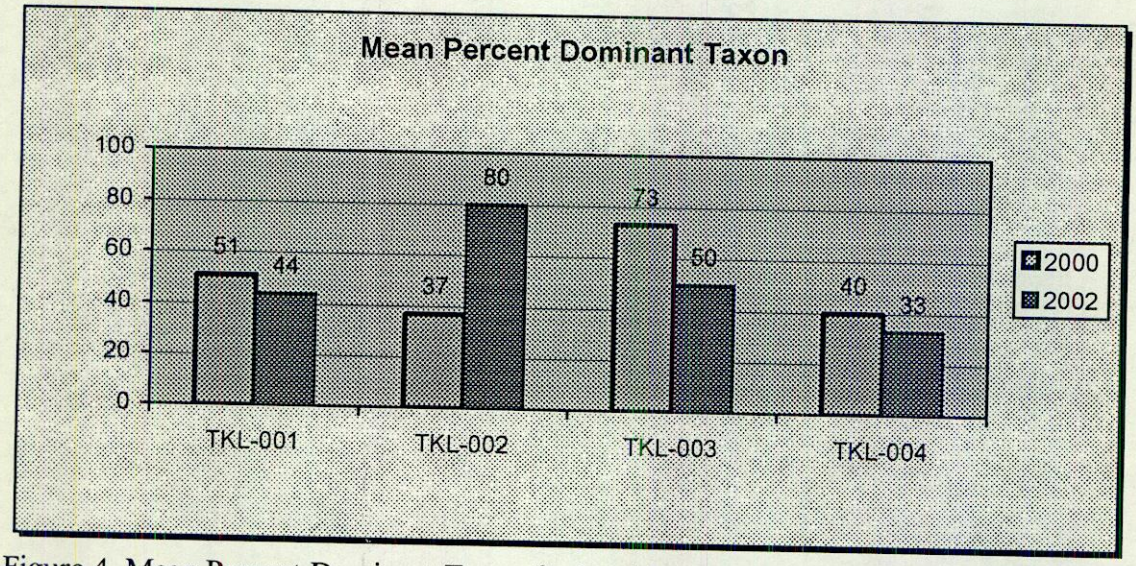


Figure 4. Mean Percent Dominant Taxon for benthic macroinvertebrates (BMI) collected on July 13, 2000 and July 12, 2002 at four areas of the Tahoe Keys Marina, South Lake Tahoe, California.

Tolerance Measures

All tolerance measures indicated communities that were very tolerant to disturbance or extremely tolerant to disturbance. The mean Tolerance Values (Figure 5) ranged between 7.4 and 7.9 in 2000 and slightly lower (6.4 - 7.7) in 2002.

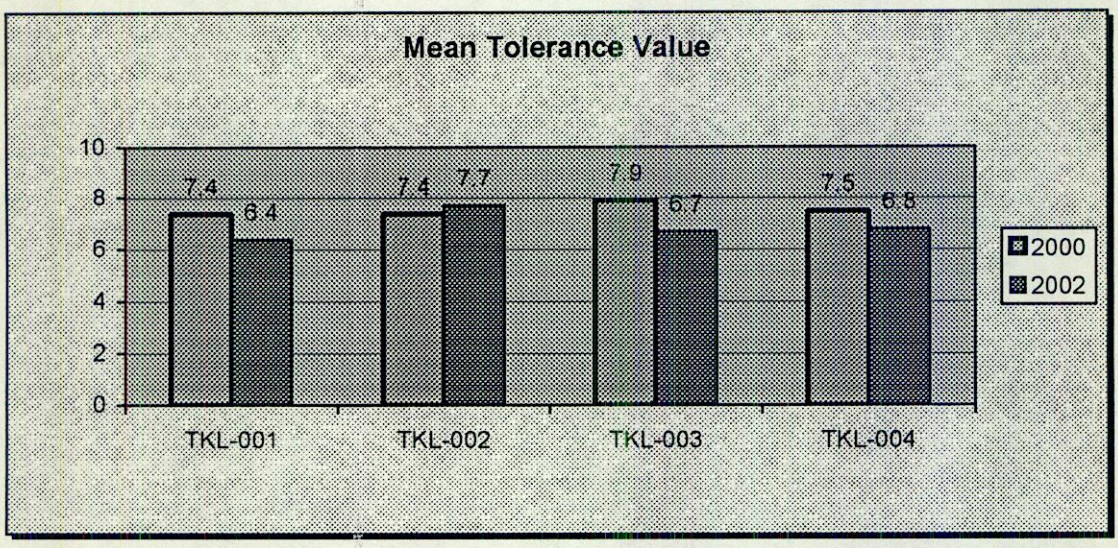


Figure 5. Mean Tolerance Value for benthic macroinvertebrates (BMI) collected on July 13, 2000 and July 12, 2002 at four areas of the Tahoe Keys Marina, South Lake Tahoe, California.

Functional Feeding Groups (FFG)

All of the FFGs were present within the Tahoe Keys Marina except shredders (Figure 6). Most organisms in this watershed were either collector-gatherers, which feed on fine particulate organic matter (FPOM) or grazers that feed on algae or vascular plant material. The community of BMIs seemed to be in balance with freshwater lotic (stillwater) environment and fairly consistent for the two sampling events. Only the BMI community at sites (TKL-002) was different having more herbivorous grazing snails than the other sites.

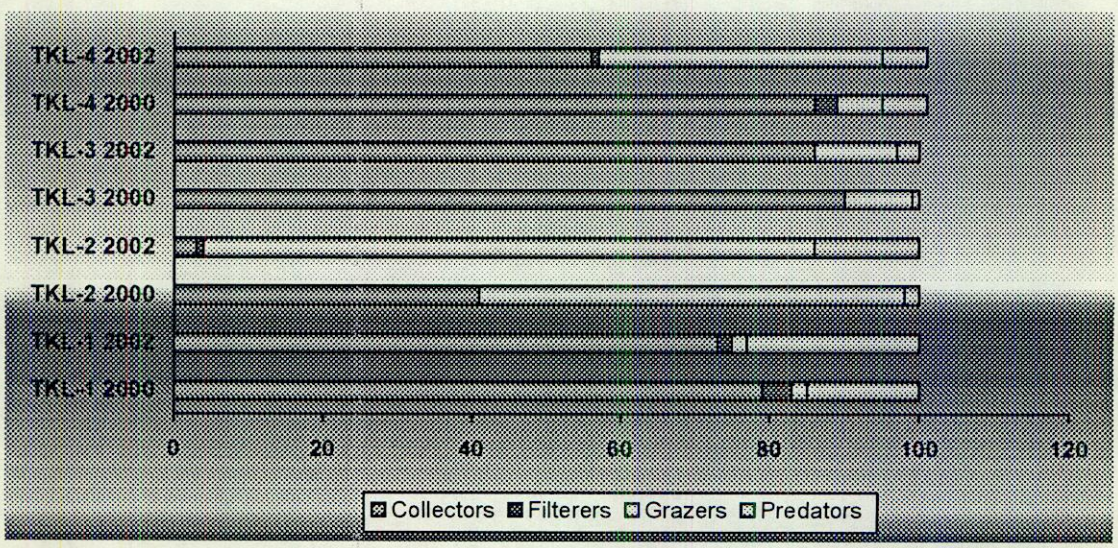


Figure 6. Percent Functional Feeding Groups for benthic macroinvertebrates (BMI) collected on July 13, 2000 and July 12, 2002 at four areas of the Tahoe Keys Marina, South Lake Tahoe, California.

Abundance

The mean number of organisms was higher in 2000 than in 2002 and was higher at sites TKL001 and TKL004 and lower at sites TKL002 and TKL003.

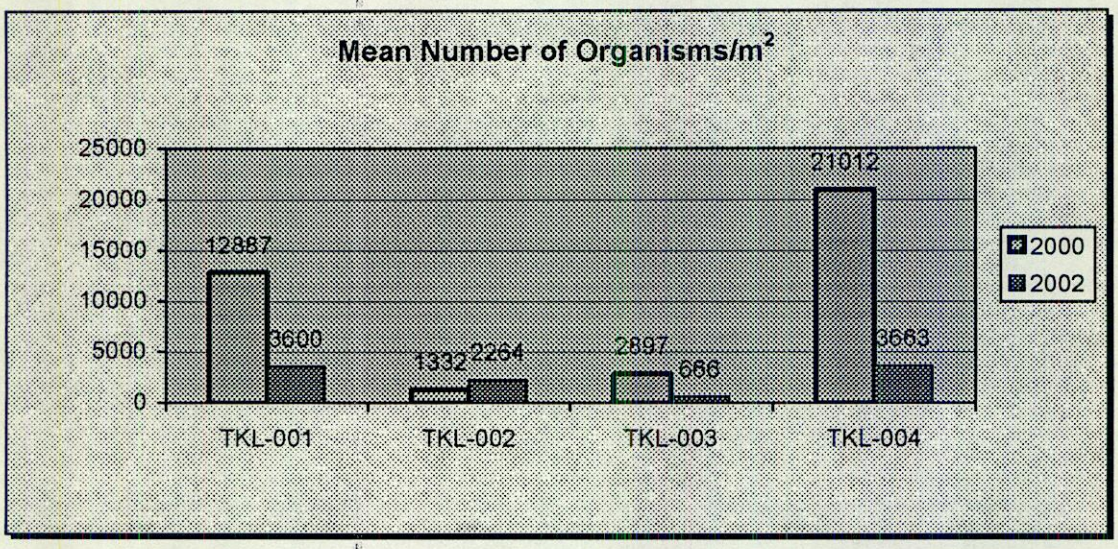


Figure 6. Mean Number of Organisms/m^2 for benthic macroinvertebrates (BMI) collected on July 13, 2000 and July 12, 2002 at four areas of the Tahoe Keys Marina, South Lake Tahoe, California.

Water Chemistry Results

Results of all water chemistry testing are presented in Table 6. All chemical contaminates were in relatively low concentrations in the water column of the four sites sampled in the Tahoe Keys Marina on July 12, 2002.

Table 6. Ambient chemistry, total metals, herbicide, base/neutral semivoatile compounds and volatile organic compounds determined for samples collected on July 12, 2002 at four areas of the Tahoe Keys Marina, South Lake Tahoe, California.

Chemical Constituent	TKL001	TKL002	TKL003	TKL004
Ambient Chemistry				
Hardness (mg/L CaCO3)	34.5	55.6	34.0	37.1
pH @ 22 °C	9.0	9.9	9.2	9.6
Conductivity (mS)	0.102	0.160	0.091	0.104
Dissolved Oxygen (mg/L)	4.0	3.9	9.0	3.1
Water Temperature (°C)	23.2	25.3	23.3	24.1
Total Metals				
Copper (ug/L)	0.37	0.72	0.28	0.89
Aluminum (ug/L)	3.91	3.67	6.12	3.65
Boron (ug/L)	68	<50	<50	<50
Herbicide				
Diazinon (ug/L)	0.040	0.035	<0.010	<0.010
Chlorpyrifos (ug/L)	<0.010	<0.010	<0.010	<0.010
Base/Neutral Semivoatile Compounds				

All 41 compounds	<5.0	<5.0	<5.0	<5.0
Volatile Organic Compounds				
Methyl tert-butyl ether (ug/L)	0.6	0.7	0.4	1.6
All other 46 compounds	<0.2	<0.2	<0.2	<0.2

DISCUSSION

The Tahoe Keys area was once the largest and most important wetland area associated with Lake Tahoe. In its natural state, it acted like a filter removing sediment and nutrients from streams draining into the Lake. It also provided habitat for many species of wildlife including important rearing and spawning grounds for endemic Lake Tahoe fishes such as the Lahontan cutthroat trout. Undoubtedly, the benthic macroinvertebrate fauna was quite diverse and abundant in the area that is now Tahoe Keys marina. Surveys of the edge of Lake Tahoe in the 1960's (Frantz and Cordone 1996) found 95 different BMI taxa with ten of those being endemic to the Lake. Using equipment similar to that used in this present day study, Frantz and Cordone calculated an average standing crop of 2500 organisms/m^2 along the edge of the lake in water up to 30 meters deep.

The Tahoe Keys wetland in its natural state probably had more types of BMIs and at higher densities than were found by Frantz and Cordone (1996) along the Lake's edges. However, in the altered condition that exists today in the Tahoe Keys, its BMI community would be more similar to the edge of the lake than a wetland. The BMI structure at the four areas within the Marina were in somewhat similar proportion with what Frantz and Cordone (1996) found; numerically, they found oligochaets, amphipods, ostacods and dipertan larvae (in that order) dominated the community. Other insects such as the mayflies (Order: Ephemeroptera), stoneflies (Order: Plecoptera) and caddisflies (Order: Trichoptera) were present, but in less numbers. We observed these same proportions, but instead of 95 different taxa, we found 27 taxa in 2000 and 19 in 2002.

Besides low richness of BMI taxa, the biological metrics indicated that the BMI community had low diversity, was dominated by high numbers of particular types of BMIs that were tolerant to low dissolved oxygen and general human disturbance. The biological metrics also indicated that sites TLK002 and TLK003 were in more degraded condition than sites TLK001 and TKL004 and that in general, BMI communities were more degraded in 2002 than 2000. The difference between sites has more validity than the difference between the years because the site difference was observed for both sampling events. Following studies (2004, etc.) would be necessary to validate whether biological conditions are truly getting worse or better over time.

The overall degraded condition of the BMI communities in Tahoe Keys Marina and the more degraded condition of the TLK002 and TLK003 sites may be more a product of habitat degradation than chemical contamination. Of all the chemical constituents measured, high pH and low dissolved oxygen values are of most concern. All the areas sampled for dissolved oxygen except TLK003, had values below that considered safe for most aquatic organisms (5.0 mg/L). Furthermore, all the areas had pH values above 9.0 which are out of the range (6.7 and 8.6) of most inland waters containing healthy fish populations (McKee and Wolf 1971).

Although copper and aluminum were present, they were in low enough concentration not to harm

aquatic life. Water quality criteria goals for copper to freshwater aquatic life is 4.8 ug/L (maximum concentration) for waters with hardness <25 mg/L $CaCo_3$ (Marshack 1993). The US EPA recommends that to protect most aquatic organisms, the concentration of aluminum in water with pH of 6.5 to 9.0 should not exceed 87 □g/l (US EPA 1988). For our measurements in July 2002, copper never exceeded 0.89 ug/L and aluminum never exceeded 6.12 ug/L. Diazinon was present at the two sites that were closest to homes and further from the open water (TLK001 and TLK002), but in very low concentrations (0.040 and 0.035 ug/L).

CONCLUSIONS AND RECOMMENDATIONS

The BMI community at the four sites we sampled within the Tahoe Keys Marina was somewhat similar in composition to that found from historic surveys along the edge of the Lake. However, compared to those surveys, the BMI community within the Marina was lower in taxonomic richness, lower in community diversity and was dominated by high numbers of BMIs that were tolerant to low dissolved oxygen and general human disturbance. The data also indicated that sites TLK002 and TLK003 were in more degraded condition than sites TLK001 and TKL004 and that in general, BMI communities were more degraded in 2002 than 2000. The chemical data indicated that the overall degraded condition of the BMI communities in Tahoe Keys Marina and the more degraded condition of the TLK002 and TLK003 sites may be more a product of habitat degradation than chemical contamination.

We recommend that monitoring continues to verify if biological integrity within the Tahoe Keys Marina is improving or becoming more degraded. We also recommend a one-time measurement of sediment chemistry and toxicity to verify whether the degraded benthic community being affected more by habitat alteration than by chemical contamination.

LITERATURE CITED

Brown, H.P. 1972. Aquatic Dryopoid Beetles (Coleoptera) of the United States. U.S. Environmental Protection Agency Project, # 18050 ELD. Washington D.C.

Erman, N.A. 1996. Status of Aquatic Invertebrates. in: Sierra Nevada Ecosystem Project: Final Report to Congress, Vol II, Assessments and Scientific Basis for Management Options. University of California Davis, Centers for Water and Wildland Resources.

Frantz, T.C. and A.J. Cordone. 1996. Observations on the macrobenthos of Lake Tahoe, California – Nevada. California Fish and Game Vol. 82 No. 1. Sacramento, CA.

Gibson, G. R. 1996. Biological Criteria: Technical guidance for streams and small rivers. EPA 822-B-96-001. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

Harrington, J. M. 1999. California stream bioassessment procedures. California Department of Fish and Game, Water Pollution Control Laboratory. Rancho Cordova, CA.

Klemm, D.J. 1985. A guide to the freshwater Annelida (Polychaeta, Naidid and Tubificid Oligochaeta, and Hirudinea of North America. Kendall/ Hunt Publishing Co., Dubuque, Iowa.

Leivestad, H.G., H.I. Muniz and E. Snekvik. 1976. Effects of acid precipitation on freshwater organisms. In F.H. Braekke (Ed.) SNSF Research Report 6/76.

Marshack J.B. 1993. A Compilation of Water Quality Goals. California Regional Water Quality Control Board - Central Valley Region. Sacramento, Ca.

McKee J.E. and H.W. Wolf. 1971. Water Quality Criteria. Publication 3-A. California State Water Resources Control Board. Sacramento, Ca.

Merritt, R. W. and K. W. Cummins. 1995. An introduction to the aquatic insects of North America. Second Edition. Kendall/Hunt Publishing Co., Dubuque, Iowa

Pennak, R. W. 1989. Freshwater invertebrates of the United States, 3rd Ed. John Wiley and Sons, Inc., New York.

Resh, V.H. and J.K. Jackson. 1993. Rapid assessment approaches to biomonitoring using benthic macroinvertebrates. In: D.M. Rosenberg and V.H. Resh, eds., Chapman and Hall, New York.

Rosenberg, D. M. and V. H. Resh (editors). 1993. Freshwater Biomonitoring and Benthic Macroinvertebrates, Chapman and Hall, New York, NY.

Sorensen E.M. 1991. Metal Poisoning in Fish. CRC Press. Boca Raton, Fl.

Stewart, K. W. and B. P. Stark. 1993. Nymphs of North American stonefly genera (Plecoptera). University of North Texas Press, Denton, Texas.

Surdick, R.F. 1985. Nearctic Genera of Chloroperlinae (Plecoptera: Chloroperlidae). University of Illinois Press. Chicago, IL.

Thorp, J. H. and A. P. Covich (eds.). 1991. Ecology and classification of North American invertebrates. Academic Press, San Diego, CA.

U. S. Environmental Protection Agency. 1998. Ambient Aquatic Life Water Quality Criteria for Aluminum. US EPA Publication No. 440/5-86-008. Dulut, Mn

Usinger, R. L. Aquatic Insects of California. University of California Press. Berkeley, Ca.

Wiederholm, T. 1983. Chironomidae of the Holarctic region - Part 1. Larvae. Entomologica Scandinavica, Supplement No. 19. Sandby, Sweden.

_____. 1986. Chironomidae of the Holarctic region - Part 2. Pupae. Entomologica Scandinavica, Supplement No.28. Sandby, Sweden.

Wiggins, G. B. 1996. Larva of North American caddisfly genera (Trichoptera), 2nd ed. University of Toronto Press, Toronto.

Wold, J. L. 1974. Systematics of the genus *Rhyacophila* (Trichoptera: Rhyacophilidae) in western North America with special reference to the immature stages. Master of Science Thesis. Oregon State University, Corvallis, OR.

Tahoe Keys July 2002 Summary Metrics

Site Name:	Lake Tahoe							
Site Code:	TKL 001		TKL 002		TKL 003		TKL 004	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV
Taxonomic Richness	8	0.38	5	0.54	5	0.40	7	0.57
Cumulative Taxa	14		10		12		13	
Percent Dominant Taxon	44	0.08	80	0.06	50	0.29	33	0.06
EPT Taxa	1	0.00	0	1.73	0	1.73	0	-
EPT Index (%)	3	0.58	1	1.73	2	1.73	0	-
Sensitive EPT Index (%)	0	-	0	-	0	-	0	-
Cumulative EPT Taxa	1		1		1		0	
Shannon Diversity	1.5	0.13	0.7	0.13	1.2	0.26	1.6	0.22
Tolerance Value	6.4	0.02	7.7	0.02	6.7	0.12	6.8	0.06
Percent Intolerant Taxa (0-2)	0	-	0	-	0	-	0	-
Percent Tolerant Taxa (8-10)	18	0.20	83	0.09	25	1.12	38	0.54
Percent Chironomidae	66	0.31	14	0.69	18	1.23	46	0.12
Percent Collectors	73	0.28	3	1.32	86	0.14	56	0.43
Percent Filterers	2	1.73	1	1.73	0	-	1	1.73
Percent Grazers	2	1.73	82	0.08	11	0.90	38	0.55
Percent Predators	23	0.74	14	0.81	3	0.97	6	0.90
Percent Shredders	0	-	0	-	0	-	0	-
Abundance (#/ sample)	108	-	68	-	20	-	110	-

Tahoe Keys July 2002 Taxa List

Site Name:			Lake Tahoe												
Site Code:			TKL 001			TKL 002			TKL 003			TKL 004			
Collection Date:			7/12/02												
Transect Number:			L1	L2	L3	L1	L2	L3	L1	L2	L3	L1	L2	L3	
ABL Laboratory Number:			8538	8539	8540	8541	8542	8543	8544	8545	8546	8547	8548	8549	
Arthropoda	TV	FFG													
Insecta															
Diptera															
Chironomidae															
Chironominae															
Chironomini	6	c	33	51	12	-	-	-	-	1	3	2	29	14	
Chironomus sp.	10	c	-	-	-	-	-	-	1	-	-	-	-	-	
Tanytarsini	6	f	-	1	-	-	1	-	-	-	-	-	1	-	
Orthocladiinae	5	c	-	2	-	1	-	-	-	-	-	1	10	-	
Tanypodinae	6	p	-	30	10	15	1	4	-	-	-	-	6	3	
Tanyderidae			12	-	-	-	-	-	-	-	-	-	-	-	
Ephemeroptera															
Caenidae															
Caenis sp.	7	c	3	1	1	-	1	-	-	1	-	-	-	-	
Crustacea															
Copepoda															
Cyclopoida	8	c	8	6	4	1	1	-	11	-	-	1	11	-	
Malacostraca															
Amphipoda															
Hyalellidae															
Hyalella sp.	6	c	11	7	-	-	1	-	6	10	1	-	-	-	
Chelicerata															
Arachnida															
Trombidiformes															
Acari			-	-	-	2	-	-	-	-	-	-	-	-	
Sperchontidae	5	p	-	-	-	2	-	-	-	-	-	-	-	-	
Annelida															
Clitellata															
Hirudinea															
Rhynchobdellida															
Glossiphoniidae	8	p	2	4	-	-	-	-	-	1	-	-	2	-	
Oligochaeta															
Tubificida			-	-	-	-	-	-	-	-	-	-	2	-	
Naididae	10	c	2	1	-	-	-	-	3	-	-	-	-	-	
Tubificidae			7	-	-	-	-	-	-	-	3	1	-	-	
Mollusca															
Bivalvia															
Veneroida															
Pisidiidae															
Sphaeriidae	8	f	-	3	-	-	-	-	-	-	-	-	2	-	
Pisidium sp.	8	f	-	1	-	-	-	-	-	-	-	-	-	-	
Gastropoda															
Basommatophora															
Physidae															
Physa/ Physella	8	g	-	-	-	2	1	-	-	-	-	-	-	-	
Planorbidae	7	g	-	-	-	-	-	-	4	-	-	1	14	-	
Gyraulus sp.	8	g	-	-	-	103	31	12	-	2	-	-	16	11	
Helisoma sp.	7	g	-	-	-	-	-	-	1	-	-	-	-	-	
Heterostropha															
Valvatidae															
Valvata sp.	8	g	-	-	2	-	-	-	-	-	-	-	-	15	
Nematoda	5	p	-	-	-	-	-	-	1	-	-	-	1	-	
Total Organisms:			78	107	29	126	37	16	27	15	7	6	94	43	
Total Organisms Recovered			78	107	29	126	37	16	27	15	7	6	94	43	
Extra Bugs			3	1	10	2	1	0	0	2	0	0	8	2	
Total Picked Bugs (includes extras)			81	108	39	128	38	16	27	17	7	6	102	45	
Grids Processed			13.00	13.00	8.00	7.00	12.00	12.00	16.00	7.00	8.00	8.00	20.00	20.00	
Total Grids Possible			13.00	13.00	8.00	7.00	12.00	12.00	16.00	7.00	8.00	8.00	20.00	20.00	
Sorted			88	107	35	125	39	16	27	16	8	12	108	46	
Discards			0	0	0	0	0	0	0	0	0	0	0	0	
Abundance (# /sample)			116	120	88	140	49	16	27	27	7	6	241	81	
Average Abundance (#/ sample)			108			68			20			110			

Lagoon Weed Removal in 2002

	2,853			$41,576.95	165
20-May	5	$	9.25	$ 46.25	
21-May	5	$	9.25	$ 46.25	
28-May	3	$	9.25	$ 27.75	
31-May	10	$	14.60	$ 146.00	
31-May	9	$	14.60	$ 131.40	
31-May	10	$	14.60	$ 146.00	
3-Jun	10	$	14.60	$ 146.00	
4-Jun	9	$	14.60	$ 131.40	
4-Jun	10	$	14.60	$ 146.00	
5-Jun	9	$	14.60	$ 131.40	
5-Jun	9	$	14.60	$ 131.40	
5-Jun	9	$	14.60	$ 131.40	
6-Jun	10	$	14.60	$ 146.00	
6-Jun	9	$	14.60	$ 131.40	
7-Jun	10	$	14.60	$ 146.00	
10-Jun	9	$	14.60	$ 131.40	
10-Jun	10	$	14.60	$ 146.00	
10-Jun	9	$	14.60	$ 131.40	
10-Jun	10	$	14.60	$ 146.00	
11-Jun	9	$	14.60	$ 131.40	
11-Jun	10	$	14.60	$ 146.00	
11-Jun	9	$	14.60	$ 131.40	
11-Jun	10	$	14.60	$ 146.00	
11-Jun	9	$	14.60	$ 131.40	
11-Jun	10	$	14.60	$ 146.00	
11-Jun	9	$	14.60	$ 131.40	
12-Jun	10	$	14.60	$ 146.00	
12-Jun	9	$	14.60	$ 131.40	
12-Jun	10	$	14.60	$ 146.00	
13-Jun	9	$	14.60	$ 131.40	
13-Jun	10	$	14.60	$ 146.00	
13-Jun	9	$	14.60	$ 131.40	
14-Jun	8	$	14.60	$ 116.80	
14-Jun	10	$	14.60	$ 146.00	
14-Jun	9	$	14.60	$ 131.40	
14-Jun	10	$	14.60	$ 146.00	
14-Jun	9	$	14.60	$ 131.40	
14-Jun	10	$	14.60	$ 146.00	

17-Jun	9	$	14.60	$	131.40
17-Jun	10	$	14.60	$	146.00
18-Jun	9	$	14.60	$	131.40
18-Jun	10	$	14.60	$	146.00
18-Jun	9	$	14.60	$	131.40
18-Jun	10	$	14.60	$	146.00
19-Jun	9	$	14.60	$	131.40
19-Jun	10	$	14.60	$	146.00
19-Jun	9	$	14.60	$	131.40
20-Jun	10	$	14.60	$	146.00
20-Jun	9	$	14.60	$	131.40
20-Jun	10	$	14.60	$	146.00
21-Jun	9	$	14.60	$	131.40
21-Jun	10	$	14.60	$	146.00
21-Jun	9	$	14.60	$	131.40
21-Jun	10	$	14.60	$	146.00
24-Jun	10	$	14.60	$	146.00
24-Jun	10	$	14.60	$	146.00
25-Jun	9	$	14.60	$	131.40
25-Jun	9	$	14.60	$	131.40
26-Jun	10	$	14.60	$	146.00
27-Jun	9	$	14.60	$	131.40
27-Jun	10	$	14.60	$	146.00
28-Jun	10	$	14.60	$	146.00
1-Jul	9	$	14.60	$	131.40
2-Jul	9	$	14.60	$	131.40
2-Jul	9	$	14.60	$	131.40
2-Jul	10	$	14.60	$	146.00
2-Jul	10	$	14.60	$	146.00
3-Jul	9	$	14.60	$	131.40
5-Jul	9	$	14.60	$	131.40
5-Jul	10	$	14.60	$	146.00
8-Jul	10	$	14.60	$	146.00
9-Jul	9	$	14.60	$	131.40
9-Jul	10	$	14.60	$	146.00
10-Jul	9	$	14.60	$	131.40
10-Jul	9	$	14.60	$	131.40
10-Jul	10	$	14.60	$	146.00
11-Jul	9	$	14.60	$	131.40
11-Jul	10	$	14.60	$	146.00
12-Jul	10	$	14.60	$	146.00
12-Jul	9	$	14.60	$	131.40

15-Jul	9	$	14.60	$	131.40
15-Jul	10	$	14.60	$	146.00
15-Jul	10	$	14.60	$	146.00
16-Jul	10	$	14.60	$	146.00
16-Jul	9	$	14.60	$	131.40
16-Jul	9	$	14.60	$	131.40
16-Jul	10	$	14.60	$	146.00
17-Jul	9	$	14.60	$	131.40
17-Jul	10	$	14.60	$	146.00
18-Jul	9	$	14.60	$	131.40
18-Jul	10	$	14.60	$	146.00
19-Jul	9	$	14.60	$	131.40
19-Jul	10	$	14.60	$	146.00
19-Jul	10	$	14.60	$	146.00
22-Jul	10	$	14.60	$	146.00
23-Jul	9	$	14.60	$	131.40
23-Jul	9	$	14.60	$	131.40
23-Jul	10	$	14.60	$	146.00
23-Jul	10	$	14.60	$	146.00
24-Jul	9	$	14.60	$	131.40
24-Jul	10	$	14.60	$	146.00
24-Jul	10	$	14.60	$	146.00
25-Jul	10	$	14.60	$	146.00
25-Jul	9	$	14.60	$	131.40
25-Jul	10	$	14.60	$	146.00
26-Jul	9	$	14.60	$	131.40
26-Jul	10	$	14.60	$	146.00
26-Jul	9	$	14.60	$	131.40
26-Jul	10	$	14.60	$	146.00
29-Jul	9	$	14.60	$	131.40
30-Jul	6	$	14.60	$	87.60
30-Jul	10	$	14.60	$	146.00
30-Jul	9	$	14.60	$	131.40
31-Jul	10	$	14.60	$	146.00
31-Jul	9	$	14.60	$	131.40
31-Jul	10	$	14.60	$	146.00
31-Jul	9	$	14.60	$	131.40
1-Aug	10	$	14.60	$	146.00
1-Aug	10	$	14.60	$	146.00
2-Aug	10	$	14.60	$	146.00
2-Aug	9	$	14.60	$	131.40
2-Aug	10	$	14.60	$	146.00

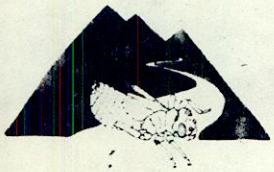
2-Aug	10	$	14.60	$	146.00		
5-Aug	9	$	14.60	$	131.40		
6-Aug	10	$	14.60	$	146.00		
6-Aug	9	$	14.60	$	131.40		
7-Aug	10	$	14.60	$	146.00		
7-Aug	9	$	14.60	$	131.40		
7-Aug	4	$	14.60	$	58.40		
7-Aug	2.5	$	14.60	$	36.50		
7-Aug	5	$	14.60	$	73.00		
7-Aug	4	$	14.60	$	58.40		
7-Aug	2	$	14.60	$	29.20		
8-Aug	3	$	14.60	$	43.80		
8-Aug	3	$	14.60	$	43.80		
8-Aug	3	$	14.60	$	43.80		
8-Aug	6	$	14.60	$	87.60		
8-Aug	6	$	14.60	$	87.60		
8-Aug	6	$	14.60	$	87.60		
8-Aug	10	$	14.60	$	146.00		
8-Aug	6	$	14.60	$	87.60		
8-Aug	6	$	14.60	$	87.60		
8-Aug	8	$	14.60	$	116.80		
9-Aug	10	$	14.60	$	146.00		
9-Aug	9	$	14.60	$	131.40		
9-Aug	10	$	14.60	$	146.00		
12-Aug	9	$	14.60	$	131.40	1/3 Weed	3.006
12-Aug	10	$	14.60	$	146.00	1/3 Weed	3.34
13-Aug	3.5	$	14.60	$	51.10	1/3 Weed	1.169
13-Aug	2	$	14.60	$	29.20	1/3 Weed	0.668
13-Aug	1.5	$	14.60	$	21.90	1/3 Weed	0.501
13-Aug	1.5	$	14.60	$	21.90	1/3 Weed	0.501
13-Aug	4	$	14.60	$	58.40	1/3 Weed	1.336
13-Aug	2.5	$	14.60	$	36.50	1/3 Weed	0.835
13-Aug	2.5	$	14.60	$	36.50	1/3 Weed	0.835
13-Aug	2.5	$	14.60	$	36.50	1/3 Weed	0.835
13-Aug	4	$	14.60	$	58.40	1/3 Weed	1.336
14-Aug	9	$	14.60	$	131.40	1/3 Weed	3.006
14-Aug	9	$	14.60	$	131.40	1/3 Weed	3.006
14-Aug	10	$	14.60	$	146.00	1/3 Weed	3.34
15-Aug	6	$	14.60	$	87.60	1/3 Weed	2.004
15-Aug	10	$	14.60	$	146.00	1/3 Weed	3.34
15-Aug	9	$	14.60	$	131.40	1/3 Weed	3.006
15-Aug	10	$	14.60	$	146.00	1/3 Weed	3.34

16-Aug	9	$	14.60	$	131.40	1/3 Weed	3.006
16-Aug	10	$	14.60	$	146.00	1/3 Weed	3.34
19-Aug	9	$	14.60	$	131.40	1/3 Weed	3.006
19-Aug	10	$	14.60	$	146.00	1/3 Weed	3.34
19-Aug	9	$	14.60	$	131.40	1/3 Weed	3.006
20-Aug	8	$	14.60	$	116.80	1/3 Weed	2.672
20-Aug	10	$	14.60	$	146.00	1/3 Weed	3.34
20-Aug	9	$	14.60	$	131.40	1/3 Weed	3.006
20-Aug	10	$	14.60	$	146.00	1/3 Weed	3.34
21-Aug	9	$	14.60	$	131.40	1/3 Weed	3.006
21-Aug	10	$	14.60	$	146.00	1/3 Weed	3.34
21-Aug	9	$	14.60	$	131.40	1/3 Weed	3.006
22-Aug	10	$	14.60	$	146.00	1/3 Weed	3.34
22-Aug	10	$	14.60	$	146.00	1/3 Weed	3.34
22-Aug	9	$	14.60	$	131.40	1/3 Weed	3.006
22-Aug	10	$	14.60	$	146.00	1/3 Weed	3.34
23-Aug	9	$	14.60	$	131.40	1/3 Weed	3.006
23-Aug	10	$	14.60	$	146.00	1/3 Weed	3.34
23-Aug	9	$	14.60	$	131.40	1/3 Weed	3.006
23-Aug	10	$	14.60	$	146.00	1/3 Weed	3.34
26-Aug	9	$	14.60	$	131.40	1/3 Weed	3.006
26-Aug	9	$	14.60	$	131.40	1/3 Weed	3.006
27-Aug	9	$	14.60	$	131.40	1/3 Weed	3.006
27-Aug	9	$	14.60	$	131.40	1/3 Weed	3.006
27-Aug	10	$	14.60	$	146.00	1/3 Weed	3.34
27-Aug	10	$	14.60	$	146.00	1/3 Weed	3.34
28-Aug	9	$	14.60	$	131.40		
28-Aug	10	$	14.60	$	146.00		
28-Aug	10	$	14.60	$	146.00		
29-Aug	10	$	14.60	$	146.00		
29-Aug	9	$	14.60	$	131.40		
29-Aug	10	$	14.60	$	146.00		
29-Aug	10	$	14.60	$	146.00		
30-Aug	9	$	14.60	$	131.40		
30-Aug	10	$	14.60	$	146.00		
30-Aug	10	$	14.60	$	146.00		
3-Sep	9	$	14.60	$	131.40		
3-Sep	10	$	14.60	$	146.00		
4-Sep	9	$	14.60	$	131.40		
4-Sep	9	$	14.60	$	131.40		
4-Sep	10	$	14.60	$	146.00		
4-Sep	10	$	14.60	$	146.00		

5-Sep	9	$	14.60	$	131.40
5-Sep	10	$	14.60	$	146.00
5-Sep	10	$	14.60	$	146.00
6-Sep	9	$	14.60	$	131.40
6-Sep	9	$	14.60	$	131.40
6-Sep	10	$	14.60	$	146.00
6-Sep	10	$	14.60	$	146.00
9-Sep	9	$	14.60	$	131.40
9-Sep	10	$	14.60	$	146.00
10-Sep	9	$	14.60	$	131.40
10-Sep	9	$	14.60	$	131.40
10-Sep	10	$	14.60	$	146.00
10-Sep	10	$	14.60	$	146.00
11-Sep	6	$	14.60	$	87.60
11-Sep	9	$	14.60	$	131.40
11-Sep	9	$	14.60	$	131.40
11-Sep	10	$	14.60	$	146.00
11-Sep	10	$	14.60	$	146.00
12-Sep	9	$	14.60	$	131.40
12-Sep	9	$	14.60	$	131.40
13-Sep	9	$	14.60	$	131.40
13-Sep	10	$	14.60	$	146.00
13-Sep	10	$	14.60	$	146.00
16-Sep	9	$	14.60	$	131.40
16-Sep	9	$	14.60	$	131.40
16-Sep	10	$	14.60	$	146.00
16-Sep	10	$	14.60	$	146.00
16-Sep	10	$	14.60	$	146.00
17-Sep	10	$	14.60	$	146.00
17-Sep	9	$	14.60	$	131.40
17-Sep	9	$	14.60	$	131.40
17-Sep	10	$	14.60	$	146.00
17-Sep	10	$	14.60	$	146.00
17-Sep	10	$	14.60	$	146.00
18-Sep	10	$	14.60	$	146.00
18-Sep	9	$	14.60	$	131.40
18-Sep	10	$	14.60	$	146.00
18-Sep	10	$	14.60	$	146.00
19-Sep	9	$	14.60	$	131.40
19-Sep	10	$	14.60	$	146.00
19-Sep	9	$	14.60	$	131.40
19-Sep	10	$	14.60	$	146.00

19-Sep	10	$	14.60	$	146.00		
20-Sep	10	$	14.60	$	146.00		
20-Sep	9	$	14.60	$	131.40		
20-Sep	9	$	14.60	$	131.40		
20-Sep	10	$	14.60	$	146.00		
23-Sep	9	$	14.60	$	131.40		
23-Sep	10	$	14.60	$	146.00		
23-Sep	10	$	14.60	$	146.00		
24-Sep	9	$	14.60	$	131.40		
24-Sep	10	$	14.60	$	146.00		
24-Sep	10	$	14.60	$	146.00		
25-Sep	9	$	14.60	$	131.40		
25-Sep	10	$	14.60	$	146.00		
26-Sep	9	$	14.60	$	131.40		
26-Sep	9	$	14.60	$	131.40		
26-Sep	10	$	14.60	$	146.00		
27-Sep	9	$	14.60	$	131.40		
27-Sep	9	$	14.60	$	131.40		
27-Sep	10	$	14.60	$	146.00		
27-Sep	10	$	14.60	$	146.00		
27-Sep	10	$	14.60	$	146.00		
30-Sep	9	$	14.60	$	131.40		
30-Sep	10	$	14.60	$	146.00		
1-Oct	9	$	14.60	$	131.40		
1-Oct	10	$	14.60	$	146.00		
2-Oct	9	$	14.60	$	131.40		
2-Oct	9	$	14.60	$	131.40		
2-Oct	10	$	14.60	$	146.00		
2-Oct	10	$	14.60	$	146.00		
3-Oct	9	$	14.60	$	131.40		
3-Oct	9	$	14.60	$	131.40		
3-Oct	10	$	14.60	$	146.00		
3-Oct	10	$	14.60	$	146.00		
4-Oct	9	$	14.60	$	131.40		
4-Oct	10	$	14.60	$	146.00		
4-Oct	10	$	14.60	$	146.00		
7-Oct	9	$	14.60	$	131.40	1/3 Weed	3.006
7-Oct	10	$	14.60	$	146.00	1/3 Weed	3.34
7-Oct	10	$	14.60	$	146.00	1/3 Weed	3.34
7-Oct	10	$	14.60	$	146.00	1/3 Weed	3.34
8-Oct	9	$	14.60	$	131.40	1/3 Weed	3.006
8-Oct	9	$	14.60	$	131.40	1/3 Weed	3.006

8-Oct	10	$	14.60	$	146.00	1/3 Weed	3.34
8-Oct	10	$	14.60	$	146.00	1/3 Weed	3.34
9-Oct	9	$	14.60	$	131.40	1/3 Weed	3.006
9-Oct	10	$	14.60	$	146.00	1/3 Weed	3.34
9-Oct	10	$	14.60	$	146.00	1/3 Weed	3.34
10-Oct	9	$	14.60	$	131.40	1/3 Weed	3.006
10-Oct	10	$	14.60	$	146.00	1/3 Weed	3.34
11-Oct	9	$	14.60	$	131.40	1/3 Weed	3.006
11-Oct	10	$	14.60	$	146.00	1/3 Weed	3.34
14-Oct	10	$	14.60	$	146.00		
14-Oct	10	$	14.60	$	146.00		
15-Oct	10	$	14.60	$	146.00		
15-Oct	10	$	14.60	$	146.00		
16-Oct	10	$	14.60	$	146.00		
16-Oct	10	$	14.60	$	146.00		
16-Oct	10	$	14.60	$	146.00		
17-Oct	9	$	14.60	$	131.40		
17-Oct	10	$	14.60	$	146.00		
18-Oct	10	$	14.60	$	146.00		
18-Oct	10	$	14.60	$	146.00		
21-Oct	10	$	14.60	$	146.00		
22-Oct	10	$	14.60	$	146.00		
22-Oct	10	$	14.60	$	146.00		
23-Oct	10	$	14.60	$	146.00		
23-Oct	10	$	14.60	$	146.00		
	2852.5	TOTALS		$41,576.95			165.33



WATER QUALITY INVENTORY SERIES
BIOLOGICAL AND PHYSICAL/ HABITATASSESSMENT
OF CALIFORNIA WATER BODIES

Bioassessment of Tahoe Keys Marina South Lake Tahoe, CA

December 2000

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INTRODUCTION

In July 2000, the California Department of Fish and Game's Aquatic Bioassessment Laboratory (ABL) was contracted by the Tahoe Keys Property Owner's Association to initiate a biological assessment of the invertebrate communities in Tahoe Keys Marina as part of their NPDES permit requirements.

[no - should be "to comply with the terms of the Settlement Agr"]

Aquatic bioassessments are valuable tools for assessing water quality (Harrington 1999), especially when supplemented with water chemistry analyses. BMIs can have a diverse community structure with individual species residing within a water body for a period of months to several years. BMIs are also sensitive, in varying degrees, to temperature, dissolved oxygen, sedimentation, nutrient enrichment and chemical and organic pollution (Resh and Jackson 1993). Together, biological and physical assessments integrate the effects of water quality over time, are sensitive to multiple aspects of water and habitat quality, and provide the public with more familiar expressions of ecological health (Gibson 1996).

This report presents results from benthic macroinvertebrate samples and water chemistry samples collected on July 13, 2000.

MATERIALS AND METHODS

Monitoring Site Descriptions

Monitoring sites descriptions are summarized in Table 1.

Benthic Macroinvertebrate Sampling

Benthic macroinvertebrate (BMI) communities were collected using a modified Van Veen grab sampler. The sampler is box shaped (30 cm X 30 cm) with closing clam-shell doors on the bottom and a screen/ rubber flap on the top to prevent sample washout. The sampler was modified by adding a stabilizing structure, which allows the sampler to be used in moving water situations. The sampler is used by lowering the device to the bottom of the Marina using a boom from the deck of a specially equipped Boston Whaler boat. The clam-shell doors were closed upon impact with the bottom and retrieved using the boom. Once the sampler was retrieved, a coring device (10 cm diameter, 14 cm long) was placed into the sediment to a depth of 12 cm. The core was removed by digging along one side, placing a hand under the corer and removing the sample. The contents of the corer (0.0075 m^2) was removed and washed through a 0.5 mm mesh sieve. The organisms were then removed and placed in a jar with 70% ethanol. This procedure was repeated three times to produce three replicate samples at each sampling location.

Water Chemistry Sampling

Water chemistry grab samples were collected in appropriate sample jars at each sampling location just below the surface of water surface. All samples were kept on ice at 4° C and submitted to the Water Polution Control Laboratory in Rancho Cordova on the day of collection.

Table 1. Benthic macroinvertebrate sampling location information for reaches sampled within the Tahoe Keys Marina.

Site ID	Location Description	Depth	Substrate	Latitude/ Longitude
TKL001	Sampled in lagoon between Kokanee Way and Wedeln Court	**3.0 m**	**clay/ sand**	N38° 55.729' W120° 00.541'
TKL002	Sampled in lagoon between Genevieve Court and Lido Drive	**2.5 m**	**clay/ sand**	N38° 55.923' W120° 01.314'
TKL003	Sampled in lagoon 300 feet west of Spinnaker Cove near West Channel	**7.3 m**	**fine clay/ sand**	N38° 56.097' W120° 01.069'
TKL004	Sampled in sailing lagoon 500 feet east of East Channel	**2.7 m**	**clay/ sand**	N38° 56.399' W120° 00.194'

BMI Laboratory Analysis

At the laboratory, each sample was rinsed through a No. 35 standard testing sieve (0.5 mm brass mesh) and transferred into a tray marked with twenty, 25 cm^2 grids. All detritus was removed from one randomly selected grid at a time and placed in a petri dish for inspection under a stereomicroscope. All invertebrates from the grid were separated from the surrounding detritus and transferred to vials containing 70% ethanol and 5% glycerol. This process was continued until 300 organisms were removed from each sample. The material left from the processed grids was transferred into a jar with 70% ethanol and labeled as "remnant" material. Any remaining unprocessed sample from the tray was transferred back to the original sample container with 70% ethanol and archived. Macroinvertebrates were then identified to a standard taxonomic level, typically genus level for insects and family or genus for non-insects using standard taxonomic keys (Brown 1972, Edmunds et al. 1976, Klemm 1985, Merritt and Cummins 1995, Pennak 1989, Stewart and Stark 1993, Surdick 1985, Thorp and Covich 1991, Usinger 1963, Wiederholm 1983, 1986, Wiggins 1996, Wold 1974).

Chemical Laboratory Analyses

All water chemistry analyses were performed in accordance with standard EPA procedures for laboratory analysis.

- Volatile organic compounds were tested for following EPA Method 8260
- Semi-Volatile compounds were tested for following EPA Method 8270
- Chlorpyifos and Diazinon were tested for following EPA Method
- Metals (Aluminum, Boron and Copper) were tested for following EPA Methods 200.7, 200.7 and 220.2 respectively
- Hardness was measured following Standard Methods 1992

Data Analysis

A taxonomic list of benthic macroinvertebrates identified from the samples was entered into a Microsoft Excel® spreadsheet program. MS Excel® was used to calculate and summarize macroinvertebrate community based metric values. A description of the metric values used to describe the community is shown in Table 2.

RESULTS

Dominant BMI Taxa/ General Taxonomic Notes

The five dominant taxa observed in each of the monitoring reaches are presented in Table 3. A complete list of macroinvertebrates identified from the samples is presented in Appendix 1.

The BMI community was dominated by 20 disturbance tolerant non-insect fauna (primarily worm taxa, copepods and a few snail species) in addition to several chironomid midge taxa (Diptera: Chironomidae). Insects were rare at all sites, with no single taxon comprising more than 6% of the total organisms. There were only 9 insect taxa found identified from all of the samples and, with the exception of a few caddisfly larvae, most of these were midges.

Invertebrates were considerably abundant and more diverse at Site 1 and Site 4 that at Site 2 and Site 3.

Benthic Macroinvertebrate Community Metrics

BMI metric values are presented by transect in Tables 4 and summarized by reach mean and coefficient of variation in Tables 5.

Richness

Taxonomic richness and associated metrics were higher in sites TKL-001 and TKL-004 than in sites TKL-002 and TKL-003, which had roughly a third as many taxa and almost no EPT taxa.

Composition Measures

Shannon Diversity values were extremely low at all sites, ranging from 0.8 to 1.9. Diversity scores were slightly higher in the fall samples. Although there were very few EPT taxa, these taxa were occasionally the most abundant organisms in samples. EPT Index scores reflect this as well.

not a healthy ecosystem if no species diversity

All sites were dominated by one or a few taxa. The Percent Dominant Taxa metric indicates that the most abundant taxon comprised between 37 and 73 percent of the total BMI.

Tolerance Measures

All tolerance measures indicated communities that were very tolerant to disturbance or extremely tolerant to disturbance. Average tolerance values ranged between 7.4 and 7.9, primarily due to an extremely strong representation by very tolerant organisms. Intolerant taxa were absent from all locations.

Functional Feeding Groups

All of the FFGs were present within the Tahoe Keys Marina except shredders (Tables 5). Most

Table 4. Bioassessment metric values calculated for macoinvertebrate samples collected from four locations within the Tahoe Keys Marina, South Lake Tahoe, California.

	Tahoe Keys Lagoon									Sailing Lagoon		
	TKL-001			TKL-002			TKL-003			TKL-004		
Sampling Location:	001-1	001-2	001-3	002-1	002-2	002-3	003-1	003-2	003-3	004-1	004-2	004-3
ABL Laboratory Number:	4042	4043	4044	4045	4046	4047	4048	4049	4050	4051	4052	4053
Taxonomic Richness	16	13	16	9	5	4	2	3	11	15	19	17
Percent Dominant Taxon	43	57	54	41	38	33	67	98	53	24	45	51
Ephemeroptera Taxa	1	0	1	0	0	0	0	0	0	1	1	1
Plecoptera Taxa	0	0	1	0	0	0	0	0	0	0	0	0
Trichoptera Taxa	0	0	1	0	0	0	0	0	1	0	2	1
EPT Taxa	1	0	2	0	0	0	0	0	1	1	3	2
EPT Index (%)	1	0	1	0	0	0	0	0	1	0	2	1
Sensitive EPT Index (%)	0	0	0	0	0	0	0	0	0	0	1	0
Shannon Diversity	1.9	1.6	1.7	1.6	1.3	1.3	0.6	0.1	1.6	2.1	1.8	1.7
Tolerance Value	7.5	7.3	7.4	7.3	7.1	7.7	8.0	8.0	7.8	7.2	7.7	7.7
Percent Intolerant Taxa (0-2)	0	0	0	0	0	0	0	0	0	0	0	0
Percent Tolerant Taxa (8-10)	78	74	75	36	21	67	100	100	78	62	85	85
Percent Collectors	84	78	75	36	21	67	100	100	71	79	87	91
Percent Filterers	5	5	3	1	0	0	0	0	1	3	2	2
Percent Grazers	2	0	2	63	74	33	0	0	26	8	7	2
Percent Predators	8	17	20	0	6	0	0	0	3	10	4	4
Percent Shredders	0	0	0	0	0	0	0	0	1	0	0	0
totals	100	100	100	100	100	100	100	100	100	100	100	100
Abundance (#/ sample)	258	237	667	81	34	6	3	77	180	239	1052	602

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Table 5. Means and coefficients of variation (CV) calculated for bioassessment samples collected from four sites on 13 July 2000, within the Tahoe Keys Marina, South Lake Tahoe, California.

	Tahoe Keys Lagoon							
	TKL-001		TKL-002		TKL-003		TKL-004	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV
Mean Taxonomic Richness	**15**	12	**6**	44	**5**	92	**17**	12
Cumualtive Taxa Richness	**18**		**12**		**11**		**23**	
Percent Dominant Taxon	**51**	15	**37**	10	**73**	31	**40**	35
Ephemeroptera Taxa	**1**	87	**0**	-	**0**	-	**1**	0
Plecoptera Taxa	**0**	173	**0**	-	**0**	-	**0**	-
Trichoptera Taxa	**0**	173	**0**	-	**0**	173	**1**	100
Mean EPT Taxa	**1**	100	**0**	-	**0**	173	**2**	50
Cumulative EPT Taxa	**2**		**0**		**1**		**3**	
EPT Index (%)	**1**	90	**0**	-	**0**	173	**1**	69
Sensitive EPT Index (%)	**0**	-	**0**	-	**0**	-	**0**	104
Shannon Diversity	**1.7**	8	**1.4**	11	**0.8**	95	**1.9**	12
Tolerance Value	**7.4**	1	**7.4**	4	**7.9**	2	**7.5**	4
Percent Intolerant Taxa (0-2)	**0**	-	**0**	-	**0**	-	**0**	-
Percent Tolerant Taxa (8-10)	**76**	3	**41**	57	**93**	13	**77**	17
Percent Collectors	**79**	6	**41**	57	**90**	19	**86**	7
Percent Filterers	**4**	31	**0**	173	**0**	173	**3**	14
Percent Grazers	**2**	65	**57**	37	**9**	173	**6**	50
Percent Predators	**15**	42	**2**	173	**1**	173	**6**	59
Percent Shredders	**0**	-	**0**	-	**0**	173	**0**	-
Abundance (#/ sample)	**387**	63	**40**	94	**87**	103	**631**	65

organisms in this watershed were either collector-gatherers, which feed on fine particulate organic matter (FPOM). The community at of the sites (TKL-002) was comprised roughly equally by collectors and herbivorous grazing snails.

Abundance

Abundance of organisms was very low, ranging between lows of 40 and 87 organisms per sample at TKL-002 and TKL-003 and highs of 387 and 631 organisms per sample at TKL-001 and TKL-004.

Water Chemistry Results

Results of all water chemistry testing are presented in Appendix 2. All of the water chemistry tests were below the reporting limits for all chemicals tested, except for copper.

Table 2. Bioassessment metrics used to describe characteristics of benthic macroinvertebrate (BMI) community at sampling reaches within the Santa Margarita River watershed.

BMI Metric	Description	Response to Impairment
Richness Measures		
Taxa Richness	Number of individual taxa collected from each replicate sample	decrease
Cumulative Taxa	Total number of individual taxa collected from each site	decrease
EPT Taxa	Number of taxa in the Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) insect orders collected from each replicate sample	decrease
Cumulative EPT Taxa	Total number of taxa in the Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) insect orders collected at each site	decrease
Composition Measures		
EPT Index	Percent composition of mayfly, stonefly and caddisfly larvae	decrease
Sensitive EPT Index	Percent composition of mayfly, stonefly and caddisfly larvae with tolerance values between 0 and 3	decrease
Percent Dominant Taxa	Percent composition of the single most abundant taxon	increase
Shannon Diversity Index	General measure of sample diversity that incorporates richness and evenness (Shannon and Weaver 1963)	decrease
Tolerance/Intolerance Measures		
Tolerance Value	Value between 0 and 10 weighted for abundance of individuals designated as pollution tolerant (higher values) or intolerant (lower values)	increase
Percent Intolerant Organisms	Percent of organisms in sample that are highly intolerant to impairment as indicated by a tolerance value of 0, 1 or 2	decrease
Percent Tolerant Organisms	Percent of organisms in sample that are highly tolerant to impairment as indicated by a tolerance value of 8, 9 or 10	increase
Functional Feeding Groups (FFG)		
Percent Collectors	Percent of macrobenthos that collect or gather fine particulate matter	increase
Percent Filterers	Percent of macrobenthos that filter fine particulate matter	increase
Percent Grazers	Percent of macrobenthos that graze upon periphyton	variable
Percent Predators	Percent of macrobenthos that feed on other organisms	variable
Percent Shredders	Percent of macrobenthos that shreds coarse particulate matter	decrease
Abundance		
Estimated Abundance	Estimated number of macroinvertebrates in sample calculated by extrapolating from the proportion of organisms in each sample	variable

Table 3. Dominant macroinvertebrate taxa (and their percent contribution) by reach from samples collected from sites within the Tahoe Keys Marina.

Site Number	Dominant Taxa				
	1	2	3	4	5
TKL-001	Tubificidae (44)	Harpacticoida (16)	Nematoda (8)	Cyclopidae (7)	Chirnomini (6)
TKL-002	*Helisoma* (39)	Planorbiidae (26)	Cyclopidae (21)	*Hyallela azteca* (3)	Daphniidae/ Cypridiidae (2)
TKL-003	Harpacticoida (80)	Planorbiidae (6)	*Hyallela azteca* (3)	Cyclopidae (3)	*Physa/ Physella* (2)
TKL-004	Cyclopidae (34)	Tubificidae (30)	Chironomini (9)	Valvata (4)	Naididae (3)

LITERATURE CITED

Brown, H.P. 1972. Aquatic Dryopoid Beetles (Coleoptera) of the United States. U.S. Environmental Protection Agency Project, # 18050 ELD. Washington D.C.

Gibson, G. R. 1996. Biological Criteria: Technical guidance for streams and small rivers. EPA 822-B-96-001. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

Harrington, J. M. 1999. California stream bioassess ment procedures. California Department of Fish and Game, Water Pollution Control Laboratory. Rancho Cordova, CA.

Klemm, D.J. 1985. A guide to the freshwater Annelida (Polychaeta, Naidid and Tubificid Oligochaeta, and Hirudinea of North America. Kendall/ Hunt Publishing Co., Dubuque, Iowa.

Merritt, R. W. and K. W. Cummins. 1995. An introduction to the aquatic insects of North America. Second Edition. Kendall/Hunt Publishing Co., Dubuque, Iowa

Pennak, R. W. 1989. Freshwater invertebrates of the United States, 3rd Ed. John Wiley and Sons, Inc., New York.

Stewart, K. W. and B. P. Stark. 1993. Nymphs of North American stonefly genera (Plecoptera). University of North Texas Press, Denton, Texas.

Surdick, R.F. 1985. Nearctic Genera of Chloroperlinae (Plecoptera: Chloroperlidae). University of Illinois Press. Chicago, IL.

Thorp, J. H. and A. P. Covich (eds.). 1991. Ecology and classification of North American invertebrates. Academic Press, San Diego, CA.

Usinger, R. L. Aquatic Insects of California. University of California Press. Berkeley, Ca.

Wiederholm, T. 1983. Chironomidae of the Holarctic region - Part 1. Larvae. Entomologica Scandinavica, Supplement No. 19. Sandby, Sweden.

_____. 1986. Chironomidae of the Holarctic region - Part 2. Pupae. Entomologica Scandinavica, Supplement No.28. Sandby, Sweden.

Wiggins, G. B. 1996. Larva of North American caddisfly genera (Trichoptera), 2nd ed. University of Toronto Press, Toronto.

Wold, J. L. 1974. Systematics of the genus *Rhyacophila* (Trichoptera: Rhyacophilidae) in western North America with special reference to the immature stages. Master of Science Thesis. Oregon State University, Corvallis, OR.

APPENDIX 1

Taxonomic list of benthic macroinvertebrates identified from samples collected 14 July 2000 from monitoring reaches within the Tahoe Keys Marina

ABL Laboratory Number:			4042	4043	4044	4045	4046	4047	4048	4049	4050	4051	4052	4053
Class Ostracoda														
Ostracoda														
Cyprididae	8	c	11	-	1	3	-	-	-	-	-	-	-	2
PHYLUM MOLLUSCA														
Class Gastropoda														
Subclass Prosobranchia														
Valvatidae														
Valvata sp.	6	g	6	1	6	-	-	-	-	-	-	18	10	6
Subclass Pulmonata														
Ancylidae														
Ferrissia sp.	6	g	-	-	-	-	-	-	-	-	-	-	4	-
Physidae														
Physa/ Physella	8	g	-	-	-	-	-	-	-	-	9	-	-	-
Planorbidae														
Helisoma sp.	7	g	-	-	-	33	12	2	-	-	7	-	-	-
Undetermined	7	g	-	-	-	18	13	-	-	-	30	-	1	-
Class Bivalvia														
Pelecypoda														
Sphaeriidae														
Pisidium sp.	8	f	-	-	-	1	-	-	-	-	-	3	-	2
PHYLUM NEMATODA	5	p	5	21	34	-	1	-	-	-	-	15	-	2
PHYLUM TARDIGRADA		c	-	1	-	-	-	-	-	-	-	-	-	-
PHYLUM ANNELIDA														
Class Hirudinea														
Rhyncobdellida														
Glossiphoniidae	8	p	6	11	12	-	-	-	-	-	5	7	7	5
Pharyngobdellida														
Erpobdellidae	8	p	-	-	-	-	-	-	-	-	-	-	1	-
Class Oligochaeta			-	-	-	-	-	-	-	-	-	-	-	-
Tubificidae	8	c	58	134	153	-	-	1	2	2	1	58	119	61
Naididae	8	c	1	4	6	2	-	-	-	-	-	10	4	7
Enchytraeidae	8	c	-	-	-	-	-	-	-	-	-	-	2	-
Total Organisms			258	235	285	81	34	6	3	287	180	239	263	293
Total Organisms Recovered			258	235	285	81	34	6	3	287	180	239	263	293
Extra Bugs			0	2	16	0	0	0	0	22	0	0	0	8
Total Picked Bugs (includes extras)			302	302	316	105	24	8	1	322	222	206	300	308
Grids Processed			20	20	9	20	12	20	4	8	20	20	5	8
Total Grids Possible			20	20	20	20	12	20	4	2	20	20	20	16
Sorted			304	260	314	93	22	7	3	298	198	207	306	300
Discards			10	1	4	3	2	1	0	0	0	10	0	1
Abundance (# /sample)			258	237	667	81	34	6	3	77	180	239	1052	602

ATTCH.5.(13-38).

APPENDIX 2

Test results for water chemistry samples collected
14 July 2000 from monitoring reaches within the Tahoe Keys Marina

DEPARTMENT OF FISH AND GAME
FISH AND WILDLIFE
WATER POLLUTION CONTROL LABORATORY
2005 NIMBUS ROAD
RANCHO CORDOVA, CA 95670
PHONE (916) 358-2858 ATSS 8-434-2858 FAX (916) 985-4301

LABORATORY REPORT

Name:	Jim Harrington	**Lab Number:**	L-240-00 VOA
Agency	Dept. of Fish and Game	**Other Number:**	
Address	2005 Nimbus Road	**Date Sampled:**	7/13/00
City:	Rancho Cordova, CA 95670	**Date Received:**	7/14/00
		Date Completed:	7/25/00
RE:		**Index-PCA Code:**	

RESULTS OF CHEMICAL ANALYSIS:

L-240-00-1	TKL001	1100	7/13/00
L-240-00-2	TKL002	1200	7/13/00
L-240-00-3	TKL003	1300	7/13/00
L-240-00-4	TKL004	1430	7/13/00

The samples were for volatile organic compounds by purge and trap/GCMS. The analytical results are attached.

COST OF ANALYSIS: **$1000.00**

Deposit recovery costs to the Fish and Wildlife Pollution Account with "cost of analysis:" identified separately.

C. R. Todd — Analyst — 7/25/00 — Date

R. B. Cruse — Reviewed — 7/25/00 — Date

R. B. Cruse — Laboratory Director — 7/25/00 — Date

ATTCH.5.(15–38).

California Department of Fish and Game
Water Pollution Control Laboratory
2005 Nimbus Road
Rancho Cordova, CA 95670

EPA Method 8260 Volatile Organic Compounds

Instrument Name: Jaime MSD
Sample Name: Blank
Misc Info:
Acq. Method File: VOAPURGE
Sample Multiplier: 1
Sample Amount: 25 mL

Compound	Ret Time	Amount	Reporting Limit	Units
1,1-Dichloroethylene	6.59	BRL	0.2	ug/L (ppb)
trans-1,2-Dichloroethylene	7.81	BRL	0.2	ug/L (ppb)
1,1-Dichloroethane	8.48	BRL	0.2	ug/L (ppb)
2,2-Dichloropropane	9.13	BRL	0.2	ug/L (ppb)
cis-1,2-Dichloroethylene	9.81	BRL	0.2	ug/L (ppb)
Bromochloromethane	9.78	BRL	0.2	ug/L (ppb)
Chloroform	9.59	BRL	0.2	ug/L (ppb)
1,1,1-Trichloroethane	10.22	BRL	0.2	ug/L (ppb)
Carbon tetrachloride	10.78	BRL	0.2	ug/L (ppb)
1,1-Dichloropropene	10.57	BRL	0.2	ug/L (ppb)
Benzene	10.83	BRL	0.2	ug/L (ppb)
1,2-Dichloroethane	10.52	BRL	0.2	ug/L (ppb)
Trichloroethylene	11.85	BRL	0.2	ug/L (ppb)
1,2-Dichloropropane	12.21	BRL	0.2	ug/L (ppb)
Dibromomethane	12.39	BRL	0.2	ug/L (ppb)
Bromodichloromethane	12.62	BRL	0.2	ug/L (ppb)
Toluene	13.86	BRL	0.2	ug/L (ppb)
1,1,2-Trichloroethane	14.60	BRL	0.2	ug/L (ppb)
Tetrachloroethylene	14.85	BRL	0.2	ug/L (ppb)
1,3-Dichloropropane	15.32	BRL	0.2	ug/L (ppb)
Dibromochloromethane	15.33	BRL	0.2	ug/L (ppb)
1,2-Dibromoethane	15.58	BRL	0.2	ug/L (ppb)
Chlorobenzene	16.47	BRL	0.2	ug/L (ppb)
Ethylbenzene	16.93	BRL	0.2	ug/L (ppb)
m/p-Xylene	16.99	BRL	0.2	ug/L (ppb)
o-Xylene	17.52	BRL	0.2	ug/L (ppb)
1,1,1,2-Tetrachloroethane	16.55	BRL	0.2	ug/L (ppb)
Bromoform	17.93	BRL	0.2	ug/L (ppb)
Isopropylbenzene	18.22	BRL	0.2	ug/L (ppb)
Bromobenzene	18.81	BRL	0.2	ug/L (ppb)
n-Propylbenzene	19.29	BRL	0.2	ug/L (ppb)
1,2,3-Trichloropropane	18.60	BRL	0.2	ug/L (ppb)
1,1,2,2-Tetrachloroethane	18.71	BRL	0.2	ug/L (ppb)
2-Chlorotoluene	19.17	BRL	0.2	ug/L (ppb)
1,3,5-Trimethylbenzene	19.34	BRL	0.2	ug/L (ppb)
4-Chlorotoluene	19.29	BRL	0.2	ug/L (ppb)
tert-Butylbenzene	19.85	BRL	0.2	ug/L (ppb)
1,2,4-Trimethylbenzene	20.00	BRL	0.2	ug/L (ppb)
sec-Butylbenzene	20.30	BRL	0.2	ug/L (ppb)
1,3-Dichlorobenzene	20.58	BRL	0.2	ug/L (ppb)
p-Isopropyltoluene	20.52	BRL	0.2	ug/L (ppb)
1,4-Dichlorobenzene	20.76	BRL	0.2	ug/L (ppb)
n-Butylbenzene	21.02	BRL	0.2	ug/L (ppb)
1,2-Dichlorobenzene	21.82	BRL	0.2	ug/L (ppb)
1,2-Dibromo-3-chloropropane	22.89	BRL	0.2	ug/L (ppb)
1,2,4-Trichlorobenzene	24.07	BRL	0.2	ug/L (ppb)
Hexachlorobutadiene	24.73	BRL	0.2	ug/L (ppb)
Naphthalene	24.55	BRL	0.2	ug/L (ppb)
1,2,3-Trichlorobenzene	25.12	BRL	0.2	ug/L (ppb)

Surrogate Recovery

Surrogate	% Recovery
Dibromofluoromethane (Surr.)	98
1,2-Dichloroethane-d4 (Surr.)	107
Toluene-d8 (Surr.)	104
Bromofluorobenzene (Surr.)	98

ATTCH.5.(16–38).

California Department of Fish and Game
Water Pollution Control Laboratory
2005 Nimbus Road
Rancho Cordova, CA 95670

EPA Method 8260 Volatile Organic Compounds

Instrument Name: Jaime MSD
Sample Name: L-240-00 TKL001
Misc Info:
Acq. Method File: VOAPURGE
Sample Multiplier: 1
Sample Amount: 25 mL

Compound	Ret Time	Amount	Reporting Limit	Units
1,1-Dichloroethylene	6.57	BRL	0.2	ug/L (ppb)
trans-1,2-Dichloroethylene	7.77	BRL	0.2	ug/L (ppb)
1,1-Dichloroethane	8.46	BRL	0.2	ug/L (ppb)
2,2-Dichloropropane	9.36	BRL	0.2	ug/L (ppb)
cis-1,2-Dichloroethylene	9.39	BRL	0.2	ug/L (ppb)
Bromochloromethane	9.92	BRL	0.2	ug/L (ppb)
Chloroform	9.59	BRL	0.2	ug/L (ppb)
1,1,1-Trichloroethane	10.24	BRL	0.2	ug/L (ppb)
Carbon tetrachloride	10.47	BRL	0.2	ug/L (ppb)
1,1-Dichloropropene	10.71	BRL	0.2	ug/L (ppb)
Benzene	10.53	BRL	0.2	ug/L (ppb)
1,2-Dichloroethane	10.93	BRL	0.2	ug/L (ppb)
Trichloroethylene	11.72	BRL	0.2	ug/L (ppb)
1,2-Dichloropropane	11.82	BRL	0.2	ug/L (ppb)
Dibromomethane	12.49	BRL	0.2	ug/L (ppb)
Bromodichloromethane	12.64	BRL	0.2	ug/L (ppb)
Toluene	13.64	BRL	0.2	ug/L (ppb)
1,1,2-Trichloroethane	14.62	BRL	0.2	ug/L (ppb)
Tetrachloroethylene	14.60	BRL	0.2	ug/L (ppb)
1,3-Dichloropropane	14.93	BRL	0.2	ug/L (ppb)
Dibromochloromethane	15.41	BRL	0.2	ug/L (ppb)
1,2-Dibromoethane	15.85	BRL	0.2	ug/L (ppb)
Chlorobenzene	16.44	BRL	0.2	ug/L (ppb)
Ethylbenzene	16.25	BRL	0.2	ug/L (ppb)
m/p-Xylene	16.46	BRL	0.2	ug/L (ppb)
o-Xylene	17.19	BRL	0.2	ug/L (ppb)
1,1,1,2-Tetrachloroethane	16.55	BRL	0.2	ug/L (ppb)
Bromoform	17.95	BRL	0.2	ug/L (ppb)
Isopropylbenzene	18.22	BRL	0.2	ug/L (ppb)
Bromobenzene	18.85	BRL	0.2	ug/L (ppb)
n-Propylbenzene	18.57	BRL	0.2	ug/L (ppb)
1,2,3-Trichloropropane	18.84	BRL	0.2	ug/L (ppb)
1,1,2,2-Tetrachloroethane	18.70	BRL	0.2	ug/L (ppb)
2-Chlorotoluene	18.98	BRL	0.2	ug/L (ppb)
1,3,5-Trimethylbenzene	18.90	BRL	0.2	ug/L (ppb)
4-Chlorotoluene	19.29	BRL	0.2	ug/L (ppb)
tert-Butylbenzene	19.63	BRL	0.2	ug/L (ppb)
1,2,4-Trimethylbenzene	20.31	BRL	0.2	ug/L (ppb)
sec-Butylbenzene	19.93	BRL	0.2	ug/L (ppb)
1,3-Dichlorobenzene	20.59	BRL	0.2	ug/L (ppb)
p-Isopropyltoluene	20.42	BRL	0.2	ug/L (ppb)
1,4-Dichlorobenzene	20.73	BRL	0.2	ug/L (ppb)
n-Butylbenzene	21.30	BRL	0.2	ug/L (ppb)
1,2-Dichlorobenzene	21.73	BRL	0.2	ug/L (ppb)
1,2-Dibromo-3-chloropropane	22.87	BRL	0.2	ug/L (ppb)
1,2,4-Trichlorobenzene	24.50	BRL	0.2	ug/L (ppb)
Hexachlorobutadiene	24.76	BRL	0.2	ug/L (ppb)
Naphthalene	24.96	BRL	0.2	ug/L (ppb)
1,2,3-Trichlorobenzene	25.40	BRL	0.2	ug/L (ppb)

Surrogate Recovery

Surrogate	% Recovery
Dibromofluoromethane (Surr.)	96
1,2-Dichloroethane-d4 (Surr.)	109
Toluene-d8 (Surr.)	100
Bromofluorobenzene (Surr.)	96

ATTCH.5.(17–38).

California Department of Fish and Game
Water Pollution Control Laboratory
2005 Nimbus Road
Rancho Cordova, CA 95670

EPA Method 8260 Volatile Organic Compounds

Instrument Name: Jaime MSD
Sample Name: L-240-00 TKL002
Misc Info:
Acq. Method File: VOAPURGE
Sample Multiplier: 1
Sample Amount: 25 mL

Compound	Ret Time	Amount	Reporting Limit	Units
1,1-Dichloroethylene	6.56	BRL	0.2	ug/L (ppb)
trans-1,2-Dichloroethylene	7.80	BRL	0.2	ug/L (ppb)
1,1-Dichloroethane	8.48	BRL	0.2	ug/L (ppb)
2,2-Dichloropropane	9.21	BRL	0.2	ug/L (ppb)
cis-1,2-Dichloroethylene	9.37	BRL	0.2	ug/L (ppb)
Bromochloromethane	9.78	BRL	0.2	ug/L (ppb)
Chloroform	9.73	BRL	0.2	ug/L (ppb)
1,1,1-Trichloroethane	10.22	BRL	0.2	ug/L (ppb)
Carbon tetrachloride	10.42	BRL	0.2	ug/L (ppb)
1,1-Dichloropropene	10.30	BRL	0.2	ug/L (ppb)
Benzene	10.84	BRL	0.2	ug/L (ppb)
1,2-Dichloroethane	10.93	BRL	0.2	ug/L (ppb)
Trichloroethylene	11.84	BRL	0.2	ug/L (ppb)
1,2-Dichloropropane	12.13	BRL	0.2	ug/L (ppb)
Dibromomethane	12.71	BRL	0.2	ug/L (ppb)
Bromodichloromethane	12.62	BRL	0.2	ug/L (ppb)
Toluene	13.64	BRL	0.2	ug/L (ppb)
1,1,2-Trichloroethane	14.67	BRL	0.2	ug/L (ppb)
Tetrachloroethylene	14.95	BRL	0.2	ug/L (ppb)
1,3-Dichloropropane	14.94	BRL	0.2	ug/L (ppb)
Dibromochloromethane	15.20	BRL	0.2	ug/L (ppb)
1,2-Dibromoethane	15.54	BRL	0.2	ug/L (ppb)
Chlorobenzene	16.46	BRL	0.2	ug/L (ppb)
Ethylbenzene	16.60	BRL	0.2	ug/L (ppb)
m/p-Xylene	16.60	BRL	0.2	ug/L (ppb)
o-Xylene	17.53	BRL	0.2	ug/L (ppb)
1,1,1,2-Tetrachloroethane	16.56	BRL	0.2	ug/L (ppb)
Bromoform	17.91	BRL	0.2	ug/L (ppb)
Isopropylbenzene	18.43	BRL	0.2	ug/L (ppb)
Bromobenzene	18.82	BRL	0.2	ug/L (ppb)
n-Propylbenzene	18.94	BRL	0.2	ug/L (ppb)
1,2,3-Trichloropropane	18.94	BRL	0.2	ug/L (ppb)
1,1,2,2-Tetrachloroethane	18.70	BRL	0.2	ug/L (ppb)
2-Chlorotoluene	19.24	BRL	0.2	ug/L (ppb)
1,3,5-Trimethylbenzene	19.07	BRL	0.2	ug/L (ppb)
4-Chlorotoluene	19.31	BRL	0.2	ug/L (ppb)
tert-Butylbenzene	19.84	BRL	0.2	ug/L (ppb)
1,2,4-Trimethylbenzene	19.85	BRL	0.2	ug/L (ppb)
sec-Butylbenzene	19.90	BRL	0.2	ug/L (ppb)
1,3-Dichlorobenzene	20.57	BRL	0.2	ug/L (ppb)
p-Isopropyltoluene	20.42	BRL	0.2	ug/L (ppb)
1,4-Dichlorobenzene	20.73	BRL	0.2	ug/L (ppb)
n-Butylbenzene	21.62	BRL	0.2	ug/L (ppb)
1,2-Dichlorobenzene	21.43	BRL	0.2	ug/L (ppb)
1,2-Dibromo-3-chloropropane	22.90	BRL	0.2	ug/L (ppb)
1,2,4-Trichlorobenzene	24.48	BRL	0.2	ug/L (ppb)
Hexachlorobutadiene	24.76	BRL	0.2	ug/L (ppb)
Naphthalene	24.96	BRL	0.2	ug/L (ppb)
1,2,3-Trichlorobenzene	25.43	BRL	0.2	ug/L (ppb)

Surrogate Recovery

Surrogate	% Recovery
Dibromofluoromethane (Surr.)	95
1,2-Dichloroethane-d4 (Surr.)	107
Toluene-d8 (Surr.)	94
Bromofluorobenzene (Surr.)	99

ATTCH.5.(18–38).

California Department of Fish and Game
Water Pollution Control Laboratory
2005 Nimbus Road
Rancho Cordova, CA 95670

EPA Method 8260 Volatile Organic Compounds

Instrument Name: Jaime MSD
Sample Name: L-240-00 TKL003
Misc Info:
Acq. Method File: VOAPURGE
Sample Multiplier: 1
Sample Amount: 25 mL

Compound	Ret Time	Amount	Reporting Limit	Units
1,1-Dichloroethylene	6.58	BRL	0.2	ug/L (ppb)
trans-1,2-Dichloroethylene	7.79	BRL	0.2	ug/L (ppb)
1,1-Dichloroethane	8.46	BRL	0.2	ug/L (ppb)
2,2-Dichloropropane	9.51	BRL	0.2	ug/L (ppb)
cis-1,2-Dichloroethylene	8.97	BRL	0.2	ug/L (ppb)
Bromochloromethane	9.93	BRL	0.2	ug/L (ppb)
Chloroform	9.74	BRL	0.2	ug/L (ppb)
1,1,1-Trichloroethane	10.22	BRL	0.2	ug/L (ppb)
Carbon tetrachloride	10.40	BRL	0.2	ug/L (ppb)
1,1-Dichloropropene	10.93	BRL	0.2	ug/L (ppb)
Benzene	10.82	BRL	0.2	ug/L (ppb)
1,2-Dichloroethane	10.93	BRL	0.2	ug/L (ppb)
Trichloroethylene	11.85	BRL	0.2	ug/L (ppb)
1,2-Dichloropropane	12.16	BRL	0.2	ug/L (ppb)
Dibromomethane	12.42	BRL	0.2	ug/L (ppb)
Bromodichloromethane	12.63	BRL	0.2	ug/L (ppb)
Toluene	14.13	BRL	0.2	ug/L (ppb)
1,1,2-Trichloroethane	14.27	BRL	0.2	ug/L (ppb)
Tetrachloroethylene	14.92	BRL	0.2	ug/L (ppb)
1,3-Dichloropropane	14.64	BRL	0.2	ug/L (ppb)
Dibromochloromethane	15.41	BRL	0.2	ug/L (ppb)
1,2-Dibromoethane	15.57	BRL	0.2	ug/L (ppb)
Chlorobenzene	16.10	BRL	0.2	ug/L (ppb)
Ethylbenzene	16.55	BRL	0.2	ug/L (ppb)
m/p-Xylene	16.64	BRL	0.2	ug/L (ppb)
o-Xylene	17.86	BRL	0.2	ug/L (ppb)
1,1,1,2-Tetrachloroethane	16.57	BRL	0.2	ug/L (ppb)
Bromoform	17.94	BRL	0.2	ug/L (ppb)
Isopropylbenzene	18.29	BRL	0.2	ug/L (ppb)
Bromobenzene	18.82	BRL	0.2	ug/L (ppb)
n-Propylbenzene	18.97	BRL	0.2	ug/L (ppb)
1,2,3-Trichloropropane	18.98	BRL	0.2	ug/L (ppb)
1,1,2,2-Tetrachloroethane	18.69	BRL	0.2	ug/L (ppb)
2-Chlorotoluene	19.13	BRL	0.2	ug/L (ppb)
1,3,5-Trimethylbenzene	19.32	BRL	0.2	ug/L (ppb)
4-Chlorotoluene	19.49	BRL	0.2	ug/L (ppb)
tert-Butylbenzene	19.72	BRL	0.2	ug/L (ppb)
1,2,4-Trimethylbenzene	19.86	BRL	0.2	ug/L (ppb)
sec-Butylbenzene	19.93	BRL	0.2	ug/L (ppb)
1,3-Dichlorobenzene	20.60	BRL	0.2	ug/L (ppb)
p-Isopropyltoluene	20.41	BRL	0.2	ug/L (ppb)
1,4-Dichlorobenzene	20.71	BRL	0.2	ug/L (ppb)
n-Butylbenzene	21.31	BRL	0.2	ug/L (ppb)
1,2-Dichlorobenzene	21.44	BRL	0.2	ug/L (ppb)
1,2-Dibromo-3-chloropropane	22.87	BRL	0.2	ug/L (ppb)
1,2,4-Trichlorobenzene	24.72	BRL	0.2	ug/L (ppb)
Hexachlorobutadiene	24.75	BRL	0.2	ug/L (ppb)
Naphthalene	24.93	BRL	0.2	ug/L (ppb)
1,2,3-Trichlorobenzene	25.01	BRL	0.2	ug/L (ppb)

Surrogate Recovery

Surrogate	% Recovery
Dibromofluoromethane (Surr.)	95
1,2-Dichloroethane-d4 (Surr.)	107
Toluene-d8 (Surr.)	93
Bromofluorobenzene (Surr.)	97

ATTCH.5.(19–38).

California Department of Fish and Game
Water Pollution Control Laboratory
2005 Nimbus Road
Rancho Cordova, CA 95670

EPA Method 8260 Volatile Organic Compounds

Instrument Name: Jaime MSD
Sample Name: L-240-00 TKL004
Misc Info:
Acq. Method File: VOAPURGE
Sample Multiplier: 1
Sample Amount: 25 mL

Compound	Ret Time	Amount	Reporting Limit	Units
1,1-Dichloroethylene	6.55	BRL	0.2	ug/L (ppb)
trans-1,2-Dichloroethylene	7.46	BRL	0.2	ug/L (ppb)
1,1-Dichloroethane	8.45	BRL	0.2	ug/L (ppb)
2,2-Dichloropropane	9.41	BRL	0.2	ug/L (ppb)
cis-1,2-Dichloroethylene	9.37	BRL	0.2	ug/L (ppb)
Bromochloromethane	9.77	BRL	0.2	ug/L (ppb)
Chloroform	9.87	BRL	0.2	ug/L (ppb)
1,1,1-Trichloroethane	10.23	BRL	0.2	ug/L (ppb)
Carbon tetrachloride	10.49	BRL	0.2	ug/L (ppb)
1,1-Dichloropropene	10.94	BRL	0.2	ug/L (ppb)
Benzene	10.84	BRL	0.2	ug/L (ppb)
1,2-Dichloroethane	10.93	BRL	0.2	ug/L (ppb)
Trichloroethylene	11.84	BRL	0.2	ug/L (ppb)
1,2-Dichloropropane	11.97	BRL	0.2	ug/L (ppb)
Dibromomethane	12.50	BRL	0.2	ug/L (ppb)
Bromodichloromethane	12.63	BRL	0.2	ug/L (ppb)
Toluene	13.64	BRL	0.2	ug/L (ppb)
1,1,2-Trichloroethane	14.63	BRL	0.2	ug/L (ppb)
Tetrachloroethylene	15.41	BRL	0.2	ug/L (ppb)
1,3-Dichloropropane	14.93	BRL	0.2	ug/L (ppb)
Dibromochloromethane	15.18	BRL	0.2	ug/L (ppb)
1,2-Dibromoethane	15.60	BRL	0.2	ug/L (ppb)
Chlorobenzene	16.46	BRL	0.2	ug/L (ppb)
Ethylbenzene	16.66	BRL	0.2	ug/L (ppb)
m/p-Xylene	16.85	BRL	0.2	ug/L (ppb)
o-Xylene	17.70	BRL	0.2	ug/L (ppb)
1,1,1,2-Tetrachloroethane	16.58	BRL	0.2	ug/L (ppb)
Bromoform	17.95	BRL	0.2	ug/L (ppb)
Isopropylbenzene	18.08	BRL	0.2	ug/L (ppb)
Bromobenzene	18.84	BRL	0.2	ug/L (ppb)
n-Propylbenzene	18.99	BRL	0.2	ug/L (ppb)
1,2,3-Trichloropropane	18.80	BRL	0.2	ug/L (ppb)
1,1,2,2-Tetrachloroethane	18.72	BRL	0.2	ug/L (ppb)
2-Chlorotoluene	19.21	BRL	0.2	ug/L (ppb)
1,3,5-Trimethylbenzene	19.39	BRL	0.2	ug/L (ppb)
4-Chlorotoluene	19.36	BRL	0.2	ug/L (ppb)
tert-Butylbenzene	19.84	BRL	0.2	ug/L (ppb)
1,2,4-Trimethylbenzene	20.20	BRL	0.2	ug/L (ppb)
sec-Butylbenzene	20.46	BRL	0.2	ug/L (ppb)
1,3-Dichlorobenzene	20.55	BRL	0.2	ug/L (ppb)
p-Isopropyltoluene	20.17	BRL	0.2	ug/L (ppb)
1,4-Dichlorobenzene	20.71	BRL	0.2	ug/L (ppb)
n-Butylbenzene	21.21	BRL	0.2	ug/L (ppb)
1,2-Dichlorobenzene	21.43	BRL	0.2	ug/L (ppb)
1,2-Dibromo-3-chloropropane	22.88	BRL	0.2	ug/L (ppb)
1,2,4-Trichlorobenzene	24.08	BRL	0.2	ug/L (ppb)
Hexachlorobutadiene	24.36	BRL	0.2	ug/L (ppb)
Naphthalene	25.06	BRL	0.2	ug/L (ppb)
1,2,3-Trichlorobenzene	25.41	BRL	0.2	ug/L (ppb)

Surrogate Recovery

Surrogate	% Recovery
Dibromofluoromethane (Surr.)	97
1,2-Dichloroethane-d4 (Surr.)	113
Toluene-d8 (Surr.)	94
Bromofluorobenzene (Surr.)	98

ATTCH.5.(20–38).

Matrix Spike and Matrix Spike Duplicate

Instrument Name: Jaime MSD
Sample Name: L-240-00 TKL001 MS
Misc Info:
Acq. Method File: VOAPURGE

Matrix Spike

Compound	Spike Amount (ng)	Recovered Amount (ng)	% Recovery	Control Limits*(%)
1,1-Dichloroethylene	10	10.8	108	64 - 112
Benzene	10	10.9	109	70 - 114
Trichloroethylene	10	10.5	105	79 - 126
Toluene	10	10.7	107	88 - 120
Chlorobenzene	10	10.2	102	80 - 114

Matrix Spike Duplicate

Compound	Spike Amount (ng)	Recovered Amount (ng)	% Recovery	Control Limits*(%)
1,1-Dichloroethylene	10	11.1	111	64 - 112
Benzene	10	11.6	116	70 - 114
Trichloroethylene	10	11.4	114	79 - 126
Toluene	10	12.4	124	88 - 120
Chlorobenzene	10	10.5	105	80 - 114

* Control Limits determined by original Method Detection Level.
They will be updated as more data points become available.

ATTCH.5.(21–38).