Summary Table:

No.	Waterbody	Title of data source	Type of data	Year	Format
1	Pacific Ocean	Local Health Agencies and Water Agencies	Bacteria indicator data	4/05-10/06	Electronic
2	Piru Creek	Montana State University; http://www.esg.montana.edu/aim/mollusca/nzms/; Collector: Colleen Martin	Exotic Species Identification; identification data and maps	January 2006	Hard Copy/website
3	Malibu Creek Watershed	Malibu Creek Watershed Monitoring Program, Bioassessment Monitoring Spring/Fall 2005, City of Calabasas	Southern California IBI Scores; BMI raw taxa list; New Zealand Mudsnail Identification	Spring/Fall 2005	Hard Copy
4	Santa Monica Bay Watershed and various subwatersheds	Mark Abramson, Heal the Bay	Southern California IBI Scores for 2005; BMI raw taxa list and abundance; New Zealand Mudsnail and Asian Clam Identification; Field Audit	2000-2003 & Winter 2005	Electronic
5	Malibu Creek Watershed	Mark Abramson, Heal the Bay	Aquatic invasive species taxa list and abundance	2001-2005	Excel Table, PDF Maps, GIS Data, Photograph
6	Malibu Creek Watershed	Heal the Bay, Watershed Assessment of Malibu Creek: Final Report. (2005).	Southern California IBI Scores	2000-2003	Electronic, Hard Copy
7	Malibu Lagoon	Resource Conservation District of the Santa Monica Mountains, Santa Monica 2005 Malibu Lagoon Fish Survey, June 2005	Invasive species identification	Jun-05	Electronic, Hard Copy
8	Malibu Creek Watershed	Santa Monica Restoration Commission/Heal the Bay, Santa Monica Mountains New Zealand Mudsnail Survey	New Zealand Mudsnail	2006	Electronic, Hard Copy
9	Malibu Creek Watershed	Various Sources compiled by Heal the Bay	Report on exotic species identified in the Malibu Creek Watershed	Various	Hard Copy

10	Malibu Creek Watershed	Santa Monica Resource Conservation District, Rosi Dagit	Steelhead Trout counts	2006	Electronic, Hard Copy
11	Malibou Lake	Malibou Lake Mountain Club; Initial Inspection and Monitoring Report of Malibou Lake (draft May 2006)	Identification of invasive aquatic species: largemouth bass, bluegill sunfish, carp	2006	Electronic
12	Calleguas Creek	Ambrose, R.F., Lee, S. F., and S.P. Bergquist, Environmental Monitoring and Bioassessment of Coastal Watersheds in Ventura and Los Angeles Counties (2003).	Creek Transect Data	2003	Electronic, Hard Copy
13	Calleguas Creek	Steve Lee, Post-Doctoral Candidate, UCLA	Photographs of excess algal growth	2004	Electronic, Hard Copy
14	Calleguas Creek	Ventura Coastkeeper	water quality data	2006	Electronic
15	Calleguas Creek	Ventura Coastkeeper, Bioassessment Monitoring of Conejo and Calleguas Creeks, Fall 2006	Bioassessment	2006	Electronic
16	Calleguas Creek Watershed - Various	Ventura Coastkeeper	Algae, trash, DO data	2006	Electronic
17	275 S.Cal Coastal sites Data not site specific in journal article provided. Region 4 - Various	Ode, P.R., A.C. Rehn and J.T. May., A Quantitative Tool for Assessing the Integrity of Southern Coastal California Streams, *Environmental Management*. 35:493-504 (2005).	Southern California IBI Scores	2000-2001	Electronic, Hard Copy
18	LA County - Various	Los Angeles County, Los Angeles County 1994-2005 Integrated Receiving Water Impacts Report (2005).	Southern California IBI Scores	2003-2004	Electronic, Hard Copy
19	Ventura County - Various	Ventura County Watershed Protection District, Ventura River Watershed 2004 Bioassessment Monitoring Report. (2005).	Southern California IBI Scores	2004-2005	Electronic, Hard Copy
20	Santa Monica Bay, Palos Verdes	Environmental Protection Agency, Sharon Lin	Fish contamination data	2002-2004	Electronic

Calleguas, Santa Clara, San Gabriel

File Details:

1. Beach Indicator Bacteria Data

As part of our weekly Beach Report Card program, Heal the Bay maintains an extensive database of routine beach monitoring data collected by local health and water agencies for the purpose of public health protection at recreational marine beaches. For the past few years, we have received routine beach data on a weekly basis from over 20 different local agencies covering 350 beaches in the winter and 460 beaches during the summer. We have included beach data for some of the Los Angeles County beaches and statewide beaches from April 2005 to October 2006. These data can be used to determine bacteria impairments.

2. Piru Creek Exotic Species Data

Montana State University maintains a website entitled "New Zealand Mudsnails in the Western USA." The website tracks New Zealand Mudsnail (*Potamopyrgus antipodarum*) identifications in the western United States. On January 10, 2006 a sample was collected on Piru Creek, and the California Department of Fish and Game identified the New Zealand Mudsnail. These data can be used to identify exotic species impairment.

3. Malibu Creek BMI Data – City of Calabasas

In the spring and fall of 2005, members of the Malibu Creek Watershed Monitoring Program and Aquatic Bioassay conducted a bioassessment survey of the Malibu Creek Watershed. Benthic macroinvertebrate (BMI) sampling was conducted at eight locations. The Malibu Creek Watershed Monitoring Program Bioassessment Monitoring Spring/Fall 2005 Report was issued in June 2006. The Report contains BMI raw taxa data and calculated Southern California IBI scores. The BMI data identify the New Zealand Mudsnail at two sites in the Spring of 2005 and 5 sites in the Fall of 2005. This indicates that this exotic species is spreading throughout the watershed over time. Therefore, these data can be used to show exotic species impairment. In addition, the IBI scores show that all of the sites sampled were in the "poor" or "very poor" range. (The scoring developed by Ode et al corresponds to the following scale: 0–19 = ''very poor'', 20–39 = ''poor'', 40–59 = ''fair'', 60-79 = ''good'', and 80–100 = ''very good.'') Thus, these data can be used to show biological communities impairment.

4. Malibu Creek BMI Data - Heal the Bay

Heal the Bay conducted BMI surveys in Malibu Creek Watershed in the spring/fall 2000, 2001, 2002, 2003 and winter 2005. During the 2005 survey, Jim Harrington of California Department of Fish and Game conducted a field audit of the monitoring efforts. Heal the Bay received high marks, and Mr. Harrington's report is included in our submittal. The survey dataset includes a taxa list and abundance calculations for BMI. Of note, the Asian Clam and the New Zealand Mudsnail was identified during various years. Asian

Clams can alter benthic substrate and compete with native mussel species for food and space. New Zealand Mudsnails can out-compete and reduce the number of native aquatic invertebrates that the watershed's fish and amphibians rely on for food. This reduction in aquatic invertebrate food supply can disrupt the entire food web with drastic consequences. Therefore, these data can be used to identify an exotic species impairment. In addition, Southern California IBI scores were tabulated for each survey site. Twelve of the seventeen sites surveyed were identified at the "poor" and "very poor" level. (The scoring developed by Ode et al corresponds to the following scale: 0–19 = ''very poor'', 20–39 = ''poor'', 40–59 = ''fair'', 60-79 = ''good'', and 80–100 = ''very good.") Thus, these data can be used to show biological communities impairment.

5. Malibu Creek Watershed Aquatic Species Data

Heal the Bay Stream Team staff conducted pool surveys in the Malibu Creek Watershed between 2001 and 2005. They documented pool habitat using the CDFG Level 4 Survey Protocol (Flossi and Reynolds, 1994). During the surveys both native and non-native fish and amphibian species were identified. All locations were mapped to sub meter accuracy using GPS and imported into GIS. These data can be used to show exotic species impairment.

6. Malibu Creek Watershed IBI Scores

Heal the Bay Stream Team staff collected BMI data in Malibu Creek Watershed over a period of several years (see dataset #4). Between 2000 and 2003, Heal the Bay calculated Southern California IBI Scores as recommended in Ode, P.R., A.C. Rehn and J.T. May., A Quantitative Tool for Assessing the Integrity of Southern Coastal California Streams, *Environmental Management*. 35:493-504 (2005). (The scoring developed by Ode et al corresponds to the following scale: 0–19 = ''very poor'', 20–39 = ''poor'', 40–59 = ''fair'', 60-79 = ''good'', and 80–100 = ''very good.'') These scores can be used to show biological communities impairment.

7. Malibu Lagoon Aquatic Species Data

In June 2005, the Resource Conservation District of the Santa Monica Mountains conducted a fish survey in the Malibu Lagoon. The surveyors collected several invasive species: Mosquitofish and Carp. In addition, they reviewed past surveys of the Lagoon that had identified the following invasive species: Green Sunfish, Bluegill, Largemouth Bass, Mosquitofish, Black Bullhead, and Carp. These identifications can be used to show an exotic species impairment.

8. Santa Monica Mountains New Zealand Mudsnail Survey Data

Heal the Bay and the SMBRC took the lead in organizing and conducting a New Zealand Mudsnail survey in the Santa Monica Mountains over a period of seven days in July 2006. Surveyors visited 44 sites throughout the Santa Monica Mountains, with special emphasis on the Malibu Creek Watershed where the presence of New Zealand Mudsnails had been confirmed through Heal the Bay's 2005 macroinvertebrate sampling. Mudsnails were present at several sites. This information can be used to show impairment from exotic species.

9. Malibu Creek Watershed Exotic Species Data

There are numerous data sets and studies documenting both the presence and abundance of native and non-native invasive species in the Santa Monica Bay Watershed. These studies cover large spatial areas and have occurred over many years. The studies include peer reviewed articles, detailed mapping surveys, snorkel survey results, and electro fishing results conducted in coastal watersheds that drain into Santa Monica Bay. Substantial data also exist regarding dramatic declines in native species abundance in these drainages. The species decline is so severe that all the native fish species are either federally endangered, or on the State list of species of special concern. Numerous research projects and studies have documented how the existing populations of exotic invasive predator species that occupy the Santa Monica Bay Watershed directly reduce the population numbers of the protected native species. This submitted document chronicles many of these studies that pertain to the Malibu Creek Watershed. These data can be used to determine impairments caused by exotic species.

10. Malibu Creek Steelhead Trout Data

The Santa Monica Restoration Commission and Heal the Bay conducted steelhead trout surveys from May 2006 to November 2006. Counts of fish were provided on a monthly basis with a few exceptions. Specifically, the scientists classified the number of trout that were "normal" (not showing sign of disease) and "yellow" (showing sign of disease). The data show the number of trout decreasing to "zero" over time, and the number of diseased fish increasing over time. These data can be used to show a biological communities impairment.

11. Malibou Lake Exotic Aquatic Species

The Malibou Lake Mountain Club conducted an assessment of the Malibou Lake system in May 2006. Their draft report entitled "Initial Inspection and Monitoring Report" was issued in May 2006. The report identifies exotic aquatic species such as largemouth bass, bluegill sunfish, and carp. These species identifications can be used to indicate exotic species impairment.

12. Calleguas Creek Transect Data

UCLA scientists gathered creek transect data at eight sights in Calleguas Creek. Ambrose, R.F., Lee, S.F., and S.P. Bergquist, *Environmental Monitoring and Bioassessment of Coastal Watersheds in Ventura and Los Angeles Counties* (2003). These data include percent coverage of algae in the Creek. Algal coverage data can be used to show an excess algal growth impairment.

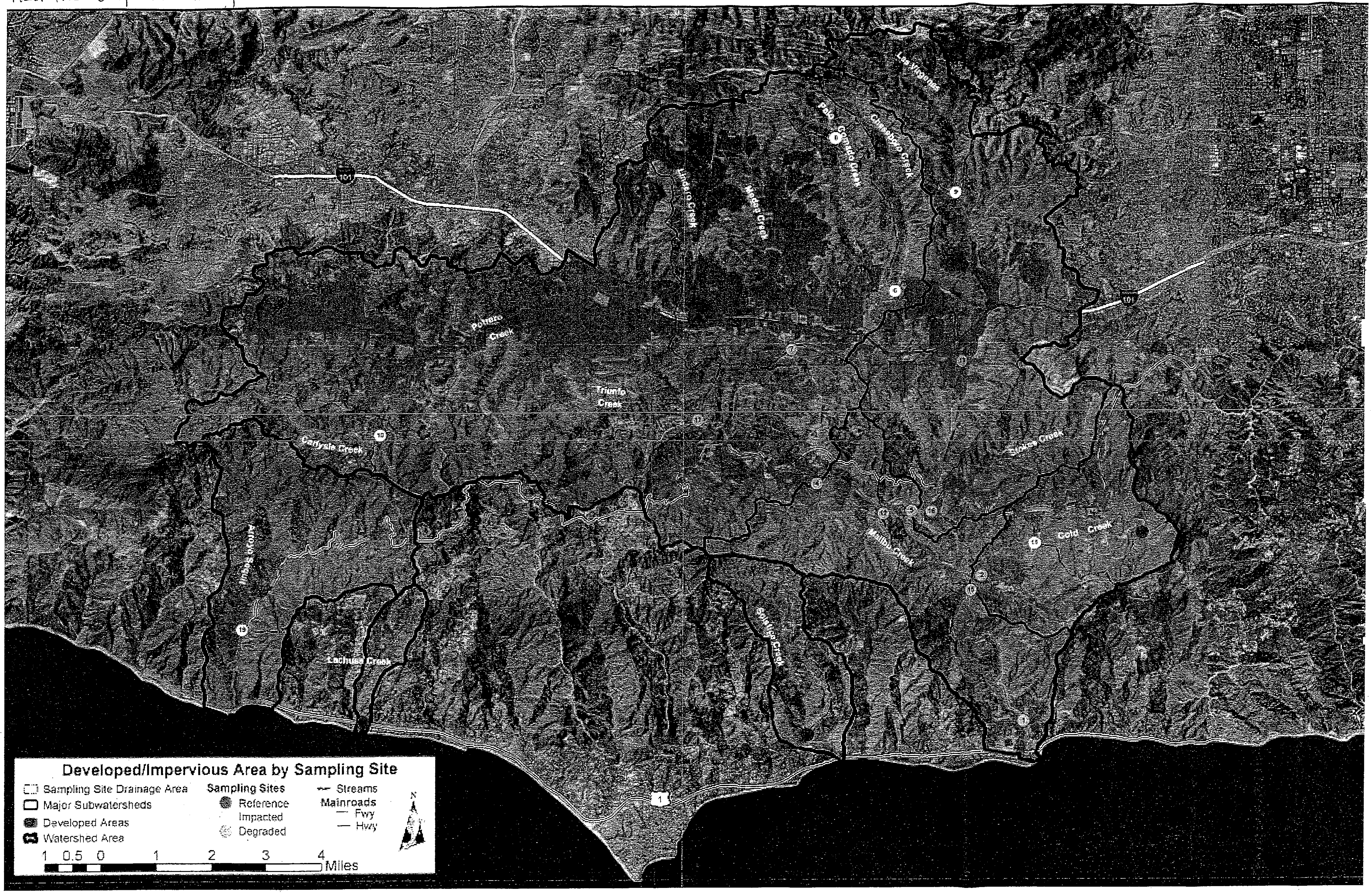
(2005); Los Angeles County, *Los Angeles County 1994-2005 Integrated Receiving Water Impacts Report*, (2005). There are sixteen sites with scores at or below 39 or designated as having "poor" or "very poor" biological conditions. These extremely low IBI scores indicate a biological community impairment.

20. Santa Monica Bay and San Pedro Bay Fish Contamination Data

Between 2002 and 2004 USEPA and MRSP completed a ocean fish survey in Santa Monica and San Pedro Bays of more than 20 species of fish. Fish tissue samples were tested for DDT, PCB, Hg, Dieldrin and chlordane. These data can be used to determine fish tissue impairment for this suite of pollutants.

This Page Intentionally Left Blank

Heal the Bay Monitoring Locations



This Page Intentionally
Left Blank

#2

AIM Search Results

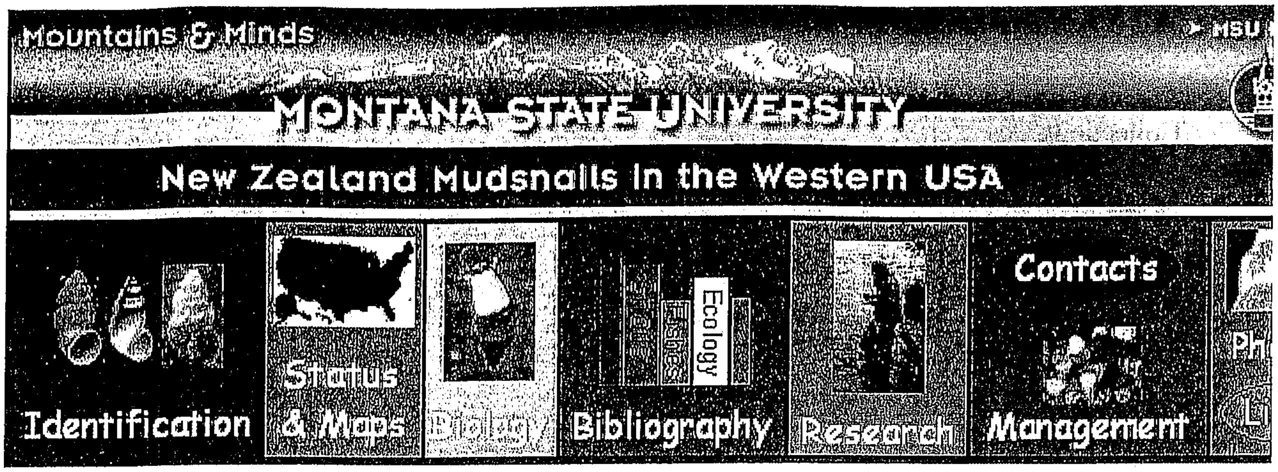
Potamopyrgus antipodarum (Gray), New Zealand mudsnail
Collection dates from 1900 through 2007
The selected location is 34.6336°N, 118.7481°W.
Get the Graphical Locater information for this location.
Make a custom map centered on this location.
HUC Options for this location.

Sample 1

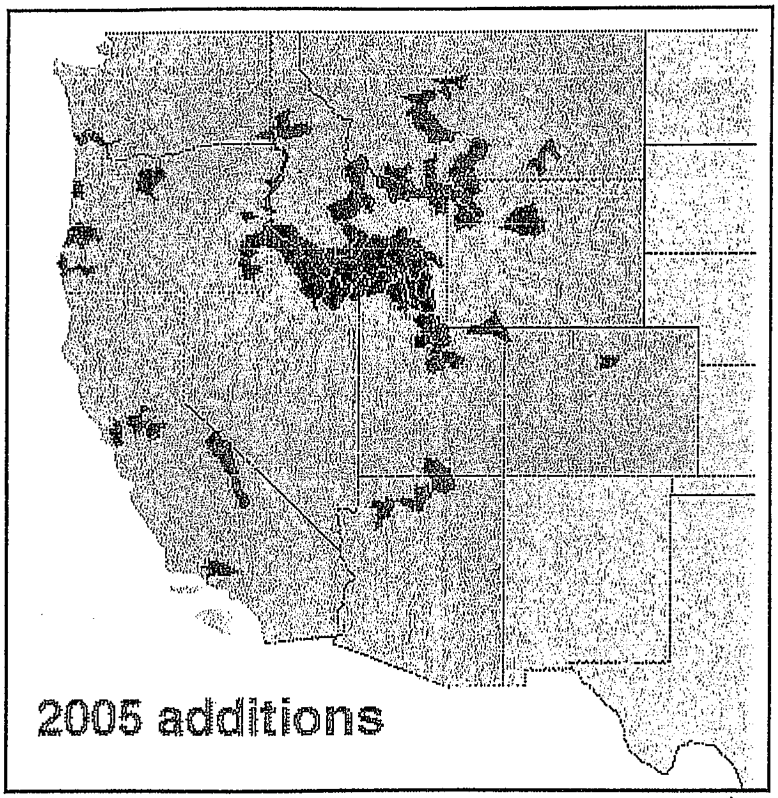
Collection site: Piru Ck 1.5 miles d/s Pyramid dam
Collection date: 2006 JAN 10
Collector: Colleen Martin
Mudsnail density: Sparse
Contact person: Bill Cox
Comments: good snail habitat, slow moving water, lots of aquatic vegetation Submitted by Dawne Becker. Identification by Doug Post at California Dept. Fish and Game Aquatic Bioassessment Lab

---

1 Sample found. 2007 FEB 5 AIM maintainer



2005 New HUC Reports



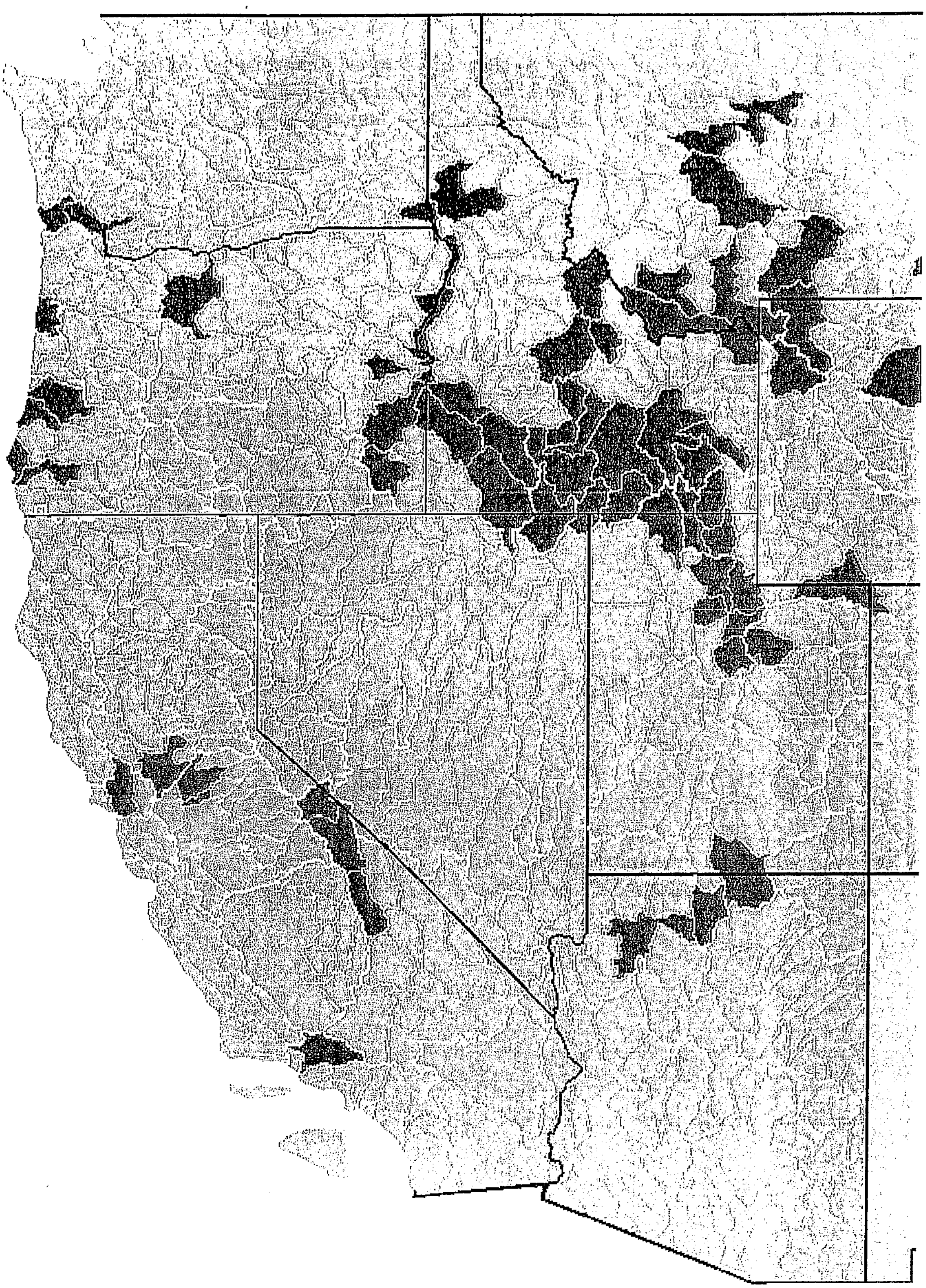
From early 2005 to early 2006, New Zealand mudsnails were reported in 8 new western HUCs (cataloging units). This is not always based on new data, only on new reports to the database here. Note: the Little Bighorn cataloging unit in Montana is not positive. It was temporarily indicated as positive due to bum location data in the database. Of the 8 new HUCs, only 2 could be natural range expansion. Two of the new HUCs appear to represent large jumps by the snails, likely with human assistance. The 4 remaining HUCs are smaller jumps and 3 of these are coastal rivers. Click on the map for a larger version. The new HUCs include:

1. The Upper Missouri-Dearborn (Montana): The snails moved downstream in the Missouri River,

but they have still not developed large populations here.

2. Bruneau (Idaho): The snails moved upstream from the Snake River, but only a short distance and in small numbers.
3. Lower Deschutes (Oregon): The snails jumped a fair distance to get into this central Oregon tailwater river. Populations were low when first discovered.
4. Umpqua (Oregon): The snails jumped into another coastal river. The population is already very large here.
5. Coos (Oregon): The snails jumped into another coastal river. They are already abundant here and occur in the intertidal zone of the river.
6. Lower Rogue (Oregon): The snails jumped into yet another coastal river. This population was known for several years before getting into the database here. The snails can be abundant here.
7. Mono Lake (California): The snails jumped a short distance (at least) into the lake headwaters. The population is at least moderate when discovered.
8. Santa Clara (California): The snails made a large jump into this southern California tailwater river. The population was small when first discovered.

2006 MAR 10, last updated on 2006 MAR 10



2005 additions

#3

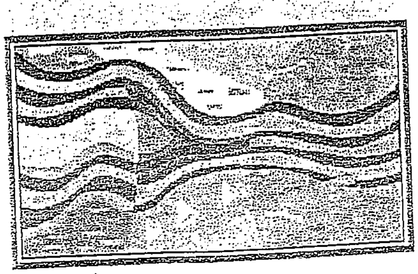
Malibu Creek Watershed Monitoring Program
Bioassessment Monitoring
Spring / Fall 2005

Presented by:

AQUATIC BIOASSAY & CONSULTING LABORATORIES, INC.
29 N. Olive St.
Ventura, CA
805 643 5621

March 2005

THE MALIBU CREEK WATERSHED MONITORING PROGRAM



AQUATIC
BIOASSAY &
CONSULTING
LABORATORIES, INC.

June 14th, 2006

Ms. Jamie Rinehart
Malibu Creek Watershed Monitoring Coordinator
City of Calabasas, Environmental Services Division
26135 Mureau Road
Calabasas, CA 91302

Dear Ms. Rinehart:

We at Aquatic Bioassay and Consulting Laboratories are pleased to present the Malibu Creek Watershed Monitoring Program, 2005 Bioassessment Monitoring Report. The report includes the summarized results for the spring and fall 2005 sampling events.

Please contact me if you have any questions regarding this submittal.

Yours very truly,

Scott C. Johnson

Scott C. Johnson
Director of Environmental Programs

Table 6. Southern California IBI scores and ratings for sites sampled in the Malibu Creek Watershed.

Station / Metric	MAL	LV2	LV1	MED2	MED1	LIN1	TRI	HV
	Spring							
Coleoptera Taxa	2	0	7	2	0	0	0	4
EPT Taxa	3	1	1	1	1	0	1	1
Predator Taxa	4	3	3	0	0	1	4	2
% Collector Taxa	7	6	3	10	9	3	8	5
% Intolerant Taxa	0	0	0	0	0	0	0	0
% Non-Insect	8	1	6	0	0	0	0	0
% Tolerant	9	1	5	0	0	8	0	0
Total	33	12	25	13	10	12	13	12
So. Cal. IBI Rating	Fair	Very Poor	Poor	Very Poor	Very Poor	Very Poor	Very Poor	Very Poor
Station / Metric	**MAL**	**LV2**	**LV1**	**MED2**	**MED1**	**LIN1**	**TRI**	**HV**
	Fall							
Coleoptera Taxa	2	0	5	0	0	0	0	NS
EPT Taxa	3	1	1	1	0	1	0	
Predator Taxa	2	0	6	0	0	1	1	
% Collector Taxa	10	10	10	10	10	10	2	
% Intolerant Taxa	0	0	0	0	0	0	0	
% Non-Insect	0	0	1	0	0	0	0	
% Tolerant	0	0	0	0	0	5	0	
Total	17	11	23	11	10	17	3	
So. Cal. IBI Rating	Poor	Very Poor	Poor	Very Poor	Very Poor	Poor	Very Poor	

AQUATIC BIOASSAY & CONSULTING

2-883

Table A-1. Spring 2005 BMI raw taxa list for all sites in the Malibu Creek Watershed.

Identified Taxa	Tolerance Value (TV)	Functional Feeding Group (FFG)	MAL	LV2	LV1	MED2	MED1	LIN1	TRI	HV
Insecta Taxa										
Ephemeroptera										
Baetis sp.	5	cg	167	50	11	19	57	2	18	64
Fallceon quilleri	5	cg	2	0	0	0	0	0	0	12
Cloeodes excogitatus	4	cg	1	0	0	0	0	0	0	3
Tricorythodes sp.	5	cg	5	0	0	0	0	0	0	0
Odonata										
Coenagrion/Enallagma sp.	9	p	0	0	0	0	0	0	1	2
Argia sp.	7	p	0	0	0	0	0	0	41	0
Hemiptera										
Corixidae	8	p	0	1	0	0	0	0	0	1
Trichoptera										
Cheumatopsyche sp.	5	cf	2	0	0	0	0	0	0	0
Hydropsyche sp.	4	cf	88	0	2	0	0	0	0	0
Hydroptila sp.	6	sc	0	8	1	1	1	0	16	0
Coleoptera										
Hydroporus sp.	5	p	0	0	1	0	0	0	0	0
Agabus sp.	8	p	0	0	1	0	0	0	0	1
Hygrotus sp.	5	p	0	0	0	0	0	0	0	1
Hydraena sp.	5	p	0	0	0	1	0	0	0	0
Microcylloepus sp.	4	cg	1	0	0	0	0	0	0	0
Pelltodytes sp.	5	sc	0	0	2	0	0	0	0	0
Stictotarsus	5	cg	0	0	1	0	0	0	0	0
Diptera										
Bezzia/Palpomyia sp.	6	p	0	2	3	0	0	0	0	0
Dasyhelea sp.	6	cg	0	0	0	0	0	0	0	4
Atrichopogon sp.	6	cg	0	1	1	0	0	0	0	0
Chironominae	6	cg	52	59	212	0	8	90	3	21
Orthocladiinae	5	cg	103	87	94	0	65	69	5	2
Tanypodinae	7	p	4	43	2	4	10	3	0	2
Dolichopodidae	4	p	0	1	0	0	0	0	0	0
Limnophora sp.	6	p	0	0	3	0	0	0	0	0
Pericoma/Telmatoscopus sp.	4	cg	0	0	0	0	0	2	0	1
Simulium sp.	6	cf	1	18	48	13	91	34	38	85
Caloparyphus/Euparyphus sp.	8	cg	0	0	0	0	1	0	0	0
Tipula sp.	4	sh	0	2	2	0	0	0	0	0
Non-Insecta Taxa										
Arachnoidea										
Lebertia sp.	5	p	1	0	2	0	0	0	0	0
Atractides sp.	8	p	1	0	0	0	0	0	0	0
Sperchon sp.	8	p	29	1	0	0	1	0	5	0
Torrenticola sp.	5	p	6	0	0	0	0	0	1	0
Ostracoda										
Cyprididae	8	cg	0	153	95	4	109	26	88	276
Malacostraca										
Hyalella sp.	8	cg	0	0	1	28	24	8	209	0
Procambarus clarkii	8	sh	0	0	0	0	0	1	0	0
Hydrozoa										
Hydra sp.	5	p	3	25	0	0	0	1	11	0
Gastropoda										
Ferrissia sp.	6	sc	0	0	0	0	0	0	6	0
Potamopyrgus antipodarum	8	sc	0	0	0	425	77	0	0	0
Physa/Physella sp.	8	sc	9	24	2	0	9	10	3	6
Helisoma sp.	6	sc								
Nematoda	5	p	0	0	0	0	0	1	0	0
Turbellaria										
Planariidae	4	p	12	0	0	2	10	11	52	0
Oligochaeta	5	cg	13	25	16	3	37	240	2	19
Enopla										
Prostoma sp.	8	p	0	0	0	0	0	2	1	0
TOTAL			500	500	500	500	500	500	500	500

Aquatic Bioassay & Consulting

2-88U

Table A-2. Fall 2005 BMI raw taxa list for all sites in the Malibu Creek Watershed.

Identified Taxa	Tolerance Value (TV)	Functional Feeding Group (FFG)	MAL	LV2	LV1	MED2	MED1	LIN1	TRI
Insecta Taxa									
Ephemeroptera									
Baetis sp.	5	cg	3	2	0	8	0	39	0
Fallceon quilleri	5	cg	13	0	0	0	0	1	0
Cloeodes excogitatus	4	cg	0	0	0	0	0	4	0
Tricorythodes sp.	5	cg	1	0	0	0	0	0	38
Odonata									
Coenagrion/Enallagma sp.	9	p	8	0	42	6	0	8	1
Argia sp.	7	p	0	0	29	0	0	8	10
Plecoptera									
Malenka sp.	2	sh	0	0	14	0	0	0	0
Hemiptera									
Abedus sp.	8	p	0	0	1	0	0	0	0
Trichoptera									
Cheumatopsyche sp.	5	cf							
Hydropsyche sp.	4	cf	20	0	9	0	0	0	0
Hydroptila sp.	6	sc	13	9	0	2	0	0	0
Coleoptera									
Microcylloepus sp.	4	cg	1	0	0	0	0	0	0
Pellodytes sp.	5	sc	0	0	2	0	0	0	0
Stictotarsus sp.	5	cg	0	0	4	0	0	0	0
Tropisternus sp.	5	p	0	0	1	0	0	0	0
Diptera									
Bezzia/Palpomyia sp.	6	p	0	0	1	0	0	0	0
Atrichopogon sp.	6	cg	1	0	0	0	0	0	0
Chironominae	6	cg	0	0	1	0	0	4	7
Orthocladiinae	5	cg	3	1	63	5	2	27	0
Tanypodinae	7	p	1	0	92	0	1	0	34
Ephydra sp.	6	sh	0	0	61	0	0	0	0
Pericoma/Telmatoscopus sp. (L)	4	cg	0	0	2	0	0	0	0
Simulium sp. (L)	6	cf	0	13	1	7	0	99	2
Euparyphus sp. (L)	8	cg	16	0	0	0	0	0	0
Caloparyphus/Euparyphus sp.	8	cg	74	0	3	0	6	2	0
Tipula sp. (L)	4	sh	1	0	0	0	0	0	0
Non-Insecta Taxa									
Arachnoidea									
Sperchon sp.	8	p	14	0	2	0	0	0	1
Ostracoda									
Cyprididae	8	cg	147	117	27	2	9	3	27
Malacostraca									
Hyalella sp.	8	cg	0	0	163	3	36	0	389
Procambarus clarkii	8	sh	0	0	0	0	0	1	1
Hydrozoa									
Hydra sp.	5	p	0	1	0	0	0	0	0
Gastropoda									
Ferrissia sp.	6	sc	0	0	0	0	0	0	2
Potamopyrgus antipodarum	8	sc	3	0	1	489	422	1	0
Physa/Physella sp.	8	sc	27	354	68	0	6	31	0
Helisoma sp.	6	sc	1	0	0	0	0	0	0
Turbellaria									
Planariidae	4	p	128	3	5	10	31	56	0
Oligochaeta	5	cg	6	7	3	2	3	151	8
Enopla									
Prostoma sp.	8	p	12	10	2	3	9	62	0
TOTAL			493	517	597	537	525	497	520

Aquatic Bioassay & Consulting

Table A-3. Spring and fall 2005 BMI metrics for each sample location in the Malibu Creek Watershed.

Metric	MAL		LV2		LV1		MED2		MED1		LIN1		TRI		HV	
	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
Taxonomic richness	19	21	16	10	20	24	10	11	14	10	15	16	17	12	16	
% dominant taxa	33.4	29.8	30.6	68.5	42.4	27.3	85.0	91.1	21.8	80.4	48.0	30.4	41.8	74.8	55.2	
EPT taxa	6	5	2	2	3	2	2	2	2	0	1	3	2	1	3	
EPT Index (%)	53.0	10.1	11.6	2.1	2.8	1.7	4.0	1.9	11.6	0.0	0.4	8.9	6.8	7.3	15.8	
Sensitive EPT Index (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Predator Taxa	7	5	6	3	6	9	3	3	3	3	4	4	7	4	5	
Coleoptera Taxa	1	1	0	0	4	3	1	0	0	0	0	0	0	0	2	
Percent Chironomidae	31.8	0.8	37.8	0.2	61.6	26.1	0.8	0.9	16.6	0.6	32.4	6.2	1.6	7.9	5.0	
Percent Non-Insect	14.8	68.6	45.6	95.2	23.2	45.4	92.4	94.8	53.4	98.3	60.0	61.4	75.6	82.3	60.2	
Shannon Diversity	1.93	2.07	2.09	0.97	1.68	2.25	0.67	0.49	2.11	0.83	1.63	2.02	1.89	1.02	1.48	
Tolerance Value	5.2	6.6	6.4	7.8	6.1	7.0	7.8	7.8	6.5	7.7	5.5	5.8	7.0	7.6	6.9	
Percent Intolerance Value (0-2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Percent Tolerance Value (8-10)	7.8	61.1	35.8	93.0	19.8	51.8	91.4	93.7	44.2	93.0	9.4	21.7	61.4	80.6	57.2	
Percent Collectors	68.8	53.8	75.0	24.6	86.2	44.6	10.8	3.7	60.2	10.7	87.4	46.5	65.0	90.2	80.4	
Percent Filterers	18.2	4.1	3.6	2.5	10.0	1.7	2.6	1.3	18.2	0.0	6.8	19.9	7.6	0.4	17.0	
Percent Grazers	1.8	8.9	6.4	70.2	1.0	11.9	85.2	91.4	17.4	81.5	2.0	6.4	5.0	0.4	1.2	
Percent Predators	11.2	33.1	14.6	2.7	2.4	29.3	1.4	3.5	4.2	7.8	3.6	27.0	22.4	8.8	1.4	
Percent Shredders	0.0	0.2	0.4	0.0	0.4	10.2	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.2	0.0	
Percent Hydropsychidae	17.6	4.1	0.0	0.0	0.4	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Percent Baetidae	34.0	3.2	10.0	0.4	2.2	0.0	3.8	1.5	11.4	0.0	0.4	8.9	3.6	0.0	15.8	
Estimated Abundance	5650	7710	2575	1587	8475	6100	3600	9982	16968	22368	8445	1965	2236	6756	5320	

2-886

Aquatic Bioassay & Consulting

#6

MALIBU CREEK WATERSHED IBI SCORES

Site	Spring 2000	Fall 2000	Spring 2001	Fall 2001	Spring 2002	Fall 2002	Spring 2003	Fall 2003
Mid-Malibu Creek -12		23	20	37	33	27	21	31
Mid-Las Virgenes Creek - 13			21	40	26	24	21	27
Malibu Creek Outlet -1	16	24	26	39	19		26	23
Outlet of Las Virgenes Creek - 5	29	34	33	33	39	26	20	29
Outlet of Madea Creek - 7	23	26	19	34	23	17	9	9
Mid-Malibu Creek - 15	33	17	24	43	40	24	34	23
Triunfo Creek - 17	20		19		19		4	

Table 4: IBI scores for Malibu Creek Watershed. Highlighted scores are in the "poor" or "very poor" ranges. Heal the Bay, Watershed Assessment of Malibu Creek: Final Report, (2005).

Score Developed in Ode, P.R., A.C. Rehn and J.T. May., A Quantitative Tool for Assessing the Integrity of Southern Coastal California Streams, Environmental Management. 35:493-504 (2005).

The scoring developed by Ode et al corresponds to the following scale: 0–19 = “very poor”, 20–39 = “poor”, 40–59 = “fair”, 60-79 = “good”, and 80–100 = “very good.”

#7

Excerpted from:

Dagit, R. and C. Swift. 2005 Malibu Lagoon Fish Survey 20 June 2005. Prepared for California Coastal Conservancy. Resource Conservation District of the Santa Monica Mountains, Topanga, CA.

4.1 Summary of Species Diversity in Malibu Lagoon

Over the years a series of studies have been done looking at the suite of fish species, abundance and seasonal fluctuations of these species in Malibu Lagoon. The diversity of species has changed over the years, not only related to the shifts between brackish and fresh water dominance, but also due to the influx of invasive exotic fishes and the re-introduction of the endangered Tidewater Goby (*Eucyclogobius newberryi)* in 1991. Soltz (1979) found a total of 10 species. Fitzgerald and Hasz (1982) found 11 species in a two year sampling period. Swift (1989) used historical accounts and documented a total of 25 potential species. Jensen (in Manion and Dillingham, 1989) noted a total of 13 species collected in 1988-89. Surveys done by Ambrose, et al (1995, 2000) found a total of 13 species as well. These studies have documented a total of 33 species of fishes from in Malibu Lagoon, depending on season and status of the lagoon entrance condition.

During this one-day survey, only eight species were captured, and we observed but did not catch Striped Mullet.

Table 8. Summary of Species Observed in Malibu Lagoon, 20 June 2005

Species	TOTAL Captured	% of Total
Atherinops sp.	244	29
Cyprinus carpio	1	0.10
Eucyclogobius newberryi	473	57
Fundulus parvipinnis	46	5.50
Gambusia affinis	65	7.75
Gillichthys mirabilis	1	0.10
Girella nigricans	1	0.10
SHRIMP	5	0.60
TOTAL	**836**	**100**

Several sensitive species are known from Malibu Lagoon, either historically, or presently. These include the native freshwater species:

Pacific Lamprey	*Entospenus tridentatus* (Petitioned for Listing)
Steelhead Trout	*Oncorhynchus mykiss* (Federally Endangered)
Arroyo Chub	*Gila orcutti* (CA Species of Special Concern)
Coho or Silver Salmon	*Oncorhynchus kisutch* (Federally Endangered)

Additionally, the endangered estuarine Tidewater Goby (*Eucyclogobius newberryi)* was historically present and re-introduced to Malibu Lagoon in 1991.

Other marine/estuarine species documented in Malibu Lagoon include:

CA Killifish	*Fundulus parvipinnis*
Pipefish	*Syngnathus sp.*
Striped Mullet	*Mugil cephalus*
Staghorn Sculpin	*Leptocottus armatus*
Long jaw Mudsucker	*Gillichthys mirabilis*
Arrow Goby	*Clevelandia ios*
Starry Flounder	*Plaichthys stellatus*
CA Halibut	*Paralichthys californicus*
Diamond Turbot	*Hypsopsetta guttalata*
Spotted Turbot	*Pleuronichthys ritteri*
Shiner Perch	*Cymatogaster aggregata*
Dwarf Surfperch	*Micrometrus minimus*
Northern Anchovy	*Engravilis mordax*
Striped Kelpfish	*Gibbonisia metzi*
Crevice Kelpfish	*Gibbonisia montereyensis*
Opaleye	*Girella nigricans*
Jacksmelt	*Atherinops californiensis*
Topsmelt	*Atherinops affinis*
Queenfish	*Seriphus politus*
Grunion	*Leuresthes tenuis*
Barred Sand Bass	*Paralabrax nebulifer*
Serranid juv.	*Paralabrax sp.*
Bay Blenny	*Hypsoblennius gentilis*

Introduced Freshwater species include:

Green Sunfish	*Lepomis cyanellus*
Bluegill	*Lepomis macrochirus*
Largemouth Bass	*Micropterus salmoides*
Mosquitofish	*Gambusia affinis*
Black Bullhead	*Ictalurus melas*
Carp	*Cyprinus carpio*

A comparison of the dominantly fresh/brackish water species found in this survey event to those in previous surveys indicates a shift from the more marine/estuarine conditions found following the 1980 restoration and accompanied by non-seasonal breaching of the lagoon mouth at Surfrider Beach into the ocean. Since non-seasonal input of reclaimed water from upstream has been reduced and eliminated during the summer months, the lagoon is open to marine influences only during the natural storm event or tidal overwash cycles. Although it was clear that a brackish to salt water lens was present throughout the lagoon at the time of the survey, the abundance of Mosquitofish, a freshwater loving species, was interesting to note. The typically dominant species found, both in the past and during this survey were larval Topsmelt and CA Killifish, followed by larval Tidewater Gobies. The relative abundance of the Topsmelt and CA Killifish are consistent with data collected at this time of year in all previous studies. This indicates their tolerance of wide ranges of temperatures and salinities and is typical for these two estuarine species at this season. Thousands of very small young-of-the-year topsmelt were seen at Station 1 and in the spot checks near Station 3, along the west side of the main lagoon.

Few individuals of the more salt-water dependent species were seen, although schools of striped mullet were observed in the deeper areas of the lagoon. This is in marked contrast to the sampling conducted by Manion and Dillingham (1989), which documented year round residence of staghorn sculpin and arrow gobies, neither of which were observed during this survey.

The most important observation is the shift in abundance of non-native *Gambusia affinis*. In 1989, a total of 16 individuals were caught out of a total of 9,648 fish. By contrast, the mosquitofish now outrank native CA Killifish in relative abundance. Mosquitofish were almost exclusively found in the highly vegetated backwater slough that was warmer than the lagoon. This live bearing exotic fish needs about three weeks above 20^0C to produce a brood of young.

While never common, we did expect to find at least a few juvenile flatfishes, like the Turbot and Halibut, both of which have used the lagoon as a nursery during this season in past years. None were observed in this survey. Grunion are not common in the lagoon. However, overwash associated with spawning cycles and the spring tides occasionally create an opportunity for them to be found as stranded adults or recently hatched larvae and small juveniles.

6. REFERENCES

Ambrose, Richard, I.M. Suffet, S.S. Que Hee. 1995. Enhanced Environmental Monitoring Program at Malibu Lagoon and Malibu Creek. Prepared for Las Virgenes Municipal Water District. UCLA, March 23, 1995.

Ambrose, Richard and A. R. Orme. 2000. Lower Malibu Creek and Lagoon Resource Enhancement and Management. Final Report to the CA Coastal Conservancy, UCLA, Los Angeles, CA.

Dagit, Rosi, S.L. Drill and B. Meyer. 2005. Historical Distribution of Southern Steelhead Trout in the Santa Monica Bay Region. Report prepared for CA Department of Fish and Game and NOAA Fisheries, July 2005.

Dagit, Rosi and S. Williams. 2005. Summary of Tidewater Goby Observations, Malibu Lagoon, Malibu, CA 1996-2000 for Permit PRT-811188. Data collected for Caltrans Mitigation Contract Repair of the Pacific Coast Highway Bridge over Malibu Lagoon. Submitted to USFWS, March 2005. Resource Conservation District of the Santa Monica Mountains, Topanga, CA.

Fitzgerald, C. and L. Hasz. 1983. Water quality and fish sampling results from Malibu Lagoon: Pre-restoration period. Unpublished report, pg. 15.

Manion, Sean. 1993. The Tidewater Goby (*Eucyclogobius newberryi*). Reintroduction of a geographically isolated fish species into Malibu Lagoon: A watershed perspective. Final Report to CA. Department of Parks and Recreation, Contract # 88-05-091. Topanga – Las Virgenes Resource Conservation District, June 1993.

Manion, Sean, and J. Dillingham. 1989. Malibu Lagoon: A Baseline Ecological Study. Topanga-Las Virgenes Resource Conservation District, Topanga, CA.

Soltz, D. L. 1979. Fishes of Malibu Creek July 1978-July 1979. Dept. of Biology, CA State University, Los Angeles.

Swift, Camm. 1975. A list of the fishes of Malibu Creek and Lagoon with a brief description of their habitat requirements and seasonal requirements. Natural History Museum of Los Angeles County, May 30, 1975.

Swift, Camm, et al. 1993. Status and Distribution of the Freshwater Fishes of Southern California. Bulletin of Southern CA Academy of Science 92(3):101-168.

#8

Santa Monica Bay Restoration Commission / Heal the Bay
Santa Monica Mountains
New Zealand Mudsnail Survey

New Zealand mudsnails, *Potamopyrgus antipodarum,* are tiny (3-5 mm), highly invasive aquatic snails (Fig. 1). Reproducing parthenogenetically, or cloning, a single snail is capable of producing a colony of 40 million in the course of a single year (Fig. 2). In large numbers, these small snails can completely cover a stream bed and wreak havoc on local stream ecosystems. New Zealand mudsnails were discovered in Idaho in the mid-1980s, and have since spread to every Western state except New Mexico. Their recent discovery in Malibu Creek threatens efforts at habitat restoration and protection, particularly those to restore populations of the endangered steelhead trout.

Following the discovery of New Zealand mudsnails in the Malibu Creek watershed, the Santa Monica Bay Restoration Commission hosted a mudsnail "summit" meeting in June 2006 to coordinate agency response to the discovery. At the meeting, it was determined that a presence / absence survey would need to be conducted to determine the extent of the invasion. Heal the Bay and the SMBRC took the lead in organizing and conducting the mudsnail survey over a period of seven days in July 2006 (17^{th} – 21^{st}, and July 26^{th} and 27^{th}).

The following report details the findings of the mudsnail survey, discusses in progress "next steps", and makes recommendations for additional measures to manage this aquatic invasive species.

Survey Method:

The survey team included the following individuals: Mark Abramson (Heal the Bay), Gwen Noda (UCLA), Jack Topel and Stephanie Parent (Santa Monica Bay Restoration Commission).

Surveyors visited 44 sites throughout the Santa Monica Mountains, with special emphasis on the Malibu Creek Watershed where the presence of New Zealand mudsnails had been confirmed through Heal the Bay's 2005 macroinvertebrate sampling. The surveys occurred at locations that are frequently monitored for water quality, macroinvertebrates, amphibians, or fish. Additionally, several sites frequented by recreational users such as anglers, hikers, cyclists, and equestrians were also surveyed. These sites were considered likely locations for the New Zealand mudsnail to be spread from its known sources.

Surveyors visited each monitoring or recreational site and surveyed a minimum of 100 yards upstream and 100 yards downstream from the point of entry at each site. Surveyors collected and visually inspected substrate and/or woody debris along transects spaced three to five yards apart. Each transect spanned the entire width of the stream, including wetted banks. A minimum of five samples were collected and inspected along each transect. Each survey consisted of inspecting a minimum of 100 samples.

At each transect, surveyors randomly picked up rocks and/or small woody debris off the bottom of the stream, inspecting each item for the presence or absence of mudsnails. If a sample yielded suspected New Zealand mudsnail(s), surveyors collected snail(s) for visual confirmation by G. Noda (UCLA) or, if necessary, genetic analysis by M. Dybdahl (Washington State University).

Field identification of New Zealand mudsnails was based on three factors: color, size, and shell shape. Adult mudsnails have an average shell length of 3-5 mm and may vary in color, but are most commonly light brown to black. Mudsnails have conical shells with five, occasionally six, convex whorls or spirals. When held tip up, the opening (aperture) facing the observer, the opening is on the right and the whorls spiral up and to the right (Fig. 3).

To prevent the unintentional spread of mudsnails during the survey, separate waders were used at each survey location. Additionally, waders were placed in a freezer for a minimum of 48 hours after each use.

Results:

Malibu Creek Watershed

New Zealand mudsnails were present in Medea Creek from the City of Calabasas monitoring site at Conifer Drive off of Kanan Road, downstream to the inlet of Malibou Lake in Paramount Ranch. Snails were also found on the edge and in shallow areas of Malibou Lake. Mudsnails were found at multiple sites on Malibu Creek, from upstream of Century Reservoir (Lake) to approximately 100-yards downstream of the Cross Creek Road Bridge at Serra Retreat. Additionally, New Zealand mudsnails were found in Las Virgenes Creek at de Anza Park and at the confluence of La Virgenes and Malibu Creeks. The number of mudsnails found at Las Virgenes Creek stations was substantially lower than those of either Medea Creek or Malibu Creek.

No New Zealand mudsnails were found at the following sites within Malibu Creek watershed: four sites on Cold Creek, one site on Lindero Canyon Creek, four sites upstream of de Anza Park on Las Virgenes Creek, including the newly acquired Upper Las Virgenes Canyon Open Space Preserve (formerly Ahmanson Ranch) at the headwaters (Fig. 4).

Other Santa Monica Mountain Watersheds

The following streams outside the Malibu Creek watershed were surveyed; Liberty Canyon, Solstice, Trancas, Temescal, Stokes Canyon, LaChusa, Palo Comado, Cheseboro, Lower Topanga, Russel, Nicholas Canyon, and Arroyo Sequit. All sites were negative for New Zealand mudsnails (Fig 4).

Conclusion:

Although the New Zealand mudsnail has become established within the Malibu Creek watershed, having been observed in three streams, many of the watershed's streams are not yet infested. Also, there is no evidence to indicate they have spread to other Santa Monica Mountain watersheds at this time.

Notes:

Many New Zealand mudsnails observed during the survey were two-toned with two or three whorls being dark to black and the base of the shell being flesh colored to tan.

Although mudsnails observed during the survey appeared to be far more abundant near the banks (stream margins) in relatively shallow areas with slow to moderate flows, they were observed under almost all stream conditions that the survey team encountered.

Very few mudsnails were found on soft bottom habitat (i.e., mud) although they were noted on almost every other type of substrate, including rocks, woody debris, and trash. Mudsnails were also observed on floating or submerged algal mats.

Snails with similar characteristics to that of the New Zealand mudsnail were found in three streams: Lindero Creek, Triunfo Creek, and Topanga Creek. Like the New Zealand mudsnail, these snails also had right-facing apertures and were similar in size and color to the New Zealand mudsnail. These snails had fewer whorls, four as opposed to five, and a slightly larger bottom whorl. Samples of all suspect snails were collected. These snails were inspected in the laboratory by G. Noda and are now thought to be a native Lymnaeidae, *Fossaria* sp.

Next Steps:

Retrieve Heal the Bay macroinvertebrate samples from the CA Department of Fish and Game to confirm the existence of a native hydrobiid in the watershed. If a native hydrobiid does exist, it is critical that we learn the native's genus and species, how to identify it, and more importantly, how to distinguish it from New Zealand mudsnails.

Both the Lindero Canyon Creek sites and the upper Las Virgenes sites that had previously sampled positive for mudsnails (fall 2005 macroinvertebrate samples collected by the City of Calabasas) were negative for mudsnails during the July survey. It is important that we verify that the snails collected by the City of Calabasas at Lindero and Las Virgenes sites in the fall 2005 samples are New Zealand mudsnails.

Complete SMBRC report on current New Zealand mudsnail control and eradication research.

Distribute English & Spanish mudsnail warning signs (Fig 5) to stakeholders for placement.

Recommendations:

Activities such as resource monitoring can be, and in the case of the New Zealand mudsnail in the Malibu Creek watershed, probably is, a pathway for the unintentional spread of both aquatic and terrestrial invasive species. Hazard Analysis and Critical Control Point (HACCP) planning was originally developed by the food industry to prevent contamination and has since been successfully adapted to natural resource management. HACCP planning is a 5-step process used to perform a comprehensive review of planned actions (monitoring, channel maintenance, restoration, construction activities, etc.) and to identify critical control points where specific actions should be implemented (dedicated equipment, decontamination protocols, etc.) to prevent the introduction or spread of invasive species, including New Zealand mudsnails.

1. Identification and description the planned activity.
2. Identification potential hazards associated with the activity.
3. Development of flow diagram to sequentially describe all tasks involved in the activity.
4. Analysis of tasks to determine Critical Control Points.
5. Description of BMPs to be implemented at each Critical Control Point.

We recommend that any agency involved in natural resource management develop and implement HACCP plans specific to their agency's activities. We also recommend that regulatory and other public agencies (CDFG, Coastal Conservancy, Coastal Commission, SWRCB) make approved HACCP plans, and the implementation of those plans, a condition of any grant/contract award or permit.

Repeat the mudsnail presence/absence survey during the summer of 2007 and 2008.

Conduct macroinvertebrate sampling in the spring and fall of 2007 and 2008. It is important to continue collecting this data, particularly at sites where there is pre-infestation benthic macroinvertebrate data. It may also be useful to compare pre- and post-infestation water quality.

Identify funding sources to support research in control and possible eradication measures, risk assessments of future invasions, and environmental/biological impacts of New Zealand mudsnails as well as other invasives in the Santa Monica Bay watershed.

Develop multi-lingual public outreach program targeted at recreational users of the Santa Monica Mountains. Outreach should focus on encouraging simple behavioral changes in order to reduce the odds on unwanted wildlife, vegetation, parasites, viruses, etc. invading our watersheds. This effort could use the introduction of the New Zealand mudsnail as a cautionary tale of what can occur when an invasive species is introduced. The effort should include brochures, signage, presentations, and public service announcements tailored to the different recreational uses such as equestrian, hiking, fishing, etc. All outreach should emphasize the dangers of invasives along with simple ways users can help prevent the spread of mudsnails and other unwanted invaders. Public outreach must be based on a positive message that encourages behavioral change without instilling a sense that the situation is hopeless.

Develop a key for local native snails including methods to distinguish them from New Zealand mudsnails.

Develop or adapt an existing on-line invasive species reporting system in which users can report the discoveries of new invasives and update with new sightings for existing invasives.

#9

Exotic Species

There are numerous data sets and studies documenting both the numbers of native and non-native invasive species in the Santa Monica Bay Watershed. These studies cover large spatial areas and have occurred over many years. The studies include peer reviewed articles, detailed mapping surveys, snorkel survey results, and electro fishing results conducted in coastal watersheds that drain into Santa Monica Bay. Substantial data also exists regarding dramatic declines in native species abundance in these drainages. The species decline is so severe that all the native fish species are either federally endangered, or on the State list of species of special concern. Numerous research projects and studies have documented how the existing populations of exotic invasive predator species that occupy the Santa Monica Bay Watershed directly reduce the population numbers of the protected native species. The sum of this data surely warrants a listing for exotic species in the affected streams and coastal watersheds of Region 4.

The following paragraphs will document the most pertinent studies regarding non-native species distribution in the area, summarize previous studies on the impacts caused to the native species by exotic invasive predator species, and recommend which streams should be placed on the State 303 (d) list as impaired for Exotic Species.

Native Aquatic Species: The Malibu Creek Watershed has three native fish species that occupy freshwater streams: Steelhead trout, Pacific lamprey, and Arroyo chub. The Tidewater goby is a fish that occurs in the Malibu Creek watershed but utilizes brackish water habitat associated with tidal lagoons. Pacific lamprey and Arroyo chub are both on the State of California list of Species of Special Concern due to their dwindling numbers. Steelhead trout and Tidewater goby are federally endangered. Other aquatic species in the Malibu Creek Watershed and other coastal watersheds that drain to Santa Monica Bay are: California newts, Western pond turtles, and Red-legged frogs. Western pond turtles are Federally listed and State listed as a Species of Concern, California newts are listed by the State of California as a Species of Special Concern, and Red legged frogs are a Federally threatened species.

Southern steelhead trout: The Southern Steelhead ESU was listed as endangered by the National Marine Fisheries Service in 1997. "Of 92 streams which it (Steelhead) historically spawned in the six coastal counties, it is now absent from 39, including all streams south of Ventura County except Malibu Creek, and San Mateo Creek. The total stream miles in which juveniles now rear is less than 1 percent of the historical number " Moyle,(Peter B., Inland Fishes of California Revised and Expanded. University of California Press, 2002, pg. 281.) Southern steelhead runs have been identified as "the most jeopardized of all California's steelhead populations and have dropped to less than 1% of their pre-1940 estimated abundance (McEwan and Jackson as reported in (Dagit et al, Topanga Creek Watershed Southern Steelhead Trout Preliminary Watershed Assessment and Restoration Plan Report, Prepared for California Department of Fish and Game, March 2003).

In 1998, a small population of steelhead trout were found in the Topanga Creek watershed south of Malibu Creek. In the Santa Monica Mountains only three streams have an existing steelhead trout population: Arroyo Sequit Creek which drains to Leo Carrillo State Beach, Malibu Creek, and Topanga Creek. Snorkel surveys in these creeks have been conducted by the Resource Conservation District of the Santa Monica Mountains for nearly two years on Malibu and Arroyo Sequit Creeks and for nearly five years on Topanga Creek. Between June of 2001 and March of 2003, the highest number of steelhead trout large enough to possibly qualify as an adult fish (>26 cm or 10.25 inches) recorded in Topanga Creek was 15 with the average hovering at approximately 3 adult sized fish. (Dagit et al, Topanga Creek Watershed Southern Steelhead Trout Preliminary Watershed Assessment and Restoration Plan Report, Prepared for California Department of Fish and Game, March 2003). Similar numbers of adult sized steelhead were found in Malibu Creek and only once was a steelhead trout observed in Arroyo Sequit Creek during the snorkel surveys (Rosi Dagit per.com. October 2005). No Pacific lamprey were identified during any of the fish snorkel surveys on Malibu Creek

"Species diversity in Malibu Creek is low, but typical of a small coastal stream in southern California. In both numbers and biomass, the fish community downstream of Rindge Dam is dominated by introduced species, especially largemouth bass, although differences in species abundance among the study reaches were apparent. Largemouth bass abundance increased with distance downstream of Rindge Dam, the inverse of the juvenile distribution pattern of steelhead trout. Moreover, largemouth bass are known to be a predator of young salmonids" (Moyle 1976 as reported in Entrix Inc., Malibu Creek /Santa Monica Steelhead Investigations 1989).

Red-legged frogs: The Red legged frog has been extirpated from 70 percent of its former range and now is found primarily in coastal drainages of central California, from Marin County south to northern Baja California, Mexico. Potential threats to the species include elimination or degradation of habitat from land development and land use activities and habitat invasion by non-native aquatic species (*Recovery Plan Red legged frog* **(Rana aurora draytonii),** *Region 1 U.S. Fish and Wildlife Service Portland, Oregon May 28, 2002 pg IV).* Its population has declined by at least 90% (Center for Biological diversity website Species section California Red-legged frog visited http://www.biologicaldiversity.org/swcbd/species/rlfrog/ January 2006) The Malibu Creek Watershed and other Coastal Watersheds in the Santa Monica Mountains were designated as critical habitat for red legged frog by the USFWS (Department of the Interior, United States Fish and Wildlife Service, Part II **50 CFR Part 17 Endangered and Threatened Wildlife and Plants; Final Determinations of Critical Habitat for the California Red-legged Frog; Final Rule** Federal Register Vol. 66, No. 49 Tuesday March 13, 2001/Rules and Regulations)

According to (CDFG) website "Establishment of a diverse exotic aquatic predator fauna that includes bullfrogs, crayfish, and a diverse array of fishes likely contributed to the decline of the California red-legged frog (Hayes and Jennings 1986 as reported by http://www.dfg.ca.gov/hcpb/cgibin/more_info.asp?idKey=ssc_tespp&specy=amphibians&query= rana%20aurora% 20draytonii) visited January 06). According to the United State

Fish and Wildlife Service (USFWS) red-legged frog recovery plan available at http://ecos.fws.gov/docs/recovery_plans/2002/020528.pdf the "Factors associated with declining populations of the frog include degradation and loss of its habitat through agriculture, urbanization, mining, overgrazing, recreation, timber harvesting, non-native plants, impoundments, water diversions, degraded water quality, use of pesticides, and introduced predators. In 1999, a remnant population of Red-legged frogs were discovered in the Malibu Creek Watershed. This population is estimated to be approximately 25 adults and is currently the only known population in any coastal watershed draining to Santa Monica Bay.

Tidewater goby: Tidewater Goby was listed as endangered by the USFWS in 1994 and has had fully protected status from the State of California since 1987. "Somewhere between 25% and 50% of its population has been lost in the last 100 years, most of them south of Point Conception."(Moyle, Peter B., Inland Fishes of California Revised and Expanded. University of California Press, 2002, pg. 432)."

Arroyo chub: Arroyo chubs are small chunky fish that reach typical adult size between 70-100 mm (Moyle, Peter B., Inland Fishes of California Revised and Expanded. University of California Press, 2002, pg. 131). Arroyo chub are found in slow-moving or backwater sections of warm to cool (10-24°C) streams with mud or sand substrates with depths typically greater than 40 cm. Presently, arroyo chubs are common at only four places within their native range: upper Santa Margarita River and its tributary, De Luz Creek; Trabuco Creek below O'Neill Park and San Juan Creek; Malibu Creek (Swift et al. 1993); and West Fork San Gabriel River below Cogswell Reservoir (J. Deinstadt, unpubl. data). According to Swift et al. (1993), arroyo chubs are scarce within their native range because the low-gradient streams in which they do best have largely disappeared. (Moyle et al, Department of Wildlife & Fisheries Biology Davis, California 1995 Fish Species of Special Concern Second Edition, Prepared for California Department of Fish and Game, pg 151). Their native range, like that of the sympatric Santa Ana sucker, is largely coincident with the Los Angeles metropolitan area where most streams are degraded and populations reduced and fragmented especially the low-gradient stream reaches which formerly contained optimal habitat (Swift et al. 1993 as reported in Moyle, Peter B., Inland Fishes of California Revised and Expanded. University of California Press, 2002, pg. 132). "Chub generally decline when red shiners and other exotics become abundant. In the Santa Margarita River a dramatic increase in arroyo chub abundance was noted after extreme high-flow events in 1997-1998 reduced the abundance of green sunfish, largemouth bass, Red-eye bass and black bullehead The potential effects of introduced species, combined with the continued degradation of the urbanized streams that constitute much of its habitat, mean that this species is not secure despite its wide range." (Moyle, Peter B., Inland Fishes of California Revised and Expanded. University of California Press, 2002, pg. 132).

California newt (Coast range newt): California newts are moderate-sized (50.0-87.0 mm SVL) dark brown salamander with bright yellow-orange to orange undersurfaces (Riemer 1958); thick, relatively textured skin that becomes markedly rough-glandular during its terrestrial phase, but reverts to a relatively smooth condition during its aquatic phase (Nussbaum and Brodie 1981). Coast Range newts frequent terrestrial habitats, but breed in ponds, reservoirs, and slow-moving streams (Stebbins 1954b, 1985 as reported Jennings & Hayes. Amphibian and Reptile Species of Special Concern for California., November 1994 Prepared for CDFG pg. 40).

Historically, *T. t. torosa* may have been one of the most abundant, if not the most abundant amphibian through much of its range. This species has been depleted by large-scale historical commercial exploitation coupled with the loss and degradation of stream habitats, especially in Los Angeles, Orange, Riverside, and San Diego counties. "Our own observations indicated that the breeding habitat of *T. t. torosa* has, at best, been severely degraded over much of its range, largely due to a shift in sedimentation dynamics that has resulted in greater filling and less frequent scouring of pools to allow them to retain their characteristic structure" (Coming 1975 as modified and cited in Faber et al. 1989 as reported Jennings & Hayes. Amphibian and Reptile Species of Special Concern for California., November 1994 Prepared for CDFG pg. 40). Aquatic predators are particularly detrimental to the egg and larval stages of most amphibians because these stages are restricted to water until metamorphisis. (Kats and Gamradt. Conservation Biology, Volume 10. No4. August 1996, pgs. 1155-1162)

Western Pond Turtle: The Western Pond Turtle, *Clemmys marmorata*, is California's only freshwater turtle. The species ranges from southern British Columbia through Washington, Oregon, California, and into northern Baja California. It is listed as endangered in Washington and Oregon and as a species of special concern in California. It has declined by an estimated 95 % since the early 1900's. The primary cause of decline is loss of wetland habitat. The secondary cause is predation of hatchlings by non-native species, especially bullfrogs and large-mouth bass (Website Nature Alley Pond Turtle Page http://natureali.org/pondturtle.htm visited January 06). Additionally, some introduced exotic aquatic predators or competitors likely extract a significant toll on turtle populations. Bullfrogs prey on hatchling or juvenile turtles (Moyle 1973; Holland 1991a; H. Basey, P. Lahanas, and S. Wray, pers. comm.), and may be responsible for significant mortality because they occupy shallow-water habitats in which the youngest age groups of turtles are frequently observed (pers. observ.). Bass *(Micropterus* spp.) are also known to prey on the smallest juveniles (Holland 1991a), and sunfishes *(Lepomis* spp.), although they are not large enough to prey on hatchling western pond turtles, probably compete with them for food since they are known to be able to keep available nekton at very low levels, stunting their own growth (see Swingle and Smith 1940). (Jennings & Hayes. Amphibian and Reptile Species of Special Concern for California., November 1994 Prepared for CDFG) pg. 102.

Exotic Invasive Aquatic Species: Several aquatic invasive species have been identified in the Malibu Creek watershed and in adjacent coastal watersheds draining to Santa Monica Bay: Carp, Largemouth bass, Green sunfish, Bluegill, Mosquitofish, Black bullhead, Red swamp crayfish, and Bullfrogs. Exotic fish species like, largemouth bass (*Micropterus salmoides*), green sunfish (*Lepomis cyanellus*), bluegill (*Lepomis macrochirus*) and black bullhead (*Ameiurus melas*), have been shown to have a strong competitive edge over resident trout. Green sunfish have been found to feed on juvenile trout and out-compete adult steelhead for benthic food (Swift 1975; Greenwood 1988). Largemouth bass take over as top predator in the habitat they occupy and can directly predate steelhead (Stouder et al, 1997). Black bullhead are highly tolerant of high water temperatures and low dissolved oxygen levels and are extremely prolific. By shear numbers, this species can exert a tremendous competitive pressure on an already limited resource. (As reported Hovey, Tim E. Current Status of Southern Steelhead/Rainbow trout In San Mateo Creek 2002).

Largemouth Bass: "Typically when largemouth bass are abundant native fishes are absent, although there are some exceptions" (Moyle, Peter B., Inland Fishes of California Revised and Expanded. University of California Press, 2002, pg. 400). " The flexible foraging strategies of largemouth bass and their wide environmental tolerances have made them a keystone predator in many bodies of water. A keystone predator is a species whose activities can cause changes throughout the ecosystem, usually by changing abundances of favored prey." (Moyle, Peter B., Inland Fishes of California Revised and Expanded. University of California Press, 2002, pg. 399). "In the lower Colorado River largemouth bass are regarded as part of the complex of predatory exotic fishes that prevent the reestablishment of native minnows and suckers. In southern California streams they prey heavily on endangered species, such as tidewater goby". Moyle,(Peter B., Inland Fishes of California Revised and Expanded. University of California Press, 2002, pg. 400.)

Bluegill and Green sunfish: "Bluegill are highly opportunistic feeders, feeding on whatever animal food is most abundant. Small fish , fish eggs, and crayfish may be eaten when available." (Moyle, Peter B., Inland Fishes of California Revised and Expanded. University of California Press, 2002, pg. 384). "The abundance, ubiquity, aggressiveness, and the broad feeding habits of bluegill in lakes and lowland streams of California make it likely that they are one of the alien fishes that limit native fish populations, especially through predation of larvae, or through indirect effects that make natives more vulnerable to larger predators." (Moyle, Peter B., Inland Fishes of California Revised and Expanded. University of California Press, 2002, pg. 384). "The upper, fresher reaches of goby lagoons often contain non-native species, such as mosquitofish, green sunfish, and largemouth bass. They can at times be significant predators on gobies; for example most of the diet of young-of-the-year largemouth bass in the upper Ynez River Estuary was tidewater gobies." (Moyle, Peter B., Inland Fishes of California Revised and Expanded. University of California Press, 2002, pg. 433).

Carp: "Carp have probably displaced or reduced populations of native fish in some areas and have been responsible for the destruction of shallow waterfowl habitat in various parts of the country. (Moyle, Peter B., Inland Fishes of California Revised and Expanded. University of California Press, 2002, pg. 174). "Fish, probably dead before eaten, and fish larvae and eggs, including carp eggs, have been found in their diets." (Moyle, Peter B., Inland Fishes of California Revised and Expanded. University of California Press, 2002, pg. 173).

Mosquitofish: "Mosquito fish have been accused of eliminating small fish species the world over through predation and competitive interactions and a number of such cases in the southwestern United States and Australia have been documented. For example, in small streams of southern California, mosquitofish can eliminate or reduce the abundance of eggs and larvae of California newts and Pacific treefrogs. In California it is quite likely that mosquitofish have contributed to the decline of isolated pupfish populations. In small experimental ponds introduction of mosquitofish resulted in large blooms of phytoplankton after zooplankton grazers had been eaten." (Moyle, Peter B., Inland Fishes of California Revised and Expanded. University of California Press, 2002, pg. 320).

Mosquitofish (*Gambusia affinis*) are native to the eastern United States and have been introduced to wetlands worldwide as biological control agents for mosquito larvae. Studies have also been conducted in Australia on the effects of a closely related species, *Gambusia holbrooki*, on frog tadpoles (*Crinia glauerti, C. insignifera,* and *Heleioporus eyrei*) under experimental conditions and on frog species richness and abundance in the field. These studies (Blyth 1994, Webb and Joss 1997) showed direct predation on tadpoles, injuries to tadpoles in tanks or ponds with *Gambusia*, and reduced survival and recruitment. This practice is a concern to conservationists because introduced Analysis of field data from Australia (Webb and Joss 1997) demonstrated a significant drop in the abundance of frogs when *Gambusia* were present. Results of a study in artificial ponds showed that mosquitofish and bluegill (*Lepomis machrochirus*) were significant predators of California red-legged frog larvae (Schmieder and Nauman 1994). as reported in *Recovery Plan Red legged frog* **(Rana aurora draytonii)**, *Region 1 U.S. Fish and Wildlife Service Portland, Oregon May 28, 2002 pg 25* http://ecos.fws.gov/docs/recovery_plans/2002/020528.pdf.

Bullfrogs and Crayfish Introduced bullfrogs, crayfish, and species of fish have been a significant factor in the decline of the California red-legged frog. Introduced aquatic vertebrates and invertebrates are predators on one or more of the life stages of California redlegged frogs. These include bullfrogs, African clawed frogs (*Xenopus laevis*), red swamp crayfish (*Procambarus clarkii*), signal crayfish (*Pacifastacus leniusculus*), and various species of fishes, especially bass, catfish (*Ictalurus* spp.), sunfish, and mosquitofish (*Gambusia affinis*) (Hayes and Jennings 1986) as reported in *Recovery Plan Red legged frog* **(Rana aurora draytonii)**, *Region 1 U.S. Fish and Wildlife Service Portland, Oregon May 28, 2002 pg 24*
http://ecos.fws.gov/docs/recovery_plans/2002/020528.pdf.

Several researchers in central California have noted the decline and eventual disappearance
of California red-legged frogs once bullfrogs become established at the same site (Moyle 1976, S. Barry *in litt.* 1992, L. Hunt *in litt.* 1993, Fisher and Schaffer 1996). as reported in *Recovery Plan Red legged frog* **(Rana aurora draytonii)**, *Region 1 U.S. Fish and Wildlife Service Portland, Oregon May 28, 2002 pg 24*
http://ecos.fws.gov/docs/recovery_plans/2002/020528.pdf.
Lawler *et al.* (1999) found that fewer than 5 percent of California red-legged frogs survived in ponds with bullfrog tadpoles, and the presence of bullfrogs delayed frog metamorphosis. Hayes and Jennings (1986, 1988) found a negative correlation between the abundance of

introduced fish species and California red legged frogs. as reported in *Recovery Plan Red legged frog* **(Rana aurora draytonii),** *Region 1 U.S. Fish and Wildlife Service Portland, Oregon May 28, 2002 pg 24* http://ecos.fws.gov/docs/recovery_plans/2002/020528.pdf. On Vandenberg Air Force Base (Santa Barbara County), the reproductive success of California red-legged frogs in dune ponds with both non-native fish and bullfrogs was nearly eliminated; in ponds with bullfrogs but no fish, reproduction of California red-legged frogs was evident, though low. Reproductive rates were very high in ponds with neither non-native fish nor bullfrogs (S. Christopher *in litt.* 1998). as reported in *Recovery Plan Red legged frog* **(Rana aurora draytonii),** *Region 1 U.S. Fish and Wildlife Service Portland, Oregon May 28, 2002 pg 24*
http://ecos.fws.gov/docs/recovery_plans/2002/020528.pdf. Overall, while California red-legged frogs are occasionally known to persist in the presence of either bullfrogs or mosquitofish (and other non-native species), the combined effects of both non-native frogs and non-native fish often leads to extirpation of red-legged frogs (Kiesecker and Blaustein 1998, Lawler *et al.*
2000, S. Christopher *in litt.* 1998). as reported in *Recovery Plan Red legged frog* **(Rana aurora draytonii),** *Region 1 U.S. Fish and Wildlife Service Portland, Oregon May 28, 2002 pg 26* http://ecos.fws.gov/docs/recovery_plans/2002/020528.pdf.

Exotic Invasive Species Distribution and Data Summary:
Heal the Bay conducted detailed GPS mapping and field surveys between 2000 and 2005. The Heal the Bay Stream Team conducted Level IV analysis based on the California Department of Fish and Game Salmonid Stream Habitat Restoration Manual methods created by Flosi and Reynolds1994 to survey and map every pool along 70.5 miles of streams throughout the Malibu Creek Watershed. In conjunction with this Level IV pool data, field crew members also conducted visual counts and identification of all aquatic species that were present at the time of the survey for each mapped and surveyed pool. These numbers were recorded on both the hard copy and GPS data forms. The map Figure 1 shows in black the precise pool locations where exotic invasive aquatic species were visually identified and counted. The map in Figure 1 further breaks down each mapped stream into 303 (d) list designated reaches, unless a reach was not previously designated on the 303 (d) list. The types and numbers of exotic invasive species were then totaled by each 303 (d) designated reach. Finally a bar graph showing the total numbers of invasive species by reach was included in the top left corner of the map. (The GIS data in the form of Arc View shapefiles and all appropriate metadata has been provided along with these comments on a CD).

The following reaches were documented as having exotic invasive species in the Malibu Creek watershed from Heal the Bay Stream Team mapping data (Figure 1).
Cold Creek, Liberty Canyon Creek, Unnamed tributary to Las Virgenes Creek (LV Trib), Las Virgenes Creek, Malibu Creek, Lindero Creek Reach 1 and Reach 2, Medea Creek Reach 1 and Reach 2, Triunfo Creek Reach 1 and Reach 2

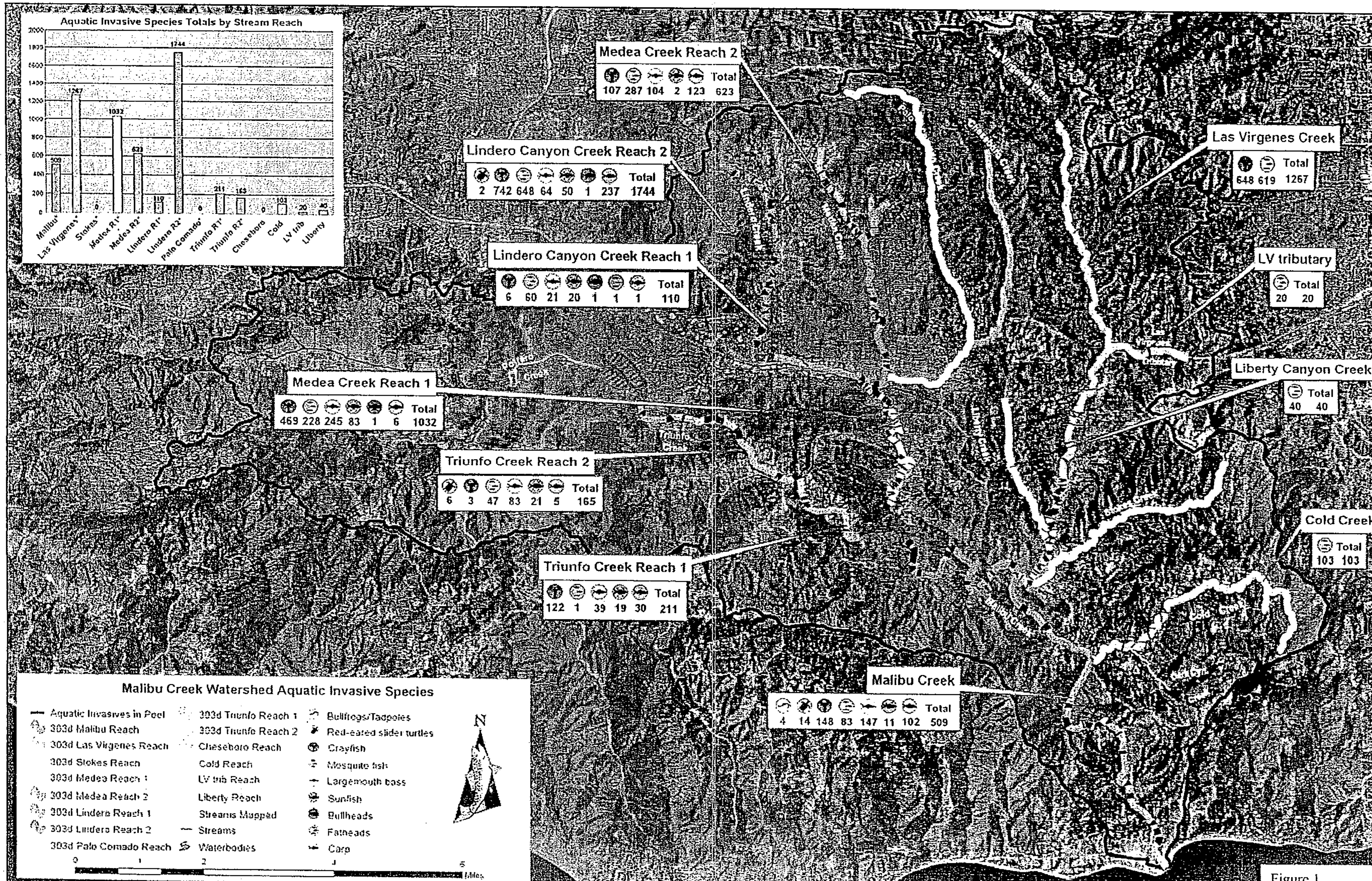

Aquatic Invasive Species Totals by Stream Reach
Malibu
Las Virgenes
Stokes
Medea R1
Medea R2
Lindero R1
Lindero R2
Palo Comado
Triunfo R1
Triunfo R2
Cheseboro
Cold
LV trib
Liberty
Medea Creek Reach 2
107 287 104 2 123 Total 623
Lindero Canyon Creek Reach 2
2 742 648 64 50 1 237 Total 1744
Lindero Canyon Creek Reach 1
6 60 21 20 1 1 1 Total 110
Medea Creek Reach 1
469 228 245 83 1 6 Total 1032
Triunfo Creek Reach 2
6 3 47 83 21 5 Total 165
Triunfo Creek Reach 1
122 1 39 19 30 Total 211
Malibu Creek
4 14 148 83 147 11 102 Total 509
Las Virgenes Creek
648 619 Total 1267
LV tributary
20 Total 20
Liberty Canyon Creek
40 Total 40
Cold Creek
103 Total 103
Malibu Creek Watershed Aquatic Invasive Species
Aquatic Invasives in Pool
303d Malibu Reach
303d Las Virgenes Reach
303d Stokes Reach
303d Medea Reach 1
303d Medea Reach 2
303d Lindero Reach 1
303d Lindero Reach 2
303d Palo Comado Reach
303d Triunfo Reach 1
303d Triunfo Reach 2
Cheseboro Reach
Cold Reach
LV trib Reach
Liberty Reach
Streams Mapped
Streams
Waterbodies
Bullfrogs/Tadpoles
Red-eared slider turtles
Crayfish
Mosquito fish
Largemouth bass
Sunfish
Bullheads
Fatheads
Carp
N
Miles

Figure 1

Heal the Bay Monitoring: Heal the Bay's monthly monitoring program has been monitoring water chemistry and aquatic vertebrates in the Malibu Creek watershed and a few adjacent reference watersheds for more than 7 years. All water quality monitoring data is available for download via the web at www.healthebay.org/streamteam. This water quality sampling data was analyzed to determine where and which exotic invasive predator species were visually observed during monthly water quality sampling events. The results can be seen in Table 1.

Site	Creek	Bull frogs	Mosquito fish	Largemouth bass	crayfish	carp	Sunfish bluegill	Fathead minnows	Black bullhead	Sample days	Observed days	Observed %
1	Malibu	2	2	1	1	1	0	0	0	83	7	8.4%
2	Cold Creek	0	5	0	3	0	0	0	0	83	7	8.4%
4	Malibu (below Malibou Lake)	0	0	0	0	2	1	0	0	59	3	5.1%
5	Las Virgenes	0	4	1	1	0	0	0	0	83	4	4.8%
7	Medea	0	5	0	3	2	1	0	0	83	2	2.4%
12	Malibu @ Rock pool	1	0	2	6	0	0	0	0	42	7	16.7%
13	Las Virgenes @ Agoura Rd	0	1	0	9	0	0	1	0	42	10	23.8%
16	Stokes Creek	0	2	0	0	0	0	0	0	19	2	10.5%
17	Triunfo Creek	2	0	3	2	0	0	0	1	42	6	14.3%

Table 1: Heal the Bay Monitoring Data

The results of the water chemistry data mining indicate that all of Malibu Creek, Cold Creek, Las Virgenes Creek, Medea Creek, Stokes Creek and Triunfo Creek should be 303 (d) listed for exotic invasive predator species. These records are visual observations recorded in the field during water quality monitoring events. These numbers are believed to be extremely conservative as fish and other aquatic species generally are sheltered and not visible when potential predators, in this case water monitoring personnel, are present.

Kats and Gamradt. Conservation Biology, Volume 10. No4. August 1996, pgs. 1155-1162 Kats surveyed 10 streams in the Santa Monica Mountains of southern California May and June 1994 and May and June 1995 which were known to have had California newts when previously surveyed between 1981 and 1986. The 1994 and 1995 Kats surveys found crayfish in Trancas and Malibu Creeks and mosquitofish in Topanga Creek and Malibu Creek. The three streams that contained mosquitofish, and/or crayfish had no California newt eggs, larvae, or adults. The seven streams without crayfish or mosquitofish did contain California newts. Further, Kats conducted laboratory and field experiments that demonstrated crayfish consume California newt egg masses and both mosquitofish and crayfish consume larval newts. In Trancas Creek heavy rains of 1995 removed the crayfish and mosquitofish from the creek and the following spring newt larvae, egg masses, and adults were found.

In a recent paper by Riley et al published in Conservation Biology 2005 Effects of Urbanization on the Distribution and Abundance of Amphibians and Invasive Species in Southern California Streams, the distribution and abundance of native amphibians and exotic predators was determined in 35 streams throughout the Santa Monica mountains and Simi Hills. The study found that streams with crayfish and exotic fish species had fewer native species such as California newt and California treefrogs. Surveys for this study occurred in 2000-2002 and documented the presence of Crayfish in the following streams: Trancas Canyon Creek, Triunfo Canyon Creek, Topanga Canyon Creek, Las Virgenes Creek, Malibu Creek, Medea Creek, and Lindero Canyon Creek. Additionally, the researchers found exotic fish species in Triunfo Canyon Creek, Topanga Canyon Creek, Las Virgenes Creek, Malibu Creek, Liberty Canyon Creek, Medea Creek, and Lindero Canyon Creek. Bullfrogs were only present in Triunfo Creek during this study period.

The Lakes: The Malibu Creek Watershed has 6 man-made lakes that are hydrologically connected to the watershed: Westlake, Lake Sherwood, Lake Lindero Lake Enchanto, Century Lake and Malibou Lake. The lakes serve as protected breeding and rearing areas for largemouth bass, blue gill, green sunfish, black bullhead, carp, mosquito fish, bullfrogs, and crayfish. It is well known that the privately owned Malibou Lake, Lake Sherwood, Lake Lindero and Malibou Lakes are prized by the lakeside residents for their excellent bass, blue gill, and carp fishing. A cursory look at real estate websites for the private lakes tout the excellent fishing as one of the amenities for living in these areas. "Westlake's 150-acre lake is stocked with bass, blue gill and catfish. Docking privileges, fishing licenses, boating and sailing are available to residents." (Website Beach California .com Westlake Village page http://www.beachcalifornia.com/westlake.html visited January 06). Additionally the Malibu Creek Stream Team has documented red ear slider turtles at Westlake and Malibou Lake. We have recently added 10 sites on Malibou Lake including the inlet to the lake at Triunfo and Medea Creeks. Visual observations during monthly monitoring at these sites confirm that bass, and carp are pervasive throughout the lake.

These lakes afford protection to these species that are not adapted to the climatic conditions normally associated with arid southern California which includes large winter flows, flash flooding, and the drying of surface flows during summers and from prolonged droughts. Because these lakes are deep and perennially wet they provide shelter from these conditions even when the exotic species are flushed from the streams or stranded due to diminished flows. The streams are readily repopulated by exotic invasive species from the lakes. For example, Trancas Creek was the one natural stream in the study with less than 8% developed area that had crayfish. Natural streams were defined as having less than 8% development in the watershed draining to a particular stream. At the top of Trancas Creek the Malibu Country Club ponds have crayfish populations that provide a recurring source of propagules, and enough influence from the irrigation of the golf course to generate perennial water in the stream. (Riley et al, Effects of Urbanization on the Distribution and Abundance of Amphibians and Invasive Species in Southern California Streams, Conservation Biology, 2005).
Crayfish are continually introduced as they are used as fishing bait in the lakes. In order to address the issue of exotic invasive predator species it is necessary to control the sources from the lakes.
It is highly recommended that all the lakes in the Malibu Creek watershed be listed for exotic invasive species. They are a continual population source that allows these predator species to quickly repopulate streams even after catastrophic flood or drought events at the expense of native species. It is recommended that the following lakes be placed on

the State 303 (d) list: Lake Sherwood, Malibou Lake, Lake Lindero, Century Lake (Century Reservoir), Lake Enchanto, and Westlake. Additionally, we recommend adding the ponds at the Malibu Country Club Golf Course which were specifically mentioned as the source problem for Trancas Creek (Riley et al Effects of Urbanization on the Distribution and Abundance of Amphibians and Invasive Species in Southern California Streams Conservation Biology 2005).

Index of Biological Integrity: Exotic species can also have a major impact on native macroinvertebrate diversity and abundance for reasons discussed throughout this document. As seen in Appendix 7-A, there are several reaches of the Malibu Creek Watershed that have calculated Index of Biological Integrity (IBI) scores in the "poor" and "very poor" ranges. Specifically, monitored sites within Malibu Creek, Medea Creek, Las Virgenes Creek, and Triunfo Creek have scores below the threshold of 39. These are all areas discussed above as having high densities of exotic predatory species. Thus, in addition to the persuasive information presented above, the low IBI scores should be used as another line of evidence which supports in the listing of exotic species in Malibu Creek Watershed.

Conclusion: This document has presented ample evidence as to the distribution of exotic invasive predator species and their impacts on the dwindling population of native aquatic species in the Santa Monica Mountains and Simi Hills. The documentation provided clearly shows the spatial locations and persistence over time of exotic invasive predator species. This document also clearly demonstrates the need to protect the remaining populations of native aquatic species whose abundance have declined so drastically that all are currently protected by the State of California, the Federal government or both. Based on the presented research and studies we believe that listing for exotic species is warranted and meets the listing criteria. Heal the Bay recommends that the following waterbodies be placed on the State 303 (d) list as impaired for exotic species:

1. Malibu Creek
2. Cold Creek
3. Las Virgenes Creek
4. LV Tributary (Unnamed tributary to Las Virgenes Creek that parallels the 101 fwy in Calabasas).
5. Stokes Creek
6. Liberty Canyon Creek
7. Triunfo Creek Reach 1
8. Triunfo Creek Reach 2
9. Medea Creek Reach 1
10. Medea Creek Reach 2
11. Lindero Creek Reach 1
12. Lindero Creek Reach 2
13. Malibou Lake
14. Lake Sherwood
15. Lake Enchanto
16. Century Lake (Century Reservoir)
17. Westlake
18. Lake Lindero

19. Malibu Country Club Golf Course Ponds
20. Trancas Creek
21. Topanga Creek

#10

Steelhead trout counts (normal and yellow or unhealthy trout) in Malibu Creek Conducted by the Santa Monica Resource Conservation District

- May 2006 - 245 trout of all size classes
- June 2006 - no survey due to NZMS
- July 2006 - 37 yellow trout under 6"
  145 normal trout of all size classes
- August 2006 - 73 yellow trout, 36 normal
- Sept. 2006 - 7 yellow trout, 2 normal
- Sept. 26 - 3 trout captured for pathology
- October 2006 - 2 normal trout
- November 2006 - No trout

#12

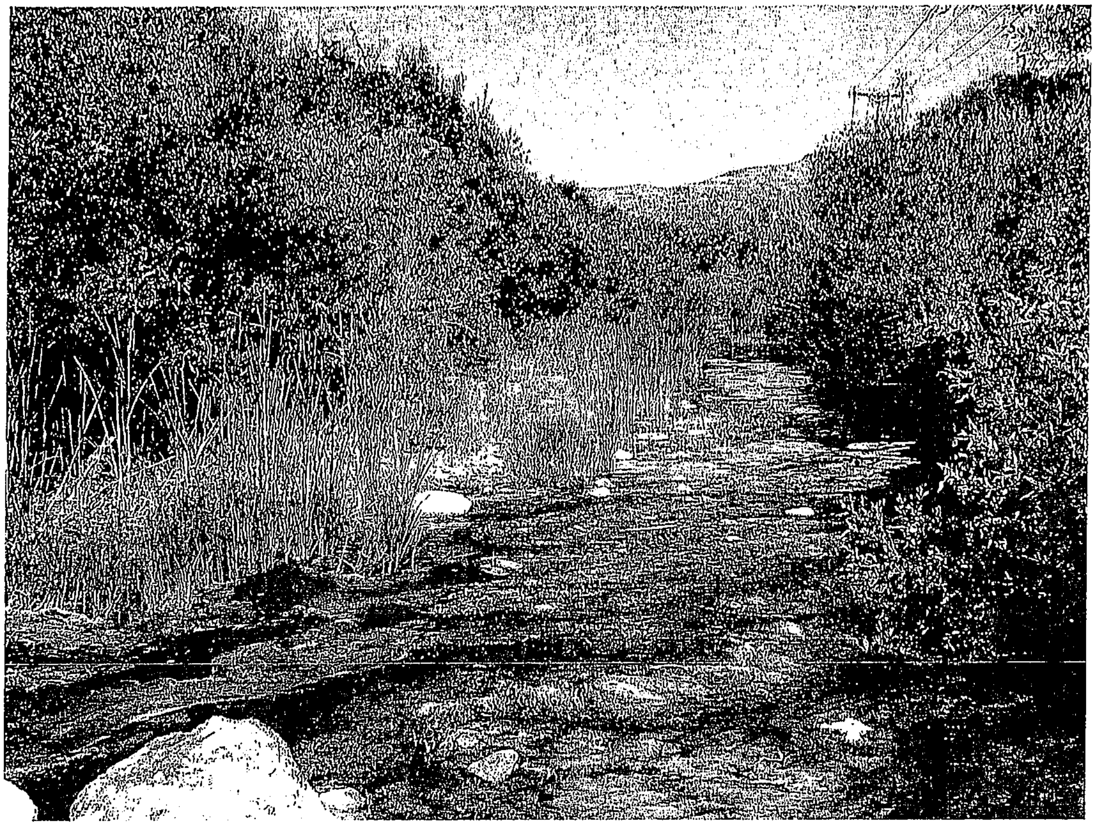
Appendix 3-A: Calleguas Creek Transect Data

Source: Ambrose, R.F., Lee, S.F., and S.P. Bergquist, Environmental Monitoring and Bioassessment of Coastal Watersheds in Ventura and Los Angeles Counties (2003).

Site	Watershed	Macroalgae	Diatoms (Periphyton)		Macroalgae	Macrophytes	Moss	No Cover	Total Cover	Total Vegetation
		Biomass (g/m2)	All diatoms % cover	med. and thick % Cover	% Cover	% Cover	% Cover	%	%	% Cover
Calleguas at Deepwood	Calleguas	0.00	5	0	0	0	0	95	100	5
Calleguas at Deepwood	Calleguas	0.00	95	0	0	0	0	5	100	95
Calleguas at Deepwood	Calleguas	0.00	95	0	0	0	0	5	100	95
Calleguas at Deepwood	Calleguas	0.00	0	0	0	0	0	100	100	0
Calleguas at Deepwood	Calleguas	0.00	55	30	0	0	0	45	100	55
Calleguas at Deepwood	Calleguas	0.00	100	55	0	0	0	0	100	100
Oaks Mall	Calleguas	0.00	65	45	0	0	0	35	100	65
Oaks Mall	Calleguas	0.00	30	10	0	0	0	70	100	30
Oaks Mall	Calleguas	0.02	90	65	0	0	0	10	100	90
Oaks Mall	Calleguas	0.00	25	25	0	0	0	75	100	25
Oaks Mall	Calleguas	0.00	40	25	0	0	0	60	100	40
Oaks Mall	Calleguas	0.00	10	10	0	0	0	90	100	10
Ramo Rd	Calleguas	0.02	50	0	0	20	0	30	100	70
Ramo Rd	Calleguas	0.02	15	5	0	5	0	80	100	20
Ramo Rd	Calleguas	0.02	40	20	0	0	0	60	100	40
Ramo Rd	Calleguas	0.02	40	0	0	5	0	55	100	45
Ramo Rd	Calleguas	0.02	50	25	0	5	0	45	100	55
Ramo Rd	Calleguas	0.02	25	5	0	5	0	70	100	30
FC @ VentuPark Rd.	Calleguas	13.65	25	15	60	5	0	10	100	90
FC @ VentuPark Rd.	Calleguas	0.45	25	10	40	0	0	35	100	65
FC @ VentuPark Rd.	Calleguas	15.95	60	10	35	0	0	5	100	95
FC @ VentuPark Rd.	Calleguas	10.12	50	40	20	5	0	25	100	75
FC @ VentuPark Rd.	Calleguas	6.29	45	30	30	10	0	15	100	85
FC @ VentuPark Rd.	Calleguas	1.40	55	10	40	0	0	5	100	95
FC @ Young Rd	Calleguas	0.04	50	0	0	0	0	50	100	50
FC @ Young Rd	Calleguas	1.23	50	0	10	0	0	40	100	60
FC @ Young Rd	Calleguas	2.05	0	0	40	0	0	60	100	40
FC @ Young Rd	Calleguas	0.56	10	0	10	0	0	80	100	20
FC @ Young Rd	Calleguas	0.04	10	0	20	0	0	70	100	30
FC @ Young Rd	Calleguas	0.05	10	0	20	0	0	70	100	30
Upper Wildwood	Calleguas	0.00	0	0	0	0	0	100	100	0
Upper Wildwood	Calleguas	0.00	5	0	0	0	0	95	100	5
Upper Wildwood	Calleguas	0.00	65	0	0	0	0	35	100	65
Upper Wildwood	Calleguas	0.00	80	60	0	0	0	20	100	80
Upper Wildwood	Calleguas	0.00	0	0	0	0	0	100	100	0
Upper Wildwood	Calleguas	0.00	0	0	0	100	0	0	100	100
Leisure Village	Calleguas	0.15	45	10	20	0	0	35	100	65
Leisure Village	Calleguas	0.02	20	10	25	0	0	55	100	45
Leisure Village	Calleguas	0.02	5	0	20	20	0	55	100	45
Leisure Village	Calleguas	0.02	20	15	0	20	0	60	100	40
Leisure Village	Calleguas	0.02	5	0	5	30	0	60	100	40
Leisure Village	Calleguas	0.45	20	5	10	15	0	55	100	45
Bottom Conejo Creek	Calleguas	0.00	0	0	0	15	0	85	100	15
Bottom Conejo Creek	Calleguas	0.00	5	5	0	5	0	90	100	10
Bottom Conejo Creek	Calleguas	0.00	5	5	0	5	0	90	100	10
Bottom Conejo Creek	Calleguas	0.00	0	0	0	0	0	100	100	0
Bottom Conejo Creek	Calleguas	0.00	0	0	0	0	0	100	100	0
Bottom Conejo Creek	Calleguas	0.00	0	0	10	5	0	85	100	15

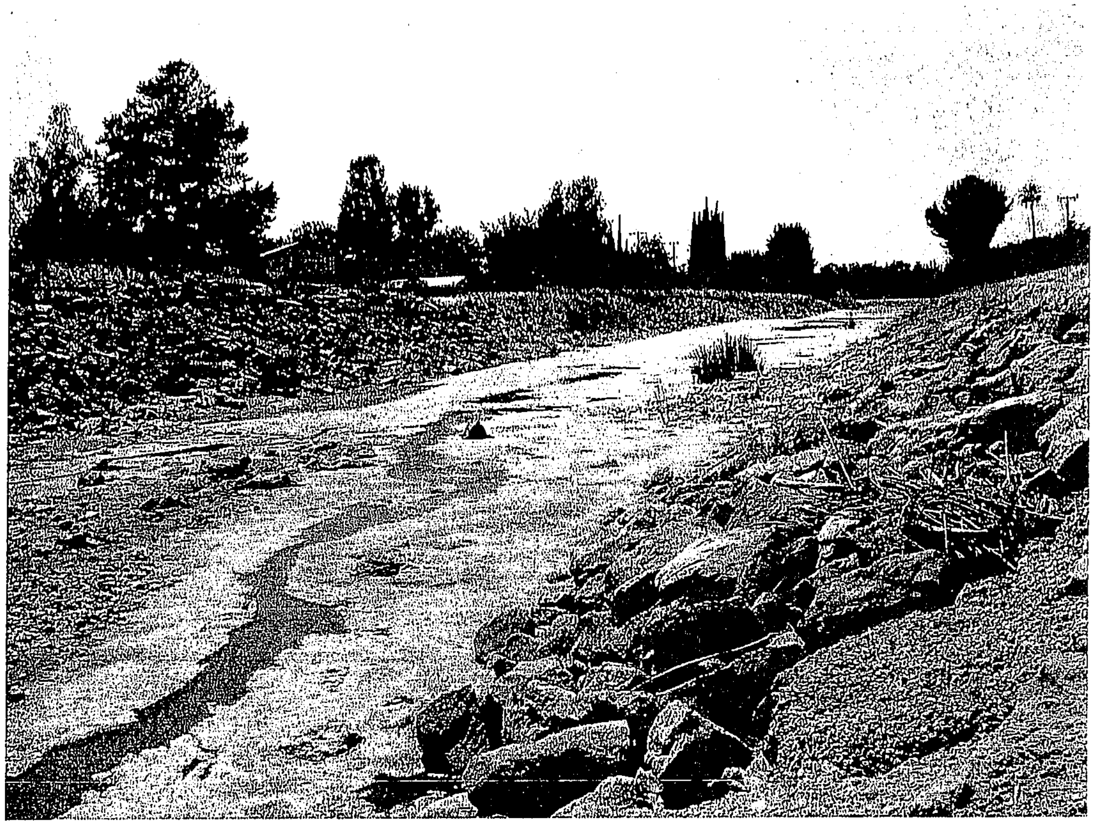
#13

Appendix 3-B: Calleguas Creek Photographs

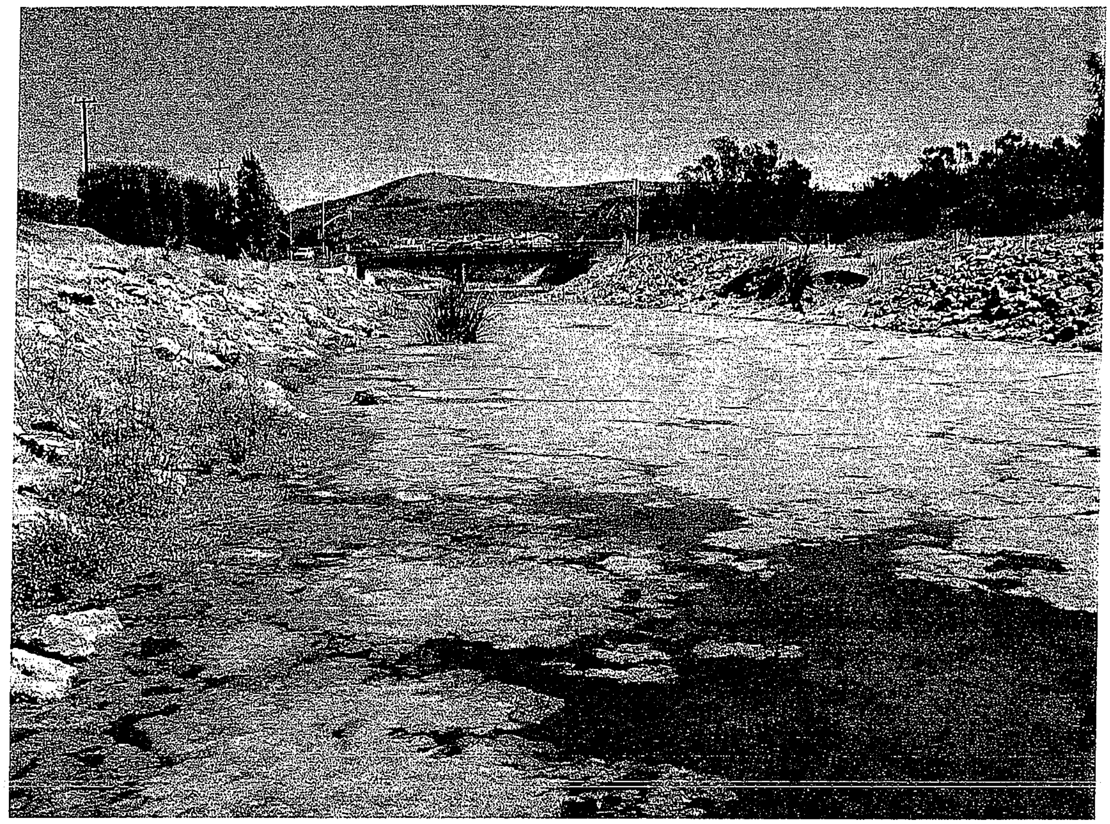


Calleguas Creek – Reach 10 (Arroyo Conejo Canyon). Photograph taken in summer 2004 by Steve Lee of UCLA.

Calleguas Creek – Reach 10 (Arroyo Conejo Canyon). Aerial photograph taken in summer 2004 by Steve Lee of UCLA.



Calleguas Creek – Reach 7 (Arroyo Simi). Photograph taken in summer 2004 by Steve Lee of UCLA.



Calleguas Creek – Reach 7 (Arroyo Simi). Photograph taken in summer 2004 by Steve Lee of UCLA.

#18 + #19

Region 4 IBI Scores

REGION 4 CDFG IBI SCORES

Stream Name	Year	IBI Score[1,2]
Piru Creek	2000	31.46
Unknown Creek	2000	27.17
Revolon Slough	2001	11.44
Unnamed Creek	2001	28.6
Cattle Creek	2000	31.46
Boulder Creek	2001	31.46
Arroyo Conejo Creek	2001	22.88
NF Arroyo Conejo Creek	2001	21.45
Arroyo Simi Creek	2001	17.16
Bouquet Canyon Creek	2001	24.31
Beardsley Wash	2001	14.3
Conejo Creek	2001	27.17
Castaic Creek	2001	25.74
Calleguas Creek	2001	1.43
Piru Creek	2001	25.74
Revolon Slough	2001	5.72
Santa Clara River	2001	20.02
Santa Clara River	2001	37.18
Santa Clara River	2001	37.18
San Francisquito Creek	2001	31.46
Simi Las Posas Creek	2001	17.16
Tapo Canyon Tributary	2001	17.16

Table 1: IBI scores for Region 4 calculated in a CDFG study. Ode, P.R., A.C. Rehn and J.T. May., A Quantitative Tool for Assessing the Integrity of Southern Coastal California Streams, *Environmental Management*. 35:493-504 (2005).

1: IBI Scores are normalized
2: Only scores in "poor" and "very poor" ranges are presented.

LA COUNTY IBI SCORES

SAMPLING LOCATION	IBI SCORE (Oct-03)[1]	IBI SCORE (Oct-04)[1]
Santa Clara River - Station 1	30	27.14
Coyote Creek - Station 2	4.29	2.86
San Jose Creek - Station 3	11.43	18.57
San Gabriel River - Station 4	42.86	57.14
Walnut Channel - Station 5	10	8.57
Arroyo Seco - Station 6	NA	NA
Arroyo Seco - Station 7	15.71	12.86
Compton Creek - Station 8	1.43	4.29
Zone 1 Ditch - Station 9	28.57	NA
Eaton Wash - Station 10	NA	NA
Los Angeles River - Station 11	1.43	4.29
Los Angeles River - Station 12	15.71	12.86
Los Angeles River - Station 13	2.86	10
Ballona Creek - Station 14	8.57	14.29
Madea Creek - Station 15	4.29	7.14
Las Virgenes Creek - Station 16	NA	NA
Cold Creek - Station 17	60	74.29
Triunfo Creek - Station 18	31.43	NA
Dominguez Channel - Station 19	4.29	8.57

Table 2: IBI scores for LA County. Highlighted scores are in the "poor" or "very poor" ranges. Los Angeles County. Los Angeles County 1994-2005 Integrated Receiving Water Impacts Report, (2005).

1: Scores are normalized to a scale of 0-100
NA: not sampled due to dry conditions

VENTURA COUNTY IBI SCORES

SAMPLING LOCATION	IBI Score (2004/2005)
Ventura River - Main St Bridge	31
Ventura River - Foster Park	47
Ventura River - Below Matilija Dam	40
Ventura River - Santa Ana Rd	NA
Canada Larga - Below Grazing	NA
Canada Larga - Above Grazing	NA
San Antonio Creek - u/s Ventura Rv Confluence	NA
San Antonio Creek - Lion Canyon u/s San Antonio	NA
San Antonio Creek - u/s Lion Canyon	45
San Antonio Creek - Stewart Canyon u/s San Antonio	54
San Antonio Creek - u/s Steward Canyon Creek	53
North Fork Matilija Creek - u/s Ventura Rv Confluence	50
North Fork Matilija Creek - At gauging station	64
Matilija Creek - Below Community	39
Matilija Creek - Above Community	NA

Table 3: IBI scores for Ventura County. Highlighted scores are in the "poor" or "very poor" ranges. Ventura County Watershed Protection District, Ventura River Watershed 2004 Bioassessment Monitoring Report, (2005).

NA: not sampled due to dry conditions

#17

Appendix 7-B

DOI: 10.1007/s00267-004-0035-8

A Quantitative Tool for Assessing the Integrity of Southern Coastal California Streams

PETER R. ODE*
Aquatic Bioassessment Laboratory
Water Pollution Control Laboratory
Department of Fish and Game
2005 Nimbus Road
Rancho Cordova, California 95670, USA

ANDREW C. REHN
Aquatic Bioassessment Laboratory
Chico State University Research Foundation
2005 Nimbus Road
Rancho Cordova, California 95670, USA

JASON T. MAY
3421 I Street 1
Sacramento, California, 95816, USA

ABSTRACT / We developed a benthic macroinvertebrate index of biological integrity (B-IBI) for the semiarid and populous southern California coastal region. Potential reference sites were screened from a pool of 275 sites, first with quantitative GIS landscape analysis at several spatial scales and then with local condition assessments (in-stream and riparian) that quantified stressors acting on study reaches. We screened 61 candidate metrics for inclusion in the B-IBI based on three criteria: sufficient range for scoring, responsiveness to watershed and reach-scale disturbance gradients, and minimal correlation with other responsive metrics. Final metrics included: percent collector-gatherer + collector-filterer individuals, percent noninsect taxa, percent tolerant taxa, Coleoptera richness, predator richness, percent intolerant individuals, and EPT richness. Three metrics had lower scores in chaparral reference sites than in mountain reference sites and were scored on separate scales in the B-IBI. Metrics were scored and assembled into a composite B-IBI, which was then divided into five roughly equal condition categories. PCA analysis was used to demonstrate that the B-IBI was sensitive to composite stressor gradients; we also confirmed that the B-IBI scores were not correlated with elevation, season, or watershed area. Application of the B-IBI to an independent validation dataset (69 sites) produced results congruent with the development dataset and a separate repeatability study at four sites in the region confirmed that the B-IBI scoring is precise. The SoCal B-IBI is an effective tool with strong performance characteristics and provides a practical means of evaluating biotic condition of streams in southern coastal California.

Assemblages of freshwater organisms (e.g., fish, macroinvertebrates, and periphyton) are commonly used to assess the biotic condition of streams, lakes, and wetlands because the integrity of these assemblages provides a direct measure of ecological condition of these water bodies (Karr and Chu 1999). Both multimetric (Karr and others 1986; Kerans and Karr 1994; McCormick and others 2001; Klemm and others 2003) and multivariate (Wright and others 1983; Hawkins and others 2000; Reynoldson and others 2001) methods have been developed to characterize biotic condition and to establish thresholds of ecological impairment. In both approaches, the ability to recognize degradation at study sites relies on an understanding of the organismal assemblages expected in the absence of disturbance. Thus, the adoption of a consistent and quantifiable method for defining reference condition is fundamental to any biomonitoring program (Hughes 1995).

KEY WORDS: Benthic macroinvertebrates; B-IBI; Biomonitoring; Mediterranean climate

Published online May 10, 2005.
*Author to whom correspondence should be addressed; *email:* pode@ospr.dfg.ca.gov

Southern California faces daunting challenges in the conservation of its freshwater resources due to its aridity, its rapidly increasing human population, and its role as one of the world's top agricultural producers. In recent years, several state and federal agencies have become increasingly involved in developing analytical tools that can be used to assess the biological and physical condition of California's streams and rivers. For example, the US Environmental Protection Agency (EPA), the US Forest Service (USFS), and California's state and regional Water Quality Control Boards (WQCBs) have collected fish, periphyton and benthic macroinvertebrates (BMIs) from California streams and rivers as a critical component of regional water quality assessment and management programs. Together, these agencies have sampled BMIs from thousands of sites in California, but no analysis of BMI assemblage datasets based on comprehensively defined regional reference conditions has yet been undertaken. In the only other large-scale study within the state, Hawkins and others (2000) developed a predictive model of biotic integrity for third- to fourth-order streams on USFS lands in three montane regions in northern California. This ongoing effort (Hawkins unpublished) is an important contribution to bioassessment in the state, but the emphasis of this work has been concentrated on logging impacts within USFS lands. The lack of a broadly defined context for interpretation of BMI-based bioassessment remains the single largest impediment to the development of biocriteria for the majority of California streams and rivers. This article presents a benthic index of biotic integrity (B-IBI) for wadeable streams in southern coastal California assembled from BMI data collected in the region by the USFS, EPA, and state and regional WQCBs between 2000 and 2003.

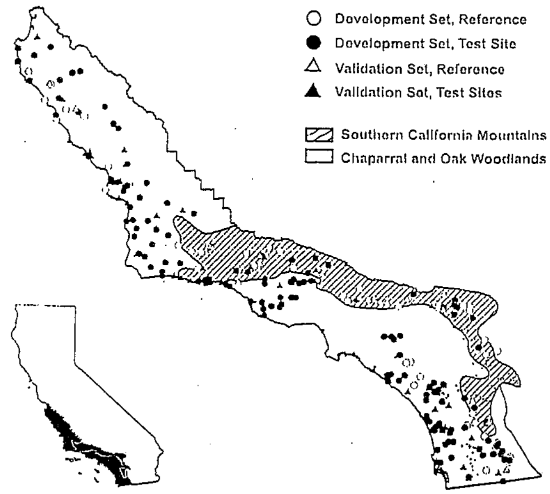


Figure 1. Map of study area showing the location of the study area within California, the distribution of test and reference sites and development and validation sites, and the boundaries of the two main ecoregions in the study area.

Methods

Study Area

The Southern Coastal California B-IBI (SoCal B-IBI) was developed for the region bounded by Monterey County in the north, the Mexican border in the south, and inland by the eastern extent of the southern Coast Ranges (Figure 1). This Mediterranean climate region comprises two Level III ecoregions (Figure 1; Omernik 1987) and shares a common geology (dominated by recently uplifted and poorly consolidated marine sediments) and hydrology (precipitation averages 10–20 in./year in the lower elevations and 20–30 in./year in upper elevations, reaching 30–40 in./year in the highest elevations and in some isolated coastal watersheds (Spatial Climate Analysis Service, Oregon State University, www.climatesource.com). The human population in the region was approximately 20 million in 2000 and is projected to exceed 28 million by 2025 (California Department of Finance, Demographic Research Unit, www.dof.ca.gov).

Field Protocols and Combining Datasets

The SoCal B-IBI is based on BMI and physical habitat data collected from 275 sites (Figure 1) using the 3 protocols described in the following subsections. Sites were sampled during base flow periods between April and October of 2000–2003.

California Stream Bioassessment Protocol (CSBP, 144 sites). Several of the regional WQCBs in southern coastal California have implemented biomonitoring programs in their respective jurisdictions and have collected BMIs according to the CSBP (Harrington 1999). At CSBP sites, three riffles within a 100-m reach were randomly selected for sampling. At each riffle, a transect was established perpendicular to the flow, from which three separate areas of 0.18 m^2 each were sampled upstream of a 0.3-m-wide D-frame net and composited by transect. A total of 1.82 m^2 of substrate was sampled per reach and 900 organisms were subsampled from this material (300 organisms were processed separately from each of 3 transects). Water chemistry data were collected in accordance with the protocols of the different regional WQCBs (Puckett 2002) and qualitative physical habitat characteristics were measured according to Barbour and others (1999) and Harrington (1999).

USFS (56 sites). The USFS sampled streams on national forest lands in southern California in 2000 and 2001 using the targeted riffle protocol of Hawkins and others (2001). All study reaches were selected nonrandomly as part of a program to develop an interpretive (reference) framework for the results of stream biomonitoring studies on national forests in California. BMIs were sampled at study reaches (containing at least four fast-water habitat units) by disturbing two separate 0.09-m^2 areas of substrate upstream of a 0.3-m-wide D-frame net in each of four separate fast-water units; a total of 0.72 m^2 was disturbed and all sample material from a reach was composited. Field crews used a combination of qualitative and quantitative measures to collect physical habitat and water chemistry data (Hawkins and others 2001). A 500-organism subsample was processed from the composite sample and identified following methods described by Vinson and Hawkins (1996).

Environmental Monitoring and Assessment Program (EMAP, 75 sites). The EPA sampled study reaches in southern coastal California from 2000 through 2003 as part of its Western EMAP pilot project. A sampling reach was defined as 40 times the average stream width at the center of the reach, with a minimum reach length of 150-m and maximum length of 500-m. A BMI sample was collected at each site using the USFS methodology described earlier (Hawkins and others 2001) in addition to a standard EMAP BMI sample (not used in this analysis). A 500-organism subsample was processed in the laboratory according to EMAP standard taxonomic effort levels (Klemm and others 1990). Water chemistry samples were collected from the midpoint of each reach and analyzed using EMAP protocols (Klemm and Lazorchak 1994). Field crews recorded physical habitat data using EPA qualitative methods (Barbour and others 1999) and quantitative methods (Kaufmann and others 1999).

As part of a methods comparison study, 77 sites were sampled between 2000 and 2001 with both the CSBP and USFS protocols. The two main differences between the methods are the area sampled and the number of organisms subsampled (discussed earlier). To determine the effect of sampling methodology on assessment of biotic condition, we compared the average difference in a biotic index score between the two methods at each site. Biotic index scores were computed with seven commonly used biotic metrics (taxonomic richness, Ephemoptera, Plecoptera, and Trichoptera (EPT) richness, percent dominant taxon, sensitive EPT individuals, Shannon diversity, percent intolerant taxa, and percent scraper individuals) according to the following equation:

$$Score = \sum (x_i - \bar{x})/sem_i$$

where x_i is the site value for the ith metric, x is the overall mean for the ith metric, and SEM_i is the standard error of the mean for the ith metric. A score of zero is the mean value.

Because USFS-style riffle samples were collected at all EMAP sites, only two field methods were combined in this study. All EMAP and CSBP samples were collected and processed by the California Department of Fish and Game's Aquatic Bioassessment Laboratory (ABL) and all USFS samples were processed by the US Bureau of Land Management's Bug Lab in Logan, Utah. Taxonomic data from both labs were combined in an MS Access© database application that standardized BMI taxonomic effort levels and metric calculations, allowing us to minimize any differences between the two labs that processed samples. Taxonomic effort followed standards defined by the California Aquatic Macroinvertebrate Laboratory Network (CAMLnet 2002; www.dfg.ca.gov/cabw/camlnetste.pdf). Sites with fewer than 450 organisms sampled were omitted from the analyses.

Screening Reference Sites

We followed an objective and quantitative reference site selection procedure in which potential reference sites were first screened with quantitative Geographical Information System (GIS) land-use analysis at several spatial scales and then local condition assessments (instream and riparian) were used to quantify stressors acting within study reaches. We calculated the proportions of different land-cover classes and other measures of human activity upstream of each site at four spatial scales that give unique information about potential stressors acting on each site: (1) within polygons delimiting the entire watershed upstream of each sampling site, (2) within polygons representing local regions (defined as the intersection of a 5-km-radius circle around each site and the primary watershed polygon), (3) within a 120-m riparian zone on each side of all streams within each watershed, and (4) within a 120-m riparian zone in the local region. We used the ArcView® (ESRI 1999) extension ATtILA (Ebert and Wade 2002) to calculate the percentage of various land-cover classes (urban, agriculture, natural, etc.) and other measures of human activity (population density, road density, etc.) in each of the four spatial areas defined for each site. Two satellite imagery datasets from the mid-1990s were combined for the land-cover analyses: California Land Cover Mapping & Monitoring Program (LCMMP) vegetation data (CalVEG) and a recent dataset produced by the Central Coast Watershed Group (Newman and Watson 2003). Population data were derived from the 2000 migrated TIGER dataset (California Department of Forestry and Fire Protection, www.cdf.ca.gov). Stream layers were obtained from the US Geological Survey (USGS) National Hydrography Dataset (NHD). The road network was obtained from the California Spatial Information Library (CaSIL, gis.ca.gov) and elevation was based on the USGS National Elevation Dataset (NED). Frequency histograms of land-use percentages for all sites were used to establish subjective thresholds for elim-

Table 1. List of minimum or maximum landuse thresholds used for rejecting potential reference sites

Stressor metric	Definition	Threshold
N_index_L	Percentage of natural land use at the local scale	≤ 95%
Purb_L	Percental of urban land use at the local scale	> 3%
Pagt_L	Percentage of total agriculture at the local scale	> 5%
Rddens_L	Road density at the local scale	> 2.0 km/km^2
PopDens_L	Population density (2000 census) at the local scale	> 150 indiv./km^2
N_index_W	Percentage of natural landuse at the watershed scale	≤ 95%
Purb_W	Percentage of urban landuse at the watershed scale	> 5%
Pagt_W	Percentage of total agriculture at the watershed scale	> 3%
Rddens_W	Road density at the watershed scale	> 2.0 km/km^2
PopDens_W	Population density (2000 census) at the watershed scale	> 150 indiv./km^2

inating sites from the potential reference pool (Table 1). Sites were further screened from the reference pool on the basis of reach-scale conditions (obvious bank instability or erosion/ sedimentation problems, evidence of mining, dams, grazing, recent fire, recent logging).

Eighty-eight sites passed all the land-use and local condition screens and were selected as reference sites, leaving 187 sites in the test group. We randomly divided the full set of sites into a development set (206 sites total: 66 reference/140 test) and a validation set (69 sites total: 22 reference/47 test). The development set was used to screen metrics and develop scoring ranges for component B-IBI metrics; the validation set was used for an independent evaluation of B-IBI performance.

Screening Metrics and Assembling the B-IBI

Sixty-one metrics were evaluated for possible use in the SoCal B-IBI (Table 2). A multistep screening process was used to evaluate each metric for (1) sufficient range to be used in scoring, (2) responsiveness to watershed-scale and reach-scale disturbance variables, and (3) lack of correlation with other responsive metrics.

Pearson correlations between all watershed-scale and reach-scale disturbance gradients were used to define the smallest suite of independent (nonredundant) disturbance variables against which to test biological metric response. Disturbance variables with correlation coefficients $|r| \geq 0.7$ were considered redundant. Responsiveness was assessed using visual inspection of biotic metric versus disturbance gradient scatterplots and linear regression coefficients. Metrics were selected as responsive if they showed either a linear or a "wedge-shaped" relationship with disturbance gradients. Biological metrics often show a "wedge-shaped" response rather than a linear response to single disturbance gradients because the single gradient only defines the upper boundary of the biological response; other independent disturbance gradients and natural limitations on species distributions might result in lower metric values than expected from response to the single gradient. Biotic metrics and disturbance gradients were log-transformed when necessary to improve normality and equalize variances. Metrics that passed the range and responsiveness tests were tested for redundancy. Pairs of metrics with product–moment correlation coefficients $|r| \geq 0.7$ were considered redundant and the least responsive metric of the pair was eliminated.

Scoring ranges were defined for each metric using techniques described in Hughes and others (1998), McCormick and others (2001), and Klemm and others (2003). Metrics were scored on a 0–10 scale using statistical properties of the raw metric values from both reference and nonreference sites to define upper and lower thresholds. For positive metrics (those that increase as disturbance decreases), any site with a metric value equal to or greater than the 80th percentile of reference sites received a score of 10; any site with a metric value equal to or less than the 10th percentile of the nonreference sites received a score of 0; these thresholds were reversed for negative metrics (20th percentile of reference and 90th percentile of nonreference). In both cases, the remaining range of intermediate metric values was divided equally and assigned scores of 1 through 9. Before assembling the B-IBI, we tested whether any of the final metrics were significantly different between chaparral and mountain reference sites in the southern California coastal region, in which case they would require separate scoring ranges in the B-IBI. Finally, an overall B-IBI score was calculated for each site by summing the constituent metric scores and adjusting the B-IBI to a 100-point scale.

Table 2. The 61 BMI metrics screened for use in the SoCal IBI

Candidate metrics	Disturbance variables: U_index_W	Pagt_W	Purb_L	RdDens_L	Channel Alteration	Bank Stability	Percent Fines	Total Dissolved Solids	Total Phosphorus	Total Nitrogen	Range Test
Taxonomic group metrics											
Coleoptera richness*	M	w	M	S	S	—	—	—	—	—	P
Crustacea + Mollusca richness	—	—	—	—	—	—	—	—	—	—	F
Diptera richness	—	—	—	—	—	—	—	—	—	—	P
Elmidae richness	w	—	w	M	S	M	S	M	—	—	F
Ephemerellidae richness					S	M	M	S	—	M	F
Ephemeroptera richness	S	S	M	S	w	M	S	S	—	S	P
EPT richness*	S	S	S	S	S	S	S	S	—	S	P
Hydropsychidae richness	—	—	w	—	S	—	—	—	—	—	F
Percent Amphipoda individuals	—	—	—	—	—	—	—	—	—	—	P
Percent Baetidae individuals	—	—	—	—	w	—	—	—	—	—	P
Percent Chironomidae individuals	—	—	—	—	—	—	—	—	M	—	P
Percent Corbicula individuals	—	—	—	—	—	—	—	—	—	—	P
Percent Crustacea individuals	—	—	—	—	—	—	—	—	—	—	P
Percent Diptera individuals	—	w	—	—	—	—	—	—	—	—	P
Percent Elmidae individuals	—	—	—	w	M	S	S	w	—	M	P
Percent Ephemeroptera individuals	—	w	w	—	M	w	—	—	—	—	P
Percent EPT individuals	—	—	M	M	M	M	—	—	—	—	P
Percent Gatropoda individuals	—	—	—	w	—	—	—	—	—	—	P
Percent Glossosomatidae individuals	—	—	—	—	w	—	—	—	—	M	F
Percent Hydropsychidae individuals	—	—	—	M	w	M	—	—	—	—	P
Percent Hydroptilidae individuals	—	—	—	M	—	w	—	—	—	—	F
Percent Mollusca individuals	—	—	—	w	w	—	—	—	—	—	P
Percent non-*Baetis/Fallceon* Ephemeroptera individuals	w	w	—	M	w	M	—	—	w	—	P
Percent non-*Hydropsyche* Hydropsychidae individuals	—	—	—	M	w	w	—	—	—	—	F
Percent non-*Hydropsyche/Cheumatopsyche* Trichoptera individuals	w	w	—	M	w	M	M	w	—	—	P
Percent non-insect Taxa*	M	w	M	M	w	—	—	—	w	M	F
Percent Oligochaeta individuals	—	—	—	—	w	—	—	—	—	—	P
Percent Perlodidae individuals	—	—	—	w	w	—	—	—	—	—	F
Percent Plecoptera individuals	—	—	—	M	M	M	M	M	w	S	P
Percent Rhyacophilidae individuals	—	—	—	w	S	S	w	—	—	M	F
Percent Simuliidae individuals	—	w	—	w	S	w	—	—		—	P
Percent Trichoptera	w	—	—	M	M	M	M	w	w	—	P
Plecoptera richness	M	S	w	M	w	w	M	S	—	S	F
Total taxa richness	M	M	w	S	w	w	w	w	w	M	P
Trichoptera richness	S	S	S	S	S	M	S	w	—	w	P

Table 2. Continued.

Candidate metrics	U_index_W	Pagt_W	Purb_L	RdDens_L	Channel Alteration	Bank Stability	Percent Fines	Total Dissolved Solids	Total Phosphorus	Total Nitrogen	Range Test
	Disturbance variables										
Functional feeding metrics											
Collector (filterers) richness	w	—	M	S	S	M	w	—	—	—	F
Collector (gatherers) richness	—	—	—	—	—	—	—	—	—	w	P
Percent collector (filterer) + collector (gatherer) individuals*	M	—	—	S	—	w	—	M	w	M	P
Percent collector (filterer) individuals	—	—	—	w	M	M	w	—	—	—	P
Percent collector (gatherer) individuals	—	—	—	w	M	—	—	w	M	w	P
Percent predator individuals	—	—	—	w	M	—	—	—	—	—	P
Percent scraper individuals	w	w	—	M	M	w	w	—	—	—	P
Percent scraper minus snails individuals	—	—	—	w	—	w	—	—	—	—	P
Percent shredder individuals	—	—	—	w	w	—	—	—	—	—	P
Predator richness*	S	S	w	M	w	—	—	S	—	M	P
Scraper richness	S	M	M	S	S	S	S	S	—	S	P
Shredder richness	M	M	—	M	S	—	—	—	—	M	F
Tolerance metrics											
Average tolerance value	M	w	w	S	w	—	M	—	—	w	P
Intolerant EPT richness	M	w	w	M	S	—	S	S	—	S	P
Intolerant taxa richness	M	w	w	M	S	M	S	S	—	S	P
Percent intolerant Diptera individuals	—	—	—	—	—	—	—	—	—	—	F
Percent intolerant individuals*	M	w	—	M	S	M	M	S	—	M	P
Percent intolerant scraper individuals	—	—	—	w	M	w	w	w	—	—	P
Percent of intolerant Ephemeroptera individuals	—	—	—	w	w	—	w	w	—	—	P
Percent of intolerant Trichoptera individuals	—	w	—	—	w	w	w	w	—	—	P
Percent sensitive EPT individuals	w	w	—	M	M	M	M	M	w	M	P
Percent tolerant individuals	—	—	—	—	—	—	w	w	—	—	P
Percent tolerant taxa*	w	—	w	M	—	—	—	w	—	M	P
Tolerant taxa richness	—	—	—	—	—	M	—	—	—	—	P
Others											
Percent dominant taxon	—	—	—	—	—	—	—	—	—	—	P
Shannon Diversity Index	w	w	w	M	M	w	—	w	w	w	P

Note: Each metric is indicated as having either no response (—), weak response (w), moderate response (M), or strong response (S) to each of eleven minimally correlated disturbance variables and whether each metric passed (P) or failed (F) the range test. The final seven minimally correlated metrics are indicated with an asterisk (*).

Table 3. Scoring ranges for seven component metrics in the SoCal B-IBI

Metric score	Coleoptera taxa (all sites)	EPT taxa		Predator taxa (all sites)	% Collector individuals		% Intolerant individuals		% Noninsect taxa (all sites)	% Tolerant taxa (all sites)
		6	8		6	8	6	8		
10	>5	>17	>18	>12	0–59	0–39	25–100	42–100	0–8	0–4
9		16–17	17–18	12	60–63	40–46	23–24	37–41	9–12	5–8
8	5	15	16	11	64–67	47–52	21–22	32–36	13–17	9–12
7	4	13–14	14–15	10	68–71	53–58	19–20	27–31	18–21	13–16
6		11–12	13	9	72–75	59–64	16–18	23–26	22–25	17–19
5	3	9–10	11–12	8	76–80	65–70	13–15	19–22	26–29	20–22
4	2	7–8	10	7	81–84	71–76	10–12	14–18	30–34	23–25
3		5–6	8–9	6	85–88	77–82	7–9	10–13	35–38	26–29
2	1	4	7	5	89–92	83–88	4–6	6–9	39–42	30–33
1		2–3	5–6	4	93–96	89–94	1–3	2–5	43–46	34–37
0	0	0–1	0–4	0–3	97–100	95–100	0	0–1	47–100	38–100

Note: Three metrics have separate scoring ranges for the two Omernik Level III ecoregions in southern coastal California region (6 = chaparral and oak woodlands, 8 = Southern California mountains).

Validation of B-IBI and Measurement of Performance Characteristics

To test whether the distribution of B-IBI scores in reference and test sites might have resulted from chance, we compared score distributions in the development set to those in the validation set. We also investigated a separate performance issue that ambient bioassessment studies often neglect: spatial variation at the reach scale. Although our use of a validation dataset tests whether the B-IBI scoring range is repeatable (Fore and others 1996; McCormick and others 2001), we designed a separate experiment to explicitly measure index precision. Four sites were resampled in May 2003. At each site, nine riffles were sampled following the CSBP, and material from randomly selected riffles was combined into three replicates of three riffles each. B-IBI scores were then calculated for each replicate. Variance among these replicates was used to calculate the minimum detectable difference (MDD) between two B-IBI scores based on a two-sample t-test model (Zar 1999). The index range can be divided by the MDD to estimate the number of stream condition categories detectable by the B-IBI (Doberstein and others 2000; Fore and others 2001).

Results

Combining Datasets

Unmodified CSBP samples (900 count) had significantly higher biotic condition scores ($t = -6.974$, $P < 0.0001$) than did USFS samples (500 count). However, there was no difference in biotic condition scores between USFS samples and CSBP samples that were randomly subsampled to reduce the 900 count to 500 ($t = -0.817$, $P = 0.416$). Thus, data from both targeted-riffle protocols were combined in B-IBI development.

Selected Metrics

Ten nonredundant stressor gradients were selected for metric screening: percent watershed unnatural, percent watershed in agriculture, percent local watershed in urban, road density in local watershed, qualitative channel alteration score, qualitative bank stability score, percent fine substrates, total dissolved solids, total nitrogen, and total phosphorous. Twenty-three biotic metrics that passed the first two screens (range and dose response) were analyzed for redundancy with Pearson product–moment correlation, and a set of seven minimally correlated metrics was selected for the B-IBI: percent collector-gatherer + collector-filterer individuals (% collectors), percent noninsect taxa, percent tolerant taxa, Coleoptera richness, predator richness, percent intolerant individuals, and EPT richness (Table 3). All metrics rejected as redundant were derived from taxa similar to those of selected metrics, but they had weaker relationships with stressor gradients. Dose–response relationships of the selected metrics to the 10 minimally correlated stressor variables are shown in Figure 2 and reasons for rejection or acceptance of all metrics are listed in Table 2. Regression coefficients were significant at the $P \leq 0.0001$ level among all seven selected metrics and at least two stressor gradients: percent watershed unnatural and road density in local watershed (Table 4). The final seven metrics included several metric types: richness, composition, tolerance measures, and func-

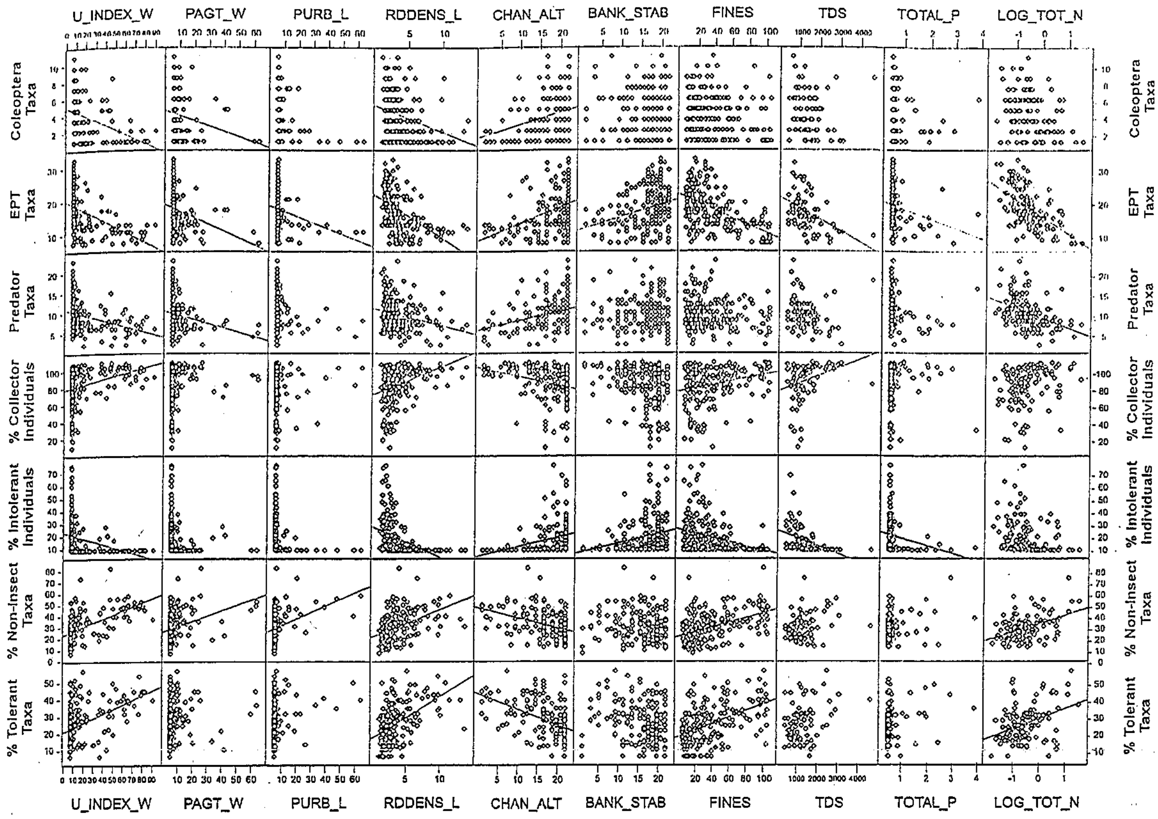


Figure 2. Scatterplots of dose–response relationships among 10 stressor gradients and 7 macroinvertebrate metrics (lines represent linear "best-fit" relationships; see text for abbreviations).

Table 4. Significance levels of linear regression relationships among 10 stressor metrics and 7 biological metrics

Metric	Coleoptera taxa	EPT taxa	Predator taxa	% Collector individuals	% Intolerant individuals	% Noninsect taxa	% Tolerant taxa
Bank Stability	0.813	<0.0001	0.3132	0.0009	0.0001	0.1473	0.0013
Fines	0.0017	<0.0001	0.0171	0.0003	<0.0001	<0.0001	<0.0001
Chan_Alt	<0.0001	<0.0001	<0.0001	0.0003	<0.0001	<0.0001	<0.0001
Log_U_Index_W	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Log_PAgT_W	0.0007	<0.0001	0.0004	0.0054	0.0014	<0.0001	0.0012
Log_PUrb_L	0.0367	0.0007	0.0344	0.6899	0.0045	0.0002	0.0215
Log RdDens_L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Log_TDS	0.0094	<0.0001	0.0035	0.0005	<0.0001	0.0271	0.004
Log_Tot_N	0.0019	<0.0001	<0.0001	0.0078	0.0019	<0.0001	<0.0001
Log_Tot_P	0.062	<0.0001	0.0085	0.0162	0.0001	0.0018	0.0059

Note: Significant *P*-values corrected for 70 simultaneous comparisons ($P < 0.0007$) are highlighted in bold. Abbreviations are defined in Table 1 and in the text.

tional feeding groups. Because there are only seven metrics in the B-IBI, final scores calculated using this IBI are multiplied by 1.43 to adjust the scoring range to a 100-point scale.

The B-IBI scores were lower in chaparral reference sites than in mountain reference sites when calculated using unadjusted metric scores (Mann–Whitney *U*-test; $P = 0.02$). Although none of the final seven metrics

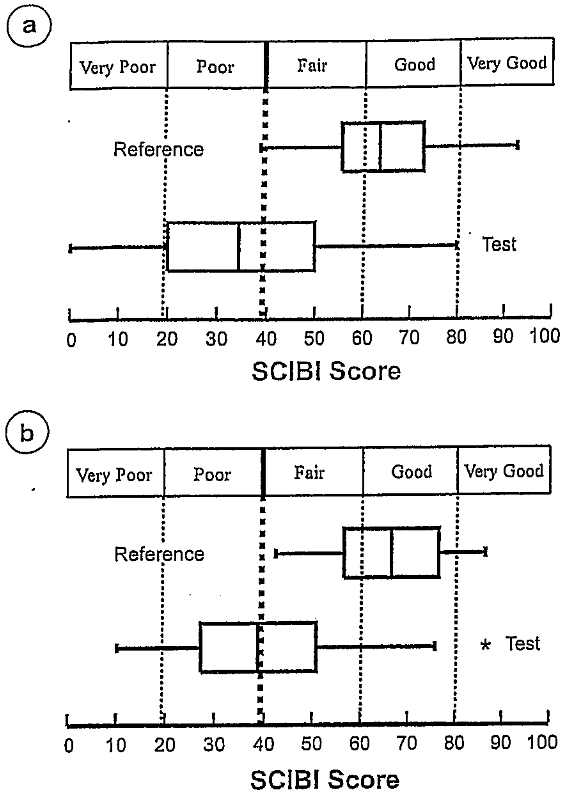


Figure 3. Box plots of B-IBI site scores for reference and test groups showing B-IBI scoring categories: (a) development sites and (b) validation sites. Dotted lines indicate condition category boundaries and heavy dotted lines indicate impairment thresholds.

were significantly different between chaparral reference sites and mountain reference sites at the $P = 0.05$ level ($P < 0.007$ after Bonferroni correction), scores for three metrics (EPT richness, percent collector-gatherer + collector-filterer individuals, and percent intolerant individuals) were substantially lower in chaparral reference sites than in mountain reference sites. We adjusted for this difference by creating separate scoring scales for the three metrics in the two ecoregions (Table 3). There was no difference in B-IBI scores between reference sites in the two ecoregions after the adjustment (Mann–Whitney *U*-test, $P = 0.364$).

Validation of B-IBI and Measurement of Performance Characteristics

The distribution of B-IBI scores at reference and nonreference sites was nearly identical between the development and validation data sets (Figure 3), indicating that our characterization of reference conditions and subsequent B-IBI scoring was repeatable and not likely due to chance. Based on a two-sample *t*-test model (setting $\alpha = 0.05$ and $\beta = 0.20$), the MDD for the SoCal IBI is 13.1. Thus, we have an 80% chance of detecting a 13.1-point difference between sites at the $P = 0.05$ level. Dividing the 100-point B-IBI scoring range by the MDD indicates that the SoCal B-IBI can detect a maximum of seven biological condition categories, a result similar to or more precise than other recent estimates of B-IBI precision (Barbour and others 1999; Fore and others 2001). We used a statistical criterion (two standard deviations below the mean reference site score) to define the boundary between "fair" and "poor" conditions, thereby setting B-IBI = 39 as an impairment threshold. The scoring range below 39 was divided into two equal condition categories, and the range above 39 was divided into three equal condition categories: 0–19 = "very poor", 20–39 = "poor", 40–59 = "fair", 60-79 = "good", and 80–100 = "very good" (Figure 3).

We ran two principle components analyses (PCAs) on the environmental stressor values used for testing metric responsiveness: 1 that included all 275 sites for which we calculated 4 watershed scale stressor values and another based on 124 sites for which we had measurements of 9 of the 10 minimally correlated stressor variables. We plotted B-IBI scores as a function of the first multivariate stressor axis from each PCA. We log-transformed percent watershed unnatural, percent watershed in agriculture, percent local watershed in urban, road density in local watershed, total nitrogen, and total phosphorous. Only PCA Axis 1 was significant in either analysis, having eigenvalues larger than those predicted from the broken-stick model (McCune and Grace 2002). In both PCAs, the B-IBI score decreased with increasing human disturbance (Figure 4) and was correlated (Spearman ρ) with PCA Axis 1 ($r = -0.652$, $P < 0.0001$ for all 275 sites; $r = -0.558$, $P \leq 0.0001$ for 124 sites). In the analysis of all 275 sites, all 4 watershed-scale stressors had high negative loadings, with percent watershed unnatural and local road density being the highest (Figure 5a). In the analysis of 124 sites, percent watershed unnatural, percent watershed in agriculture, and local road density had the highest negative loadings on the first axis, and channel alteration had the highest positive loading (Figure 4b).

Finally, we found no relationship between B-IBI scores and ecoregion (Mann–Whitney U, $P = 0.364$), Julian date ($R^2 = 0.01$, $P = 0.349$), watershed area ($R^2 = 0.002$, $P = 0.711$), or elevation ($R^2 = 0.01$, $P = 0.349$), indicating that the B-IBI scoring is robust with respect to these variables (Figure 5). Our ecoregion scoring adjustment probably corrects for the

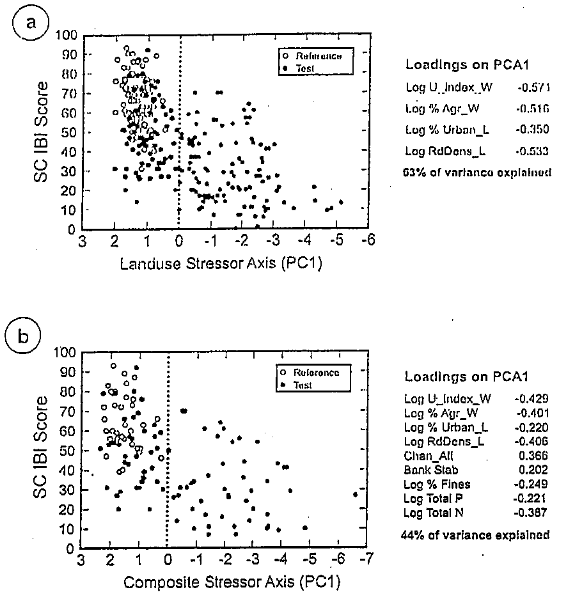


Figure 4. Scatterplots of SoCal B-IBI scores against two composite stressor axes from PCA: (a) values for all 275 sites; composite axis includes 4 land-use gradients; (b) values for 124 sites; composite axis includes 9 local and watershed scale stressor gradients.

strongest elevation effects, but there is no evidence that B-IBI scores are related to elevation differences within each ecoregion.

Discussion

The SoCal B-IBI is the most comprehensive assessment to date of freshwater biological integrity in California. As in other Mediterranean climate regions, the combination of aridity, geology, and high-amplitude cycles of seasonal flooding and drying in southern coastal California makes its streams and rivers particularly sensitive to disturbance (Gasith and Resh 1999). This sensitivity, coupled with the burgeoning human population and vast conversion of natural landscapes to agriculture and urban areas, has made it the focus of both state and federal attempts to maintain the ecological integrity of these strained aquatic resources.

Unfortunately, growing interest in biomonitoring is unmatched by financial resources available for this monitoring. Thus, combination of data among programs is very desirable, although this goal is rarely achieved in practice. We demonstrated that macroinvertebrate bioassessment data from multiple agencies could be successfully combined to produce a regional index that is useful to all agencies involved. This index is easy to apply, its fundamental assumptions are transparent, it provides precise condition assessments, and it is demonstrated to be responsive to a wide range of anthropogenic stressors. The index can also be applied throughout a long index period (mid-spring to mid-fall): Just as biotic factors tend to have more influence on assemblage structure during the summer dry period of Mediterranean climates than during the wet season when abiotic factors dominate (Cooper and others 1986; Gasith and Resh 1999), it is likely that our biotic index is more sensitive to anthropogenic stressors during the summer dry period. Because of these qualities, we expect the SoCal B-IBI to be a practical management tool for a wide range of water quality applications in the region.

This B-IBI is a regional adaptation of an approach to biotic assessment developed by Karr (1981) and subsequently extended and refined by many others (Kerans and Karr 1994; Barbour and others 1996; Fore and others 1996; Hughes and others 1998). We drew heavily upon recent refinements in multimetric index methodology that improve the objectivity and defensibility of these indices (McCormick and others 2001; Klemm and others 2003). A central goal of bioassessment is to select metrics that maximize the detection of anthropogenic stress while minimizing the noise of natural variation. One of the most important recent advances in B-IBI methods is the emphasis on quantitative screening tools for selecting appropriate metrics. We also minimized sources of redundancy in the analysis: (1) between watershed and local-scale stressor gradients for dose–response screening of biotic metrics and (2) in the final selection of metrics. The former guards against a B-IBI that is biased toward a set of highly correlated stressors and is, therefore, of limited sensitivity; the latter assures a compact B-IBI with component metrics that contribute independent information about stream condition. Combined with an assessment of responsiveness to specific regional disturbance gradients, these screening tools minimize the variability of B-IBI scores and improve its sensitivity.

The seven component metrics used in this B-IBI are similar to those selected for other B-IBIs (DeShon 1995; Barbour and others 1995, 1996; Fore and others 1996; Klemm and others 2003), but some of the metrics are either unique or are variations on other commonly used metrics. Like Klemm and others (2003), we found noninsect taxa to be responsive to human stressors, but richness was more responsive than percent of individuals. Some authors have separated the EPT metric into two or three metrics based on its component orders because the orders provided unique signals (Clements 1994; Fore and others 1996; Klemm

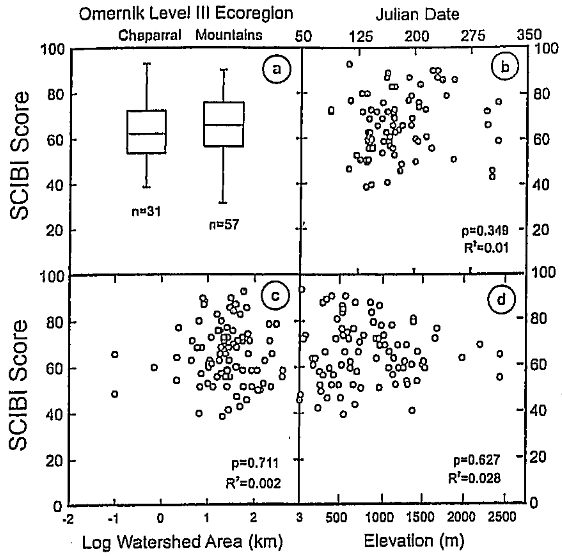


Figure 5. Relationship between B-IBI scores at 88 reference sites and (a) Omernik Level III ecoregion, (b) Julian date, (c) log watershed area, and (d) elevation.

and others 2003), but we found very similar patterns in these orders' response to various stressors we measured. To our knowledge, Coleoptera richness has not previously been included in a B-IBI, but beetle taxa might be a good indicator of the effects of fine sediments at impaired sites in this region (Brown 1973). A recent study of benthic assemblages in North Africa noted a high correspondence between EPT and EPTC (EPT + Coleoptera) (Beauchard and others 2003), but these orders were not highly correlated in our dataset. Feeding groups appear less often in B-IBIs than other metric types (Klemm and others 2003), but they were represented by two metrics in this B-IBI: predator richness and percent collectors (gatherers and filterers combined). Scraper richness was also responsive, but was rejected here because it was highly correlated with EPT richness.

The SoCal IBI should prove useful as a foundation for state and regional ambient water quality monitoring programs. Because the 75 EMAP sites were selected using a probabilistic statistical design, it will also be possible to use those samples to estimate the percentage of stream miles that are in "good", "fair", and "poor" condition in the southern California coastal region. These condition estimates, combined with stressor association techniques, have great potential to serve as a scientifically defensible basis for allocating precious monitoring resources in this region.

Acknowledgments

Major funding for this study was provided by David Gibson of the San Diego WQCB and Joseph Furnish of the USFS, with supplemental funding from other regional WQCBs in southern California. We thank James Harrington and other staff of California Department of Fish and Game's Aquatic Bioassessment Laboratory for efforts that contributed to the success of this project. Biologists Mike Dawson, Shawn McBride, and Jennifer York collected much of the field data; taxonomists Dan Pickard, Doug Post, Brady Richards, and Joe Slusark performed most of the taxonomy, except for the USFS samples, which were processed by the Bug Lab at Utah State University. Dan Heggem (US EPA, Landscape Ecology Branch), Mark Rosenberg (California Department of Forestry), and Mark Angelo (Central Coast WQCB) helped identify appropriate GIS land-use layers, and Glenn Sibbald (CDFG) assisted with watershed delineation. Mary Adams (Central Coast WQCB) collected invertebrate samples and provided local site condition data for sites in the Central Coast region. This manuscript was greatly improved by comments from Larry Brown, Joseph Furnish, Robert Hughes, Leska Fore, and three anonymous reviewers.

Literature Cited

Barbour, M. T., J. B. Stribling, and J. R Karr. 1995. The multimetric approach for establishing biocriteria and measuring biological conditions. Pages 63–77 *in* W. S. Davis, T. Simon (eds.), Biological assessment and criteria: tools for water resource planning and decision making. Lewis Publishers, Boca Raton, Florida.

Barbour, M.T., J. Gerritson, G. E. Griffith, R. Frydenborg, E. McCarron, J. S. White, and M. L. Bastian. 1996. A framework for biological criteria for Florida streams using benthic macroinvertebrates. *Journal of the North American Benthological Society* 15:185–211.

Barbour, M.T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. 1999. Revision to rapid bioassessment protocols for use in stream and rivers: periphyton, BMIs and fish. EPA 841-D-97-002. US Environmental Protection Agency, Washington, DC.

Beauchard, O., J. Gagneur, and S. Brosse. 2003. Macroinvertebrate richness patterns in North African streams. *Journal of Biogeography* 30:1821–1833.

Brown, H. P. 1973. Survival records for elmid beetles, with notes on laboratory rearing of various dryopoids (Coleoptera). *Entomological News* 84:278–284.

Clements, W. H. 1994. Benthic invertebrate community response heavy metals in the Upper Arkansas River Basin, Colorado. *Journal of the North American Benthological Society* 13:30–44.

Cooper, S .D., T. L. Dudley, and N. Hemphill. 1986. The biology of chaparral streams in southern California. Pages 139–151 *in* Proceedings of the Chaparral Ecosystems Research Conference, J. J. DeVries (ed.). California Water

Resources Center Report 62. University of California, Davis, California, 155 pp.

DeShon, J. E. 1995. Development and application of the invertebrate community index (ICI). Pages 217–243 *in* W. S. Davis, T. P. Simon (eds.), Biological assessment and criteria: Tools for water resource planning and decision making. CRC Press, Boca Raton, Florida.

Doberstein, C.P., J. R. Karr, and L. L. Conquest. 2000. The effect of fixed-count subsampling on macroinvertebrate biomonitoring in small streams. *Freshwater Biology* 44:355–371.

Ebert, D. W., and T. G. Wade. 2002. Analytical tools interface for landscape assessments (ATtILA), Version 3.0. US EPA, Office of Research and Development, Washington, DC.

ESRI. 1999. ArcView GIS, Version 3.2. Spatial Analyst Extension. Environmental Systems Research Institute, Inc., Redlands, CA.

Fore, L.S., J. R. Karr, and R. W. Wisseman. 1996. Assessing invertebrate responses to human activities: Evaluating alternative approaches. *Journal of the North American Benthological Society* 15:212–231.

Fore, L.S., K. Paulsen, and K. O'Laughlin. 2001. Assessing the performance of volunteers in monitoring streams. *Freshwater Biology* 46:109–123.

Gasith, A., and V. H. Resh. 1999. Streams in Mediterranean climate regions: Abiotic influences and biotic responses to predictable seasonal events. *Annual Review of Ecology and Systematics 30* : 51–81.

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

Hawkins, C. P., R. H. Norris, J. N. Hogue, and J. M. Feminella. 2000. Development and evaluation of predictive models for measuring the biological integrity of streams. *Ecological Applications* 10:1456–1477.

Hawkins, C. P., J. Ostermiller, and M. Vinson. 2001. Stream invertebrate, periphyton and environmental sampling associated with biological water quality assessments. Unpublished manuscript, Utah State University, Logan, Utah.

Hughes, R. M. 1995. Defining acceptable biological status by comparing with reference conditions. Pages 31–47 *in* W. S. Davis, T .P. Simon (eds.), Biological assessment and criteria: Tools for water resource planning and decision making. CRC Press, Boca Raton, Florida.

Hughes, R. M., P. R. Kaufmann, A. T. Herlihy, T. M. Kincaid, L. Reynolds, and D. P. Larsen. 1998. A process for developing and evaluating indices of fish assemblage integrity. *Canadian Journal of Fisheries and Aquatic Sciences* 55:1618–1631.

Karr, J. R. 1981. Assessment of biotic integrity using fish communities.. *Fisheries* 6:21–27.

Karr, J. R., K. D. Fausch, L. Angermeyer, P. R. Yant, and I. J. Schlosser. 1986. Assessment of biological integrity in running waters: A method and its rationale. Illinois Natural History Survey Special Publication No. 5, Illinois Natural History Survey, Urbana Champaign, IL.

Karr, J. R., and E. W. Chu. 1999. Restoring life in running waters: Better biological monitoring. Island Press, Covelo, California.

Kaufmann, P. R., P. Levine, E. G. Robison, C. Seeliger, and D. V. Peck. 1999. Surface waters: Quantifying physical habitat in wadeable streams. EPA/620/R-99/003. US EPA. Office of Research and Development, Washington, DC.

Kerans, B. L., and J. R. Karr. 1994. A benthic index of biotic integrity (B-IBI) for rivers of the Tennessee Valley. *Ecological Applications* 4:768–785.

Klemm, D. J., P. A. Lewis, F. A. Fulk, and J. M. Lazorchak. 1990. Macroinvertebrate field and laboratory methods for evaluating the biological integrity of surface waters. EPA/600/4-90/030. US Environmental Protection Agency, Cincinati, Ohio.

Klemm, D. J., and J. M. Lazorchak. 1994. Environmental monitoring and assessment program, surface water and Region 3 regional monitoring and assessment program, 1994 pilot laboratory methods manual for streams. EPA/62/R-94/003. US EPA, Office of Research and Development, Washington, DC.

Klemm, D. J., K. A. Blocksom, F. A. Fulk, A. T. Herlihy, R. M. Hughes, P. R. Kaufmann, D. V. Peck, J. L. Stoddard, W. T. Thoeny, M. B. Griffith, and W. S. Davis. 2003. Development and evaluation of a macroinvertebrate biotic integrity index (MBII) for regionally assessing Mid-Atlantic Highland streams. *Environmental Management* 31:656–669.

McCormick, F. H., R. M. Hughes, P. R. Kaufmann, D. V. Peck, J. L. Stoddard, and A. T. Herlihy. 2001. Development of an index of biotic integrity for the Mid-Atlantic Highlands Region. *Transactions of the American Fisheries Society* 130:857–877.

McCune, B., and J. B. Grace. 2002. Analysis of ecological communities. MjM Software Design. Gleneden Beach, Oregon.

Newman, W. B., and F. R. G. Watson. 2003. Land use history and mapping in California's Central Coast region. The Watershed Institute, California State University, Monterey Bay, California.

Omernik, J. M. 1987. Ecoregions of the conterminous United States. Map (scale 1:7,500,000). *Annals of the Association of American Geographers* 77(1):118–125.

Puckett, M. 2002. Quality Assurance Management Plan for the State of California's Surface Water Ambient Monitoring Program (SWAMP). Prepared for California State Water Resources Control Board, Division of Water Quality, Sacramento, CA. First version. December 2002. Available at http://www.swrcb.ca.gov/swamp/qapp.html.

Reynoldson, T. B., D. M. Rosenberg, and V. H. Resh. 2001. Comparison of models predicting invertebrate assemblages for biomonitoring in the Fraser River catchment, British Columbia. *Canadian Journal of Fisheries and Aquatic Sciences* 58:1395–1410.

Vinson, M. R., and C. P. Hawkins. 1996. Effects of sampling area and subsampling procedures on comparisons of taxonomic richness among streams. *Journal of the North American Benthological Society* 15:392–399.

Wright, J. F., M. T. Furse, and P. D. Armitage. 1983. RIVPACS: A technique for evaluating the biological quality of rivers in the U.K. *European Water Pollution Control* 3:15–25.

Zar, J. H. 1999. Biostatistical analysis, 4th ed. Prentice-Hall, Upper Saddle River, New Jersey.

This Page Intentionally
Left Blank