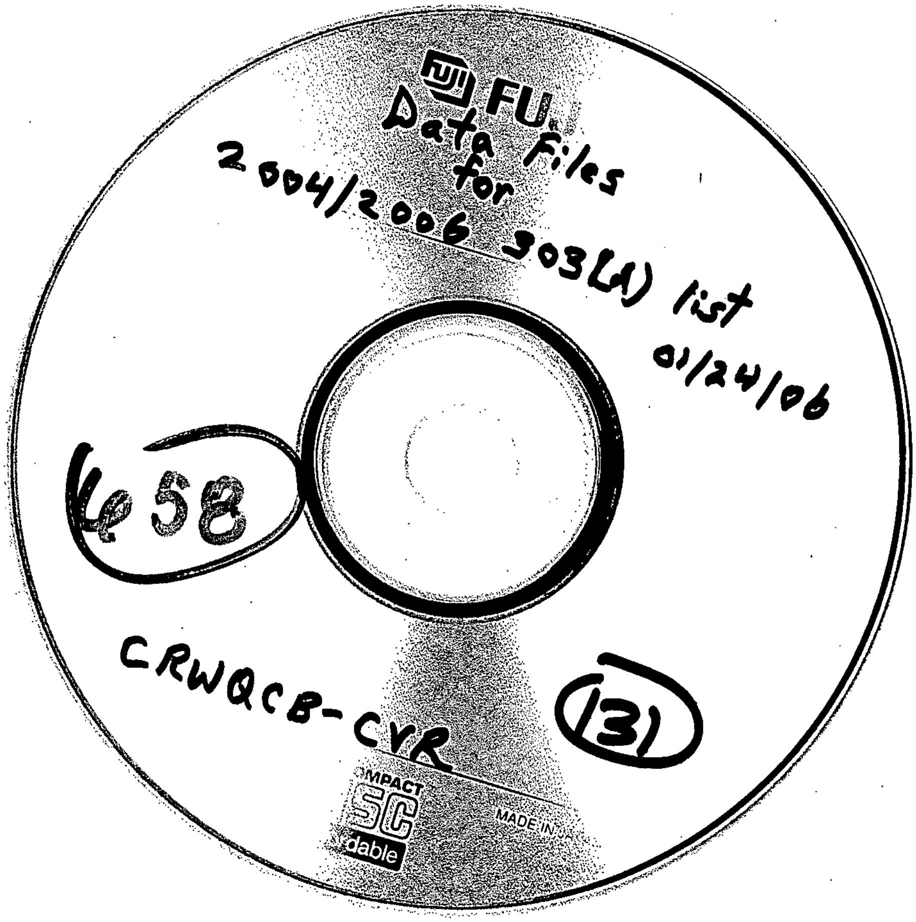
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California Regional Water Quality Control Board

Central Valley Region

Robert Schneider, Chair

Alan C. Lloyd, Ph.D.
Agency Secretary

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Arnold Schwarzenegger
Governor

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TO: Selica Potter, Acting Clerk to the Board
State Water Resources Control Board

FROM: Kenneth D. Landau
Acting Executive Officer

DATE: 24 January 2006

SIGNATURE: ____________

SUBJECT: COMMENTS ON THE PROPOSED REVISION TO FEDERAL CLEAN WATER ACT SECTION 303(D) LIST OF WATER QUALITY LIMITED SEGMENTS FOR CALIFORNIA (303(D) LIST)

The California Regional Water Quality Control Board, Central Valley Region (Central Valley Water Board) appreciates the opportunity to comment on the State Water Resources Control Board's (State Water Board) proposed revisions to the 303(d) List. We also appreciate the changes State Water Board staff made in response to our comments on earlier draft fact sheets.

We have focused our review on those fact sheets that suggest changes to our Region's listed waters and pollutants. Our understanding is that a water body and pollutant that is currently listed will remain listed, unless the fact sheets recommend a change. Should the State Water Board consider additional changes to the list based on comments from interested parties, the Central Valley Water Board would like an opportunity to review those proposed changes prior to a final decision.

We have indicated in the attached detailed comments our recommendations with respect to your staff's draft recommendations. In addition to those detailed comments, we have identified four general issues related to the implementation of the Listing Policy – 1)"exotic" species; 2) temperature; 3) evaluation of attainment of water quality objectives; and 4) identification of Delta waterways.

"Exotic" species – The Listing Policy does not address "exotic" [1] species, nor does any Regional Water Board or State Water Board water quality plan make a distinction between protection of "native" versus "non-native" aquatic species. We believe it is premature for the State Water Board, through a 303(d) listing, to identify "non-native" species as a "pollutant". We recommend that prior to any such listing, the Listing Policy be amended to explicitly identify the legal and analytical basis for identifying "exotic" species as causing non-attainment of water quality standards.

[1] The fact sheets identify "exotic" species as the pollutant, but discuss "non-native" species in the description of the impairment. The term "non-native" species will generally be used in our comments. In the context of the 303(d) list, our discussion of non-native species refers to those species that are not indigenous to the Central Valley's aquatic ecosystems.

Temperature – Although the State Water Board proposes to list only two Central Valley waterways for non-attainment of temperature objectives, we are concerned with the precedent being set. The Listing Policy (§ 6.1.5.9) suggests a rather robust analysis of temperature and fisheries information. A review of fisheries resource data, although potentially available from the Division of Water Rights, is not included in the fact sheets. The single annual maximum criterion used in the fact sheets could lead to the unnecessary listing of hundreds of Central Valley waterways. We recommend the fact sheets be changed to include the information required by the Listing Policy for temperature listings.

Evaluation of Attainment of Objectives – The Listing Policy includes use of the binomial distribution with assumed allowable exceedance rates to determine whether a water body is attaining objectives. The Listing Policy also includes a "weight of evidence" listing factor, which is to be used when other Listing Factors would lead to an incorrect decision. We have identified a few instances in which the "weight of evidence" suggests a listing decision when the binomial method suggests delisting. We recommend that the State Water Board apply the "weight of evidence" listing factor in those cases.

Identification of Delta Waterways – Delta impairments are currently listed inconsistently - three areas that cover the whole Delta are identified, as well as eight individual Delta waterways within those three areas. The Delta TMDLs, which we will have before our Board within the year, will identify all of the individual Delta waterways to which our TMDLs and water quality objectives apply. We have digitized the Delta waterways to facilitate incorporation into the State Water Board's database. We recommend that the individual Delta waterways be identified, rather than areas, to provide consistency within the 303(d) list and with our upcoming Basin Plan Amendments.

Please see the attached for a detailed discussion of our review of the State Water Board's recommended changes to the Clean Water Act Section 303(d) List.

If you have any questions, please give me a call at (916) 464-4839 or Joe Karkoski at (916) 464-4668.

Attachments: Central Valley Regional Board Staff Comments on Fact Sheets
Memo from Redding Office re : 303(d) Listing for Fall River
Memo from Redding Office re : Proposed 303(d) Listing for North Fork Feather River

cc: Celeste Cantu, SWRCB (w/o attachments)
Tom Howard, SWRCB (w/o attachments)
Craig J. Wilson, SWRCB (w/attachments & CD)
Pam Buford, CVRWQCB, Fresno (w/o attachments)
Dennis Heiman, CVRWQCB, Redding (w/o attachments)
Joe Karkoski, CVRQCB, Sacramento (w/attachments)
Jerry Bruns, CVRWQCB, Sacramento (w/o attachments)
Jim Pedri, CVRWQCB, Redding (w/attachments)
Lonnie Wass, CVRWQCB, Fresno (w/attachments)
Central Valley Water Board members (w/o attachments)
Regional Board TMDL Program Managers (w/attachments)

Detailed Comments on Fact Sheets

General Issue 1. "Exotic" Species

Our most significant concerns are with the proposed "Exotic Species" listings. We believe that there are sound legal, policy, and scientific reasons to not identify "exotic species"[2] on the 303(d) list.

The fundamental difficulty for the Water Boards is the lack of any beneficial uses, water quality objectives, or water quality policies that suggest a difference between our regulatory view of native versus non-native species. In fact, the State Water Board has salinity objectives in the Delta to protect a non-native species (striped bass) and the Regional Water Board has beneficial uses that identify two non-native species (striped bass and shad). When we establish water quality policies or permit limits, we make sure our actions are protective of aquatic life, not just native aquatic life. For more than 30 years, the Water Boards have protected all aquatic species from traditional pollution sources. A State Water Board action that identifies non-native species as pollutants has sweeping policy implications that could complicate the work the Water Boards have done and continue to do to protect our State's waters.

Note that we are not suggesting that non-native species should not be addressed. The proper regulation of ballast water could go a long way in assuring that new, potentially damaging non-native species are not introduced into our waterways. With the exception of discharges of ballast water, the authority of the State and Regional Water Boards to regulate populations of non-native aquatic species is limited or non-existent. Rather than a 303(d) listing, we suggest that the State Water Board embark on a more deliberative process to identify: 1) the potential scope of the problem; 2) the regulatory authorities and agencies that are or could be involved in the regulation of non-native species populations; 3) the water quality policies that would need to be developed for the Water Boards to regulate non-native species; 4) the potential consequences, impacts, and benefits of regulating the populations of established non-native species. Our primary concern is that by attempting to use a program and statutory authorities that are clearly not designed to solve this problem, precious resources and time will be wasted. The State Water Board considered "exotic" species information on over 30 water body segments in the Central Valley. Our comments address both the approach used in the Fact Sheets and the appropriateness of identifying "exotic" species on the 303(d) list.

Policy Considerations

Potential Conflicts with other Agencies and Basin Plan Provisions

The Department of Fish and Game has regulations to protect non-native species (e.g. striped bass). One of the CalFed Bay-Delta program's ecosystem restoration objectives is to "Maintain, to the extent consistent with ERP goals, fisheries for striped bass, American shad, signal crayfish, grass shrimp, and nonnative warm water game fishes." Mosquito fish are "non-native" but are used as a biological control by most mosquito abatement districts.

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[2] The fact sheets identify "exotic" species as the pollutant, but discuss "non-native" species in the description of the impairment. The term "non-native" species will generally be used in our comments. In the context of the 303(d) list, our discussion of non-native species refers to those species that are not indigenous to the Central Valley's aquatic ecosystems.

The State Water Board's Water Quality Control Plan for Salinity (SWRCB, Resolution No. 95-24) includes specific outflow and salinity objectives for the protection of striped bass. The Central Valley Water Board's Basin Plan mentions two non-native species in the definition of the WARM migration and spawning beneficial uses. A generic listing of "exotic" species would immediately put us into potential conflict with our own water quality standards and with other State programs. The State Water Board and Central Valley Water Board have objectives and uses designed to protect non-native species, yet an "exotic" species listing would suggest that we take action to remove or reduce the populations of those species.

Potential Environmental Justice Issues

A number of non-native species are also species that are fished for sport and possibly subsistence. Catfish, bass, and bluegill are considered non-native fish species in the Delta. Asiatic clams are harvested for consumption. Significant environmental justice issues would be raised if the Central Valley Water Board or State Water Board targeted aquatic species for population reduction that are relied upon by disadvantaged populations for subsistence.

Clean Water Act Pollutant Definition

The State Board appears to be considering "exotic" species to be a pollutant based on a recent federal district court judgment against U.S. EPA regarding the regulation of ballast water discharges. Section 502(6) of the Clean Water Act defines "pollutants" to include "biological materials...*discharged into water*". The courts have interpreted the term "biological materials" to include "invasive" species that might be found in ballast water. It is not clear that these Clean Water Act definitions and court interpretations apply equally to invasive species that are discharged from ships and invasive or non-native species that are established in our water ways (i.e. non-native species whose populations are not sustained or increased by ongoing discharges). In the former case, it appears the court rulings to date have suggested there is an obligation to regulate the discharge of ballast water and the discharge of invasive species in the ballast water would be subject to that regulation. In the latter case, it is not at all clear that the courts would consider established non-native species to be "pollutants" subject to regulation under the Clean Water Act.

Clean Water Act Listing/ TMDL Considerations

Should the State Water Board conclude that established non-native species are "pollutants" that are resulting in non-attainment of water quality standards, the State Board should consider whether a non-native species "pollutant" is suitable for TMDL calculation. If exotic or non-native species do not appear to be suitable for TMDL calculations, the State Board should petition the U.S. EPA Administrator to revise the list of pollutants suitable for TMDL calculation (see §§ 303(d)(1)(C) and 304(a)(2) of the Clean Water Act). Non-native or invasive species should not be on the list of pollutants suitable for TMDL calculation. Central Valley Water Board or State Water Board work to develop an "exotic" species TMDL would put the State in the awkward position of trying to allocate discharges of pollutants when there are no dischargers.

Porter-Cologne

Porter-Cologne gives the Regional Boards and State Boards a broad range of authorities to regulate the discharge of waste. These authorities could be used to regulate the discharge of ballast water and prevent the introduction of new invasive species. It is not clear how these authorities could be applied to address non-native species that are already established. A 303(d) listing would trigger an obligation by the Regional Board to develop a program to address any identified "exotic" species impairment. Porter-Cologne does not provide us with the authority or tools to directly regulate the population and diversity of aquatic species. Absent changes to our statutory authority, it is unclear what type of regulatory program we could construct to regulate the population of established non-native species.

Fact Sheets

Definition of "Exotic" Species

The term "exotic" species is not defined in the fact sheets and appears only as the "pollutant". The discussion in the Fact Sheets refers to native and non-native species, presumably with non-native species as being "exotic". We suggest that the State Water Board use the term non-native aquatic species and define the term – e.g. aquatic organisms that are not indigenous to the aquatic ecosystem to which they were introduced and which are capable of surviving and reproducing without human intervention. Such a definition would help distinguish between those non-native species that are established and other aquatic species that are discharged (e.g. from ballast water).

Specifying the "Exotic" Species Causing non-attainment of the Water Quality Standard

The State Water Board should identify the specific "exotic" species that are causing non-attainment of the water quality standard. This will help in clarifying the problem and determining an appropriate solution. The fact sheets currently refer generically to "native" and "non-native" species. The references used by the State Water Board to prepare the Fact Sheets clearly identify specific non-native species. If the State Water Board believes some or all of those species are causing non-attainment of a water quality standard, those species should be identified. It should be noted, we identified only one case in which a non-native species (redeye bass in the Cosumnes River) was implicated as the cause of the decline in native fisheries.

Identifying the Water Quality Objective not Attained

The fact sheets currently identify the "Toxicity" narrative objective as not being attained due to the presence of exotic species. The "Toxicity" narrative objective states that "All waters shall be maintained free of toxic substances that produce detrimental physiological responses in human, plant, animal, or aquatic life". We do not believe that exotic species can be considered a "toxic substance" as described in our narrative toxicity objective, since the exotic species are not acting as a poison. The "Toxicity" narrative objective should not be identified as the water quality objective not attained unless the exotic species produces a toxic substance.

The Regional Water Board does not have numeric or narrative water quality objectives that apply to exotic or invasive species. The Regional Water Board's aquatic life beneficial uses do not make a distinction between native and non-native species. However, two non-native species specifically define two of our beneficial uses (WARM migration and spawning refer to striped bass and shad). We believe that any exotic species listing must reference the appropriate water quality objective (or beneficial use) that is not being attained.

At this point, we do not have an appropriate reference to suggest to you and, therefore, believe that there is no basis in applicable water quality standards for identifying "exotic species" as causing non-attainment of water quality standards.

Data Analysis/ Analytical Procedure
The analytical procedure used by State Board to demonstrate an impairment by exotic species is not clear. In some cases, non-native species are present, but are not considered to be causing an impairment (e.g. Upper Tuolumne River). The rationale appears to be that populations of native species changed in a similar or more favorable fashion when compared to populations of non-native species. In contrast, if native species populations changed in a less favorable fashion when compared to non-native species, exotic species are identified as causing the impairment. The problem with this approach is the effect is being equated to the cause. Changes in relative diversity and abundance of native species may be primarily driven by habitat alteration, flow changes, or hydromodification (the potential causes). The effect is that the habitat and flow conditions favor the propagation of non-native species over native species.

A review of the references used by the State Water Board for the three proposed listings (Delta, Cosumnes River, and San Joaquin River) clearly identifies a non-native species as causing a native fish species decline in one instance (redeye bass in the Cosumnes River). The San Joaquin River listing is based on a reference that clearly states the cause of the native fish decline is a result of hyrdomodification – the operation of Friant Dam that has resulted in changes in flow and temperature.

For the Delta biological opinion by the U.S. Fish and Wildlife Service, the primary causes for Delta smelt decline are identified as modifications to the flow regime and water exports. Invasive species and contaminants are identified as potential contributors to the decline. More recently, the Resources Agency released an action plan to address the decline of Delta smelt and other open water fish species (http://www.publicaffairs.water.ca.gov/newsreleases/2005/10-19-05DeltaSmeltActionPlan.pdf). The conceptual model developed as part of that effort identified three potential factors contributing to the decline – 1) toxic effects; 2) exotic species effects; and 3) water project effects. It appears premature to associate exotic species with the decline in pelagic fish in the Delta.

We recommend that the State Board more clearly describe the analytical procedure used to make a determination that exotic species are causing non-attainment of water quality objectives.

In summary, there are significant legal, policy, and technical reasons to significantly revise or abandon any attempt to identify "exotic" species as impairing Central Valley water ways. The legal necessity for making such listings is not clear and the proposed listings are vague. It is not clear which standards are being violated, whether non-native species are causing the standards to be violated, and how the available information demonstrates that "exotic" species are causing the standard's violation.

General Issue 2. Temperature

Central Valley Water Board staff are concerned that the analyses for the proposed temperature listings are not consistent with either the Listing Policy or the Water Quality Control Plan for the Sacramento and San Joaquin River Basins (Basin Plan). The temperature objective in the Basin Plan states: "The natural receiving water temperature of intrastate waters shall not be altered unless it can be demonstrated to the satisfaction of the Regional Water Board that such alteration in temperature does not adversely affect beneficial uses....At no time or place shall the temperature of COLD or WARM intrastate waters be increased more than 5°F above natural receiving water temperature....In determining compliance with the water quality objectives for temperature, appropriate averaging periods may be applied provided that beneficial uses will be fully protected."

The temperature objective suggests some understanding or definition of the "natural receiving water temperature". Without an understanding of the natural receiving water temperature, it is not possible to determine whether the temperature has increased by more than 5°F or whether the natural receiving water temperature has been altered.

The Listing Policy (Section 6.1.5.9) identifies the approach to be used to evaluate temperature data. The Listing Policy suggests that if information on natural receiving water temperature is not available, historic and current information on the status of the fishery should be evaluated. Current ambient temperatures are also compared to literature values for the temperature requirements of sensitive life stages of aquatic life. If the fishery has degraded over time and the current temperature regime is above the literature values, then a listing is suggested.

The draft Fact Sheets do not discuss or evaluate a number of the key items identified in the Listing Policy. We recommend that the State Board include information on the status of the fishery over time; identify the rationale for the temperature criteria and averaging period chosen; and discuss the relevance of the criteria to the life stage of the aquatic life (e.g. if the criteria applies to a life stage that occurs seasonally, such as spawning, then only the temperature data for that time period should be compared to the criteria). We understand that Division of Water Rights staff working on FERC relicensing projects on the North Fork of the Feather River may have additional information that could support this Listing decision.

The Sullivan report cited in the Fact Sheets discusses a risk-based approach, which it does not appear that State Board is applying to analyzing the temperature data. Since the Sullivan report does not recommend a specific criterion, it is important that the State Board discuss the choice of criteria and how those criteria are being applied to the temperature data sets.

Please also see the attached discussion from our Redding office with respect to the temperature issue on the North Fork of the Feather River.

General Issue 3. Evaluation of Attainment of Water Quality Objectives

Section 3.1 of the Listing Policy uses a binomial distribution to determine whether waters should be listed. Section 4.1 of the Listing Policy uses a binomial distribution to determine whether waters should be delisted. The nominal acceptable exceedance rate of numeric water quality objectives or criteria is defined as 3 percent when the binomial method is used. Based on the confidence limits applied to the distribution, an observed exceedance rate of up to 8% may result in a conclusion that water quality standards are attained.

In many cases this approach does not present any problems. The conclusions reached by application of the binomial method are consistent with how the water quality objectives are expressed. If there are no exceedances, then application of section 4.1 would result in a conclusion that water quality standards are attained. If the rate of exceedance is 9% or greater, then application of section 3.1 would result in a conclusion that water quality standards are not attained.

The application of sections 3.1 and 4.1 to analysis of standards attainment can break down when the exceedance rate is between 0% and about 9%. Most water quality objectives and criteria for toxic substances are expressed as a maximum (not to be exceeded concentration) or have a very low allowable frequency of exceedance (once every three years). In these cases, the "weight of evidence" approach outlined in sections 3.11 and 4.11 must be applied to confirm (or provide evidence refuting) the conclusions reached by application of the binomial method described in section 3.1 and 4.1.

Our attached analysis suggests that there are a couple of instances in which "delisting" suggested by application of section 4.1 is not consistent with conclusions that would be reached by a "weight of evidence" approach. We raise this issue not to suggest any fundamental problem with the Listing Policy, but to point out the need to apply the "weight of evidence" section of the Policy when low exceedance rate situations are evaluated.

A second issue that we identified is the need to evaluate pollutants that exhibit additive toxicity when they co-occur. The application of our narrative toxicity objective requires consideration of the additive and synergistic effects of pollutants with a similar mode of action. We have observed the co-occurrence of diazinon and chlorpyrifos, which exhibit additive toxicity, in a number of waters evaluated in the draft 303(d) list. We believe that co-occurrence must be evaluated to determine whether those pollutants are causing or contributing to an exceedance of water quality objectives.

General Issue 4. Identification of Delta Waterways

The proposed 303(d) list identifies several areas of the Delta and pollutants associated with those areas. More than a year ago, State Water Board and Regional Water Board staff had worked on delineating these areas. Since that time, Regional Water Board staff has created GIS coverages for the specific waterways in the Delta. As part of two pending Basin Planning efforts in the Delta (for mercury and diazinon/chlorpyrifos), we will be identifying the specific Delta waterways, rather than broad areas, to which our Amendments apply. In addition, our NPDES program staff turn to the 303(d) list to help identify which pollutants should potentially be addressed in permits. References to general areas instead of specific waterways can make such identification difficult.

State Water Board staff had previously indicated that they did not have the time or resources to incorporate the specific Delta waterways into the GeoWBS database system. We understand that concern, however, we believe it is important that the 303(d) list waterbody identification be consistent with how our Basin Plan Amendments will identify Delta waterways. We request that the State Water Board identify the specific Delta waterways associated with each pollutant that is currently identified by Delta area. We are willing to have our staff make the necessary data entries into the GeoWBS system.

Fact Sheet Specific Comments

The following tables and comments provide recommendations directed to specific proposed changes to the 303(d) list. We have also attached comment letters from our Redding office that are directed towards a proposed listing and a currently listed waterbody.

Summary of CVRWQCB Responses and Comments to SWRCB September 2005 *Fact Sheets Supporting Revision to the Section 303(d) List*
List Recommendations

Waterbody	Pollutant/ Stressor	SWRCB September 2005 Fact Sheet Recommendation	CVRWQCB Response	CVRWQCB Comments	CVRWQCB Data Sources
American River, South Fork ds Slab Creek Reservoir	Mercury	List	List	Change BU from CM & CO to REC-1. See Comment 1.	See Reference A
Bear River (Amador Co. Lower Bear Reservoir to Mokelumne River, N Fork)	Copper	List	List		
Carson Creek (from WWTP to Deer Creek)	Aluminum	List	List	Add WARM BU; under *Weight of Evidence*, item 3., change "2 of the **3** exceeded..." to "2 of the 11 exceeded..."	
Carson Creek (from WWTP to Deer Creek)	Copper	List	List	Add WARM BU	
Carson Creek (from WWTP to Deer Creek)	Manganese	List	List		
Clear Lake	Mercury	List	Already on the 303(d) list for mercury.		
Cosumnes River	Exotic Species	List	Do Not List	See Attachment 1	See Reference B
Deer Creek (Sacramento County)	Iron	List	List	BU should only be MUN	
Del Puerto Creek	Bifenthrin, lambda cyhalothrin, esfenvalerate/ fenvalerate and permethrin producing sediment and/or water toxicity.	List	List	BU should only be WARM; already listed for diazinon and chlorpyrifos. See Comment 2.	See Reference C

Summary of CVRWQCB Responses and Comments to SWRCB September 2005 *Fact Sheets Supporting Revision to the Section 303(d) List*

List Recommendations

Waterbody	Pollutant/ Stressor	SWRCB September 2005 Fact Sheet Recommendation	CVRWQCB Response	CVRWQCB Comments	CVRWQCB Data Sources
Delta Waterways (Stockton Ship Channel)	Exotic Species	List	Do Not List	See Attachment 1	See Reference D
Delta Waterways (central Portion)	Exotic Species	List	Do Not List	See Attachment 1	See Reference D
Delta Waterways (eastern portion)	Exotic Species	List	Do Not List	See Attachment 1	See Reference D
Delta Waterways (export area)	Exotic Species	List	Do Not List	See Attachment 1	See Reference D
Delta Waterways (northern portion)	DDT	List	Already on 2002 303(d) List [for DDT]		
Delta Waterways (northern portion)	Exotic Species	List	Do Not List	See Attachment 1	See Reference D
Delta Waterways (northern portion)	Mercury	List	Already on 2002 303(d) List [for Hg]		
Delta Waterways (northern portion)	Polychlorinated biphenyls	List	List	Delete CM, add REC-1 BUs. See Comment 3.	
Delta Waterways (northwestern portion)	Exotic Species	List	Do Not List	See Attachment 1	See Reference D
Delta Waterways (southern portion)	DDT	List	List		
Delta Waterways (southern portion)	Exotic Species	List	Do Not List	See Attachment 1	See Reference D

Summary of CVRWQCB Responses and Comments to SWRCB September 2005 *Fact Sheets Supporting Revision to the Section 303(d) List*

List Recommendations

Waterbody	Pollutant/ Stressor	SWRCB September 2005 Fact Sheet Recommendation	CVRWQCB Response	CVRWQCB Comments	CVRWQCB Data Sources
Feather River (Lake Oroville Dam to confluence with Sacramento River)	Chlorpyrifos	List	List	See Comment 4. Additive toxicity from both diazinon and chlorpyrifos.	
Feather River, North Fork (below Lake Almanor)	Temperature, water	List	Supplement with fisheries data to support adding to 303(d) List, or else Do Not List	See Attachment 1.	
Feather River, North Fork (below Lake Almanor)	Mercury	List	List		
Grasslands Marshes	Selenium	List	List		See Reference E
Grayson Drain (at outfall)	Sediment bioassays--chronic toxicity--Freshwater	List	List	Delete CM and Sport Fishing (CA) BUs; leave only WARM BU	See Reference F
Ingram Creek (from confluence with Hospital Creek to Hwy 33 crossing)	Bifenthrin, *lambda* cyhalothrin, esfenvalerate/ fenvalerate and permethrin producing sediment and/or water toxicity.	List	List	List specific pollutants. See Comment 5. Already listed for diazinon and chlorpyrifos. WARM BU only.	See Reference C
Ingram Creek (from confluence with San Joaquin River to confluence with Hospital Creek)	Bifenthrin, lambda cyhalothrin, esfenvalerate/ fenvalerate and permethrin producing sediment and/ or water toxicity.	List	List	List specific pollutants. See Comment 5. Already listed for diazinon and chlorpyrifos. WARM BU only.	See Reference C
Kaweah Lake	Mercury	List	List	BU is REC-1. See Comment 6.	See Reference A
Lower Bear River Reservoir	Copper	List	List		

Summary of CVRWQCB Responses and Comments to SWRCB September 2005 *Fact Sheets Supporting Revision to the Section 303(d) List*

List Recommendations

Waterbody	Pollutant/ Stressor	SWRCB September 2005 Fact Sheet Recommendation	CVRWQCB Response	CVRWQCB Comments	CVRWQCB Data Sources
Main Drainage Canal	Diazinon	List	List		
Merced River, Lower (McSwain Reservoir to San Joaquin River)	Mercury	List	List	REC-1 BU. See comment 7.	
Mokelumne River, North Fork	Copper	List	List	Add WARM BU	
Morrison Creek	Chlorpyrifos	List	List	See Comment 8. Additive toxicity from both diazinon and chlorpyrifos.	
Natoma Lake	Mercury	List	List	REC-1 BU only	
Orestimba Creek (below Kilburn Road)	Bifenthrin, lambda (cyhalothrin), esfenvalerate/ fenvalerate and permethrin producing sediment toxicity.	List	List	List specific pollutants. See Comment 5.	See Reference C
Sacramento River (Keswick Dam to Cottonwood Creek)	Cadmium	List	List		
Sacramento River (Keswick Dam to Cottonwood Creek)	Copper	List	List		
Sacramento River (Keswick Dam to Cottonwood Creek)	Zinc	List	List		
Sacramento River (Red Bluff to Knights Landing)	Mercury	List	List	See Comment 9.	

Summary of CVRWQCB Responses and Comments to SWRCB September 2005 *Fact Sheets Supporting Revision to the Section 303(d) List*

List Recommendations

Waterbody	Pollutant/ Stressor	SWRCB September 2005 Fact Sheet Recommendation	CVRWQCB Response	CVRWQCB Comments	CVRWQCB Data Sources
Salt Slough (upstream from confluence with San Joaquin River)	Selenium	List	Delist	Salt Slough at Crows Landing has been meeting the monthly mean objective of 2 µg/L since February 1998.	See Reference E
San Joaquin River (Friant Dam to Mendota Pool)	Exotic Species	List	Do Not List	See Attachment 1	See Reference H
San Joaquin River (Merced River to Tuolumne River)	Selenium	List	List	See Comment 10.	See Reference E
Sugar Pine Creek (tributary to Lower Bear Reservoir)	Copper	List	List		
Wadsworth Canal	Diazinon	List	List	Change reference from "Siepmann & Finlayson, 2002" to "Finlayson, 2004"; add WARM BU	
Willow Creek (Madera County)	Temperature, water	List	No recommendation	See Comment 11.	

Summary of CVRWQCB Responses and Comments to SWRCB September 2005 *Fact Sheets Supporting Revision to the Section 303(d) List*

Delist Recommendations

Waterbody	Pollutant/ Stressor	September Fact Sheet SWRCB Recommendation	CVRWQCB Response	CVRWQCB Comments	CVRWQCB Data Sources
Feather River (Lake Oroville Dam to confluence with Sacramento River)	Diazinon	Delist	Do not Delist	See Comment 12.	See Reference G
Morrison Creek	Diazinon	Delist	Do not Delist	See Comment 13.	See Reference I
Sacramento River (Knights Landing to the Delta)	Diazinon	Delist	Do not Delist	See Comment 14.	See Reference G
Sacramento Slough	Diazinon	NA	Delist	See Comment 15.	See Reference J
Sutter Bypass	Diazinon	Delist	Delist	See Comment 16.	See Reference J

Summary of CVRWQCB Responses and Comments to SWRCB September 2005 *Fact Sheets Supporting Revision to the Section 303(d) List*

Area Change Recommendations

Waterbody	September Fact Sheet SWRCB Recommendation	CVRWQCB Response
Delta Waterways (Stockton Ship Channel)	Change area	Change area
Delta Waterways (eastern portion)	Change area	Change area
Delta Waterways (western portion)	Change area	Change area
Marsh Creek (Dunn Creek to Marsh Creek Reservoir)	Change area	Change area
Marsh Creek (Marsh Creek Reservoir to San Joaquin River)	Change area	Change area
Salt Slough (upstream from confluence with San Joaquin River)	Change area	Change area

Summary of CVRWQCB Responses and Comments to SWRCB September 2005 *Fact Sheets Supporting Revision to the Section 303(d) List*

Comments

1. **American River, South Fork ds Slab Creek Reservoir – Mercury:** Upper extent should be more limited - closer to Camp Lotus than to Slab Creek Reservoir. First reservoir upstream of Hwy 49 on the S.F. American is Slab Creek. The data comes from the TSMP database. American River near Hwy 49 is likely the same location as Camp Lotus.
2. **Del Puerto Creek - Bifenthrin, lambda cyhalothrin, esfenvalerate/ fenvalerate, and permethrin:** Specific pollutants should be listed. Add Basin Plan language to Water Quality Objectives section: "Discharges shall not result in pesticide concentrations in bottom sediments or aquatic life that adversely affect beneficial uses."
3. **Delta Waterways (northern portion) – Polychlorinated biphenyls:** The OEHHA screening value (20 ng/g) was exceeded in the Delta in 1 of 2 samples in 1997, in 0 of 5 samples in 1998, in 4 of 7 samples in 1999, and in 3 of 9 samples in 2000-2002, for a total exceedance rate of 8 of 23 samples (SRWP, 2004), and thus meets the SWRCB listing guidelines (section 3.5 [Table 3.1]).
4. **Feather River (Lake Oroville Dam to confluence with Sacramento River) – Chlorpyrifos:** 0.03 μg/L chlorpyrifos on 02/20/2003; 0.35 μg/L chlorpyrifos on 02/19/2004; and 0.051 μg/L on 07/28/2004 exceed the chlorpyrifos acute toxicity criterion of 0.025 μg/L. Additive diazinon and chlorpyrifos levels (1.17, 1.63, and 2.55 on 01/28/2004, 02/19/2004 and 07/28/2004, respectively) out of 106 samples collected from 2000 to 2005 exceeded the additive toxicity threshold value of 1.0. A site-specific water quality objective of 0.080 μg/L for diazinon was used in the additivite toxicity calculations. There have been greater than 1 exceedance in every three-year period and, as defined by additive toxicity criterion, this supports the listing.
5. **Ingram Creek (from confluence with Hospital Creek to Hwy 33 crossing) and Ingram Creek (from confluence with San Joaquin River to confluence with Hospital Creek) and Orestimba Creek (below Kilburn Road) - Bifenthrin, lambda cyhalothrin, esfenvalerate/fenvalerate and permethrin:** See comments for Ingram/Hospital Creek and for Orestimba Creek in 26 August 2005 letter from Jerry Bruns to Ken Harris, for list of pyrethroids associated with sediment toxicity.
6. **Kaweah Lake – Mercury:** Data show two of three bass collected between 1986 and 2001 exceed the 0.3 ppm screening value (TSM electronic data). Two largemouth bass, 276 and 335mm had wet weight mercury values of 0.390 and 0.517 mg/kg, respectively. Exceedance of two of three fish meets SWRCB listing guidelines (section 3.5 [table 3.1]).
7. **Merced River – Mercury:** Using TSM data for composites collected in 1998, three of five composites exceeded the screening value of 0.3 ppm, thus meeting the SWRCB listing guidelines (section 3.5 [table 3.1]). Composites consisted of trophic level four fish with composite average lengths between 319 and 349 mm. A separate study by UC Davis for fish collected in 1999 (four composite samples) did not show impairment; however, they collected extremely small fish, with all of the composite median lengths <=35.5 mm.
8. **Morrison Creek – Chlorpyrifos:** 0 of 14 samples collected from Morrison Creek at Sunrise Blvd. between 02/10/2001 and 04/24/2003 exceeded the chlorpyrifos acute toxicity criterion

Comments

of 0.025 µg/L. 0 of 3 samples collected from Morrison Creek at Hedge Avenue between 02/10/2001 and 02/19/2001 exceeded the chlorpyrifos acute toxicity criterion. One (0.110 µg/L) of 11 samples collected from Morrison Creek at Franklin Blvd. exceeded the acute chlorpyrifos criterion on 03/23/2003. Three of 11 samples, in addition, collected from Morrison Creek at Franklin Blvd. between 02/19/2001 and 04/24/2003 contained levels of diazinon and chlorpyrifos such that the sum of the diazinon and chlorpyrifos concentrations (relative to their respective acute toxicity criteria of 0.160 µg/L and 0.025 µg/L, respectively) exceed the additive toxicity threshold value of 1.0 on 01/23/2001, 03/23/2003, and 04/13/2003. There have been greater than 1 exceedance for every three-year period and, as defined by the additive toxicity criteria, this supports the listing. Applicable beneficial uses associated with this listing should be WARM and COLD. The extent of impairment is from Elk Grove-Florin Road to Stone Lakes.

9. **Sacramento River (Red Bluff to Knights Landing) – Mercury:** Fish tissue data collected for the Regional Board in 2003 on the Sacramento River between the Keswick Reservoir and Veterans Bridge show impairment on the river as far upstream as Bend Bridge. Staff recommends listing begin at Bend Bridge, just upstream of Red Bluff. Fish tissue data collected for the Regional Board in 2003 on the Sacramento River between the Keswick Reservoir and Veterans Bridge show impairment on the river as far upstream as Bend Bridge. At Bend Bridge, two of six Pike Minnow exceed the screening value of 0.3 ppm, thus meeting the SWRCB listing guidelines (section 3.5 [table 3.1]). At all five locations sampled downstream of Bend Bridge, fish tissue exceedances meet SWRCB listing criteria. Impairment does not appear to extend upstream to Keswick Reservoir. Only the REC-1 Benficial Use applies to this listing.

10. **San Joaquin River (Merced River to Tuolumne River) – Selenium:** 72 (4.5%) 4-day running averages, out of 1,580 calculated 4-day running averages exceeded 5.0 µg/L, for measurements made between 1 January 2000 and 30 June 2005. 5.0 µg/L is the Water Quality Objective for 4-day running averages specified in the Basin Plan. The Water Quality Objective is a maximum value with no allowed exceedances. 0 (zero) instantaneous measurements (out of 1,669 measurements) exceeded the 12 µg/l Water Quality Objective applicable for the San Joaquin River, mouth of the Merced River to Vernalis.

11. **Willow Creek (Madera County) – Temperature, water:** Comments 29 and 30 from 17 June 2005 letter from Jerry Bruns to Ken Harris apply. Also see General Comment 2 above.

12. **Feather River (Lake Oroville Dam to confluence with Sacramento River) – Diazinon:** 0.092 µg/L and 0.097 of diazinon were detected at Yuba City on 01/31/2000 and on 02/01/2000, respectively (Dileanis, P. et al., 2002). Diazinon was detected at µg/L 0.11 µg/L on 01/28/2004 near Verona; all of these values exceed the diazinon acute toxicity Site-Specific Water Quality Objective for the Feather River of 0.080 µg/L. On 02/19/2004, the additive toxicity value for diazinon and chlorpyrifos, based on concentrations of 0.029 µg/L diazinon + 0.020 µg/L chlorpyrifos = 1.16 "TU", exceeding the additive toxicity threshold value of 1.0 (Calanchini, 2004). The acute toxicity criterion of 0.025 µg/L for chlorpyrifos was used in the calculation. A total of 135 samples were collected from 2000 to 2005. There

Comments

have been greater than 1 exceedance in every three-year period and, as defined by the additive toxicity criteria, this supports the listing.

13. **Morrison Creek - Diazinon:** Of 28 samples collected and analyzed for diazinon from Morrison Creek (Spector et al., 2004), three samples collected at Franklin Blvd. between 02/19/2001 and 04/24/2003 exceeded the additive toxicity diazinon + chlorpyrifos objective, with the sum of diazinon and chlorpyrifos concentrations (relative to their respective acute toxicity criteria of 0.160 μg/L and 0.025 μg/L) exceeding the additive toxicity threshold value of 1.0 on 01/23/2001, 03/23/2003, and 04/13/2003 (Spector et al., 2004). Two of 14 samples collected at Brookfield in 2005 by Sacramento Stormwater Quality Partnership, October 2005, contained: 0.25 μg/L diazinon and additive toxicity (2.08) on 1/28/2005; and 0.37 μg/L diazinon on 02/15/2005. There have been greater than 1 exceedance in every three-year period and, as defined by the additive toxicity criterion, this supports the listing. The applicable beneficial uses associated with this listing should be WARM and COLD. The extent of impairment is from Elk Grove-Florin Road to Stone Lakes.

14. **Sacramento River (Knights Landing to the Delta) – Diazinon:** Two diazinon exceedances occurred at Veterans Bridge (Alamar): 0.22 μg/L diazinon on 02/04/2004 and 0.084 μg/L on 01/28/2001. The concentrations of diazinon and chlorpyrifos measured on 02/19/2004 (relative to their respective objective [diazinon] and criterion [chlorpyrifos]) = 1.63 "TUs", which exceeded the additive toxicity threshold value of 1.0. The site-specific acute toxicity water quality objective for diazinon of 0.080 μg/L, and the acute toxicity criterion of 0.025 μg/L for chlorpyrifos, were used for the additive toxicity calculations. A total of 266 samples were analyzed for diazinon from 2000 to 2005. There have been greater than 1 exceedance in every three-year period and, as defined by the additive toxicity criterion, this supports the listing.

15. **Sacramento Slough – Diazinon:** There have been no reported exceedances of the applicable acute toxicity criterion of 0.160 μg/L for diazinon, out of 109 samples collected from Sacramento Slough from 2000 to 2005, based on analysis of the available data in the data files located under subfolder "Sac & Feather rivers OP data files". There have been fewer than 1 exceedance in every three-year period and , as defined by the additive toxicity criterion, this does not support listing Sacramento Slough for diazinon.

16. **Sutter Bypass – Diazinon:** There have been no reported exceedances of the applicable acute toxicity diazinon criterion of 0.160 μg/L, nor have there been exceedances of the diazinon and chlorpyrifos additive toxicity threshold value of 1.0, in the Sutter Bypass in 2000 - 2002 or 2004 - 2005 out of 19 samples (no sample data available for 2003), based on analysis of the available data in the data files located under subfolder "Sac & Feather rivers OP data files". There have been fewer than 1 exceedance in every three-year period and, as defined by the additive toxicity criterion, this does not support listing Sutter Bypass for diazinon.

Referenced Data Sources

A. See data in the Excel file: "Data refs for 303(d) mercury listings.xls" and data review summary comments in the Word file: "303(d) mercury data and comments.DOC" on CD under folder: "Hg comments data"

B. Moyle et al., 2003; peer-reviewed article for July, August, September 2001 fish species sampling; SWRCB has this document.

C. The results from the 2002 SJR basin bioassessment sampling have been posted in a report [D. Markiewicz, K. Goding, V. de Vlaming, and J. Rowan, 2002, *Benthic Macroinvertebrate Bioassessment of San Joaquin River Tributaries: Spring and Fall 2002;* UCD ATL.] at:
http://www.waterboards.ca.gov/centralvalley/available_documents/waterqualitystudies/SJR02_Bioassess_final_083005.pdf
According to this report, "A toxicity identification evaluation (TIE) and chemical analysis on sediment collected from Del Puerto Creek in June and September, 2002 suggest pyrethroid insecticides as the cause of toxicity. Chemical analysis revealed 43.2 ng bifenthrin/g dry sediment weight and 20.4 ng permethrin/g dry sediment weight in June samples and 7.51 to 8.25 ng bifenthrin/g dry sediment weight in September samples." TIE results for "Ingram Creek samples following BMI sample collections for this project '...point to multiple pyrethroid pesticides as the cause of toxicity."

See also SWAMP data file "SWAMP sediment sampling summary table 01-05.xls" on CD under "SJR trib pyrethroids" folder.

D. Jassby, et al., 2003; 2004 (Five Year Review of Recovery Plan for Delta Smelt, USFWS, Federal Register 68 (148): 45270-45271).

USFWS, 2005 (Final Rule of Delta Smelt. RIN 1018-AB66). SWRCB also has this document.

SWRCB has these documents.

E. See files on CD under folder: "SJR Se data"; this folder contains two subfolders and two files. The raw data files and a page (Word document) with hyperlinks to raw data files for the Grasslands waterways, several San Joaquin River locations, and for Salt Slough are named according to sample location and found under the "raw data subfolder". The data that has been analyzed for monthly mean Se concentrations for the San Joaquin River at Crows Landing and at Patterson and sorted by descending Se concentrations for other locations, is located under the "Analyzed data for Se exceedances" subfolder. This subfolder also contains a file of calculated 4-day Se concentration averages for Crows Landing.

F. SWAMP data; see file "SWAMP sediment sampling summary table 01-05.xls" on CD under "SJR trib pyrethroids" folder.

G. Calanchini et al., 2004, *A Brief Summary of the 2004 TMDL monitoring for Diazinon in California's Sacramento Valley Waterways January-March 2004*
http://www.waterboards.ca.gov/centralvalley/available_documents/waterqualitystudies/2004_Sac_TMDL_Rpt_070204.pdf

Referenced Data Sources

Data file for this report is located on CD under folders: "Sac & Feather rivers OP data files\raw data files" as "final data base Sacramento 2003 2004 042604HJC.xls"

Data files for other years are on CD under the folder: "raw Sac & Feather rivers OP data files". Raw data (in seven additional Excel format files and URL links to SRWP reports in a Word document file: "Sacramento River Watershed Program monitoring data links.doc") are under subfolder "raw data files".

Seven Excel data files containing modifications of the raw data files, in order to account for potential additive diazinon and chlorpyrifos toxicity exceedances, are found in the subfolder "modified for additivity analyses". Exceedances of either diazinon or chlorpyrifos individually, and exceedances of additive toxicity of the two pesticides, are summarized in a Word document in the same subfolder as file "Diaz & Chlor conc summary.doc".

H. Moyle and Nichols, 1974; SWRCB has this report.

I. See file on CD under folder: "Morrison Creek reports & data".

J. See data files on CD under folder: "Sac & Feather rivers OP data files" for Sacramento Slough and Sutter Bypass data.

California Regional Water Quality Control Board

Central Valley Region

Alan C. Lloyd, Ph.D.
Agency Secretary

Redding Branch Office
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Arnold Schwarzenegger
Governor

23 November 2005

Mr. Joe Karkoski
Regional Water Quality Control Board
11020 Sun Center Drive, Suite 200
Rancho Cordova, CA 95670-6114

303(d) LISTING FOR FALL RIVER SHASTA COUNTY

We have reviewed the 23 November 2005 letter from Fall River Resource Conservation District, which requests revisions to descriptions contained in the current and proposed 303(d) listing of upper Fall River. As stated in the RCD letter, in order to accurately identify existing conditions of impairment, the stressor causing that impairment, and the source of the stressor; the listing descriptions should be modified. The "stressor" should be identified as "sedimentation (i.e. accumulated sand size sediment in upper Fall River), and the "source" of the stressor (and the impairment) should be identified as "historic land management activities (i.e. logging, grazing, channelization, roads, and railroads) and natural catastrophic events (i.e. fire)."

As described by the RCD, in recent years there has been a substantial restoration effort underway in the tributary watershed to Fall River. The principal objective of these restoration projects has been to reduce active stream channel erosion and restore the sediment trapping capability of the upstream meadow complex. Forest landowners have participated in this restoration effort and have also responded through the implementation of improved management practices for their silvicultural operations. Restoration/remediation efforts are now focused on the 'sediment slug' that remains in upper Fall River. We will consider recommendations for delisting Fall River once this sedimentation issue is addressed (either by project activities or by natural causes).

If you have any questions please contact Dennis R. Heiman of my staff at (530) 224-4851 or the letterhead address

JAMES C. PEDRI, P.E.
Assistant Executive officer
Shasta Cascade Watershed

DRH: sae

cc: Mr. Robert Rynearson, Fall River RCD, Fall River Mills

California Regional Water Quality Control Board
Central Valley Region

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Arnold Schwarzenegger
Governor

257

1 December 2005

709

Mr. Joe Karkoski, TMDL Unit
Regional Water Quality Control Board
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PROPOSED 303(D) LISTING FOR NORTH FORK FEATHER RIVER

This letter is in response to the SWRCB two-page summary proposing a 303(d) listing for temperature impairment in the North Fork Feather River (NF Feather). Though our staff has had limited involvement with the ongoing FERC re-license process for the NF Feather (and the temperature issues which we know have been a part of that process), we have had extensive experience in recent years working with local watershed management programs throughout the northern part of the Sacramento River watershed area. The activities of those programs have included preparation of watershed assessments, watershed management plans, and the conduct of ambient water quality monitoring (including temperature monitoring). Our comments below are a reflection of our experience in working with these individual watershed programs and the water quality monitoring activities undertaken by our Redding office staff.

1. The summary document cites numerous temperatures in excess of 21C as the basis for listing the NF Feather for temperature impairment. While our listing policy may allow for a listing based on only one line of evidence, it seems in this instance additional evidence should be presented to substantiate impairment. To the best of our knowledge, if there is temperature impairment in NF Feather, the only 'controllable factor' causing this impairment would be the ongoing hydroelectric operations in the river. It has been our experience that hydroelectric operations can alter temperature regimes in rivers and streams, but that alteration can be towards a warmer or a colder temperature regime, depending on site specific conditions. It would seem in this instance that an additional line of evidence to support listing should include one or more of the following:

   a. that the overall temperature regime of the NF Feather was colder (not exceeding 21C) prior to the construction and operation of the hydro facilities

   b. that populations of cold water species (i.e. trout) were more robust prior to the hydro operations and that the change appears to be temperature related

   c. that current populations of cold water species are suppressed and that situation appears to be temperature related (as opposed to changes in habitat quality or some other factor)

   d. that the 'natural or background' temperature regime in NF Feather (without hydro operations) would not exceed 21C

It is not clear to us what information exists with regard to a. through d. above, and this should have a major bearing on the decision to place NF Feather on the 303(d) list for temperature impairment.

2. Exceedence of an instantaneous daily maximum as basis for listing seems to grossly oversimplify temperature and cold water species relationships in our rivers and streams. Most rivers and streams in the Sacramento River watershed (above the valley floor) are Beneficial Use designated as Cold Freshwater Habitat (COLD). Annual temperature regimes in these waters vary seasonally and spatially (generally cold in the headwaters and progressively warm towards lower elevations). Some streams and some stream reaches are suitable COLD habitat only seasonally for both resident and anadramous species. Some are suitable COLD habitat only in their upper reaches. Some have 'micro-habitat' where cold-water species can seek refuge during critical times of year even though generally recorded stream temperatures substantially exceed reported tolerance levels of these species. There are also issues of life stage, some waters being temperature suitable for adult survival but not for earlier life stages. Some waters have modified temperature regimes (modified from "natural or background levels") from human activities, which are 'controllable'. Other COLD waters have modified temperature regimes that are due entirely to natural, climatic conditions or are do to human activities that are not 'controllable' or reversible. Our point here is that understanding temperature/cold water species relationships and determining 'impairment' in the real world of modified rivers and streams is a very complex process. Bottom line is that we believe a 303(d) temperature listing is merited only under the following circumstances:

   a. there is clear evidence that the water quality objective is exceeded or there is documented BU impairment,

   b. temperature can be identified as the cause of the objective exceedances or the BU impairment,

   c. the exceedances or impairment is the result of controllable activities.

3. With the advent of continuous recording temperature devices that are technically efficient and inexpensive, we are now seeing a substantial increase in available information to better identify annual temperature regimes. Examples where this kind of information has recently come available include:

- Upper Sacramento River (above Shasta Lake)
- Pit River and numerous tributary streams
- Lower Sacramento River (below Shasta Lake)
- Upper Feather River (NF and MF above Oroville) and numerous tributary streams
- Cow Creek watershed
- Deer Creek watershed

All of these waters are COLD listed. A cursory review of the existing temperature data shows that, using the same criteria proposed for the NF Feather listing, most (not all) of the above waters would be 303(d) listed for temperature impairment. In some instances, a listing may be appropriate. However, for reasons discussed in #2 above, a temperature listing in many of these waters would not be appropriate. Given the reality that 303(d) listing and subsequent TMDL activity is a principal driving force for so much of our agency work and priorities, it is important that initial listings are well founded in order to make the most efficient use of our limited time and $.

4. We were surprised to see exceedance of an instantaneous daily maximum used as the basis for determining temperature impairment. Literature references and water quality criteria discuss several different metrics for assessing the implications of temperature to aquatic species. These include

   - number of successive days exceeding a specified daily max
   - number of total days exceeding a specified daily max
   - maximum weekly average temperature (MWAT)
   - maximum weekly maximum temperature
   - diurnal temperature variation

   It is our understanding that temperature impacts to cold-water species are most commonly judged by use of the MWAT and determination if it exceeds a specified temperature deemed necessary for protection of that life stage of the species.

5. In recognition of the complexity of determining 'temperature impairment' in any individual watercourse or watershed, we suggest that some of our available 303(d)/TMDL funding be used for case studies on selected waters where we now have (or soon will have) an extensive data set on annual temperature regime. Scope of the study could include detailed analysis of that data, together with the watershed conditions that influence that temperature regime, with the desired outcome being a recommendation to the Regional Board as to the validity of temperature listing in that watercourse. We believe this would bring some needed additional science to the listing process and could provide a protocol template for consideration of temperature listings in other waters. We would be interested in working closely with and managing a contract study of this type.

In conclusion, we do not support 303(d) temperature listing for the NF Feather River based on information we have (including information referenced in the two page listing summary). We request that you include this letter with your comments to SWRCB on the current proposed listings. If you have questions or comments, please contact Dennis R. Heiman of my staff at (530) 224-4851, or at the letterhead address noted above.

James C. Pedri, P.E.
Assistant Executive Officer

DRH: sae

cc: Sharon Stohrer, SWRCB, Div. Of Water Rights, Sacramento

Central Valley Water Board Recommendations

Staff Comments

Joe Karkoski

STATE OF CALIFORNIA
CENTRAL VALLEY REGION
REGIONAL WATER QUALITY CONTROL BOARD

Outline of Comments

- Exotic species
- Temperature
- Other listing issues

"Exotic" Species

- Legal, technical, policy problems in listing
- Fact sheets equate "exotic" to "non-native"
- "Non-native" fish include striped bass, catfish, and mosquitofish

"Exotic" Species Legal Issues

- Driven by Federal Court ruling calling "invasive" species in ballast water discharge "pollutants"
- Ruling is being extended to *established* non-native species
  - I.e. – there is no discharge of waste

"Exotic" Species Technical Issues

- San Joaquin River – reference indicates flow / hydromod cause
- Cosumnes River – redeye bass should be specified
- Delta – pelagic fish decline – *potential* causes flow changes, toxics, and invasives

"Exotic" Species Policy Issues

- If non-native species are pollutants – must we protect pollutants from pollutants?
- Are Regional and State Board programs protecting non-natives undermined?
- What regulatory authorities do we use to control propagation of established non-native species?
- Is the Delta listing getting ahead of the scientific investigations of the causes of the pelagic fish decline?

"Exotic" Species Recommendations

- Do not list "exotic" species
  - Legal and technical foundation lacking
  - Policy implications not considered
- Consideration of impacts of non-natives/ Board role should be deliberative
- At minimum, specify species causing impairment – general listing causes confusion

Temperature

- Single line of evidence not appropriate
- Temperature regime may be consistent with "natural" conditions
- Describe evidence of fishery impacts & site specific

Temperature Recommendations

- Include summary of all lines of evidence re: temperature impacts
- Do not list if only one line of evidence available based on literature values
- Regional Board will pursue TMDL contract funds to study further

Other Listing Issues

- Evaluate more recent data
- Identify specific pollutants when known
- Consider additive toxicity

Questions?

Refered to in comment letter. (13) 65-8

California Regional Water Quality Control Board

Central Valley Region

Robert Schneider, Chair

Alan C. Lloyd, Ph.D.
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Arnold Schwarzenegger
Governor

TO: Ken Harris, Chief
TMDL Section
SWRCB, DWQ

FROM: Jerry Bruns, Chief
Sacramento Watershed Section

DATE: 17 June 2005

SIGNATURE: ______________________

SUBJECT: SUMMARY OF REGIONAL BOARD STAFF'S REVIEW OF STATE BOARD'S DOCUMENTATION FOR SELECTED WATERBODIES/POLLUTANTS FOR 2004/2006 303(D) LIST UPDATE

In my May 2 memo to you I had requested additional time for my staff to review some of your staff's 303(d) list fact sheets and listing recommendations. I appreciate the additional time you provided. My staff has been able to carefully review a number of the fact sheets Craig J. Wilson provided in his March 29, 2005 e-mail.

We have indicated in the attached table our recommendations with respect to your staff's draft recommendation, as well as our comments on the fact sheets. We understand that your staff may develop additional fact sheets based on SWAMP data. We would appreciate an opportunity to review those fact sheets, once you have prepared them. If you have any questions, please give me a call at (916) 464-4831 or Joe Karkoski at (916) 464-4668.

6/24/05 – Completed most changes
– Temp. Changes?

Attachment: Detailed Review of Selected Fact Sheets by Cental Valley Regional Board Staff

cc: Pam Buford, CVRWQCB, Fresno
Dennis Heiman, CVRWQCB, Redding
Joe Karkoski, CVRQCB, Sacramento
Ken Landau, CVRWQCB, Sacramento
Jim Pedri, CVRWQCB, Redding
Lonnie Wass, CVRWQCB, Fresno
Regional Board TMDL Program Managers

Waterbody	Pollutant	SWRCB Recomm.	RWQCB Recomm.	SWRCB Data Source	SWRCB Data Summary	RWQCB Staff Review Comments
Carson Creek (from WWTP to Deer Creek)	Copper	List	List	SWRCB Source SL-1, Effluent and Receiving Water Quality Assessment for the El Dorado Hills Wastewater Treatment Plant	"Two of 11 samples exceed the CTR Freshwater acute criteria…"	2 of 11 samples contain total recoverable copper exceeding the copper aquatic life CTR criteria, based on an assumed hardness of 100 mg/L as $CaCO_3$.
Carson Creek (from WWTP to Deer Creek)	Manganese	List	List	SWRCB Source SL-1, Effluent and Receiving Water Quality Assessment for the El Dorado Hills Wastewater Treatment Plant	"Three of 4 samples exceeded the DHS Title 22 Secondary MCL criteria (0.05 mg/L)…"	3 of 4 samples contain total recoverable manganese exceeding the manganese MCL based on an assumed hardness of 100 mg/L as $CaCO_3$.
Cherokee Canal	Diazinon	List	Do not list	Used Sac Diaz Conc V 3.1.xls from Regional Board.	"Two of 9 samples exceeded the CDFG Hazard Assessment Criteria 4-day average (50 ng/L)…"	See comment 10.
Deer Creek (Sacramento County)	Iron	List	List	SWRCB Source SL-1, Effluent and Receiving Water Quality Assessment for the Deer Creek Wastewater Treatment Plant	"Five of 12 samples exceeded the chemical constituents water quality objective…"	5 of 12 receiving water samples contained levels of total recoverable iron that exceeded secondary MCLS of 300 ppb.
Feather River, North Fork (below Lake Almanor)	Temperature	List	No recommendation.	Poe Hydroelectric Project FERC No. 2107 Application for New License. Final: December 2003. Volumes 1 and 3.	"Eight hundred sixty-five of 2088 samples exceeded the temperature criteria (20°C) for steelhead, 360 of 441 samples exceeded the temperature criteria (16.5°C) for coho…"	See comments 11 and 30.
Feather River, North Fork (below Lake Almanor)	Turbidity	List	No recommendation	Poe Hydroelectric Project FERC No. 2107 Application for New License. Final: December 2003. Volume 3.	"Six of 14 samples exceeded the Ca. Dept. of Health Services (DHS) Drinking water standards of secondary MCL…"	See comment 12.
Greenhorn Creek	Aluminum	List	Do not list	USGS Alpers, Greenhorn Creek_PreliminaryData_6-14-04.xls	"Thirty-two of 70 samples exceeded the Drinking Water Secondary MCL criteria (0.2 mg/L)…"	See comment 13.
Greenhorn Creek	Copper	List	No recommendation	USGS Alpers, Greenhorn Creek_PreliminaryData_6-14-04.xls	"Fourteen of 89 samples exceeded the CTR chronic criteria (8.96 ppb)…"	See comment 14.
Greenhorn Creek	Iron	List	Do not list	USGS Alpers, Greenhorn Creek_PreliminaryData_6-14-04.xls	"Thirty-seven of 69 samples exceeded the Drinking Water Secondary MCL (0.3 mg/L)…"	See comment 15.
Greenhorn Creek	Methyl-mercury (tissue)	Do not list	No recommendation	USGS Alpers, Greenhorn Creek_PreliminaryData_6-14-04.xls	"A methyl-mercury water quality guideline is not available that complies with the requirements of section 6.1.3 of the Policy"	See comment 16.
Greenhorn Creek	Nickel	List	No recommendation	USGS Alpers, Greenhorn Creek_PreliminaryData_6-14-04.xls	"12 of 89 samples exceeded the CTR Freshwater chronic criteria (52.06 ppb)…"	See comment 17.
Greenhorn Creek	Zinc	List	No recommendation	USGS Alpers, Greenhorn Creek_PreliminaryData_6-14-04.xls	"Eight of 89 samples exceeded the CTR Freshwater acute criteria…"	See comment 18.
Lindo Channel	Diazinon	List	Do not list	Sac Diaz Conc V 3.1.xls from Regional Board.	"Two of 2 samples exceeded the CDFG Hazard Assessment Criteria 1-hour average (80 ng/L)…"	See comment 19.
Lower Bear River Reservoir	Copper	List	List	SWRCB Source 5-10/+CD, Mokelumne River Report, FERC 137, Water Quality Monitoring Program, March 2003-September 2003, and Supplemental Copper Monitoring Preliminary Data, January 2003-September 2003.	"Ten of 22 samples exceeded the hardness based criteria (13.44 ppb) from USEPA (CTR) for freshwater acute (CMC)..."	See comment 20.

Waterbody	Pollutant	SWRCB Recomm.	RWQCB Recomm.	SWRCB Data Source	SWRCB Data Summary	RWQCB Staff Review Comments
agree, Done Lower Bear River Reservoir	pH (low)	List	Do not list	SWRCB Source 5-10/+CD, Mokelumne River Report, FERC 137, Water Quality Monitoring Program, March 2003-September 2003, and Supplemental Copper Monitoring Preliminary Data, January 2003-September 2003.	"Five of 22 samples exceeded the Basin Plan water quality objective for pH…"	See comment 21.
agree, change made Main Drainage Canal	Diazinon	List	List	Sac Diaz Conc V 3.1.xls from Regional Board.	"Twenty-four of 80 samples exceeded the CDFG Hazard Assessment Criteria 4-day average; 37 of 114 samples - CDFG Hazard Assessment Criteria 1-hour average…"	See comment 22.
No Δ necessary Manzanita Lake (Madera Co.)	Temperature	Do not list	Do not list	SWRCB Source 5-2, "Water Quality in the Crane Valley Project" Oct 1985	"Only one sample exceeded the temperature water quality objective. More data is needed to determine if the water quality objective is exceeded."	RWQCB staff concurs with SWRCB data summary and recommendation. See comment 30.
agree, change made Mokelumne River, North Fork	Copper	List	List	SWRCB Source 5-10/+CD, Mokelumne River Report, FERC 137, Water Quality Monitoring Program, March 2003-September 2003, and Supplemental Copper Monitoring Preliminary Data, January 2003-September 2003.	"Three of 39 samples exceeded the CTR criteria for freshwater acute (CMC)…"	See comment 23.
Mokelumne River, North Fork	Temperature	List	List	SWRCB Source 5-10/+CD, Mokelumne River Report, FERC 137, Water Quality Monitoring Program, March 2003-September 2003, and Supplemental Copper Monitoring Preliminary Data, January 2003-September 2003.	"Sixteen of 91 samples exceeded the temperature criteria…"	See comments 24 and 30.
agree, Done, Sacramento River (Red Bluff to Knights Landing)	Done Chlorpyrifos	List	Do not list	Sac Diaz Conc V 3.1.xls from Regional Board.	"Eleven of 38 samples collected in 2004 exceeded the CDFG criteria…"	See comment 25.
agree, Sacramento River (Knights Landing to the Delta)	done Chlorpyrifos	Do not list	Do not list	Sac Diaz Conc V 3.1.xls from Regional Board.	"Two of 32 samples exceeded the CDFG criteria, none of the samples from 2000 exhibit toxicity…"	See comment 26.
Deleted, *San Joaquin River (Merced River to Tuolumne River)*	Fact *Mercury*	Sheet *No decision*	*Keep on List*	SWRCB reportedly used TSMP and SFEI data (includes fish data from outside the Merced River to *Tuolumne River section).*	*"No Decision"*	*See comment 27.*
agree, Sugar Pine Creek (tributary to Lower Bear Reservoir)	Δ made Copper	List	List	SWRCB Source 5-10/+CD, Mokelumne River Report, FERC 137, Water Quality Monitoring Program, March 2003-September 2003, and Supplemental Copper Monitoring Preliminary Data, January 2003-*September 2003.*	Three of 4 samples contained dissolved copper at levels that exceeded the hardness-based criteria from USEPA (CTR) *for freshwater acute (CMC).*	2 of 3 samples collected at Sugar Pine Creek exceed the CTR 1-hour criterion for dissolved copper. In addition, 1 sample of snowmelt collected near Sugar Pine Creek exceeded the CTR 1 hour criterion *for dissolved copper*

Waterbody	Pollutant	SWRCB Recomm.	RWQCB Recomm.	SWRCB Data Source	SWRCB Data Summary	RWQCB Staff Review Comments
Wadsworth Canal	Diazinon	List	List	Sac Diaz Conc V 3.1.xls from Regional Board.	"Sixteen of 127 samples exceeded the CDFG Hazard Assessment Criteria 4-day average (50 ng/L) and 114 of 166 samples exceeded the 1-hour average (80 ng/L)..."	See comment 28.
Willow Creek (Madera County)	Temperature	List	No recommendation	SWRCB Source 5-2, "Water Quality in the Crane Valley Project" Oct 1985	"Of 43 samples recorded, 24 exceeded the mean temperature, 36 the maximum and 13 the minimum temperature; ancillary data record 13 exceedances greater than 20 degrees Celsius in 1989-90 and 1995 on the NFWC, 15 exceedances greater than 20 degrees Celsius in 1987-90, 1992, 1994 and 1996 on the SFWC and 54 exceedances in 1988."	See comments 29 and 30.

Comments:

1. All 4 lines of evidence are from 2003, not 2002 as described in SWRCB Fact Sheets. Unable to verify 7-day maximum water temperatures or associated temperature exceedances. Lake Almanor maximum, minimum, and mean surface temperatures at Canyon Dam (near surface) exceeded 20.5°C during July, August, and September 2003. Lake Almanor maximum, minimum, and mean surface temperatures at Canyon Dam (at depth) were well below 20.5°C during July, August, and September 2003. Temperatures for individual dates not found in data reviewed. Fact Sheet should be revised to indicate elevated temperatures occurred at the lake surface.
2. 34 of 35 samples collected from Bear River exceeded the hardness-based CTR criterion for freshwater acute (CMC) for **dissolved** copper. SWRCB numeric lines of evidence included numerous samples collected from tributaries to Bear River Reservoir that were not included in Regional Board count. Unknown why available 2003 data not considered by SWRCB so Regional Board used only 2002 data as well. 2000 through 2003 data indicate the 67 of 69 samples exceeded the hardness-based CTR criterion for copper. 4 of 5 samples collected from below the Bear River Reservoir reportedly contained **total** copper at levels that exceeded the "USEPA National Ambient Water Quality Criterion for the protection of freshwater aquatic life1-hour average and/or 4-day average..." Fact Sheet should be revised to remove the tributary data or explain the use of the tributary data.
3. 1 of 42 samples collected from Bear River below Bear River Reservoir in 2002 had a pH value below 6.5. Aailable 2003 data was not considered by SWRCB. 2000 through 2003 sample data indicates that 9 of 77 samples had pH values below 6.5. SWRCB numeric lines of evidence included numerous samples collected from tributaries to Bear River Reservoir that were not included in Regional Board count. Fact Sheet should be revised to remove tributary data from the Fact Sheet, or use of the tributary data should be explained.
4. Review should not list based on old CTR freshwater aquatic life water criteria. Zero of 49 filtered water samples contained mercury exceeding the CTR criterion of 50 ng/L. Fact Sheet should be revised to reflect the correct CTR value and number of samples.
5. Data SWRCB reviewed appears to be from three distinct water bodies – Butt Creek above the Butt Valley Reservoir, the Reservoir itself, and Butt Creek below the reservoir. Maximum temperature values for the creek below the reservoir were below the criteria used by State Board, so it does not appear that portion of the creek should be listed. For the reservoir and the creek above the reservoir, it is not possible to tell whether the maximum weekly temperature was exceeded more often then allowed, since the individual data points were not available (only monthly summary information was provided).

6. Cannot verify the number of SWRCB measurements ("620"). However, RWQCB staff counted 65 of 604 samples exceeding 20.0°C, which does not support listing (>68 minimum exceedances required per binomial distribution equation for conventional or other pollutants). Also, SWRCB staff used 20.0°C as the (presumably for steelhead) criterion.
7. Unable to determine whether all sample sites are from the Calaveras River or not, since only site numbers given, not site names. Only one site (L-CAL-1) seems to be on the Calaveras River. Since only 1 of 2 samples from this site exceeds the Primary MCL for MTBE, listing of the Calaveras River is not supported.
8. Unable to determine whether all sample sites are from the Calaveras River or not, since only site numbers given, not site names. Only one site (L-CAL-1) seems to be on the Calaveras River. 3 of 9 samples from this site exceed 20.5°C for steelhead protection. 9 of 9 temperatures from this site exceed 16.0°C for Coho protection. These exceedances support listing the Lower Calaveras River for elevated temperature. Locations of the other "65 of 90" samples (either on or not on the Calaveras River) should be determined and the Fact Sheet updated to describe appropriate waterbody(ies).
9. RWQCB staff concurs with SWRCB staff that 2 of 11 stream ("R1" samples contained total recoverable aluminum exceeding the aluminum Primary MCL (1,000 ppb) criterion; 3 of the 11 samples also exceeded the aluminum Secondary MCL (200 ppb) based on an assumed hardness of 100 mg/L as $CaCO_3$.
10. The CDFG recently (Finlayson, 2004) reviewed one of the studies used to calculate their diazinon water quality criteria (Siepmann and Finlayson, 2000). Based on that review, CDFG suggested a CMC of 0.16 µg/L and a CCC of 0.10µg/L. Of nine total samples, six were analyzed using ELISA methods. We suggest that ELISA results not be used unless they are verified with GCMS data. Based on these criteria, 0 of 3 samples analyzed using GCMS methods exceed the acute criterion. Fact sheet should be revised to account for the correct number of samples and the SWRCB recommendation changed to "Do not list.'
11. Unable to locate data to support SWRCB's lines of evidence.
12. Unable to locate data to support SWRCB's lines of evidence.
13. One of 10 samples exceeded the Drinking Water Secondary MCL criterion that does not require listing. SWRCB used tributaries and drainages into Greenhorn Creek, but RWQCB counted data from Greenhorn Creek only. Fact Sheet should be revised to include only Greenhorn Creek data or explain why tributary and drainage data included in analysis.
14. The data did not include hardness data, so we cannot determine the appropriate CTR Freshwater Chronic Criterion to use (SWRCB used 8.96 ppb, but did not substantiate.)
15. Only one of 10 samples from Greenhorn Creek exceeded the Drinking Water Secondary MCL criterion for iron, which does not support listing. SWRCB also used tributaries and drainages into Greenhorn Creek. The Fact Sheet should be revised to include only Greenhorn Creek data (and change listing status to "Do not list") or explain why tributary and drainage data were included in SWRCB's analysis.
16. Since methyl mercury tissue data was not provided and was not compared to the EPA tissue criterion of 0.3 ppm, RWQCB staff cannot make a recommendation regarding listing Greenhorn Creek for methyl mercury (in tissue).
17. The data source did not include hardness data, so the CTR Freshwater Chronic Criteria for nickel (52.06 ppb) cannot be validated and the number of exceedances cannot be verified. Many of the data points seem to be taken from drainages or tributaries to Greenhorn Creek. Fact Sheet should be revised to indicate source for hardness data and include only data from Greenhorn Creek or explain why tributary and drainage data included in analysis.

18. The data source did not include hardness data, so the CTR Freshwater Chronic Criteria for zinc cannot be determined and the number of exceedances cannot be verified. Many of the data points seem to be taken from drainages or tributaries to Greenhorn Creek. Fact Sheet should be revised to indicate source for hardness data and include only data from Greenhorn Creek or explain why tributary and drainage data included in analysis.
19. See comment 10. Based on revised acute criterion, only 1 of 2 samples exceeds the criterion and, according to Table 3.1 this does not support listing. Fact sheet should be revised to account for the correct number of sample exceedances and SWRCB's recommendation should be changed to "Do not list."
20. Dissolved copper and hardness values were measured at the top, middle and bottom of the Lower Bear River Reservoir on each of 7 dates (approximately monthly) in 2002. Regional Board staff averaged the hardness and dissolved copper values for each date and compared the daily average hardness-corrected copper criteria to the daily average copper concentrations (excluding one anomalously high copper concentration flagged as possibly contaminated). Based on this analysis, 3 of 7 average dissolved copper concentrations exceeded their respective average hardness-corrected copper criteria, suggesting the waterbody be added to the 303(d) list for copper. It is unclear how the SWRCB staff derived the 13.44 ppb copper criterion. The Fact Sheet should be revised to indicate average hardness values used to compare with average dissolved copper levels in the analysis.
21. pH was measured on up to 13 (approximately monthly) dates in 2002 and 2003, at the top, middle, and bottom of the Lower Bear Reservoir. 3 (of 13) average pH measurements from Lower Bear River Reservoir were below the Basin Plan pH criterion (6.5), which suggest the waterbody should be listed for low pH. The Fact Sheet should be revised to account for the correct average pH values and number of exceedances in 2002-2003.
22. Refer to comment 10. 50 of 98 samples exceeded the revised acute criterion. Fact Sheet should be revised to indicate the correct number of samples.
23. Data used for North Fork (NMFR3 and NMFR5) only; other data included by SWRCB is not from North Fork. 3 of 30 data points exceed the hardness-based copper criterion, which still supports listing. Fact Sheet should be revised to include only North Fork data.
24. Data used for North Fork (NMFR3 and NMFR5) only; other data included by SWRCB is not from the North Fork. 12 of 45 data points exceed the Coho temperature criterion of 16.5°C, which still supports listing. Fact Sheet should be revised to include only North Fork data.
25. Zero of 36 samples collected from stations (Hamilton City and Colusa) in this stretch of the Sacramento River contained chlorpyrifos at levels that exceeded the criteria, although the LOQs were higher than the criteria for some samples. SWRCB used samples from Bryte and Wadsworth canal, which are not representative of the Sacramento River between Red Bluff and Knights Landing. Fact Sheet should be revised to include only relevant stations.
26. Zero of 193 samples collected from stations in this stretch of the Sacramento River contained chlorpyrifos at levels that exceed the relevant criteria, although the LOQs were often higher than the criteria for many of the samples. SWRCB used samples not in the stretch of the Sacramento River between Knights Landing and Delta. Fact Sheet should be revised to include only relevant stations.
27. San Joaquin river was placed on the 303(d) list in 2002 for impairment due to mercury. Available data does not suggest a change in the listing of mercury in the San Joaquin River.
28. Refer to comment 10. 87 of 162 samples exceeded the acute criterion. Fact Sheet should be revised to account for use of revised criteria.

29. Although the number of days exceeding 20°C between 1986 and 1996 are listed in a table for the NFWC and the SFWC, the total number of days measured in each year is not given, so exceedances cannot be determined from data set obtained from SWRCB.
30. Regional Board staff note that the evaluation of compliance with our temperature objectives is complex. The objective states that the natural receiving water temperature shall not be altered unless such alteration does not adversely affect beneficial uses. There is also a statement that the temperature shall not be increased by more than 5 degree Fahrenheit above natural receiving water temperature. Evaluation of compliance with this objective assumes an understanding and evaluation of the natural receiving water temperature. A comparison of temperature data to literature values for fish species does not necessarily take into consideration the "natural receiving water temperature". We have provided comments on the State Board staff's evaluation of temperature data relative to the evaluation guidelines used by State Board. Due to the complexity of evaluating compliance with the temperature objective, our comments to list or not list are based on the evaluation guidelines used by State Board staff and do not reflect Regional Board staff conclusions regarding attainment of the temperature objective.

guidelines
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Aquatic Toxicity Due to Residential Use of Pyrethroid Insecticides

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Pyrethroids are the active ingredients in most insecticides available to consumers for residential use in the United States. Yet despite their dominance in the marketplace, there has been no attempt to analyze for most of these compounds in watercourses draining residential areas. Roseville, California was selected as a typical suburban development, and several creeks that drain subdivisions of single-family homes were examined. Nearly all creek sediments collected caused toxicity in laboratory exposures to an aquatic species, the amphipod *Hyalella azteca*, and about half the samples caused nearly complete mortality. This same species was also found as a resident in the system, but its presence was limited to areas where residential influence was least. The pyrethroid bifenthrin is implicated as the primary cause of the toxicity, with additional contributions to toxicity from the pyrethroids cyfluthrin and cypermethrin. The dominant sources of these pyrethroids are structural pest control by professional applicators and/or homeowner use of insecticides, particularly lawn care products. The suburbs of Roseville are unlikely to be unique, and similar sediment quality degradation is likely in other suburban areas, particularly in dry regions where landscape irrigation can dominate seasonal flow in some water bodies.

Introduction

Pyrethroid insecticides now fill most of the residential needs previously met by organophosphates. Use of organophosphates was drastically curtailed in the United States by the recent withdrawal of nearly all products for residential use that contain chlorpyrifos or diazinon. The vast majority of insecticides sold for consumer use now contain pyrethroids, and they are widely used around homes by professional pest control applicators as well. Agricultural use of pyrethroids has resulted in residues in runoff (*1*), with resulting contamination of creeks receiving return flow from irrigated fields (*2*). Similarly, the pyrethroid bifenthrin has been found in runoff from a commercial nursery (*3, 4*). Landscape irrigation or stormwater runoff could play similar roles in transporting residentially used pyrethroids into urban water bodies. However, there is no monitoring for most pyrethroids in urban environments. The U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program, the largest effort to monitor urban drainages, monitors sediments for permethrin, only one of many residential use pyrethroids and the one with the lowest aquatic toxicity (*5*). Given the minimal monitoring that has been done for these pesticides with widespread use, there is a need to determine the following: (1) if residential use of pyrethroids results in residues in nearby aquatic systems; (2) if concentrations reach levels that cause mortality in sediment toxicity tests; and (3) if the presence of pyrethroids is a factor controlling the distribution of resident aquatic invertebrates.

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Materials and Methods

Study Area. The area surrounding Sacramento, California has experienced rapid population growth, and within the past few years, thousands of homes have been built on land that was historically open grassland. Roseville is one of many such suburban communities surrounding Sacramento. The western portion of Roseville is characterized by numerous contiguous subdivisions of single-family homes, most of which are less than 10 years old. There is no industry in the area and only minimal commercial development and agriculture. The area was selected as a candidate for a case study on residential pesticide use because of the few pesticide sources other than residential application, and the fact that historical data had indicated the presence of *Hyalella azteca* (Arthropoda: Crustacea) in streams in the area, a species of particular interest in this study.

The main watercourse west of Roseville is Pleasant Grove Creek, a slow-moving stream 2–4 m wide and 0.5–1 m deep in most reaches. Kaseberg Creek and the South Branch of Pleasant Grove Creek (hereafter referred to as the South Branch) are the main tributaries (Figure 1). Precipitation of typically 40–60 cm/yr occurs primarily from November through March. During the summer, the primary source of water to the system is runoff from residences from over-irrigation of landscapes and lawns. Many stormwater drains from the housing subdivisions discharge to Pleasant Grove Creek, and particularly its tributaries, along much of their lengths.

Sampling Procedures. Sampling sites were established at 3–6 locations along the mainstem of each of the three creeks, and in 2–3 secondary tributaries entering each creek. These smaller tributaries originate at the outfall of storm drains serving the residential areas, and carry water from the outfalls to the main creeks.

Pyrethroids are rapidly adsorbed to soil particles, so sediments would expected to be the main repository for these compounds (*4*). Bottom sediments were collected from most sampling sites in September 2004, with the remainder of the sites sampled in either the preceding or following month. There were rain events between each of these sampling occasions, though 1–3 sites were resampled before and after each rain. No appreciable change in toxicity or pyrethroid concentrations was observed, and results from these few sites with multiple samples are sometimes averaged in the data presented.

All sites were sampled from the bank or by wading into the creek, using a steel scoop to skim the upper 1 cm of the sediment column. Approximately 3 L of sediment was collected at each site, placed in pre-cleaned glass jars, and held on ice until return to the laboratory. All sediments were

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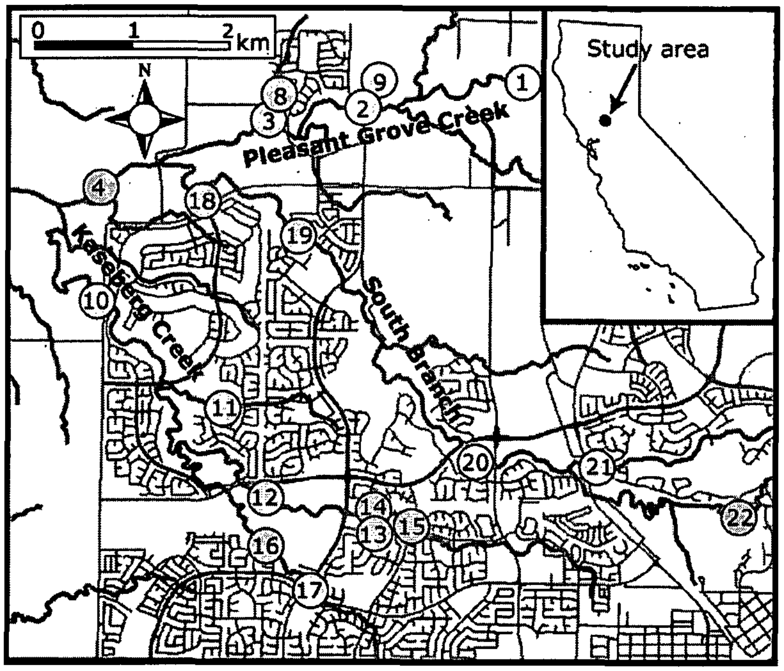

FIGURE 1. Map of study area with sampling sites shown. Inset map shows location of study area within California. Areas of housing development can be inferred from density of roads. Water flow in all creeks shown is from east to west. Stations 5, 6, and 7 are in Pleasant Grove Creek off the left side of the map, approximately 7, 10, and 13 km downstream of station 4, respectively. They are not shown because doing so would substantially reduce the detail visible in the map.

homogenized in the laboratory by hand mixing, then held at 4 °C (toxicity samples) or −20 °C (chemistry samples).

A physical habitat assessment was conducted at each site to document any heterogeneity among sites that could affect availability of *H. azteca* habitat. Physical habitat assessments consisted of collection of the standardized Habitat Assessment Field Data Sheet (*6*) for low-gradient wadeable streams. Site habitat data included estimates of epifaunal substrate/available cover, pool substrate characterization, pool variability, sediment deposition, channel alteration, channel sinuousity, bank stability, vegetation protection, and riparian vegetative zone width. Data are not presented, though the assessment documented comparable habitat throughout the study area. Water quality measurements were taken for dissolved oxygen, temperature, pH, and specific conductivity.

Field sampling for resident *H. azteca* was conducted using a low-gradient modification of the California Stream Bioassessment Procedure (*7*). All of the sample sites were low gradient (slope <0.2) and did not contain riffle habitat. Each sampling site consisted of a relatively homogeneous 100-m sampling reach. The reach was divided into three equal segments and each segment was sampled by approximately 20 jabs followed by a sweeping motion using a 0.5-mm mesh D-frame kick net. Sampling included aquatic macrophytes and overhanging riparian vegetation along the banks, as well as scraping along the surface of the bottom sediments. The sample from each segment was preserved with 10% formalin and later transferred to 70% ethanol. Laboratory processing included enumeration of only the *H. azteca* in each sample.

Analytical Methods. Chemical analytes included seven pyrethroids, 20 organochlorine pesticides or their degradation products, and one organophosphate (chlorpyrifos). Individual pyrethroid isomers were quantified, though they are summed in all data presented. Analysis followed the methods described by You et al. (*8*), differing only in quantification of 3 additional pyrethroid analytes. Briefly, sediment samples were sonicated with a solution of acetone and methylene chloride and the extracts were cleaned by column chromatography with deactivated Florisil. Analysis was performed on an Agilent 6890 series gas chromatograph with an Agilent 7683 autosampler, an electron capture detector, and two columns, an HP-5MS and a DB-608 (Agilent Technologies, Palo Alto, CA). Qualitative identity was established using a retention window of 1% with confirmation on a second column, and calibration was based on area using external standards at concentrations ranging from 10 to 100 μg/L diluted from stock solutions. Analytical grade standards were used throughout the study. The pyrethroids were purchased from Chem Service (West Chester, PA). Organochlorines, organophosphates, and surrogate standards were purchased from Supelco (Bellefonte, PA). Detection limits for the individual pyrethroids ranged from 0.1 to 0.6 ng/g, though a consistent reporting limit of 1.0 ng/g was used for all analytes. Recovery of pyrethroids from fortified samples analyzed blind ranged from 61 to 105%.

Two samples (sites 13 and 15) were also analyzed by a second laboratory for quality assurance purposes. This second laboratory extracted the sediments using pressurized fluid extraction (Dionex 200 Accelerated Solvent Extractor, Dionex, Sunnyvale, CA). Gel permeation chromatography followed by Florisil column chromatography were used for extract cleanup. Analysis was done with an Agilent 6890plus gas chromatograph with autosampler, equipped with two ^{63}Ni micro-electron capture detectors and dual 60-m capillary columns (DB-5 and DB-17MS, Agilent Technologies). Positively identified pyrethroids were confirmed using gas chromatography with mass spectrometry-ion trap detection (GC/MS-ITD) when possible. A Varian GC/MS-ITD, Saturn 2000 (Varian, Palo Alto, CA) was used with a 30-m DB-5MS column (Agilent Technologies). The GC/MS-ITD was used in select ion storage (SIS) and/or MS−MS mode. All concentration data presented were derived from analyses by the primary laboratory, rather than the second laboratory that was used primarily for confirmation of analyte identity by GC/MS. However, results from the second lab confirmed both the identity and quantification of analytes as reported herein.

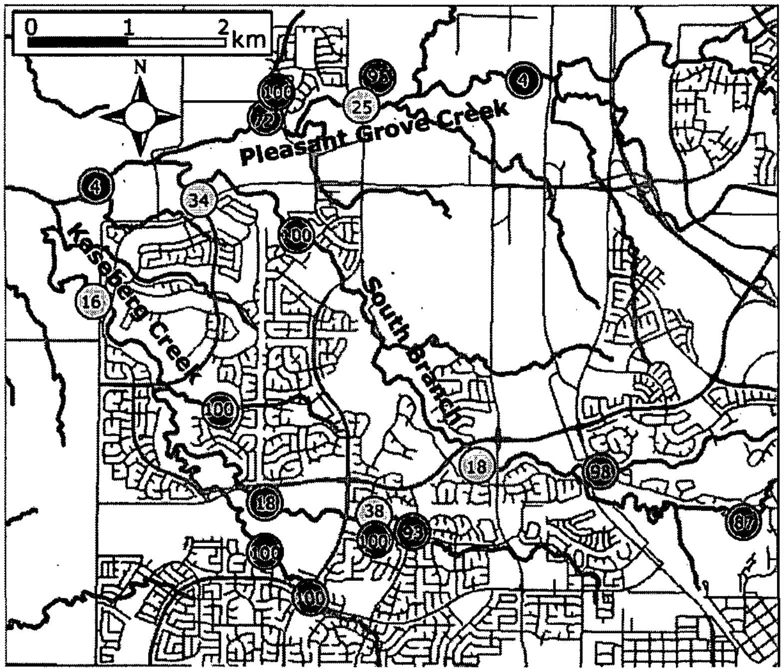

FIGURE 2. Distribution of sediment toxicity among the study sites. The numerical values at each site indicate the percent mortality of *H. azteca* in 10-d toxicity tests. Results are also illustrated by color coding (red = high toxicity with >70% mortality; yellow = moderate toxicity with mortality significantly greater than control but <70%; green = nontoxic with mortality not significantly different than control). Two stations (sites 5 and 6) not shown, but located on Pleasant Grove Creek 7 and 10 km, respectively, further downstream of station 4 were also nontoxic.

Total organic carbon was determined on a CE-440 elemental analyzer from Exeter Analytical (Chelmsford, MA), following acid vapor treatment to remove inorganic carbon.

Toxicity Testing. Toxicity testing was performed using 7–10-d old *H. azteca*, following standard methods (*9*). Testing was done in 400-mL beakers containing about 75 mL of sediment, with eight replicate beakers per sample. Test protocols included use of moderately hard water reconstituted by addition of salts to Milli-Q purified water (Millipore, Billerica, MA), a temperature of 23 °C, a 16:8-h light/dark cycle, and daily feeding with YCT (yeast, cerophyll, trout chow). Two volume additions of water were supplied daily to each testing chamber by an automatic water delivery system. This rate of water renewal was sufficient to keep dissolved oxygen levels high (5–7 mg/L) in most instances. However, three sediments required gentle aeration. Sediment from site 8 was aerated for the full test duration. Sediments from sites 21 and 22 received aeration beginning on day 5 when dissolved oxygen had declined to about 3 mg/L. After a 10-d exposure period, the amphipods were recovered, survival rate was determined, and biomass was measured after drying at 70 °C to determine growth.

All test batches included control sediment containing 1.87% organic carbon, collected from the South Fork of the American River in Placer County, CA near Folsom Lake. Sediment from this location was one of three sediments that had previously been amended with pyrethroids to determine the LC_{50} values used herein (American River sediment of Amweg et al. (*10*)).

Toxicity data were analyzed using ToxCalc Version 5.0 (Tidepool Scientific Software, McKinleyville, CA). Dunnett's Multiple Comparison test was used to identify stations with significantly greater mortality than the control. Arcsin squareroot transformation was used when necessary to meet assumptions of normality and homogeneity of variance. If these assumptions were not met even after transformation, comparison to control was done using Steel's test.

Results and Discussion

Toxicity Testing. Sediments throughout Pleasant Grove Creek and its tributaries were tested for acute toxicity to the amphipod, *H. azteca*, a species widely used for freshwater sediment testing. Sediment from 9 of the 21 sites caused total or nearly total (>90%) mortality of *H. azteca* in a 10-d exposure (Figure 2). Sediments from the smaller secondary tributaries, all of which originate at storm drain outfalls and carry runoff to the three creeks, were particularly toxic with mortalities ranging from 34 to 100% (mean = 90%). Growth data are provided in the Supporting Information (Table S1), but are not discussed herein as they do not substantially alter the results gained from the mortality endpoint alone.

Sediments from most of the mainstem of Pleasant Grove Creek showed no toxicity (~4% mortality). However, sediments were acutely toxic (25–72% mortality) in Pleasant Grove Creek at the confluence with two tributaries that drain housing developments to the north. Sediments collected within these two tributaries caused total or nearly total mortality.

Sediments throughout most of Kaseberg Creek showed mortality rates greater than the control, and mortality rates tended to increase from its confluence with Pleasant Grove Creek (16% mortality) to the most upstream sites (93 and 100% mortality). Similarly, every site in the South Branch showed significant mortality (18–100%).

Sediment Chemistry. To help identify the cause of the observed toxicity, sediments were analyzed for 28 pesticides including one organophosphate (chlorpyrifos), 20 organochlorines, and 7 pyrethroids. The concentrations of chlorpyrifos and the organochlorines were below levels associated with toxicity to *H. azteca* (*2*). Those results are presented in the Supporting Information (Table S2) but not discussed here. All seven of the pyrethroid analytes were detected in sediments from at least some sites, but esfenvalerate and lambda-cyhalothrin were found infrequently and at low concentrations (Table 1).

TABLE 1. Pyrethroid Concentrations in Creek Sediments (ng/g Dry Weight)[a] (Sites with a and b Designations Indicate Two Samples Taken at the Same Location Approximately One Month Apart)

sampling site	Compound[b]						
	bif	cyfl	cyper	delta	esf	lam	perm
Pleasant Grove Creek							
mainstem							
1	3.3	u	u	u	u	u	14
2	9.0	u	u	u	u	u	24
3a	17	5.2	2.4	5.1	u	u	17
3b	14	3.5	2.6	2.8	u	2.5	11
4	1.7	u	u	u	u	u	8.2
5	1.5	u	u	u	u	u	3.1
6	1.2	u	u	u	u	u	2.1
tributaries							
9	40	8.3	14	2.0	u	1.6	19
8	77	70	18	5.1	u	2.0	22
South Branch							
mainstem							
21	36	27	23	8.7	2.5	3.4	57
20	5.8	u	u	u	u	u	7.4
19a	146	11	8.0	4.9	u	1.6	54
19b	78	12	3.7	3.1	1.6	1.6	29
tributaries							
22	74	48	40	u	u	3.4	154
18	11	u	4.0	u	u	u	u
Kaseberg Creek							
mainstem							
17	340	161	64	46	u	9.3	188
15	201	96	30	17	5.8	12	117
14	30	6.5	u	1.8	u	1.3	22
12	13	u	u	u	u	1.2	u
10a	6.1	u	u	1.6	u	1.6	u
10b	7.4	3.1	1.3	u	u	1.2	4.5
tributaries							
13	413	167	736	5.7	u	13	225
16	217	90	36	11	5.8	3.5	100
11	437	169	38	15	5.3	8.7	335

[a] u indicates concentration below reporting limit (<1 ng/g). [b] bif = bifenthrin, cyfl = cyfluthrin, cyper = cypermethrin, delta = deltamethrin, esf = esfenvalerate, lam = lambda-cyhalothrin, perm = permethrin.

Pleasant Grove Creek generally had no detectable pyrethroids except for small quantities of permethrin and bifenthrin. However, an exception was the region around stations 2 and 3, the only portion of Pleasant Grove Creek within the study area where there is housing immediately adjacent to the creek. This region contained moderate concentrations of bifenthrin (9–15 ng/g), probably from two small tributaries draining the developed area to the north. Sediments in the two tributaries (stations 8 and 9) contained 40–77 ng/g bifenthrin and up to 70 ng/g cyfluthrin.

Kaseberg Creek and the South Branch, both of which pass through extensive housing developments, contained far higher concentrations of pyrethroids than Pleasant Grove Creek, which borders the northern fringe of the developed area. Secondary tributaries of Kaseberg Creek had the highest concentrations of pyrethroids, particularly bifenthrin, cyfluthrin, cypermethrin, and permethrin. Contamination in the Kaseburg Creek mainstem was less severe, with the exception of the most upstream sites (stations 15, 17).

The extent of pyrethroid contamination in these suburban sediments is remarkable, particularly in comparison to the lesser levels of contamination for some of the same compounds reported in water bodies affected by agriculture. Bifenthrin concentrations in the secondary tributaries reached 437 ng/g, about 15 times greater than the highest bifenthrin concentration reported from about 70 samples from creeks and drains in areas of intensive agriculture in California (*2*). Peak concentrations of permethrin and lambda-cyhalothrin were comparable in the suburban and agricultural areas. These comparisons, however, may be distorted by the fact that samples with the highest concentrations in the current study were often collected near the point of storm drain inputs, whereas agriculture-related samples have been farther from individual outfalls.

The data suggest that sediment contamination was localized near storm drain outfalls and at points where the secondary tributaries enter the main creeks. For example, station 14 in Kaseberg Creek contained 62 ng/g total pyrethroids, far less than at a site only 0.2 km upstream (station 13, 1560 ng/g) or another site 0.5 km upstream (station 15, 479 ng/g). The fact that Pleasant Grove Creek is relatively unaffected despite the widespread contamination in Kaseberg Creek and the South Branch also suggests minimal transport of contaminated sediments, probably due to the low current speeds in the creeks. Overall, it appears that any given outfall affects sediment quality for a distance of tens to hundreds of meters downstream. However, given the numerous outfalls scattered throughout the system, the result is a patchwork of highly contaminated reaches.

Pyrethroid concentrations were used to calculate toxicity units (TU) in the sediments as follows:

$$TU = \frac{\text{Actual concentration (organic carbon normalized)}}{\text{Reported } H.\ azteca\ LC_{50} \text{ concentration (organic carbon normalized)}}$$

LC_{50} concentrations for a 10-d exposure of *H. azteca* to pyrethroid-contaminated sediments have been determined for 3 sediments (*10*). The LC_{50} values used in the TU analysis are the means from these 3 sediments: bifenthrin = 0.52 μg/g organic carbon (oc), cyfluthrin = 1.08 μg/g oc, cypermethrin = 0.38 μg/g oc, deltamethrin = 0.79 μg/g oc, esfenvalerate = 1.54 μg/g oc, lambda-cyhalothrin = 0.45 μg/g oc, and permethrin = 10.83 μg/g oc. All pyrethroids are extremely hydrophobic, thus, LC_{50} values are more consistent and the TU analysis is improved by expressing concentrations normalized to sediment organic carbon (*10*).

When the pyrethroid concentrations are expressed as TUs, it is apparent that nearly all of the sites had concentrations that would be expected to be acutely toxic (Figure 3). All sites but one (station 20) in Kaseberg Creek and the South Branch had at least 1 TU, indicating that *H. azteca* would be expected to show high mortality in sediment toxicity tests due to pyrethroids nearly anywhere in either creek. The tributaries of Kaseberg Creek are particularly noteworthy because their sediments had 14–41 times the acutely lethal concentrations of pyrethroids.

Pleasant Grove Creek was the only creek where TU analysis suggests pyrethroids concentrations were low enough to allow survival of *H. azteca*. Sediments in its two small northern tributaries (stations 8 and 9) had 7–13 TU, and Pleasant Grove Creek had 2–3 TU in the region where these tributaries enter. However, the remainder of Pleasant Grove Creek was well below 1 TU.

When the pyrethroid concentration data are weighted by toxicity of the individual compounds, as in the TU analysis, it is apparent that most of the expected toxicity is attributable to bifenthrin. Bifenthrin alone comprised an average of 70% of the TUs among all sites. While bifenthrin is the dominant contributor to the toxicity, it is not the sole contributor. Other pyrethroids, particularly cyfluthrin and cypermethrin, were found in some locations at concentrations expected to be toxic to *H. azteca*. Of the 16 sites with one or more TU, 11 sites would still have more than 1 TU if bifenthrin were excluded from the analysis.

Permethrin was commonly found in creek sediments, having the highest or second highest concentration of all

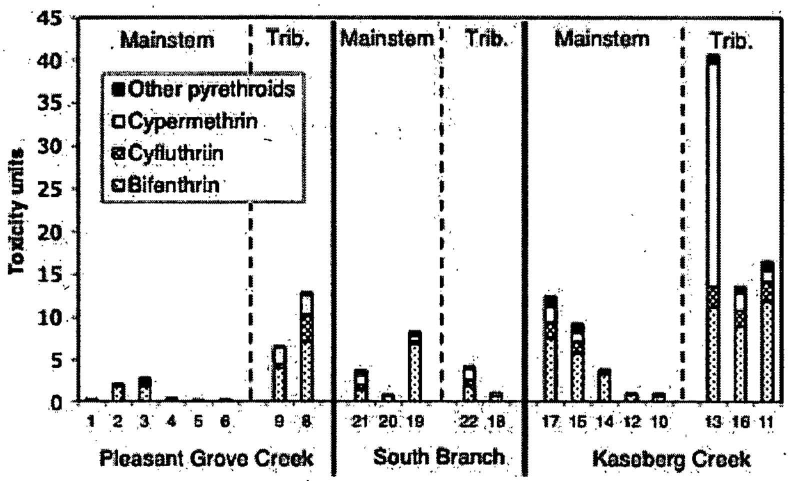

FIGURE 3. *H. azteca* TUs in the sediments at each sampling site, and the contribution of the various pyrethroids to the total TU. At one TU, data in the literature (*10*), suggests that the concentration of pyrethroids would be sufficient to cause 50% mortality to *H. azteca* in 10-d sediment toxicity tests.

pyrethroid analytes in over $^3/_4$ of the samples. However, it contributed little to the pyrethroid TUs. It is among the least toxic of the pyrethroids to *H. azteca* (*10*) and to aquatic life in general (*5*).

The TU analysis identifies sites where *H. azteca* mortality would be expected based on chemical concentrations and previously reported toxicity thresholds. It was a good predictor of the actual toxicity testing results (Figure 4a) with the correlation between pyrethroid TUs and observed *H. azteca* mortality being highly significant ($p < 0.001$; Spearman rank correlation). At sites with less than 1 TU, little mortality would be expected, and little was observed. At all sites with more than 4 TUs there was, as would be expected, little or no survival. Between 1 and 4 TUs there was some divergence between expected and observed mortality. Mortality of 50% would be expected at 1 TU, but only 15–30% mortality was observed. This discrepancy is not unusual since pyrethroid sediment LC_{50} values can vary somewhat among sediments even after adjustment for organic carbon content (*10, 11*).

Resident Macroinvertebrates. *H. azteca* is resident in the Pleasant Grove Creek system, and its distribution was studied to determine if patterns were correlated with pyrethroid concentrations and toxicity test results. Populations were present at all sites in Pleasant Grove Creek, although densities were reduced at the mouths of the two northern tributaries and sampling sites nearest to and downstream of the South Branch and Kaseberg Creek tributaries (Table S3). The species was completely absent from both the South Branch and Kaseberg Creek.

The abundance of resident *H. azteca* was inversely correlated with pyrethroid TUs (Figure 4b; $p < 0.05$; Spearman rank correlation). Sediments containing more than 1 TU of pyrethroids had few or no resident *H. azteca*. Densities were variable at sites having less than 1 TU, presumably due to factors other than pyrethroid concentrations. The distribution of resident *H. azteca* was consistent with the patterns of sediment pyrethroid concentrations and toxicity test results, but the patterns were confounded by other habitat factors, for example, the low dissolved oxygen concentrations in some regions of the system. The low input of water in the summer results in low current speeds, and with the accumulation of decaying riparian vegetation in the bottom of the creeks, dissolved oxygen levels can be low (measured at 1.0–7.6 mg/L in Pleasant Grove Creek, 3.6–7.8 mg/L in the South Branch, and 0.5–4.5 mg/L in Kaseberg Creek).

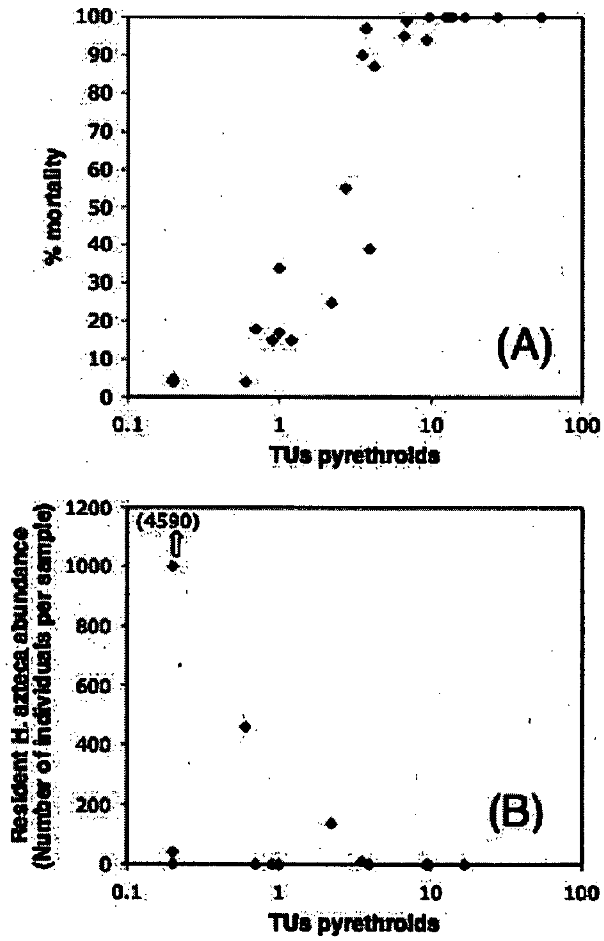

FIGURE 4. Relationship between the number of TUs of pyrethroids in creek sediments and the biological measures: (A) the toxicity to *H. azteca* in 10-d laboratory exposures to the sediments; (B) the density of resident *H. azteca* in Pleasant Grove Creek, South Branch, and Kaseberg Creek. When tested by Spearman rank correlation, both relationships were significant ($p < 0.001$ and $p < 0.05$ for (A) and (B), respectively).

Identifying the Source of pyrethroids. The strong relationship between pyrethroid TUs and observed sediment toxicity, and the fact that *H. azteca* mortality appeared when

TABLE 2. Reported Pyrethroid Use (kg/year) in Placer County, California in 2003 (Reported Data Include Only Commercial Applications, Not Use by Homeowners)

pyrethroid	agricultural use	structural pest control	landscape maintenance
bifenthrin	0.01	141.4	6.2
cyfluthrin	0	275.1	3.9
cypermethrin	0	3337.9	0.05
deltamethrin	0	32.1	0.83
esfenvalerate	17.8	0.02	0
lambda-cyhalothrin	22.6	2.3	0
permethrin	0	673.5	157.5
other	0	1.2	0

sediment pyrethroid concentrations reached levels at which the literature suggests it should if pyrethroids were the responsible agent (at or slightly below 1 TU; Figure 4a), provide strong evidence implicating pyrethroids as the cause of toxicity. The potential sources of the pyrethroids observed in the creek sediments include the following: (1) agriculture; (2) mosquito control; (3) landscape treatment by professional applicators; (4) structural pest control by professional applicators; and (5) landscape application by homeowners or their gardening services. It is possible to eliminate some of these potential sources using statistics taken from the Pesticide Use Reporting database maintained by the California Department of Pesticide Regulation (www.cdpr.ca.gov). All commercial pesticide applications in California require an entry into the database, including information on product used, active ingredient, amount used, date, and place of application. The database includes all agricultural pesticide use and residential applications by licensed pest control firms, but it does not include products purchased from retail stores and used by homeowners or gardening services they may employ.

It is unlikely that the pyrethroids observed were of agricultural origin. There is very little agriculture in the watershed studied or in the county as a whole. In Placer County in 2003 only 1% of the reported pyrethroid use was agricultural (Table 2). Bifenthrin appeared most widespread of all the pyrethroids in Pleasant Grove Creek and its tributaries and made the greatest contribution to the toxicity, but county-wide agricultural use of bifenthrin was only 0.01 kg compared to 147.6 kg of reported nonagricultural use.

Mosquito control spraying can also be eliminated as a source of the contamination observed. The Placer County Mosquito Abatement District controls adult mosquitoes using Scourge, a product containing the pyrethroid resmethrin and the synergist piperonyl butoxide (J. Scott, Placer County Mosquito Abatement District, personal communication). Thus, none of the seven pyrethroid analytes in this study could have originated from mosquito spraying. Two sediment samples (sites 13 and 15) were analyzed specifically for resmethrin with no detectable residues found (GC/MS-ITD screening, 10 ng/g detection limit).

Landscape treatment by professional applicators may have contributed to permethrin in the creeks, as permethrin is the primary compound used for this purpose. However, landscape treatment was unlikely to have been the major bifenthrin source. Reported landscape use of bifenthrin by professional applicators was very low, with only 6.2 kg used county-wide in 2003.

In 2003, 4463.5 kg of pyrethroids was used by professional applicators in Placer County for structural pest control (i.e., in or around the exterior perimeter of homes and other structures). Cypermethrin comprised 75% of the total, followed by permethrin (15%), cyfluthrin (6%), and bifenthrin (3%). The cypermethrin and permethrin products used have substantial below-ground use as termiticides where they would be less prone to runoff, though the product labeling does permit above-ground application as well. Reported structural pest control use of bifenthrin and cyfluthrin were primarily in products intended for above-ground treatment (bifenthrin = Talstar CA granular insecticide, Talstar lawn and tree flowable insecticide; cyfluthrin = Tempo 20 WP, Prescription Treatment brand Cy-Kick CS). Twice as much cyfluthrin was used as bifenthrin for structural pest control, but cyfluthrin concentrations in creek sediments were much lower than bifenthrin. The dominance of bifenthrin in the creeks is not consistent with structural pest control as its dominant source, however, differences in environmental persistence among the pyrethroids may confound this comparison. Bifenthrin half-life in sediments is about a year (*12*), but sediment persistence data on most other pyrethroids are lacking. Thus, it is uncertain if the dominance of bifenthrin in the sediments reflects greater input or greater persistence. Structural pest control could be a significant source for many of the pyrethroids (bifenthrin, cyfluthrin, cypermethrin, and permethrin), but it is not possible with available data to determine its relative magnitude, particularly for the bifenthrin that appears to be the major contributor to toxicity.

An alternative potential source of bifenthrin to the Pleasant Grove Creek system is landscape use by homeowners or their gardening services. Retail pesticide sales data are not publicly available, so it is not possible to quantify usage as was done for the other potential sources. However, the majority of bifenthrin-containing products available in retail outlets are granular products that are broadcast onto lawns using a spreader. Consumer surveys in California have found that about half of retail pesticide purchases are made at large home supply stores (*13*). In a shelf survey of a Home Depot store in the Roseville area, six insecticide products intended for lawn application were found, three of which contained bifenthrin as the active ingredient. One of these three products (Scott's Turf Builder with SummerGuard) is a mixture of bifenthrin and fertilizer; the other two (Ortho Basic Solutions Lawn and Garden Insect Killer, Ortho Bug-B-Gon Max Insect Killer for Lawns) are intended solely for use as insecticides for control of pests such as ants, mole crickets, ticks, and fleas. The remaining three available lawn products contained lambda-cyhalothrin (Spectracide Triazide Soil and Turf Insect Killer (granular)), esfenvalerate (Ortho Bug-B-Gon Max Lawn and Garden Insect Killer (liquid)), or permethrin (Ortho Basic Solutions Lawn and Garden Insect Killer (liquid)).

Using the bifenthrin-containing Ortho Bug-B-Gon Max Insect Killer for Lawns product as an example, if the product were applied to a 100-m^2 lawn at the recommended application rate (738 g product/100 m^2, containing 0.115% bifenthrin), off-site transport of a hypothetical 1% of the applied amount would equate to 8.5 mg of bifenthrin. This amount of bifenthrin would have to be dispersed in over 0.8 metric tons of sediment (dry weight) before the concentration would decrease below the *H. azteca* 10-d LC_{50} (*10*; assuming 2% oc), and even further dilution would be necessary to reach nontoxic concentrations. If the bifenthrin were in the dissolved phase, dilution with at least 2.2 million L of water would be required to reduce the concentration below that acutely lethal to sensitive aquatic species (*5*; given a 5th percentile LC_{50} of all aquatic species tested of <3.8 ng/L). These values used for lawn area and off-site transport are hypothetical, but they illustrate it is plausible that even a very small amount of product carried by irrigation runoff from the lawn to which it was applied could adversely affect sensitive aquatic life in nearby creeks.

This study documented the presence of pyrethroids in the sediments of creeks within a residential neighborhood, and it is possible to identify likely sources, though further work will be necessary to determine their relative magnitudes.

The compounds of greatest concern are bifenthrin, and secondarily, cyfluthrin and cypermethrin, and their potential sources appear to be limited to structural applications by professional pest control applicators and homeowner use of insecticides, particularly lawn care products. The question arises as to whether these results are unique to Roseville, California or representative of suburban systems in general. Factors such as high-density housing, the cultural emphasis on intensive lawn and landscape care, and efficient storm drain systems that carry irrigation runoff directly to nearby creeks all undoubtedly play a role. However, none of these factors are unique to Roseville, but are typical of countless suburban communities across the United States.

One factor that may exacerbate conditions in the study area is the low rainfall from May through October. During this period, much of the water and suspended sediment entering suburban creeks consists of runoff from landscape irrigation. This situation exists in much of California and other relatively dry regions in the western U.S., and suggests that degradation of sediment quality in suburban watersheds may be more severe in these areas. Other urban and suburban creeks in several additional California cities are under study, and acutely toxic concentrations of bifenthrin have been found in creeks in many of these communities as well (D. Weston, unpublished data). These results indicate that monitoring for pyrethroids in urban and suburban streams is overdue, and that the public, regulators, and scientific community should give greater consideration to the potential effects of residential use of pyrethroid pesticides on aquatic systems.

Acknowledgments

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Supporting Information Available

Mortality and growth data for the toxicity tests (Table S1), chemistry data for analytes other than pyrethroids (Table S2), and abundance data for resident *H. azteca* (Table S3). This material is available free of charge via the Internet at http://pubs.acs.org.

Literature Cited

(1) Werner, I.; Deanovic, L. A.; Hinton, D. E.; Henderson, J. D.; de Oliveira G. H.; Wilson, B. W.; Krueger, W.; Wallender, W. W.; Oliver, M. N.; Zalom, F. G. Toxicity of stormwater runoff after dormant spray application of diazinon and esfenvalerate (Asana) in a French prune orchard, Glenn County, California, USA. *Bull. Environ. Contam. Toxicol.* **2002**, *68*, 29–36.

(2) Weston, D. P.; You, J.; Lydy, M. J. Distribution and toxicity of sediment-associated pesticides in agriculture-dominated water bodies of California's Central Valley. *Environ. Sci. Technol.* **2004**, *38*, 2752–2759.

(3) Lee, S.; Gan, J.; Kim, J.-S.; Kabashima, J. N.; Crowley, D. E. Microbial transformation of pyrethroid insecticides in aqueous and sediment phases. *Environ. Toxicol. Chem.* **2004**, *23*, 1–6.

(4) Liu, W.; Gan, J. J.; Lee, S.; Kabashima, J. N. Phase distribution of synthetic pyrethroids in runoff and stream water. *Environ. Toxicol. Chem.* **2004**, *23*, 7–11.

(5) Solomon, K. R.; Giddings, M. J.; Maund, S. J. Probabalistic risk assessment of cotton pyrethroids: I. Distributional analyses of laboratory aquatic toxicity data. *Environ. Toxicol. Chem.* **2001**, *20*, 652–659.

(6) U.S. EPA. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish*; EPA Publication 841-B-899-002; U.S. Environmental Protection Agency: Washington, DC, 1999.

(7) CDFG. *California Stream Bioassessment Procedure (CSBP)*; California Department of Fish and Game Aquatic Bioassessment Laboratory: Rancho Cordova, CA, 1999.

(8) You, J.; Weston, D. P.; Lydy, M. J. A sonication extraction method for the analysis of pyrethroid, organophosphate and organochlorine pesticides from sediment by gas chromatography with electron-capture detection. *Arch. Environ. Contam. Toxicol.* **2004**, *47*, 141–147.

(9) U.S. EPA. *Methods for Measuring the Toxicity and Bioaccumulation of Sediment-Associated Contaminants with Freshwater Invertebrates*; EPA Publication 600/R-99/064; U.S. Environmental Protection Agency: Washington, DC, 2000; 192 pp.

(10) Amweg, E. L.; Weston, D. P.; Ureda, N. M. Use and toxicity of pyrethroid pesticides in the Central Valley, California, U.S.A. *Environ. Toxicol. Chem.* **2005**, *24*, 966–972 (with correction in *Environ. Toxicol. Chem.* **2005**, *24*, 1300–1301).

(11) Maund, S. J.; Hamer, M. J.; Lane, M. C. G.; Farrelly, E.; Rapley, J. H.; Goggin, U. M.; Gentle, W. E. Partitioning, bioavailability, and toxicity of the pyrethroid insecticide cypermethrin in sediments. *Environ. Toxicol. Chem.* **2002**, *21*, 9–15.

(12) Gan, J.; Lee, S. J.; Liu, W. P.; Haver, D. L.; Kabashima, J. N. Distribution and persistence of pyrethroids in runoff sediments. *J. Environ. Qual.* **2005**, *34*, 836–841.

(13) Flint, M. L. *Residential pesticide use in California. A report of surveys taken in the Sacramento (Arcade Creek), Stockton (Five-Mile Slough) and San Francisco Bay areas with comparisons to the San Diego Creek Watershed of Orange County, California*; University of California, Integrated Pest Management Program: Davis, CA, 2003.

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From the CD (131)

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Site name	Date	Tox survival %	TOC %	Bifenthrin ppb	Lambda-cyhalothrin ppb	Permethrin ppb	Cyfluthrin ppb	Esfenvalerate ppb	Fenvalerate ppb	Diazinon ppb	Chlorpyrifos ppb
Orestimba Creek @ RR	10/16/2001	65%	0.63%								
Del Puerto Creek @ Vineyard	10/16/2001	0%	0.64%								
Del Puerto Creek @ Vineyard	6/7/2002	61%	0.91%							0.056 ug/L	0.047 ug/L
Del Puerto Creek @ Vineyard	9/16/2002	0%		43.2		20.4					
Orestimba Creek @ RR	9/27/2002	41%	0.53%							0.037 ug/L	
Ingram Creek @ RR	9/27/2002	0%	0.96%								
Grason Rd. Drain	9/27/2002	58%	0.83%								
Del Puerto Creek @ Vineyard	10/28/2002	5%	0.83%	7.51	ND	ND	ND	ND	ND		
Del Puerto Creek 100 yards up stream of Vineyard	10/28/2002	46%	1.77%	<RL	ND	ND	<RL	ND	ND		
Del Puerto Creek @ 33	10/28/2002	79%	0.57%	ND	ND	ND	ND	ND	ND		
Del Puerto Creek @ Rogers	10/28/2002	33%	2.30%	ND	ND	ND	ND	ND	ND		
Orestimba Creek @ RR	4/3/2003	55%	0.70%	0.14	0.437	ND		0.985		ND	ND
Grason Rd. Drain	4/3/2003	0%	0.34%	0.768	0.644	50.6		6.48		1.26	6.8
Ingram Creek @ RR	4/3/2003	19%	0.37%	1.35	1.46	4.84		11.4		1.23	1.67
Harding Drain @ Carpenter	4/3/2003	60%	0.68%	0.401	0.432	2.27		1.23		2.26	1.82
Del Puerto Creek @ Vineyard	4/3/2003	38%	0.88%	2.08	0.809	4.72		3.56		1.23	9.2
Ingram Creek @ RR	11/13/2003	3%									
Grason Rd. Drain	6/15/2005	38%	0.72%								
Del Puerto Creek @ Vineyard Ln	6/15/2005	39%	0.82%	ND	ND	3.88	ND	ND	ND		
French Camp Slough @ Airport Rd	6/15/2005			1.02	ND	ND	ND	ND	ND		
Lone Tree Creek @ Escalon Belota Rd	6/15/2005			ND	ND	ND	ND	ND	ND		
French Camp Slough @ Airport Rd	9/19/2005										
Lone Tree Creek @ Escalon Belota Rd	9/19/2005										

TIE's are persuasive but eval. guidelines were generally unavailable.

Data located online

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Benthic Macroinvertebrate Bioassessment of San Joaquin River Tributaries: Spring and Fall 2002

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Executive Summary

The objective of this study was to assess benthic macroinvertebrate (BMI) community structure and physical stream habitat conditions at several sites on tributaries to the San Joaquin River. Some sites were on agriculture-dominated waterways while other sites were not. Sites were sampled in spring and fall 2002. A further aim was to identify environmental factors that potentially affect BMI assemblage structure and integrity/condition. Generalizations of stressor response 'signatures' from other regions in the U.S. were employed to distinguish sites most likely to be subject to contaminant effects above the effects of channel modification and flow alteration.

A range of BMI community types occurred at sites on river tributaries, but most consisted of some to several (EPT) taxa (indicative of good habitat and water quality conditions. Sites on agriculture-dominated waterways were also characterized by a wide range of BMI community types. The sites on agriculture-dominated waterways are subject to multiple stressors and contain BMI communities comprised of multivoltine (short life cycles) insects and other organisms able to quickly re-establish populations after toxic events. This characteristic suggests that there are periodic events (e.g., flow alterations, contaminant pulses, etc.) that preclude existence of long-lived taxa in BMI communities. Sites on some agriculture-dominated waterways manifested an absence of larval insects, which may indicate severe contamination of water or sediment at those sites.

Analysis of the spring dataset revealed that BMI community structure correlated with many physical and water quality environmental variables. In the fall dataset flow, nutrients, arsenic, zinc, total organic carbon (TOC), and several physical habitat variables correlated with BMI community structure. As proposed in an earlier report (de Vlaming et al., 2004b), current results suggest that many environmental (physical and water quality) factors interact to determine BMI community composition and condition. Data collected in both studies provide convincing evidence that physical habitat quality is an important determinant of BMI diversity.

Efforts to identify BMI community that occur in the presence of particular stressors suggest that insect-poor aquatic communities reflect exposure to recurring toxicity (Yoder and Rankin, 1995). A number of the least diverse BMI communities in this study consisted of very few insect taxa and low abundances of chironomids, inferring that these sites are potentially contaminant-impacted. Multivariate analyses revealed other sites with community characteristics similar to these least diverse sites, where the risk of contamination may be lower, but still present.

At two sites sampled by both the multi-habitat protocol and the California Stream Bioassessment Protocol (CSBP), the CSBP sample manifested greater taxonomic diversity. These findings intimate that further comparison of BMI collection methods in low-gradient soft-bottomed waterways is needed and suggest that BMI data gathered by multihabitat and CSBP methods in these waterways may not be directly comparable.

Introduction

One criterion that can be used for placing a waterway on the Clean Water Act §303(d) list of impaired waterways is reduced biological diversity or abundance relative to reference sites (a group of sites that are not subject to intense anthropogenic stress and that define healthy biological condition). In agricultural areas subject to widespread anthropogenic stress, reference conditions are often difficult or impossible to establish, and as a consequence, aquatic life uses are difficult to evaluate effectively. The Central Valley of California is a prime example of this type of region. The California Department of Fish and Game (CDFG) has a project underway in the Central Valley to locate reference (or best attainable/least impacted) sites and describe the associated benthic macroinvertebrate (BMI) communities. Nonetheless, in the Central Valley and other similar areas, approaches to creating biocriteria without recourse to reference sites may be very useful (e.g., Chessman and Royal, 2004). One alternative to using reference sites in the development of biological indices is assessing the responses of communities along gradients of specific environmental variables (stressors).

Over the past 30 years, bioassessment methods have progressed from the development of community health indices to initial attempts at using biological community composition to study the effects of particular stressors (Southerland and Stribling, 1995; Brazner and Beals, 1997; Yoder and DeShon, 2003; Karr and Yoder, 2004). One successful attempt to associate community types with particular stressors can be seen in bioassessment programs in Ohio (Yoder and Rankin, 1995). Reference conditions for Ohio streams and small rivers were identified and categorized by geographic area. This allowed the development of numeric criteria for the integrity of both fish and BMI communities. Furthermore, their large database of complementary bioassessment, toxicity testing, water quality, physical habitat, and land use information (over 1200 sites) enabled identification of community type 'signatures' that tend to be associated with particular stressors.

The stressors shown to be associated with distinct characteristics of BMI communities in the Ohio studies included both urban and agricultural influences. The signatures of most relevance to the sites examined in the present study are those associated with agricultural runoff, channel modification, flow volume alteration, and complex toxicity. Yoder and Rankin (1995) defined the 'complex toxic' site category as being composed of those sites with land uses involving urban and industrial point sources where the following were detected: "serious water quality impairments involving toxics, recurrent whole effluent toxicity, fish kills, or severe sediment contamination involving toxics." Although our primarily agricultural dataset does not involve urban point sources, the 'complex toxic' category is relevant to the current study because the taxonomic composition of the benthic communities at some of the agricultural sites in the Central Valley bears a striking resemblance to the sites in the 'complex toxic' site category, as distinct from the other categories more usually associated with agricultural land uses.

In comparison to less agriculturally impacted sites, Yoder and Rankin (1995) found that agricultural runoff is associated with lowered diversity and lowered abundances of sensitive insect species, including most Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (EPT) taxa, and high abundances of chironomids (Diptera) species. However, sites exposed to complex toxicity revealed lowered diversity and abundances of all insect taxa, including a majority of chironomid taxa (Yoder and Rankin, 1995).

Differentiating between communities fitting the profiles of these different stressor categories is important when examining sites surrounded by intensive agriculture. Intensive agriculture as currently practiced in the Central Valley is associated with chronic impacts from sedimentation, altered channel flows, removal of instream habitat and riparian vegetation, as well as effects from toxic substances including pesticides. The community signatures detected in Ohio can complement knowledge gained in the Central Valley about relationships between environmental parameters and local BMI communities.

Contributions from many investigators of Central Valley BMI communities show clear correlational relationships between composition of the invertebrate community and anthropogenic stressors (see de Vlaming et al., 2004a, b and works cited therein, including Leland and Fend, 1998; Brown and May, 2000; and Griffith et al., 2003). In the analysis of bioassessment and environmental data collected during 2001 at some of the sites examined in the present study, de Vlaming et al. (2004b) noted three major environmental factors that were associated with between-site differences in BMI communities. Metals concentrations were negatively correlated with aquatic insect diversity and amphipod abundance, but positively correlated with the abundance of flatworms (Planariidae), which are generally found to be less sensitive to contaminants than insects and amphipods (Preza and Smith, 2001; Martinez-Tabche, 2002). Total organic carbon (TOC) was not correlated with metals concentrations, but like metals, TOC showed negative correlations with the diversity and abundance of insect taxa. TOC was associated with the presence of naidid oligochaetes, which, like flatworms, are more tolerant of contaminants than most insects (Preza and Smith, 2001; De Lange et al., 2004). Nitrogen concentration and biochemical oxygen demand (BOD) formed a third suite of stressors, uncorrelated with metals or TOC, but important to the community composition at the sites studied. The identification of these three separate gradients allowed both the characterization of BMI communities in the San Joaquin River watershed and the identification of possible stressor variables.

Metals, TOC, and nutrients are relatively inexpensive to measure and it is therefore relatively easy to characterize BMI community responses to these parameters. However, BMI community responses to other parameters such as water and sediment toxicity and the presence of pesticides are equally important but are more expensive and more difficult to measure. Extrapolation of bioassessment findings from other regions is both warranted and important in examining potential effects of these stressors. The possible prevalence of toxicity in the Central Valley can be seen by examining the listed causes of impairment in CWA 303(d) listed waters. In the Central Valley, out of 103 segments that are 303(d) listed, 52 list metals as stressors, 37 list pesticides, 7 list organic enrichment, and 3 list sedimentation (CVRWQCB 2003). Examining Central Valley BMI communities for signatures associated with stressors that have resulted in CWA 303(d) listings in other states can increase confidence in presumed causes of impairment.

Further, the appearance of a stressor "signature" in the BMI community of an unlisted waterway would suggest that further investigation of conditions in the waterway is warranted to determine if the waterway should be CWA 303(d) listed.

The objective of the current study was to assess BMI community structure and physical stream habitat conditions at several agriculture-dominated sites in the lower San Joaquin River watershed. A further aim was to identify environmental factors that potentially affect BMI assemblage structure and integrity. Generalizations of stressor response signatures from other regions were employed to distinguish sites most likely to be subject to effects of contamination above the effects of channel modification, flow alteration, and uncontaminated agricultural runoff.

Materials and Methods

This study focused on agriculture-dominated sites on tributaries of the lower San Joaquin River watershed (Table 1). Benthic macroinvertebrates were sampled in the spring and fall of 2002 (Spring event: 5/13/02 – 5/23/02; Fall event: 9/30/02 – 10/23/02). Habitat measurements were taken at the times of BMI sample collection. Water quality was measured monthly throughout the period of the study. Metals, nutrients, TOC and TSS data were collected multiple times per sampling event at selected sites.

Drainage Basin Inflows to the lower San Joaquin River

Based on evaluations conducted during the Inland Surface Water Plan (Chilcott, 1992) and initial TMDL evaluations, sub-watersheds have been identified in the San Joaquin River Basin (Figure 1a, b): Each sub-area is bounded by either the Sierra Nevada or Coast Range and is comprised of like land uses and drainage patterns. All natural and constructed water bodies have been identified in each sub-area as well as potential water quality concerns and major representative discharges to the Lower SJR (Chilcott, 1992). Bioassessment monitoring in these basins is designed to link into the multi-constituent monitoring being conducted by the SWAMP, and TMDL monitoring programs.

Northeast Basin

This sub-area has four major watershed areas, which drain to the Sacramento-San Joaquin Delta (Delta) downstream of Vernalis. The southern-most watershed area in this basin is the Farmington Flood control basin. This 371,861-acre area contains two major creeks, Lone Tree and Little Johns. Lone Tree and Little Johns Creeks are mainly used for agricultural supply and return flows, as well as flood control for the Farmington Flood Control Basin during extreme high water events. Water is stored in Salt Springs Valley, and Woodward Reservoirs and released as needed for irrigation and flood control. Lone Tree and Little Johns Creeks merge southeast of Stockton to form French Camp Slough. French Camp Slough then flows into the SJR just upstream of the Federal Deep Water Ship Channel at the south end of Stockton. The next watershed to the north is the Calaveras River watershed. During the irrigation season a large portion of the water from the Calaveras River below New Hogan Reservoir is diverted into Mormon Slough for agricultural use and returned as tail water to the river upstream of its confluence with the SJR Federal Deep Water Ship Channel in Stockton. The third watershed in this sub-area is the Mokelumne River Watershed. The Mokelumne, similar to other eastside rivers, contains cool, high quality, low TDS water from Camanche Reservoir. The Mokelumne receives discharges from various urban and agricultural sources before flowing into the Sacramento-San Joaquin River Delta (Delta) near New Hope Landing. The fourth major watershed in the Northeast Basin sub-area is the approximately 501,373-acre Cosumnes River Watershed. The Cosumnes is one of the few rivers in California that does not have a major in-stream impoundment although there are several small drinking water reservoirs on tributaries of the Cosumnes. The Cosumnes River is affected by several land uses including rural and urban communities, range cattle, vineyards and other agricultural activities. During the summer months, the Cosumnes is normally dry from just down stream of the Highway 16 Bridge in Rancho Murieta to its confluence with the Mokelumne River near Mokelumne City.

Sites in the northeast basin

SAC 003-Cosumnes River at Michigan Bar

The Cosumnes River at Michigan Bar is a natural cobble lined channel with a fairly wide riparian zone and its origins in the Sierra Nevada Mountains. The Cosumnes River mainly contains flow from natural runoff, snowmelt and off stream reservoirs including Jenkenson Lake. Up stream influences, include rural communities, vineyards, open range cattle grazing and mining. Local influences include possible runoff from extensive livestock grazing and historic mine tailings. Cattle can often be found grazing in or near the river at this site.

SAC 004-Cosumnes River at Hwy 16

The Cosumnes River at Hwy 16 is approximately 3 miles downstream of the Cosumnes at Michigan Bar sampling site. The stream is physically similar to the river at Michigan Bar; with the main land use difference being this site is down stream of the community of Rancho Murieta, and the Rancho Murieta golf course.

SJC 512 Mokelumne River at Van Assen County Park

The Mokelumne River at Van Assen Park is just down stream of Comanche Reservoir. Land uses surrounding the River at this point include rural housing and cattle grazing, and the Mokelumne River Fish Hatchery, which was not in operation when these samples were taken. It is hoped that this site will be able to be directly compared with the other river sites sampled in this study.

SJC 515 Bear Creek at Lower Sacramento Rd.

Bear Creek at Lower Sacramento Road receives agricultural discharges as well as urban storm water runoff from the Northern Stockton area. This area is urbanizing rapidly and this site should reflect any changes to the stream over time. The creek is a modified channel that has levees on both sides with an upper and lower bank. The creek banks are vegetated with grasses and there are some tules in the stream. Substrate in the creek consists mostly of hardpan clay and small gravel with some cobble around the bridge abutment.

SJC 514 Calaveras River @ Shelton Road

The Calaveras River at this point is a deeply incised channel with steep densely vegetated banks. Flow in the Calaveras River is controlled by releases from New Hogan Lake and up stream discharges of treated wastewater from the Jenny Lind Waste Water Treatment Plant (WWTP). The channel substrate is almost completely hardpan clay with some larger cobble and large woody debris. Surrounding land uses include almond and walnut orchards and cattle grazing.

SJC 503-Lone Tree Creek at Austin Road

Lone Tree Creek is a 20-mile long modified natural channel originating south of Woodward Reservoir. This mostly hardpan clay, ephemeral stream, carries natural runoff for the Farmington flood control basin during high flow periods and has a narrow but fairly diverse riparian zone. (Chilcott, 1992) During the irrigation season Lone Tree creek carries agricultural supply and return flows to its confluence with Little Johns Creek to form French Camp Slough. Local influences at this site are mainly agricultural including row and truck crops, and possible effects from dairy and other confined animal facilities.

SJC 504-French Camp Slough at Airport Rd.

Lone Tree and Little Johns Creeks come together just east of Hwy 99 to create French Camp Slough. French Camp Slough then flows to its confluence with the San Joaquin River southwest of Stockton. The slough is dominated by agricultural return flows and operational releases during the irrigation season and contains mostly storm water from the Farmington Flood Control basin in the winter months. Upstream land use include row and truck crops, confined animal facilities, a golf course and a landfill. Substrate in French Camp slough is dominated by hardpan clay, similar to the Calaveras River and Lone Tree Creek.

Eastside Basin

The Eastside Basin contains the three largest SJR tributaries in terms of flow, the Merced, Tuolumne, and Stanislaus Rivers. Below the major upstream reservoirs, McClure, Don Pedro, and New Melones, the Eastside Rivers have varying discharges to support withdraws from municipalities and agriculture before flowing into the SJR. All three Rivers are considered to be high quality water containing low levels of salts, Total dissolved solids (TDS) and other Trace elements. The Merced River Watershed is the southern most watershed in the Eastside basin. The lower Merced River Watershed below New Exchequer Dam covers about 180,000 acres, and contributes approximately 15 percent of the lower SJR flow. The next major watershed to the North is the Tuolumne River Watershed. The Tuolumne River Watershed below New Don Pedro Reservoir is approximately 162,000 acres and contributes approximately 27 percent of the total flow of the lower SJR. The Stanislaus is the Northern-most Watershed in the Eastside Basin. The Stanislaus River Watershed below New Melones Reservoir contributes approximately 18 percent of the total lower SJR flow at Vernalis from its 97,000 acres. Aside from the three major tributaries in the Eastside Basin, there is an area of about 305,000 acres, which is being called the East Valley Floor that drains directly to the lower SJR via a series of irrigation and drainage canals.. These canals contain water from a variety of sources including agricultural surface returns, urban runoff, treated municipal wastewater, ground water, and natural stream flows. The area draining directly to the SJR has three major sections. One large section between the Merced and Tuolumne Watersheds, one smaller area in the North between the Stanislaus and Tuolumne Watersheds, and one to the South between the Merced River Watershed and the Southeast Basin. These laterals and drainage canals contribute approximately 4 percent of the lower SJR total flow. (CVRWQCB Staff report September 2003)

Sites in the eastside basin

East Valley Floor

STC 501-Harding Drain at Carpenter Road (TID lateral 5)

The Harding Drain is a site that is representative of a municipal and agricultural discharge in the area that drains directly to the SJR. The Harding Drain is a constructed, soft bottomed, channel, which carries discharges from the city of Turlock wastewater treatment plant (WWTP), storm runoff from the City of Turlock as well as agricultural tail water discharges and possible discharges and or seepage from confined animal facilities. The channel is deeply incised and completely channelized with no riparian zone.

Merced River Watershed

MER 581 Merced River at Hwy 59

The Merced River at Hwy 59 contains mostly clean cold water from Lakes McClure and McSwain. The site is upstream from most major agricultural influences, however it is down stream from a large gravel mining operation. The site is also directly down stream from a major stream channel, rehabilitation project and it is hoped that positive affects can be seen over time. The streambed is mainly large cobble and gravel. The site should also be directly comparable to the Mokelumne, and Cosumnes River sites.

MER 579 Ingalsby Slough @ J 17

Ingalsby Slough is small agricultural dominated channel receiving tail water from a verity of field and row crops. Ingalsby discharges to the Merced River downstream of the Hwy 59 site. The slough banks are well vegetated and the channel substrate is predominantly fine organic matter. Sediment load reduction Best Management Practices have been instituted in the area and are comprised mostly of grower education programs.

MER 580 Merced River at J16 Oakdale Rd.

This site is several miles down stream of the Hwy 59 site, and is one of the first sites were the Merced River begins to get agricultural influences. The substrate is mostly cobble with larger proportions of gravel and sand than at Hwy 59.

MER 546 Merced River at River Road

The Merced River at River Road is the last sampling site on the Merced River before it's confluence with the San Joaquin River. The stream receives agricultural discharges from field and row crops as well as orchards and wastewater treatment plants. The stream banks are well vegetated and the channel substrate is almost exclusively sand. The Merced River in the River Road area is 303 (d) listed for a variety of pollutants including organophosphate pesticides.

Southeast Basin

The South East Basin reaches from the SJR in the south up to the watershed divide between Bear Creek and the Merced River in Merced Co. to the north. The SJR upstream of the Mendota Pool is typically dry for most of the year due to agricultural diversions. Most of the water in this sub-area enters at the Mendota Pool, an in-stream impoundment, which receives agricultural supply water from the Delta Mendota Canal (DMC) as well as some upstream releases during extreme rainfall events or diversions from the Merced River. The majority of the water released from the Mendota Pool and irrigation return flows, are diverted out of the lower SJR at Sack Dam for irrigation supplies. The lower SJR is usually dry from Sack Dam until near where it reaches the Eastside Bypass and Bear Creek, which are the main SJR tributaries that drain this sub-area. Including agricultural supply and return flows, this sub-area accounts for approximately 23 percent of the SJR flow at Vernalis. (CVRWQCB Staff report September 2003)

Sites in the southeast basin

MER 007-Bear Creek at Bert Crane Road

Bear Creek is a sandy bottomed, modified, natural eastside creek that receives the majority of its flow from Burns and Bear Reservoirs via the Merced River. The channel is deeply incised and has a narrow but diverse riparian zone. Bear Creek at this point carries both irrigation supply water and return flows from varying crop types, as well as seasonal discharges from heavy storm events. Bear Creek flows to the East Side Bypass which then discharges into the SJR upstream of the town of Stevenson.

Grassland Watershed

The Grassland Watershed is located on the southwest side of the SJR basin. The majority of the water in this area originates in the Delta and is delivered via the DMC for agricultural use. This 871,000-acre area contains an 115,000-acre portion of the Grasslands Ecological Area (GEA), which is made up of private, State, and Federally owned and operated wetlands. The soils in this area are from rocks of marine origin and are very high in salts, boron and selenium. As a result of the high amount of salts and the intensive agricultural practices in the area, elevated electrical conductivity, selenium, and boron concentrations occur in these waters. This led to a selenium control program to be developed in the Drainage Project Area (DPA), 97,000 acres of agricultural area drained by subsurface tile drains. The control program has led to intense management of all drainage within the basin. The Grassland sub-area contributes around 6 percent of the lower SJR total flow at Vernalis. (CVRWQCB, Staff report September 2003).

Sites in the grassland watershed

MER 531-Salt Slough at Lander Ave (Hwy 165)

Salt Slough is a high TDS perennial slough dominated by Agricultural return flows and wetland discharges. It has a soft mud and sand bottom with a natural channel that winds its way through private, State and Federal wetlands to its confluence with the SJR near the town of Stevenson. Salt Slough has a wide and diverse riparian buffer that is dominated by grasses. The Grasslands Bypass Project removed High EC tile water, from the 97,000 ac. Grasslands area, from Salt slough and put it into the San Luis Drain (SLD) where it discharges to Mud Slough before entering the SJR.

MER 554 Los Banos Creek at Hwy 140

Los Banos Creek at Hwy 140 contains water from several different types of discharges including field and row crops, different types of orchards from almonds to stone fruits, discharges from state, private and federal wetlands, and treated waste-water from the city of Los Banos. Garzas creek, which has a mix of agricultural supply and return water mixes with Los Banos Creek up stream of this site, and it ultimately discharges into Mud Slough North. The creek is narrow and incised and contains very little riparian vegetation except for grasses and tules. The channel substrate is predominantly mud and other soft organic material.

MER 536-Mud Slough North Up stream of the San Luis Drain (SLD)

Mud slough is a perennial slough dominated by high TDS agricultural drain water, seepage from surrounding wetlands and Agriculture lands and ground water accretions. During the spring, flows in Mud Slough are dominated by discharges from wildlife refuges and duck clubs. Mud Slough at this location is located within the Kesterson National Wildlife Refuge and has a soft mud bottom with some areas of sand and hardpan clay and marl. The channel is deeply incised in places and the wide riparian zone is dominated completely by grasses and small shrubs.

MER 542 Mud Slough North Down Stream of the San Luis Drain (SLD)

Mud Slough down stream of the SLD is physically very similar to the up stream site. The down stream site has a slightly higher percentage of sand substrate and less mud. The key difference is the discharge of the San Luis Drain into Mud Slough between these two sites. The SLD carries agricultural tile drain water, which is high in salt, selenium and boron from the grasslands area. The SLD was designed to remove this water from the surrounding wetland channels in the grasslands area for the protection of waterfowl.

Northwest Basin

This area encompasses the watersheds of the Westside creeks and is approximately 386,000 acres, contributing 6 percent of the total SJR flow. Land use in this sub-area is predominantly agriculture including; confined animal facilities, row crops and orchards, there are also several small municipalities. Creeks in this area are naturally ephemeral but valley floor sections are kept running through the traditionally dry summer months with irrigation supply and return water. Water in this sub-area is of relatively poor quality and is high in TDS. Irrigation supply water in this area comes from several different sources including the DMC, pumped ground water, and diversions from the SJR.

Sites in the northwest basin

STC 019-Orestimba Creek at River Road

Orestimba is one of the largest Westside tributaries. It is representative in terms of land use to other Westside agricultural dominated waterbodies and has large amount of historic monitoring data. Orestimba Creek at this site has a deeply incised channel with mostly soft mud bottom with some areas of fine gravel and a narrow but very diverse riparian zone. It appears to be a natural creek channel however some relocation/construction may have occurred in the past. There are several areas at this site where the banks have been stabilized with concrete riprap. Downstream of the Eastin Road under crossing to the SJR, the creek is dominated by agriculture return flows (tail water and operational spills from the CCID main canal). Flows from the coast range reach the area down stream of Interstate 5 only during high flow, winter runoff periods and large storm events.

STC 517-Orestimba Creek at Bell Road

Orestimba Creek at Bell Road is a hardpan channel with large cobble in some areas. The creek at this site does not receive tail water from upstream agriculture and only receives surface flow from the upstream watershed during high flow storm events although water remains at this site just below the DMC year around. The water is believed to be groundwater or subsurface flow from the upper watershed. The area around the sampling site appears to have been impacted by high storm flows in the 1997 storms and by mining sometime in the last 20 years. The channel is deeply incised and has a wide riparian zone but is dominated by grasses and very young trees and shrubs.

STC 516-Del Puerto Creek at Vineyard Road

Del Puerto is an agricultural dominated Westside tributary to the SJR. The Creek has been channelized or modified in almost its entire length down stream of the DMC for agricultural discharges and has a soft mud to hard packed small gravel bottom and little to no riparian zone. The creek is historically ephemeral in the valley floor reaches, but receives agricultural return flows and operational spills during the irrigation season. There are often agriculture return flows during the late fall through winter months depending on water year type and over winter crops.

STC 040-Ingram Creek at River Road

Ingram Creek is a natural ephemeral Westside tributary upstream of I-5and only carries water from its upper watershed for 2-3 months per year. The portion of the creek, down stream of the DMC was formerly a dry wash that has been straightened and channelized. The creek channel has a soft mud, sand, and small gravel bottom with little to no riparian zone. Ingram Creek carries mainly agricultural return flows during the irrigation season as well as some ground water seepage during winter and early spring.

Sacramento-San Joaquin Delta (Delta)

The Delta sub-area contains over 1000 miles of waterways and is defined as the area North of Vernalis on the SJR, South of the I Street Bridge on the Sacramento River, and the Antioch Bridge as the Western boundary. Water in the Delta comes from both the Sacramento and San Joaquin Rivers and has varying quality and Beneficial Uses.

Bioassessment sampling in the main Delta waterways will be preformed under a separate project using TMDL funds. The only site in the Delta sub-basin for this project is an "Urban Creek background" site.

Baseline Conditions for Future Urban Creek: Land use patterns in the basin are changing as traditionally rural and agricultural areas are developed into cities. A new city of approximately 55,000 people is slated for development north of Tracy California.

SJC 509-Mountain House Creek

Mountain House Creek was a naturally ephemeral stream that has been highly altered for use as an agricultural drain. It is a constructed channel with a soft mud bottom and a narrow strip of willows for a riparian zone. The last 3.5 mi. of the creek before emptying into Old River are dominated by agricultural return flows during the irrigation season mainly from alfalfa. As work progresses for the community of Mountain House, which will completely surround the creek, houses will replace the alfalfa fields that drain to the creek. The stream channel and riparian zone will be reconstructed and restored for recreational use including a green belt and a walking and bicycle path.

BMI field collection

BMIs were collected from each site using a multi-habitat sampling method outlined in the EPA's rapid bioassessment protocols (Barbour, 1999). Reach lengths were designated at 100 meters. This method entails partitioning out the existing reach habitat into five different categories if present. The five categories were hard substrate (e.g., cobble, riprap, gravel), snags, vegetated banks, submerged macrophytes, and fine sediments. For a category to be included, it must have comprised at least five percent of the available reach habitat. A total of twenty jabs (each jab sampling half a square meter) were partitioned out proportionally based on available habitat types. For example, if snags comprised fifty percent of the reach habitat and riffles comprised twenty percent, then ten jabs were taken in snag material and four jabs were taken in riffle areas. The remaining jabs (six) were taken in any other habitat type(s) present. Sampling always began at the most downstream section of the reach. Sample material was rinsed and transferred into a sample jar containing ninety five percent ethanol every few jabs, or as needed, to prevent the net from clogging. After all twenty jabs were collected and placed into the sample container the net was inspected for clinging organisms. Any organisms found were removed with forceps and placed into the sample container. If possible all twenty jabs were composited into a single sample container, which then received internal and external labels containing site name and location, site code, date, time, and sampler's initials. If multiple sample jars were used, each one received identical labeling with an alphabetical code (A, B, C, etc...) which was also noted in the sample log book.

For methods comparison analysis at two sites BMIs were also collected using a modified low gradient version of the California Stream Bioassessment Procedure (CDFG, 2003). Using the same reach BMIs were collected from three randomly chosen transects from all possible meter marks (one to one hundred). Within each transect three two square foot areas were sampled and composited into a sample container and preserved with ninety-five percent ethanol. Each sample received labels as above, with the addition of a transect number (1-3) and CSBP designation. CSBP samples were collected when the corresponding meter mark was encountered during the multi-habitat sampling so as not to disturb the organisms in the reach, and collected using a separate net.

Habitat assessments

For a more comprehensive understanding of spatial variations in BMI community structure/integrity and potential causes of biotic disturbances, semi-quantitative habitat assessments were conducted simultaneously with BMI collections. Physical habitat assessments were conducted at each site. These included two components: (1) the CSBP

Worksheet that focuses on water quality and habitat parameters at the individual riffle/transect level and (2) the US EPA nationally standardized Habitat Assessment Field Data Sheet (Barbour *et al.*, 1999) that targets habitat conditions along the entire reach. Each of these physical habitat assessments has a low and high gradient version. Riffle/transect data collected included depth, velocity, and substrate composition. These measurements were recorded as the mean of three transect measurements. Substrate composition was recorded as an observational estimate of percentages of mud (<0.2 cm), sand (<0.2 cm), gravel (0.2 to 5.0 cm), cobble (5.0 to 25.0 cm), boulder (>25.0 cm), and bedrock/hardpan (solid rock or clay forming a continuous surface). Substrate consolidation was determined to be 'loose', 'moderate', or 'tight'. Gradient (percent slope) was determined as the change in elevation between upstream and downstream ends of a sampling reach.

Reach habitat data included estimates of ten physical habitat parameters (epifaunal substrate, sediment deposition, channel sinuosity, riparian vegetative zone width, pool substrate, available cover, channel flow status, bank stability, pool variability, channel alteration, and vegetative protection). Each habitat parameter was scored from 0 – 20, divided into quartile categories of 'poor', 'marginal', 'sub-optimal', and 'optimal' scoring categories. Each habitat parameter is scored using semi-qualitative criteria (Barbour *et al.*, 1999). Canopy cover was estimated with a hand held densiometer. At high gradient (slope > 0.2) sites, gradient was measured using a stadia rod and a clinometer. GPS coordinates were recorded at the second riffle/transect of all sites for CSBP samples, or at the bottom of the reach for multi-habitat samples.

Water quality measurements

Water quality measurements were recorded prior to collection of BMIs at the second riffle/transect (CDFG, 2003). Measurements included pH, specific conductance (SpC), dissolved oxygen (DO), and temperature. Collection of water quality data occurred at the time of BMI sampling and on a fixed monthly monitoring program. Monthly monitoring consisted of SpC, DO, pH, temperature, hardness and alkalinity determinations as well as measurements of metals, nutrients, total organic carbon (TOC), and biochemical oxygen demand (BOD) throughout the study.

Metal concentrations in site water samples were determined according to US EPA method 200.7 at Twining Laboratory in Fresno, CA. Nutrients in these site water samples were analyzed at Twining Laboratory or under the direction of Dr. Randy Dahlgren at the University of California, Davis, Department of Land Air and Water Resources. Procedures followed were US EPA method 300 for nitrate and ortho-phosphate, 350.3 for ammonia, 4500 for total nitrogen (Kjeldahl), and 365.3 for total phosphorus. Ceriodaphnia LC50s for diazinon and chlorpyrifos were calculated as averages of multiple datapoints found in the EcoTox database <http://www.epa.gov/ecotox/>. For more information on water quality measurements see the Surface Water Ambient Monitoring Program Quality Assurance and Protection Plan.

Laboratory sub-sampling

In the laboratory, five hundred or three hundred organisms were sub-sampled and removed from each composited sample for multi-habitat and CSBP methods, respectively. The removed BMIs were used for taxonomic identification, metric analysis, and abundance estimations. Sub-sampling consisted of: (1) transferring each sample to a 500 μm sieve, gently rinsing to flush out fine particles, (2) removing large debris such as gravel, fresh leaves, and sticks after thoroughly inspecting for entangled BMIs, (3) submerging the sieve containing BMIs in a 2.5 liter container of water to homogenize the sample, (4) draining the sieve, and (5) inverting the sieve over a white tray with numbered grid lines. Samples were spread evenly over 5X5 cm grids so as to accommodate the entire sample volume. Grids to be examined by dissecting microscope were selected at random. BMIs were removed from grids and transferred to a vial containing 70% ethanol (EtOH) until a 300 count was achieved. The last grid examined to achieve the three hundred count was completely processed, with additional BMIs placed into an 'extras' vial. BMIs from the 'extra' vial are necessary for an accurate estimate of sample BMI abundance. Sample abundance was estimated as the total number of BMIs removed from a sample, divided by number of grids processed, multiplied by total number of grids covered by the sample.

Sub-Sampling is the procedure in which the BMIs were removed from the sample material in a systematic way for identification, metric analysis, and sample abundance calculations. For this study five hundred and three hundred BMIs were removed from multi-habitat and CSBP samples respectively. After retrieving a sample from storage, the internal, external, and unique identification number were checked against each other to verify the correct sample was being processed. The sample material was then placed into a five hundred micron sieve and gently rinsed free of alcohol and fine particles. If desired, the technician rinsed and removed any large debris such as gravel, sticks, and leaves after inspecting for entangled BMIs. The sample was then homogenized as best as possible by partially submerging the sieve into a tub of water and gently stirring the sample material around to distribute it evenly. The sieve was then removed from the tub, and excess water allowed to drain. The sample material was then emptied into one or more white gridded (2 x 2 inches) trays. Grids were randomly selected, the sample material from each grid placed into a Petri dish containing ethanol, and all BMIs were removed using a dissecting scope with 7x minimum magnification and placed into an ethanol filled vial. Grids were processed until the target number of BMIs was obtained. For abundance calculations, the last selected grid was always completely processed, and all BMIs over the target number placed into an "extra" vial. All processed sample material was transferred into a "remnant" jar for QA/QC procedures. Sample abundance was estimated as the total number of BMIs removed from a sample, divided by number of grids processed, multiplied by total number of grids covered by the sample.

BMI identification

Taxonomic identification followed level I taxonomic effort set forth by the California Aquatic Bioassessment Laboratory Network (CAMLnet). Most insect taxa were identified to genus, and if monotypic given a species name as well. Chironomids were identified to tribe and worms to family. Non-insect taxa were taken to genus if possible, or left at a higher resolution. The taxonomy process was performed by first emptying the sub-sampled BMIs into a small Petri dish and covering them with 70% ethanol. Individuals of each unique taxon were removed, enumerated, and placed into a vial. Each vial received a site label and taxon label. The number of individuals in each vial and the taxonomist's initials were recorded in pencil on the taxon label. All vials from each sample were bundled together to maintain a voucher collection for the project and data entry.

Data analysis

Multivariate and multimetric analyses were applied to investigate spatial and temporal variability in BMI communities. Relationships between community structure, a range of environmental variables describing habitat and water quality, and a number of widely used metrics indicative of BMI community integrity were also examined.

Community composition

Community composition was evaluated through multivariate methods and by calculation of metrics summarizing components of the BMI community. Thirty-seven metrics were calculated, focusing on taxa which existing evaluations of BMI communities have shown to be potential indicators of the extent of anthropogenic stress acting on benthic communities.

Community composition was probed by ordination with non-metric multidimensional scaling (NMS) to reveal the strongest patterns in BMI community structure across sites. NMS ordination created axes that summarize BMI assemblages based on the proportions of taxa at the sites. Correlations with these axes showed the strength and direction of associations between species composition, environmental variables, and metrics indicative of BMI community integrity.

Proportional abundance of taxa (# of individuals of a given taxon / total # individuals collected) was utilized when examining community composition, as opposed to estimated absolute abundance, because the BMI sampling and sample processing methods are not designed to determine actual abundances at a site. The proportional abundance data were arcsine-square root transformed to moderate the influence of common and rare taxa (McCune and Grace, 2002). Taxa occurring only at one site (rare taxa) were excluded from statistical analyses to improve resolution of commonalities among sites.

Ordination relies on calculation of a distance measure to quantify taxa composition similarities among sites. Sorenson distance, which has been shown to be a more accurate representation of community structure than Euclidean distance, was used as a measure of overall site similarity (McCune and Grace, 2002). Cluster analyses and ordinations were performed using PC-ORD 4.0 (McCune and Mefford, 1999).

Seasonal variation may influence diversity and abundance of BMI communities. We sought to control for this seasonal variation by performing separate ordinations of data collected during the spring and fall sampling events.

NMS ordination was applied to visualize the relative positions of the sites along gradients representing aspects of the benthic macroinvertebrate community structure. Sites with similar communities appear close to one another in the ordinations. NMS is well suited to summarizing nonlinear associations among the abundances of a large number of rare species (McCune and Grace, 2002). NMS is distance-preserving: it maintains the rank-order of dissimilarity values between the sites. It is an iterative optimization method that improves the fit of the ordination to the original distance matrix through a series of small steps, until a stable, well-fitting solution is obtained.

NMS was performed with random starting coordinates and a step length of 0.20. Forty starting configurations were used, and for each starting configuration solutions were computed using dimensionalities ranging from 2-6 dimensions. The lowest stress solution for each dimensionality (in which the distances in the ordination space most resemble the distances in the original distance matrix) was compared to the lowest stress solutions for the other dimensionalities. The solution chosen was the highest dimensionality solution with a final stress more than 5 units lower than the next lower dimension, provided that the solution had a stress lower than 95% of 50 solutions calculated at that dimensionality with randomized data (McCune and Grace, 2002).

NMS was selected in preference to canonical correspondence analysis (CCA) because in CCA the pattern of biological samples is constrained by the environmental variables included in the analysis. With NMS, measured environmental variables do not bias the ordination of biological data. This yields a more accurate picture of the overall community structure.

Taxonomic composition, environmental variables, and BMI metrics gradients

Pearson product-moment correlations between the NMS axes and taxa proportional abundance revealed the major taxonomic gradients represented by the axes. Correlations between these axes and environmental variables and BMI metrics indicative of community integrity indicated the strength and direction of environmental gradients (i.e., environmental parameters likely to be determinants of community structure) and gradients of BMI community integrity (i.e., indication of community structure changes relevant to community integrity/health) associated with each axis, respectively. Environmental variables examined include water quality parameters as well as measures of substrate and physical habitat.

For reference of those interested in the utility of a particular metric in examining potential effects of a particular stressor, we calculated Pearson product-moment correlations between environmental variables and BMI metrics.

Data variability and sampling method comparison

Evaluation of data variability seen in the field duplicate at Lone Tree Creek and method comparison with the CBSP was achieved by direct comparison of the metrics calculated in the relevant samples, and by plotting predicted NMS scores of the duplicate and CSBP samples on the existing NMS axes calculated using the multi-habitat dataset.

Results

Environmental data

Sites with a wide range of environmental conditions and habitat types were investigated, ranging from 1 meter wide agricultural tributaries with mud substrate and conductivity readings (EC) above 3000 µmhos to riffle-dominated rivers approaching 50 meters in width where EC was below 100 µmhos. Dissolved oxygen (DO) tended to be fairly high (> 6.0 mg/L), and was unlikely to present a major stressor to the benthic macroinvertebrates at the sites examined. Dissolved minerals, metals, nutrients, and organic carbon were present at elevated levels in some samples. Substrate and instream habitat varied between narrow, straight channeled sites dominated by mud and sand to wider waterways containing many riffles and cobble substrates. The ranges and mean values of quantitative and ordinal environmental variables are summarized in Table 2.

Insecticide data collected during 2001 and 2002 at a small number of sites show a range of concentrations. Insecticide monitoring data including measurements of diazinon during 2001 and 2002 and chlorpyrifos during 2002 show long periods of low concentrations marked by occasional high spikes, some of which exceed *Ceriodaphnia* LC50s (Figures 2 and 3). Chlorpyrifos data from Del Puerto Creek were the exception (Figure 3). At this site, 44% of measurements of chlorpyrifos concentrations recorded between May 2002 and August 2002 exceeded 0.01 ppb (0.2 TUs for *Ceriodaphnia* acute mortality; seven of 16 observations).

Benthic macroinvertebrate communities

Metrics summarizing BMI community components revealed that fauna was dominated by multivoltine taxa that feed on fine particulate organic matter (FPOM). These taxa are capable of quickly re-establishing populations after local extinctions, and thrive in the absence of solid substrates. Number of taxa observed at a site ranged from 10 to 27, and the percent insects varied from less than 10 to near 100 percent. The percent BMI community composed of amphipods varied from 0 to 40 percent, while the percent oligochaetes varied from 0 to 80 percent. Both amphipods and oligochaetes are able to live in soft, unstable substrate. Amphipods tend to be somewhat sensitive to water quality, while oligochaetes are highly tolerant of poor water quality. No major taxonomic shifts were seen between the spring and fall samples (Figure 4).

Associations of BMI community differences with environmental parameters

Figures 5 and 6 depict NMS ordinations of BMI community data collected in spring and fall, 2002. Sites in close proximity on these plots possessed similar BMI communities, while sites with less similar BMI communities are farther apart. Each axis represents a gradient in BMI community structure comprised of a correlated set of changes in BMI taxa abundance. The figures each illustrate two different views of a three dimensional ordination, and highlight the environmental variables significantly correlated with each ordination axis. Tables 3 and 4 depict environmental variables, BMI metrics, and BMI taxa most strongly correlated with the NMS axes during each sampling event. Appendix A provides correlation values between environmental variables and individual BMI metrics. These correlation values are useful in determining utility of a particular metric in assessing potential stressors.

Spring BMI communities

During the spring sampling event, only the first NMS axis was strongly correlated with a suite of environmental variables and BMI metrics (Figure 5 and Table 3). This axis ordinated communities grading from oligochaete-dominated assemblages of pollution-tolerant taxa to more diverse insect-dominated assemblages consisting of more pollution-sensitive taxa. Many correlated potential stressor variables were associated with low scores on this axis, including erosion and mud dominated substrate, high nutrients, irrigation return water, and agricultural land use. Taxa most strongly correlated with potential stressors and less diverse communities were the tubificid and nematode worms. Taxa most strongly correlated with more diverse communities included a number of Ephemeroptera (mayfly) and Trichoptera (caddisfly) taxa, as well as chironomids (Diptera) of the tribe Tanytarsini and amphipods of the genus *Crangonyx*.

Abundance of many taxa were correlated with NMS axis 2, including more insects and *Hyalella* amphipods towards the negative end of the axis and more *Corophium* amphipods towards the positive end of the axis. However, this axis did not correlate strongly with suites of environmental variables (to indicate possible causes of community differences) or BMI metrics (to summarize community differences). Axis 3 did not correlate strongly with many environmental variables, BMI metrics, or BMI taxa.

Fall BMI communities

Table 4 summarizes the environmental variables, BMI metrics, and BMI taxa most strongly correlated with each NMS axis for the fall sampling event (Figure 6). This ordination may allow more discrete associations between environmental variables and taxonomic differences than the ordination of the spring data, because a different suite of environmental variables was correlated with each NMS axis.

Axis 1 appears to be less associated with environmental variables than the other two axes. Rather, it captures community differences associated with varying levels of flow. Low flow volume sites, appearing towards the negative end of axis 1, were distinguished by large amounts of detritus, sand, macrophytes, and organic muck (FPOM). These sites had more FPOM consumers, more chironomids, and more amphipods, as well as more organic pollution-tolerant taxa. Certain Ephemeroptera and chironomids were the taxa most strongly associated with low flow sites, while filter feeding *Simulium* (black fly larvae) was associated with high flow sites.

Axis 2 was associated with water quality variables, including arsenic and nutrients, which increased toward the positive end of the axis. Some measures indicating habitat quality increase towards the negative end of the axis. The diversity and abundance of many larval insects were negatively correlated with this axis. Agriculture-dominated waterway communities tended to score higher on this axis than river communities, but there was overlap between creeks/drains and rivers along the axis. Del Puerto Creek, Ingram Creek, and Harding Drain were the agriculture-dominated waterways that scored highest on this axis; Cosumnes River sites were the highest scoring river sites. Therefore, these are the sites in each category most likely impacted by water quality variables.

Axis 3 was primarily associated with habitat variables, representing a gradient from mud-dominated pool habitats at the positive end of the axis to cobble-dominated riffle habitats at the negative end of the axis. Ephemeroptera, pollution-sensitive EPT, and univoltine taxa metrics exhibited the strongest negative correlations with this axis, while multivoltine, pollution-tolerant, and oligochaete taxa abundance manifested the strongest positive correlations. A large number of agriculture-dominated waterways scored high on this axis. These sites were dominated by fine substrates and were characterized by organisms accepting of such substrates, including worms and chironomids. The agriculture-dominated waterway sites scoring highest on this axis are likely more subject to sedimentation than other sites examined.

Spatial patterns and upstream-downstream comparisons

Table 5 summarizes proportional abundances of key BMI community components at sites during each sampling event. These measures are useful for comparing BMI communities of different sites, and for detecting major differences in BMI communities along individual waterways. The NMS analyses demonstrated that these proportional abundance measures summarize and are correlated with major components of variation in the BMI community. Further, these measures likely reveal anthropogenic stress over the range of sites. Refer to Figure 1 for locations of sites and waterways discussed.

%EPT: Most EPT taxa are predominantly riffle-dwelling contaminant sensitive organisms. EPT taxa (%EPT) proportional abundance showed a wide variation among the riffle-containing sites. This variation may be due to differences in the benthic habitats sampled, or differences in water quality between sites.

% Other (non-EPT) insect and amphipod taxa (%IA): Non-EPT insects and amphipods show a wide range of pollution-tolerance levels, but are more pollution-sensitive than most non-insect taxa in the BMI community. Non-EPT insect and amphipod taxa (%IA) proportional abundance varied considerably among sites on agricultural waterways; EPT taxa diversity and abundance were low at sites on these waterways.

% Non-insect non-amphipod taxa (%NIA): Taxa that are neither insects nor amphipods form the most pollution-tolerant component of the BMI community.

River Communities

The upstream sites on the Merced River (MER581 and MER580) manifested the highest %EPT. In spring, the other sites on rivers consisted of approximately equal %EPT. In fall, the Cosumnes River sites (SAC003 and SAC004) had lower %EPT, whereas %EPT was slightly higher at Mokelumne and Calaveras River sites (SJC512 and SJC514). During fall sampling event, the Cosumnes River was shallow and very warm compared to other rivers, which may explain the low %EPT.

During both sampling events, the site on the Cosumnes River downstream of Rancho Murieta (SAC004) revealed lower %EPT, higher %IA and %NIA, compared to the upstream site (SAC003). This change in the BMI community indicates that factors associated with the city or upstream cattle grazing may be reducing the river's capacity to support pollution-sensitive taxa.

MER580, downstream of the confluence of the Merced River and Ingalsbe Slough, had a higher percent insects and amphipods than the upstream site (MER581), suggesting little or no BMI community degradation from input from the agricultural slough. The farthest downstream site on the Merced River (MER546) is 303(d) listed for pesticide contamination. This site exhibited lower EPT abundance than the upstream sites during both sampling events. However, a considerable portion of the BMI community at this site was composed of EPT and other insects, indicating that potential pesticide contamination was not severe enough to extirpate EPT or other insect populations.

Agricultural Stream Communities

All communities in agriculture-dominated waterways, except the upstream site (above agricultural inputs) on Orestimba Creek (STC517), were characterized by very low %EPT. Most of these waterways manifested high %IA. Abundance of all insect and amphipod taxa, including generally pollution-tolerant chironomids, were low at a few sites indicating possible contamination severe enough to prevent large populations of aquatic insects. These sites included Ingram Creek and Mountain House Creek in spring (STC040 and SJC509), and Harding Drain, Del Puerto Creek, Ingram Creek, and Lone Tree Creek in fall (STC501, STC516, STC040 and SJC503).

During both sampling events the downstream Mud Slough site (MER542) consisted of a higher %NIA than the upstream site (MER536). Further, the insect community of the downstream site was dominated more by chironomids than the upstream site. These findings indicate that factors associated with San Luis Drain input may compromise the ability of Mud Slough to support more pollution-sensitive insect and amphipod taxa.

The BMI community at the upstream Orestimba Creek site (STC517) differed greatly from the community at the downstream site (STC019). The upstream site (above agricultural input) was dominated by *Caenis* mayflies, while the downstream site contained mainly non-insect organisms and chironomids. Although the substrates of the two sites were similar, clear water and low flow velocities were present at the upstream site, while turbid conditions and faster flows were characterized the downstream site. Agricultural inputs likely result in water quality changes that impact the BMI community at the lower site.

French Camp Slough is downstream of Lone Tree Creek, but the fauna at both sites varied radically between sampling events, rendering comparison of the two sites difficult. A large population of *Simulium* (larval black flies) was noted at Lone Tree Creek in spring, but was characterized by few larval insects in fall. In contrast, the French Camp Slough site manifested mainly chironomids and non-insects in the spring, but had a large population of *Hydropsyche* (mayflies) in fall.

Data variability and comparison of low gradient modified CSBP and multi-habitat sampling methods

During the fall sampling event, two simultaneous multi-habitat samples were taken at Lone Tree Creek (SJC503). BMI taxa diversity and abundance at the site were similar in the two samples (Table 6). The major difference was a markedly higher tubificid worm abundance in the duplicate sample (reflected by a dramatic increase in percent Oligochaeta and percent collectors, and in a large decrease in percent filterers). Most metrics were not noticeably affected by this difference. Variation between spring and fall BMI samples from a given site was generally low (Table 5). The high variation between the fall Lone Tree Creek sample and its duplicate was likely, therefore, an anomaly. Including the Lone Tree Creek duplicate in a fall sample cluster analysis allowed an estimate of our sampling method resolution and ability to detect site to site differences. The Lone Tree Creek primary sample appeared to bear as much similarity to samples from a number of other agriculture-dominated waterways as to duplicate sample taken simultaneously (Figure 7).

Also during the fall event, the Lone Tree Creek and French Camp Slough sites (SJC503 and SJC504) were sampled simultaneously with the low gradient modified CSBP (LGCSBP) and multi-habitat sampling protocols. A comparison of BMI metrics between the two sampling protocols suggested that the LGCSBP detected greater taxonomic diversity (Tables 6 and 7). This detection of greater taxonomic diversity was maintained irrespective of metrics recalculation from sub-samples of 500 specimens chosen randomly from the 900 specimen LGCSBP samples. Metrics summarizing taxon proportional abundance did not appear to depend on sampling protocol. Figure 7 illustrates taxonomic difference between multi-habitat and LGCSBP samples collected at the same site relative to the degree of taxonomic difference between sites.

Discussion

Between site comparisons of BMI communities

Sites sampled in this investigation can be divided into those sites on rivers that contained some riffle habitat and those in agriculture-dominated waterways did not contain riffle habitat. The sites on rivers manifested a wide variation in percent EPT taxa in the community. Upstream sites on the Merced River (MER580 and MER 581) had the highest percent EPT, while the lowest percent EPT among river sites was seen in the Cosumnes River during a fall period of shallow, warm conditions. The sites in agriculture-dominated waterways contained few EPT, but exhibited wide variation in percent total insects and amphipods. Amphipods were included in this measure because they are often used as subjects of toxicity tests (e.g., *Hyalella* and *Gammarus*), and are sensitive to many contaminants (Cold and Forbes, 2004; Schroer et al., 2004). Most agriculture-dominated waterway sites were characterized by sizable larval insect populations. Notable exceptions, dominated by non-insects at times, included Ingram Creek (STC040), Mountain House Creek (SJC509), the Harding Drain (STC501), Del Puerto Creek (STC040) and Lone Tree Creek (SJC503). This lack of insects cannot be completely attributed to poor habitat, since chironomids often inhabit depositional environments of fine substrate. Samples with an absence of insects may indicate contaminated water or sediment. More research is needed, however, to ascertain if either the life cycles of indigenous species or the periodic desiccation of ephemeral waterways could cause an absence of insects to be a part of natural temporal variation in aquatic communities.

Some comparisons of sites along the same waterway revealed a loss of pollution-sensitive taxa at downstream sites. This was the case on the Cosumnes River, Orestimba Creek and Mud Slough. On the Cosumnes River, inputs from the community of Rancho Murieta may contribute to this loss of pollution-sensitive taxa. On Orestimba Creek, influences on the downstream fauna included inputs from row crops and orchards. On Mud Slough, the downstream site received water from the San Luis Drain, which may have affected BMI community composition. Loss of pollution-sensitive taxa was not observed either at the two upstream sites on the Merced River or at the Lone Tree Creek and French Camp Slough sites. Percent EPT taxa was lower at the most downstream Merced River site than at the upstream sites, but the downstream site consisted of more sand and less gravel and cobble than the upstream sites, and was therefore, less favorable for habitation by most EPT taxa.

Correlations between BMI communities and environmental variables

The spring dataset consisted of one major gradient in BMI community structure which was correlated with many environmental variables and associated with changes in several BMI community metrics. The fall dataset revealed three separate BMI community gradients, each correlated with a separate set of environmental variables, and associated with somewhat different (compared to spring) sets of BMI metrics. The two major BMI community composition gradients (Fall Axis 1 and Fall Axis 2 that summarized 35.8% and 36.7% of the variability in BMI communities, respectively) appeared to be associated with 1) flow and 2) nutrients and arsenic. The sites with the least diverse communities and the lowest percent insect taxa tended to be characterized by higher nutrient or arsenic concentrations. The third BMI community composition gradient (Fall Axis 3, 11.6% of the variability) was associated with physical habitat, TOC, and zinc. BMI community composition did not show a clear relationship to local agricultural land uses (row crops, orchards, or pasture) during either sampling event. Other environmental variables not considered by this study may drive or contribute to the observed correlations with community structure.

Relative to BMI data collected in June and September 2001 at many of the same sites (de Vlaming et al., 2004b), current results suggest that many of the same environmental factors determine BMI community composition. However, in this investigation environmental variables were not correlated to one another in the same ways as in the earlier study. Compared to data collected in the 2001 study, the 2002 dataset revealed weaker correlations between metals and BMI communities, but stronger associations between community composition and channel flow variables. The strong relationships with channel flow seen in 2002 may be related to the greater number of sites on river channels. Reasons for the weaker relationship between metal concentrations and BMI community structure are not clear. Data collected in both years indicated that physical habitat quality is an important determinant of BMI diversity. Significant relationships between several water quality factors, including nutrients and TOC, and BMI community composition (low biodiversity) were seen in both years.

Detection of associations between BMI community and various environmental variables fits into a framework outlining cumulative anthropogenic impacts on habitat and water quality. Cumulative and interacting anthropogenic stressors that affect aquatic biota include alterations of the following (Karr, 1991; Karr and Yoder, 2004):

1. Energy Source
2. Chemical variables
3. Flow regime
4. Habitat structure
5. Biotic factors (including predator-prey and competitive interactions).

In the Clean Water Act §502(19), the effects of pollutant substances as well as nonpollutant stressors such as flow alteration, loss of riparian zone, physical habitat degradation, and introduction of alien taxa are all considered pollution and, thus, subject to regulation (Karr and Yoder, 2004). Data collected in this study and two earlier studies (de Vlaming et al., 2004a, b) illustrate that all five types of alterations to aquatic communities are likely to be widespread in the Central Valley.

Contamination signatures

The ability to distinguish contaminant-related from other stressor impacts would be of considerable value in evaluating causes of non-attainment of aquatic life beneficial uses. A limitation of bioassessment, however, is the inability to directly identify cause(s) of impact/impairment (e.g., Barbour et al., 1996; Clements and Kiffney, 1996; Holdway, 1996; McCarty and Munkittrick, 1996; Wolfe, 1996; Power, 1997; Bart and Hartman, 2000; Adams, 2003). An integrated monitoring/weight-of-evidence approach is preferred for identification of impacts/impairment and cause(s) thereof (e.g., Taylor and Kovats, 1995; Culp et al., 2000; National Research Council, 2001; Collier, 2003; Hewitt et al., 2003; de Vlaming et al., 2004a).

As a result of integrated toxicological and community studies, Yoder and Rankin (1995) reported that BMI communities lacking most insect taxa, including an absence of chironomids (usually ubiquitous in low gradient systems), tended to be associated with toxic conditions. The work presented here supports this finding. During each 2002 sampling event in the San Joaquin River watershed some sites, including Del Puerto Creek (STC516), had very few insects (Figures 5 and 6). Chlorpyrifos concentrations in Del Puerto Creek frequently approached the *Ceriodaphnia* LC50 (Figure 3). At the same site in Del Puerto Creek, Domagalski and Munday (2003) reported chlorpyrifos concentrations twice the *Ceriodaphnia* LC50 during early May 2001. Sediment toxicity samples taken in October 2001 by the Surface Water Ambient Monitoring Program in Del Puerto Creek resulted in 100 percent mortality to *Hyalella azteca* (Phillips 2002). A toxicity identification evaluation (TIE) and chemical analysis on sediment collected from Del Puerto Creek in June and September, 2002 suggest pyrethroid insecticides as the cause of toxicity. Chemical analysis revealed 43.2 ng bifenthrin/g dry sediment weight and 20.4 ng permethrin/g dry sediment weight in June samples and 7.51 to 8.25 ng bifenthrin/g dry sediment weight in September samples. The June samples also contained 0.056 μg/L chlorpyrifos and 0.047μg/L diazinon. Several organochlorines also were identified in the pore water and sediment of the June sample, most notably DDE, p,p' at 39.5 ng/g in sediment (Phillips 2002).

Del Puerto Creek and the other sites with insect-poor communities are candidates for further investigation and possible contaminant mitigation actions. Other sites located in close proximity to insect-poor sites on the NMS axes (Figures 5 and 6) also may bear the toxicity signature, though to a lesser extent. Among spring samples (Figure 5) the sites exhibiting a paucity of larval insects clustered at the negative end of axis 1. One possible interpretation is that the other sites positioned towards the negative end of the NMS axis were contaminant impacted, but to a lesser extent.

Among fall samples, Del Puerto Creek (STC516) and Ingram Creek (STC040) contained very few insects (Figure 6). *Hyalella* acute sediment toxicity was noted in several Ingram Creek samples following BMI sample collections for this project (Phillips 2002). TIEs point to multiple pyrethroid pesticides as the cause of toxicity. Other sites that positioned towards the positive end of NMS axis 2, along with the Del Puerto Creek and Ingram Creek sites, may have been contaminant impacted.

The sites included in this project are subject to multiple stressors (e.g., flow alterations, contaminant pulses, etc.) and contain communities comprised of multivoltine organisms able to quickly re-establish populations after toxic events. Among these impacted communities it appears to be possible to detect contaminant signatures. Weight-of-evidence investigations combining BMI bioassessments and toxicology have proceeded to the point where we can now rely on the results of past work to calibrate probable toxicological implications of particular BMI community profiles. While evaluations of ecological health must continue to include multiple lines of evidence from water chemistry, toxicology, and bioassessment, the existing body of integrative research greatly increases the utility of bioassessments in the preliminary identification of sites most likely to be impacted by particular stressors.

Data variability and comparison between methods

The duplicate multi-habitat sample collected at Lone Tree Creek during fall sampling event suggests that variation between multi-habitat replicates at Lone Tree Creek (SJC503) was greater than variation in BMI communities between some sites. Therefore, the communities at a number of sites examined were too similar for the reliable detection of between-site differences by the multi-habitat sampling procedure (Figure 7). This result is contradicted to some extent by the similarity in community composition seen between fall and spring samples taken at most sites. Replication at a greater number of sites is desirable in order to further quantify the precision of the multi-habitat rapid bioassessment protocol. Between-site differences may be especially difficult to detect when biodiversity is low, as is the case in the agriculture-dominated waterways of the Central Valley.

Samples collected according to the LGCSBP at Lone Tree Creek and French Camp Slough both showed higher diversity, but roughly similar taxonomic composition, compared to the multi-habitat samples collected at the same time (see Tables 6 and 7, Figure 7). This heightened diversity in CSBP samples was observed even after the size of each sample was randomly reduced to 500 organisms to match the multi-habitat samples. This finding is unlikely due to species/area relationships because these methods sample similar areas of substrate (LGCSBP: 9 jabs x 2 ft^2 = 18 ft^2; Multi-habitat: 20 jabs x 1 ft^2 = 20 ft^2). The difference in estimated diversity may have been haphazard as a consequence of high variability of BMI samples (variability among rapid bioassessment replicates is typically high—e.g., Barbour et al., 1992; Resh, 1994; Hannaford and Resh, 1995) collected or caused by the larger number of CSBP sampling "jabs" collected in close proximity to stream banks. While "jabs" in the multi-habitat method are collected in proportion to the quantity of each habitat type at a site, a CSBP sample consists of three transects, each of which is made up of one "jab" in the thalweg, and two "jabs" near the banks of the stream, so six out of nine CSBP "jabs" are likely to be taken near the banks. When a site has very poor instream habitat, the greater portion of the taxa at the site are likely to occur near the banks (Roy et al., 2003) and, thus, more likely to be collected by the CSBP approach.

Summary

Benthic macroinvertebrate bioassessment revealed a wide range of BMI community types in agriculture-dominated waterways of the San Joaquin River watershed. Anthropogenic stressors including nutrients, total organic carbon, and poor instream habitat correlated with differences in BMI communities. The least diverse communities contained few larval insect taxa and low chironomid abundance, which may consequent to recurring toxicity. In cases where multiple sites were sampled on the same waterway, downstream sites sometimes displayed a loss of pollution-sensitive taxa compared to upstream sites. Stressors associated with the loss of pollution-sensitive taxa varied from waterway to waterway, and included urban land use, agricultural land use, and poor instream habitat. Multivariate analyses revealed other sites with community characteristics similar to these least diverse sites. Some sites consisted of communities too similar to be differentiated by the multi-habitat bioassessment protocol used. At two sites sampled by the multi-habitat protocol and the CSBP, the CSBP sample yielded greater taxonomic diversity even after its sample size was reduced to be comparable to the multi-habitat sample.

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References

Adams SM. 2003. Establishing causality between environmental stressors and effects on aquatic ecosystems. *Human Ecol. Risk Assess.* 9:17-35.

Barbour MT, Diamond JM, Yoder, CO. 1996. Biological assessment strategies: Applications and limitations. In: Grothe DR, Dickson KL, Reed-Judkins DK. Editors, *Whole Effluent Toxicity Testing: An Evaluation of Methods and Predictions of Receiving System Impacts*. SETAC Press, Pensacola, FL, USA, pp. 245-270.

Barbour MT, Gerritsen J, Snyder BD, Stribling JB. 1999. Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates, and Fish. Washington DC: United States Environmental Protection Agency, Office of Water. Second Edition, EPA 841-B-899-002.

Barbour MT, Platkin JL, Bradley BP, Graves CG, Wisserman, RW. 1992. Evaluation of EPA's rapid bioassesment benthic metrics: Metric redundancy and variability among reference stream sites. *Environ. Toxicol. Chem.* 11:437-449.

Bart D, Hartman JM. 2000. Environmental determinants of *Phragmites australis* expansion in a New Jersey salt marsh: An experimental approach. *Oikos* 89:59-69.

Brazner JC, Beals EW. 1997. Patterns in fish assemblages from coastal wetland and beach habitats in Green Bay, Lake Michigan: a multivariate analysis of abiotic and biotic forcing factors. *Can. J. Fish. Aquat. Sci.* 54:1743-1761.

Brown LR, May JT. 2000. Macroinvertebrate assemblages on woody debris and their relations with environmental variables in the lower Sacramento and San Joaquin River drainages, California. *Environ. Monit. Assess.* 64:311-329.

California Department of Fish and Game (CDFG). 2003. Measuring the Health of California Streams and Rivers. A Methods Manual for: Water Resource Professional, Citizen Monitors, and Natural Resources Students. California Department of Fish and Game Aquatic Bioassessment Laboratory, Rancho Cordova, CA.

Central Valley Regional Water Quality Control Board (CVRWQCB). 2002. Regional Board Staff Report - Total Maximum Daily Load for Salinity and Boron in the Lower San Joaquin River, January 2002.

Central Valley Regional Water Quality Control Board (CVRWQCB). 2003. Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Salt and Boron Discharges to the Lower San Joaquin River, September 2003 Peer Review Draft Staff Report; Appendix B Geographic Information

System Processing Information and Metadata. California Regional Water Quality Control Board, Central Valley Region. Sacramento, CA.

Chessman BC, Royal MJ. 2004. Bioassessment without reference sites: use of environmental filters to predict natural assemblages of river macroinvertebrates. *J. N. Am. Benthol. Soc.* 23: 599-615.

Chilcott, J., 1992. Consideration of Water Body Designations to Comply with Provisions of the Water Quality Control Plan for Inland Surface Waters of California (ISWP). Regional Water Quality Control Board, Central Valley Region Report.

Clements WH, Kiffney M. 1996. Validation of whole effluent toxicity tests: Integrated studies using field assessments. In: Grothe DR, Dickson KL, Reed-Judkins DK. Editors, *Whole Effluent Toxicity Testing: An Evaluation of Methods and Predictions of Receiving Systems Impacts*. SETAC Press, Pensacola, FL, pp. 229-244.

Cold A, Forbes VE. 2004. Consequences of a short pulse of pesticide exposure for survival and reproduction of *Gammarus pulex*. *Aquat. Toxicol.* 67: 287-299.

Collier TK. 2003. Forensic Ecotoxicology: Establishing causality between contaminants and biological effects in field studies. *Human Ecol. Risk Assess.* 9:259-266.

Culp JM, Lowell RB, Cash KJ. 2000. Integrating mesocosm experiments with field and laboratory studies to generate weight-of-evidence risk assessments for large rivers. *Environ. Toxicol. Chem.* 19:1167-1173.

De Lange HJ, De Jonge J, Den Besten PJ, Oosterbaan J, Peeters ETHM. 2004. Sediment pollution and predation affect structure and production of benthic macroinvertebrate communities in the Rhine – Meuse delta, The Netherlands. *J. N. Am. Benthol. Soc.* 23: 557-579.

de Vlaming, V., Markiewicz, D., Goding, K., Kimball, T. and Holmes, R., 2004a. Macroinvertebrate assemblages in agriculture- and effluent-dominated waterways of the lower Sacramento River Watershed. pp. 136. Aquatic Toxicology Laboratory, University of California, Davis 95616. Technical Report submitted to Central Valley Regional Water Quality Control Board.
http://www.waterboards.ca.gov/swamp/docs/sacriver_bioreport.pdf

de Vlaming, V., Markiewicz, D., Goding, K., Morrill, A. and Rowan, J., 2004b. Macroinvertebrate assemblages of the San Joaquin River watershed. Aquatic Toxicology Laboratory, University of California, Davis 95616. Technical Report submitted to Central Valley Regional Water Quality Control Board.
http://www.waterboards.ca.gov/centralvalley/available_documents/waterqualitystudies/SJR_Bioassessment_Final_Rpt.pdf

Griffith MB, Husby P, Hall RK, Kaufmann PR, Hill BH. 2003. Analysis of macroinvertebrate assemblages in relation to environmental gradients among lotic habitats of California's Central Valley. *Environ. Monit. Assess.* 28:281-309.

Hannaford MJ, Resh VH. 1995. Variability in macroinvertebrate surveys and habitat assessments in a northern California stream. *J. N. Am. Benthol. Soc.* 14:430-439.

Hewitt ML, Dube MG, Culp JM, MacLatchy DL, Munkittrick KR. 2003. A proposed framework for investigation of cause for environmental effects monitoring. *Human Ecol. Risk Assess.* 9:195-211.

Holdway DA. 1996. The role of biomarkers in risk assessment. *Human Ecol. Risk. Assess.* 2:263-267.

Karr JR. 1991. Biological integrity: a long-neglected aspect of water resource management. *Ecol. Appl.* 1:66-84.

Karr JR, Yoder CO. 2004. Biological assessment and criteria improve total maximum daily load decision making. *J. Environ. Engin.* 130:594-604.

Leland HV, Fend SV. 1998. Benthic invertebrate distributions in the San Joaquin River, California, in relation to physical and chemical factors. *Can. J. Fish. Aquat. Sci.* 55:1051-1067.

Martinez-Tabche L. 2002. Toxicity and uptake of zinc in the planarian *Dugesia dorotocephela* in natural sediments. *J. Freshwater Ecol.* 17: 415-421.

McCarty LS, Munkittrick, KR. 1996. Environmental biomarkers in aquatic toxicology: Fiction, fantasy, or functional? *Human Ecol. Risk Assess.* 2:268-274.

McCune B, Grace JB. 2002. *Analysis of Ecological Communities*. MjM Software Design, Gleneden Beach, Oregon.

McCune B, Mefford MJ. 1999. *PC-ORD.* Multivariate Analysis of Ecological Data. Version *4.0.* MjM Software, Gleneden Beach, Oregon, USA.

National Research Council. 2001. Assessing the TMDL approach to water quality management. National Academy Press, Washington, DC.

Phillips B. 2002. Toxicity Identification Evaluation Results, Region 5, December 2002 – Station 541STC516. Surface Water Ambient Monitoring Program. UC Davis, Department of Environmental Toxicology, Marine Pollution Studies Laboratory.

Power M. 1997. Assessing the effects of environmental stress on fish populations. *Aquat. Toxicol.* 39:151-169.

Preza DDC, Smith DH. 2001. Use of newborn *Girardia tigrina* (Girard, 1850) in acute toxicity tests. *Ecotoxicol. Environ. Safety* 50:1-3.

Resh VH. 1994. Variability, accuracy, and taxonomic costs of rapid assessment approaches in benthic biomonitoring. *Boll. Zool.* 61:375-383.

Roy AH, Rosemund AD, Leigh DS, Paul MJ, Wallace JB. 2003. Habitat-specific responses of stream insects to land cover disturbance: biological consequences and monitoring implications. *J. N. Am. Benthol. Soc.* 22: 292-307.

Schroer AFW, Belgers JDM, Brock TCM, Matser AM, Maund SJ, Van den Brink PJ. 2004. Comparison of laboratory single species and field population-level effects of the pyrethroid insecticide lambda-cyhalothrin on freshwater invertebrates. *Arch. Env. Contaminat. Toxicol.* 46:324-335.

Southerland MT, Stribling JB. 1995. Status of biological criteria development and implementation. In: Davis WS, Simon, TP. Editors, *Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making.* Lewis, Ann Arbor, MI, USA, pp. 81-96.

Taylor, B.R. and Kovats, Z., 1995. Review of artificial substrates for benthos sample collection. Prepared for Canada Centre for Mineral and Energy Technology (CANMET), Ottawa, Ontario.

Wolfe, D.A., 1996. Insights on the utility of biomarkers or environmental impact assessment and monitoring. *Human Ecol. Risk Assess.* 2:245-250.

Yoder CO, DeShon JE. 2003. Using biological response signatures within a framework of multiple indicators to assess and diagnose causes and sources of impairments to aquatic assemblages in selected Ohio rivers and streams. In: Simon, TP. Editor, *Biological Response Signatures: Indicator Patterns Using Aquatic Communities.* CRC Press, Boca Raton, FL, USA, pp. 23-81.

Yoder CO, Rankin ET. 1995. Biological response signatures and the area of degradation value: New tools for interpreting multimetric data. In: Davis WS, Simon, TP. Editors, *Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making.* Lewis, Ann Arbor, MI, USA, pp. 263-286.

Table 1. Locations and codes of sampling sites in the San Joaquin River watershed.

Site Name	Site Code	Latitude	Longitude	Ecoregion
Bear Creek @ Bert Crane Rd.	MER007	37.2556	-120.6519	Manteca-Merced Alluvium
Salt Slough @ Lander/Hwy 165	MER531	37.2486	-120.8511	San Joaquin Basin
Mud Slough Up Stream of SLD	MER536	37.2550	-120.8742	San Joaquin Basin
Mud Slough Down Stream of SLD	MER542	37.2625	-120.9056	San Joaquin Basin
Merced River @ Hatfield Park (River Rd)	MER546	37.3497	-120.9578	San Joaquin Basin
Los Banos Creek @ Hwy 140	MER554	37.2764	-120.9539	San Joaquin Basin
Ingalsby Slough @ J17 Turlock	MER579	37.4918	-120.5578	Hardpan Terraces
Merced River @ J16 Oakdale Rd.	MER580	37.4540	-120.6092	Manteca-Merced Alluvium
Merced River @ Hwy 59	MER581	37.4702	-120.5005	Manteca-Merced Alluvium
Cosumnes R. @ Michigan Bar Rd.	SAC003	38.5006	-121.0450	Camanche Terraces
Cosumnes River @ Hwy 16	SAC004	38.4904	-121.0978	Camanche Terraces
Lone Tree Creek @ Austin Rd.	SJC503	37.8556	-121.1847	Delta Basins
French Camp Slough @ Airport Rd.	SJC504	37.8817	-121.2492	Delta Basins
Bear Creek @ Lower Sacramento Rd.	SJC515	38.0431	-121.3486	Delta Basins
Mtn. House Creek @ Byron Rd.	SJC509	37.7856	-121.5356	Westside Alluvial Fans &Terraces
Mokelumne R. @ Van Assen Co. Park	SJC512	38.2225	-121.0344	Camanche Terraces
Calaveras River @ Shelton Rd.	SJC514	38.0727	-120.9310	Camanche Terraces
Orestimba Creek @ River Rd.	STC019	37.4139	-120.0142	Westside Alluvial Fans & Terraces
Ingram Creek @ River Rd.	STC040	37.6003	-121.2242	Westside Alluvial Fans & Terraces
TID 5/ Harding Drain @ Carpenter Rd.	STC501	37.4644	-120.0303	Caswell Basin
Del Puerto Creek @ Vineyard	STC516	37.5214	-121.1486	Westside Alluvial Fans & Terraces
Orestimba Creek @ Bell Rd.	STC517	37.3458	-121.0792	Westside Alluvial Fans & Terraces

Table 2. Ranges and means of environmental variables measured during the spring 2002 and fall 2002 sampling events. Trend monitored water quality variables were averaged at each site over the three months preceding each sampling event.

	Spring				Fall			
	Lowest Site Average	Mean	Highest Site Average	# Sites	Lowest Site Average	Mean	Highest Site Average	# Sites
Temp (C)	10.8	15.8	18.5	15	14.0	21.4	25.1	16
pH	7.4	7.9	8.3	15	7.1	7.8	8.3	16
DO (mg/L)	6.3	8.8	11.0	14	3.1	6.9	8.8	15
Field EC (umhos)	41.9	979.2	4248.9	15	51.5	735.3	3191.5	16
HDNS	45	176	520	8	38	181	470	12
Alkalinity (mg/L)	44	99	230	8	31	103	200	8
TDS	92	696	1785	7				
Sodium (mg/L)	5.2	152.7	651.3	13	4.0	111.4	487.0	13
Potassium (mg/L)	0.9	4.5	9.1	14	0.8	4.5	7.9	14
TSS	1.9	31.5	81.4	3				
Se	0.0	8.6	40.6	5	0.0	5.1	28.4	6
Mo	0.8	8.6	14.9	5	0.0	3.9	10.8	4
Cr	0.0	3.0	18.2	12	0.0	3.6	13.0	12
Cu	2.9	4.5	9.8	12	2.7	5.6	8.0	4
Ni	0.0	5.5	29.3	12	0.0	4.4	18.0	12
Pb	0.0	0.3	3.3	12	0.0	0.0	0.0	12
Zn	3.1	7.9	31.0	12	0.0	7.6	20.0	12
Total Cadmium (ug/L)	0.0	0.0	0.0	12	0.0	0.0	0.0	11
Total Arsenic (ug/L)	0.0	1.7	6.9	12	0.0	3.3	7.9	12
B	0.0	1.0	5.4	11	0.0	0.7	5.2	12
Cl	3.9	137.7	487.2	13	3.2	122.5	424.9	13
SO4	4.8	242.3	1429.6	13	4.0	141.6	1054.6	13
Kjeldhal N (mg/L)	0.10	1.10	2.09	8	0.08	2.71	15.70	9
Nitrite + Nitrate (mg/L)	0.05	1.24	5.51	10	0.03	2.15	11.55	10
Nitrate N (mg/L)	0.67	3.71	11.14	5	0.56	3.52	7.74	5
TotalP (mg/L)	0.02	0.25	0.56	13	0.06	0.32	1.11	14
Ammonia N (mg/L)	0.00	0.11	0.37	14	0.00	0.22	1.37	15
BOD5 (mg/L)	1.2	2.7	5.8	12	0.4	2.0	4.1	13
BOD10 (mg/L)	2.1	4.5	9.7	12	0.8	3.9	6.9	13
TOC (mg/L)	3.2	7.7	19.0	9	2.9	4.0	4.7	5
96h FHM surv (%)	90	97	100	4	93	97	100	5
48h Cerio surv (%)	0	75	100	4	70	93	100	5
Elev (ft)	15	100	181	19	15	100	181	19
Cobble Habitat (%)	0	13	60	20	0	13	60	20
Snag Habitat (%)	0	7	20	20	0	7	20	20
Veg. Banks Habitat (%)	0	12	40	20	0	12	40	20
Sand Habitat (%)	0	24	60	20	0	24	60	20
Macrophyte Habitat (%)	0	2	15	20	0	2	15	20
Gravel Habitat (%)	0	11	35	20	0	11	35	20
Mud Habitat (%)	0	21	95	20	0	21	95	20
Local NPS Pollution	1	1.7	2	19				

(continued)

(Table 2 cont'd.)

	Spring				Fall			
	Lowest Site Average	Mean	Highest Site Average	# Sites	Lowest Site Average	Mean	Highest Site Average	# Sites
Erosion	1	1.5	2	18				
Width (m)	1.0	15.3	40.0	19	1.0	15.3	40.0	19
Depth (m)	0.1	0.8	2.0	17				
High Water Mark (m)	0.5	2.1	6.0	15	0.5	2.1	6.0	15
Riffle (%)	0	18	80	20	0	18	80	20
Run (%)	0	39	100	20	0	39	100	20
Pool (%)	0	43	100	20	0	43	100	20
WaterOils	0.0	0.1	2.0	21				
Sediment Oils	0.0	0.1	2.0	21				
Boulder (%)	0	1	10	19				
Cobble (%)	0	11	60	19				
Gravel (%)	0	14	50	19				
Sand (%)	5	33	80	19				
Silt (%)	3	16	45	19				
Clay (%)	2	12	45	19				
Detritus (%)	0	15	45	18				
Muck (%)	0	16	80	18				
Marl (%)	0	0	2	18				
Epifaunal Substrate	4	10	18	21				
Pool Substrate	7	11	18	21				
Pool Variability	6	11	17	21				
Sediment Deposition	4	9	17	21				
Channel Flow	5	14	18	21				
Channel Alteration	2	12	19	21				
Channel Sinuosity	2	10	18	21				
Bank Stability	4	10	16	20				
Vegetated Banks	5	10	16	21				
Riparian Zone Width	2	9	19	21				

Table 3. Environmental variables and benthic macroinvertebrate metrics significantly correlated with the axes of the NMS ordination performed on the spring 2002 BMI data ($P < 0.05$), along with taxa correlated with the axes ($|r| > 0.400$). Shading indicates negative correlations.

	Environmental Variables				Metrics				Taxa	
NMS Axis	Environmental Variable	Correlation [r]	N	*P*	BMI Metric	Correlation [r]	N	*P*	Taxon	Correlation [r]
Spring	Erosion	-0.7152	18	0.001	Oligochaeta %	-0.8337	21	0.000	Tubificidae	-0.8090
NMS	Total Phosphorus	-0.6887	13	0.009	Tolerance Value	-0.8331	21	0.000	Nematoda	-0.6330
Axis 1	K	-0.6523	14	0.012	Tolerant %	-0.7876	21	0.000	Crangonyx	0.5670
32.3%	Mud Habitat	-0.6213	20	0.004	Multivoltine %	-0.7025	21	0.000	Tanytarsini	0.5810
	Channelization	-0.6199	18	0.006	Collectors %	-0.4455	21	0.043	*Hydropsyche*	0.6980
	Turbidity	-0.5579	20	0.011	Chironomidae %	0.5090	21	0.018	Ephemerella	0.7500
	Clay	-0.5411	19	0.017	Odonata Taxa	0.5319	21	0.013	Baetis	0.7870
	Ag Land	-0.5403	20	0.014	Shannon Diversity	0.5351	21	0.012		
	Irrigation Return	-0.5365	21	0.012	Hydropsychidae %	0.6228	21	0.003		
	Silt	-0.4879	19	0.034	Filterers %	0.6523	21	0.001		
	Perennial	0.4567	21	0.037	Ephemeroptera %	0.6617	21	0.001		
	Boulder	0.4870	19	0.035	Sensitive EPT %	0.6943	21	0.001		
	Vegetated Banks	0.4935	21	0.023	Trichoptera Taxa	0.6958	21	0.001		
	Riffle	0.5030	20	0.024	Univoltine %	0.7035	21	0.000		
	Pasture	0.5571	20	0.011	ETO %	0.7169	21	0.000		
	Cobble	0.6338	19	0.004	Intolerant %	0.7179	21	0.000		
	Channel Sinuosity	0.6402	21	0.002	EPT %	0.7221	21	0.000		
	Elevation	0.6602	19	0.002	Baetidae %	0.7282	21	0.000		
	Epifaunal Substrate	0.6758	21	0.001	Trichoptera %	0.7343	21	0.000		
	Cobble Habitat	0.7260	20	0.000	Taxonomic Richness	0.7390	21	0.000		
	Pool Variability	0.7837	21	0.000	Ephemeroptera Taxa	0.7744	21	0.000		
	Width	0.7847	19	0.000	Insects %	0.7947	21	0.000		
					EPT Taxa	0.8075	21	0.000		
					ETO Taxa	0.8146	21	0.000		
					Sensitive EPT Taxa	0.8412	21	0.000		
					Intolerant Taxa	0.8686	21	0.000		
					Insect Taxa	0.8828	21	0.000		
Spring	High Water Mark	-0.6168	15	0.014	Odonata %	-0.6533	21	0.001	Coenagrionidae	-0.6700
NMS	Riparian Trees	-0.4745	19	0.040	Odonata Taxa	-0.5526	21	0.009	Hyalella	-0.6640
Axis 2	Rip. Zone Width	0.4481	21	0.042	Taxonomic Richness	-0.4747	21	0.030	Callibaetis	-0.6360
43.9%	Pasture	0.4695	20	0.037	Amphipods %	0.6211	21	0.003	Oxyethira	-0.5860
	Floating Algae	0.6154	18	0.007					Caenis	-0.5610
									Corophium	0.6930
Spring	Emergent Veg.	-0.5343	18	0.022	Predators %	-0.4762	21	0.029	Crangonyx	-0.5540
NMS	Urban Land	-0.4638	20	0.039	Filterers %	-0.4693	21	0.032	Tipulidae	0.5620
Axis 3	Sediment Odor	0.4652	21	0.034	Shredders %	0.4694	21	0.032	Naididae	0.5850
10.9%	Floating Algae	0.4980	18	0.035	Collectors %	0.5959	21	0.004		
	EC	0.5510	15	0.033						
	Cl	0.5599	13	0.047						
	Arsenic	0.6485	12	0.023						

Table 4. Environmental variables and benthic macroinvertebrate metrics significantly correlated with the axes of the NMS ordination performed on the fall 2002 BMI data ($P < 0.05$), along with taxa correlated with the axes ($|r| > 0.400$). Shading indicates negative correlations.

	Environmental Variables				Metrics				Taxa	
NMS Axis	Environmental Variable	Correlation [r]	N	*P*	BMI Metric	Correlation [r]	N	*P*	Taxon	Correlation [r]
Fall	Detritus	-0.6562	18	0.003	Collectors %	-0.7497	22	0.000	Tanypodinae	-0.6540
NMS	Sand Habitat	-0.5665	20	0.009	Chironomidae %	-0.6838	22	0.000	Caenis	-0.6280
Axis 1	Macrophyte Habitat	-0.5193	20	0.019	Amphipod Taxa	-0.5969	22	0.003	Hyalella	-0.5150
35.8%	Muck	-0.4997	18	0.035	Amphipods %	-0.4783	22	0.024	Planariidae	0.5040
	Channel Flow	0.4369	21	0.048	Tolerance Value	-0.4383	22	0.041	Simulium	0.5530
Fall	Pool Variability	-0.5929	21	0.005	Trichoptera Taxa	-0.7324	22	0.000	Baetis	-0.6520
NMS	Vegetated Banks	-0.5168	21	0.016	Sensitive EPT Taxa	-0.7053	22	0.000	Hydrobiidae	-0.5770
Axis 2	Attached Algae	-0.5041	18	0.033	EPT Taxa	-0.7039	22	0.000	Hydropsyche	-0.5570
36.7%	Elevation	-0.5024	19	0.028	Insect Taxa	-0.6899	22	0.000	Protoptila	-0.5150
	K	0.5488	14	0.042	ETO Taxa	-0.6896	22	0.000	Prostoma	0.5130
	Ammonia Nitrogen	0.6806	15	0.005	Intolerant Taxa	-0.6721	22	0.001	Planariidae	0.5350
	Kjeldhal Nitrogen	0.6968	9	0.037	EPT %	-0.6357	22	0.002	Polychaeta	0.6000
	Arsenic	0.7477	12	0.005	ETO %	-0.6165	22	0.002		
	Alkalinity	0.7885	8	0.020	Grazers %	-0.6025	22	0.003		
					Ephemeroptera Taxa	-0.5499	22	0.008		
					Baetidae %	-0.5418	22	0.009		
					Insects %	-0.5246	22	0.012		
					Trichoptera %	-0.4666	22	0.029		
					Coleoptera Taxa	-0.4655	22	0.029		
					Ephemeroptera %	-0.4588	22	0.032		
					Predators %	0.5784	22	0.005		
Fall	Cobble Habitat	-0.6573	20	0.002	Intolerant %	-0.6461	22	0.001	Oxyethira	-0.5110
NMS	Cobble	-0.6366	19	0.003	Univoltine %	-0.5922	22	0.004	Tubificidae	0.7540
Axis 3	Epifaunal Substrate	-0.5805	21	0.006	Intolerant Taxa	-0.5709	22	0.006		
11.6%	Riffle	-0.5763	20	0.008	Sensitive EPT %	-0.5236	22	0.012		
	Elevation	-0.5093	19	0.026	Sensitive EPT Taxa	-0.4738	22	0.026		
	Width	-0.5070	19	0.027	Shannon Diversity	-0.4587	22	0.032		
	Bank Stability	-0.5052	20	0.023	EPT Taxa	-0.4381	22	0.041		
	Gravel	-0.5025	19	0.028	Ephemeroptera Taxa	-0.4306	22	0.045		
	Pool Substrate	-0.4846	21	0.026	Tolerant %	0.5765	22	0.005		
	Boulder	-0.4625	19	0.046	Multivoltine %	0.5922	22	0.004		
	Sediment Deposition	-0.4369	21	0.048	Tolerance Value	0.6340	22	0.002		
	Mud Habitat	0.4898	20	0.028	Oligochaeta %	0.6888	22	0.000		
	Pool	0.5367	20	0.015						
	Irrigation Return	0.5451	21	0.011						
	Zn	0.6039	12	0.038						
	Total Organic Carbon	0.9552	5	0.011						

Table 5. Major taxonomic components of the BMI communities at sites on agricultural waterways in the San Joaquin River watershed sampled during spring and fall of 2002. %EPT: proportional abundance of EPT taxa; %IA: proportional abundance of non-EPT insect taxa plus amphipod taxa; %NIA: proportional abundance of non-insect, non-amphipod taxa. Sites along the same waterway are listed in order from upstream to downstream.

			Spring			Fall		
Site Category	Site		% EPT	% IA	%NIA	% EPT	% IA	%NIA
Rivers	Merced River @ Hwy 59	MER581	74	16	10	57	12	31
	Merced River @ J16 Oakdale Rd.	MER580	59	31	10	54	27	19
	Merced River @ Hatfield Park (River Rd)	MER546	22	63	16	14	51	36
	Cosumnes R. @ Michigan Bar Rd.	SAC003	33	63	4	9	52	39
	Cosumnes River @ Hwy 16	SAC004	23	68	9	2	52	46
	Mokelumne R. @ Van Assen Co. Park	SJC512	19	53	28	32	29	39
	Calaveras River @ Shelton Rd.	SJC514	22	44	34	33	9	57
Southern Aqricultural Streams	Mud Slough Up Stream of SLD	MER536	1	73	26	2	76	22
	Mud Slough Down Stream of SLD	MER542	0	69	31	0	60	39
	Salt Slough @ Lander/Hwy 165	MER531	7	91	3	2	30	69
	Bear Creek @ Bert Crane Rd.	MER007	4	16	79	2	15	83
	Los Banos Creek @ Hwy 140	MER554	0	23	77	1	32	68
	Ingalsby Slough @ J17 Turlock	MER579	6	37	57	2	45	53
	Harding Drain @ Carpenter Rd.	STC501	-	-	-	5	4	91
West Side Aqricultural Streams	Orestimba Creek @ Bell Rd.	STC517	69	20	11	71	29	0
	Orestimba Creek @ River Rd.	STC019	2	17	81	1	21	77
	Del Puerto Creek @ Vineyard	STC516	0	37	63	0	9	91
	Ingram Creek @ River Rd.	STC040	0	14	86	0	4	96
Northern Aqricultural Streams	Lone Tree Creek @ Austin Rd.	SJC503	1	64	35	3	5	92
	French Camp Slough @ Airport Rd.	SJC504	3	25	73	66	12	22
	Bear Creek @ Lower Sacramento Rd.	SJC515	0	41	59	0	19	81
	Mtn. House Creek @ Byron Rd.	SJC509	0	6	94	4	39	57

Table 6. Benthic macroinvertebrate community metrics of samples collected at Lone Tree Creek (SJC503) on 16 October 2002, where two multihabitat samples and one CSBP sample were taken simultaneously.

	Multihabitat	Multihabitat Duplicate	CSBP Random 500 Bugs	CSBP Cumulative 900 Bugs	CSBP Transect 1	CSBP Transect 2	CSBP Transect 3
Taxonomic Richness	11	9	19	19	8	14	16
Insect Taxa	6	6	9	9	4	8	7
EPT Taxa	3	1	4	4	1	3	2
ETO Taxa	3	1	4	4	1	3	2
Ephemeroptera Taxa	1	1	2	2	0	2	1
Plecoptera Taxa	0	0	0	0	0	0	0
Trichoptera Taxa	2	0	2	2	1	1	1
Coleoptera Taxa	0	0	0	0	0	0	0
Odonata Taxa	0	0	0	0	0	0	0
Amphipod Taxa	0	0	1	1	0	1	1
Sens EPT Taxa	0	0	0	0	0	0	0
Intolerant Taxa	0	0	0	0	0	0	0
EPT Index	3.0	2.7	5.2	4.4	0.3	3.5	9.5
ETO Index	3.0	2.7	5.2	4.4	0.3	3.5	9.5
Sensitive EPT Index (<4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shannon Diversity	0.84	0.86	1.97	1.93	1.43	1.73	2.18
Tolerance Value	8.7	9.3	7.9	7.9	8.5	8.1	7.3
Percent Intolerant Organisms	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percent Tolerant Organisms	90.0	88.8	72.6	73.9	80.5	79.4	61.8
Percent Amphipods	0.0	0.0	0.8	0.6	0.0	0.3	1.4
Percent Insects	8.3	11.2	19.0	17.1	9.8	14.7	27.0
Percent Trichoptera	0.8	0.0	1.0	1.3	0.3	0.3	3.2
Percent Hydropsychidae	0.6	0.0	0.8	1.2	0.3	0.0	3.2
Percent Ephemeroptera	2.2	2.7	4.2	3.1	0.0	3.1	6.3
Percent Baetidae	2.2	2.7	4.0	3.0	0.0	2.8	6.3
Percent Coleoptera	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percent Ceratopogonidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percent Chironomidae	4.1	8.0	12.4	11.7	9.4	10.5	15.1
Percent Odonata	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percent Oligochaeta	10.2	78.4	45.2	44.8	39.4	50.7	44.2
Percent Dominant Taxon	79.3	78.0	27.2	29.0	41.1	28.7	30.9
% Univoltine/Longer	0.2	0.0	0.4	0.2	0.0	0.7	0.0
% Bivoltine or More	99.8	100.0	99.6	99.8	100.0	99.3	100.0
Percent Collectors	16.9	86.3	60.2	58.3	47.0	63.3	64.6
Percent Filterers	79.9	12.0	30.4	32.2	43.2	29.4	23.9
Percent Grazers	1.8	0.0	1.2	1.3	0.0	0.7	3.2
Percent Predators	0.2	1.0	6.8	7.2	9.8	5.9	6.0
Percent Shredders	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 7. Benthic macroinvertebrate community metrics of samples collected at French Camp Slough (SJC504) on 16 October 2002, where one multihabitat sample and one CSBP sample were taken simultaneously.

	Multihabitat	CSBP Random 500 Bugs	CSBP Cumulative 900 Bugs	CSBP Transect 1	CSBP Transect 2	CSBP Transect 3
Taxonomic Richness	12	17	17	12	12	9
Insect Taxa	8	9	9	6	7	5
EPT Taxa	2	3	3	3	2	2
ETO Taxa	3	4	4	3	3	2
Ephemeroptera Taxa	1	2	2	2	1	1
Plecoptera Taxa	0	0	0	0	0	0
Trichoptera Taxa	1	1	1	1	1	1
Coleoptera Taxa	0	0	0	0	0	0
Odonata Taxa	1	1	1	0	1	0
Amphipod Taxa	1	1	1	1	0	1
Sens EPT Taxa	0	0	0	0	0	0
Intolerant Taxa	0	0	0	0	0	0
EPT Index	66.0	42.0	40.5	78.9	36.8	5.7
ETO Index	66.4	42.2	40.7	78.9	37.2	5.7
Sensitive EPT Index (<4)	0.0	0.0	0.0	0.0	0.0	0.0
Shannon Diversity	1.27	1.64	1.69	1.03	1.88	0.80
Tolerance Value	5.3	6.7	6.7	4.5	6.3	9.3
Percent Intolerant Organisms	0.0	0.0	0.0	0.0	0.0	0.0
Percent Tolerant Organisms	19.3	43.6	43.1	4.7	36.5	88.2
Percent Amphipods	0.4	0.4	0.6	0.3	0.0	1.3
Percent Insects	77.4	48.4	48.5	88.3	48.3	8.8
Percent Trichoptera	63.7	41.0	39.0	75.8	35.4	5.4
Percent Hydropsychidae	63.7	41.0	39.0	75.8	35.4	5.4
Percent Ephemeroptera	2.3	1.0	1.6	3.0	1.4	0.3
Percent Baetidae	2.3	0.8	1.2	2.3	1.4	0.0
Percent Coleoptera	0.0	0.0	0.0	0.0	0.0	0.0
Percent Ceratopogonidae	0.0	0.0	0.0	0.0	0.0	0.0
Percent Chironomidae	8.3	5.8	7.5	9.1	10.4	3.0
Percent Odonata	0.4	0.2	0.1	0.0	0.3	0.0
Percent Oligochaeta	16.4	33.4	34.0	4.0	16.7	80.8
Percent Dominant Taxon	63.7	41.0	39.0	75.8	35.4	80.8
% Univoltine/Longer	0.0	0.0	0.0	0.0	0.0	0.0
% Bivoltine or More	100.0	100.0	100.0	100.0	100.0	100.0
Percent Collectors	26.6	40.2	42.9	16.1	27.8	84.5
Percent Filterers	66.4	50.0	47.0	76.8	50.7	13.5
Percent Grazers	3.3	7.4	7.2	4.7	15.6	1.7
Percent Predators	1.0	2.0	2.5	2.0	5.2	0.3
Percent Shredders	0.0	0.0	0.0	0.0	0.0	0.0

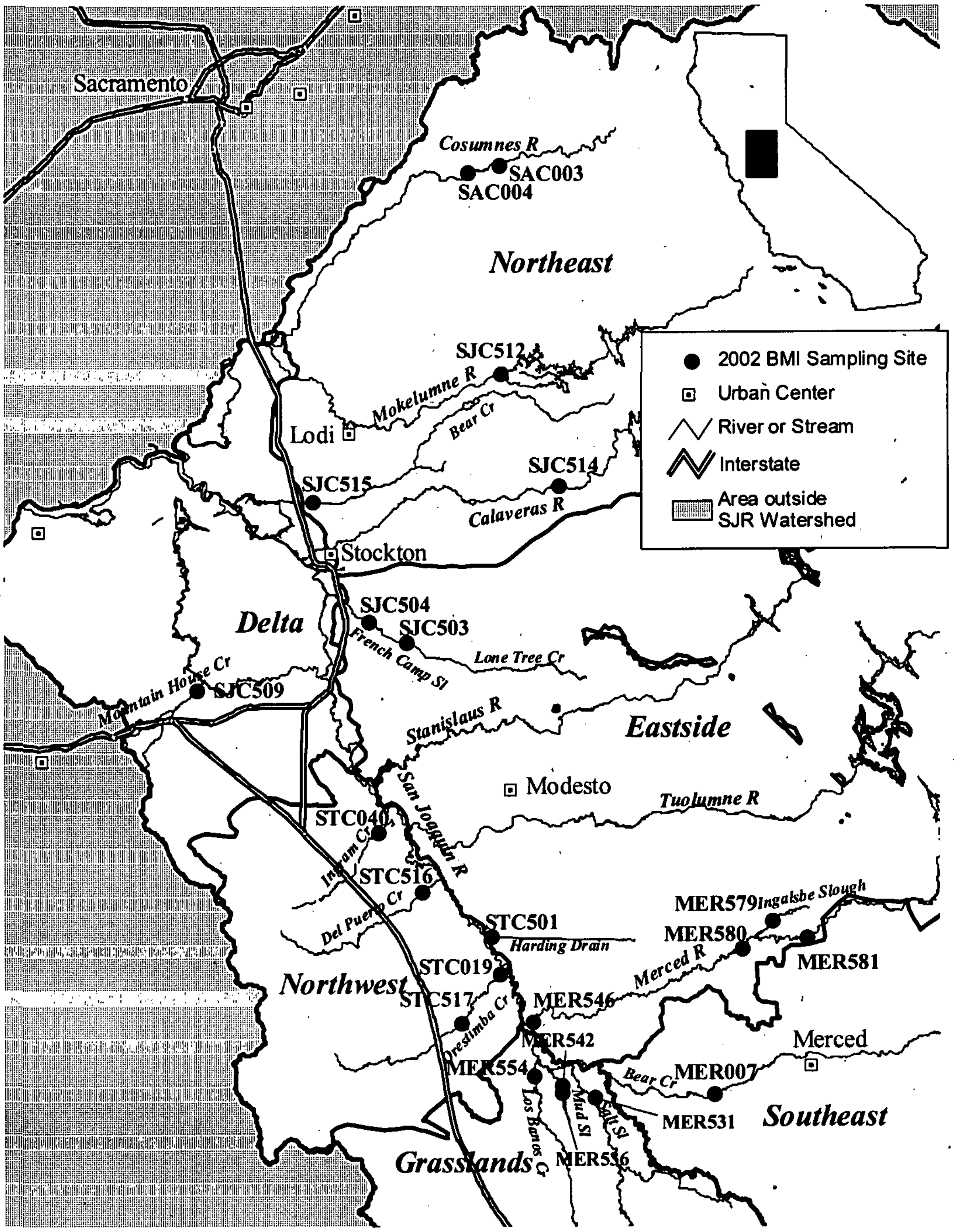


Figure 1a. Site locations for BMI community sampling in spring and fall 2002 and sub-watersheds of the San Joaquin River watershed.

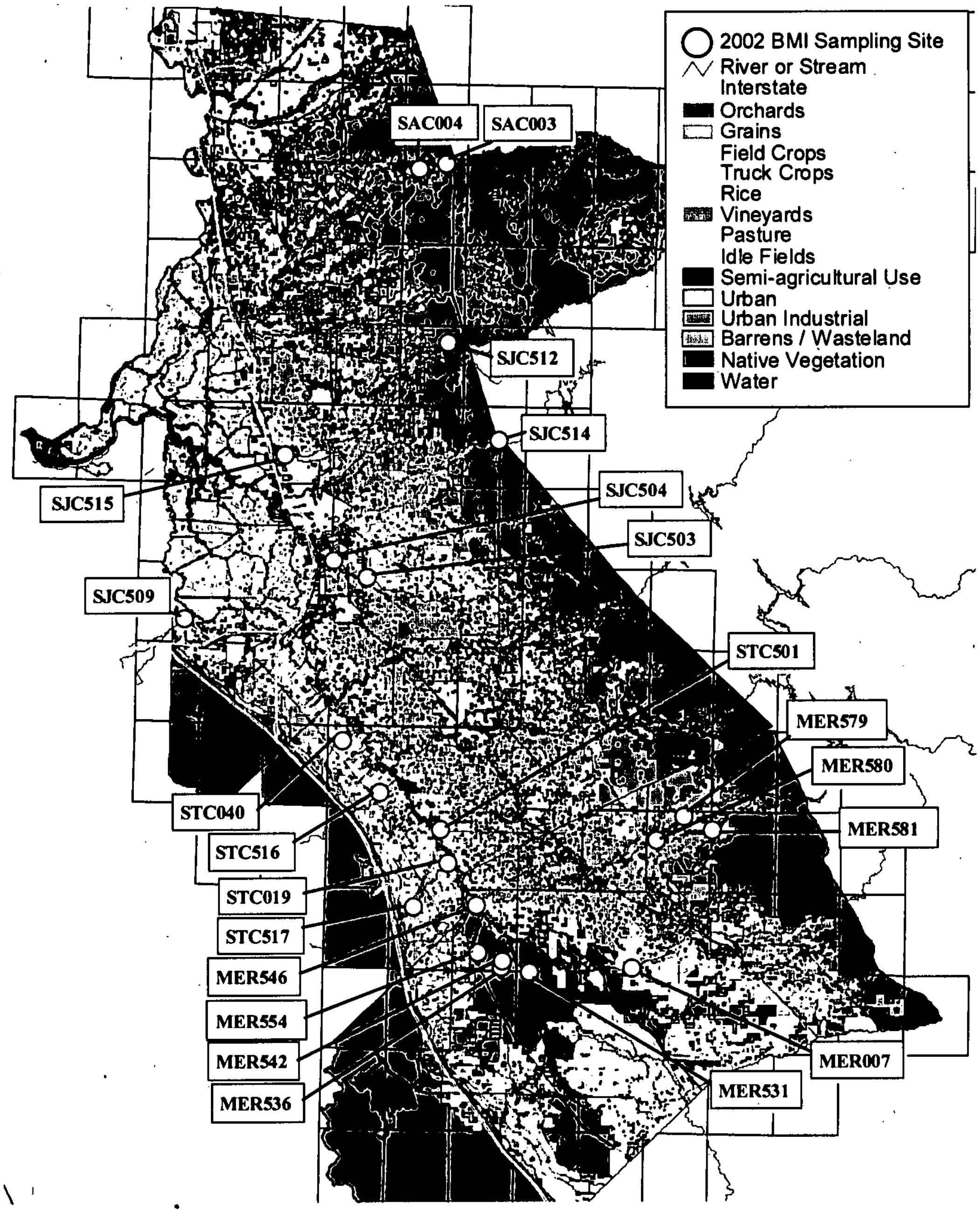


Figure 1b. Site locations for BMI community sampling in spring and fall 2002 and sub-watersheds of the San Joaquin River watershed.

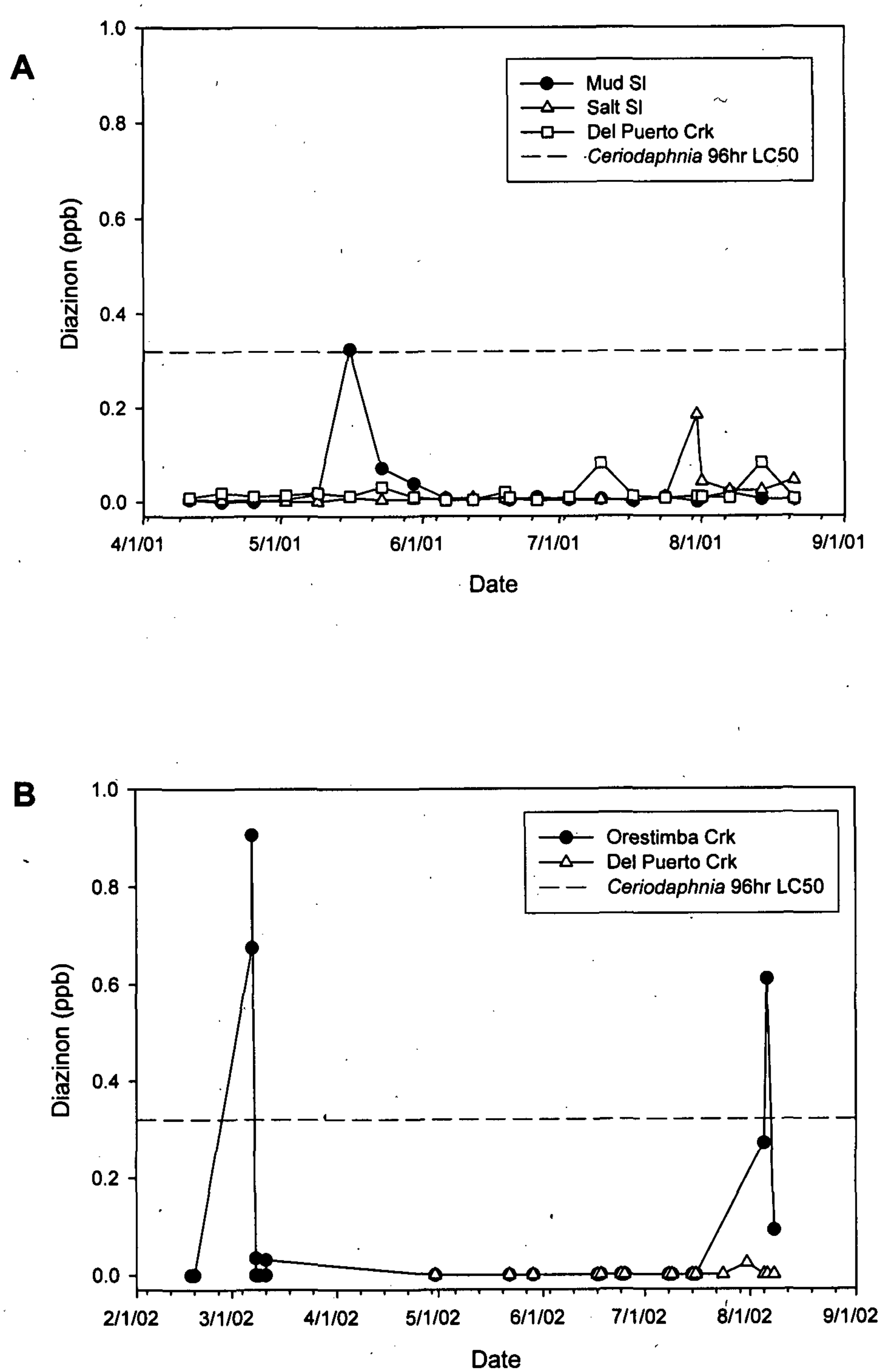


Figure 2. Water column diazinon concentrations before and during the seasons of benthic macroinvertebrate community sampling. A: 2001 data; B: 2002 data.

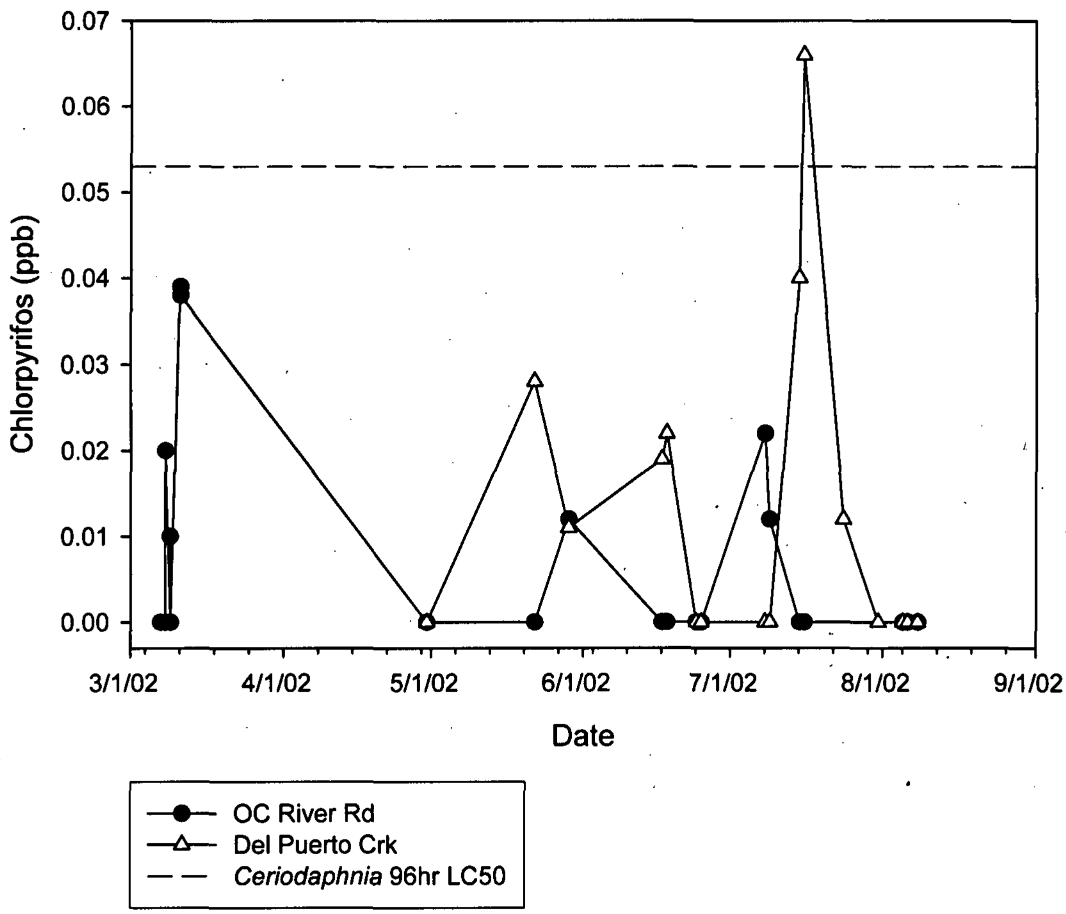


Figure 3. Water column chlorpyrifos concentrations before and during the seasons of benthic macroinvertebrate community sampling.

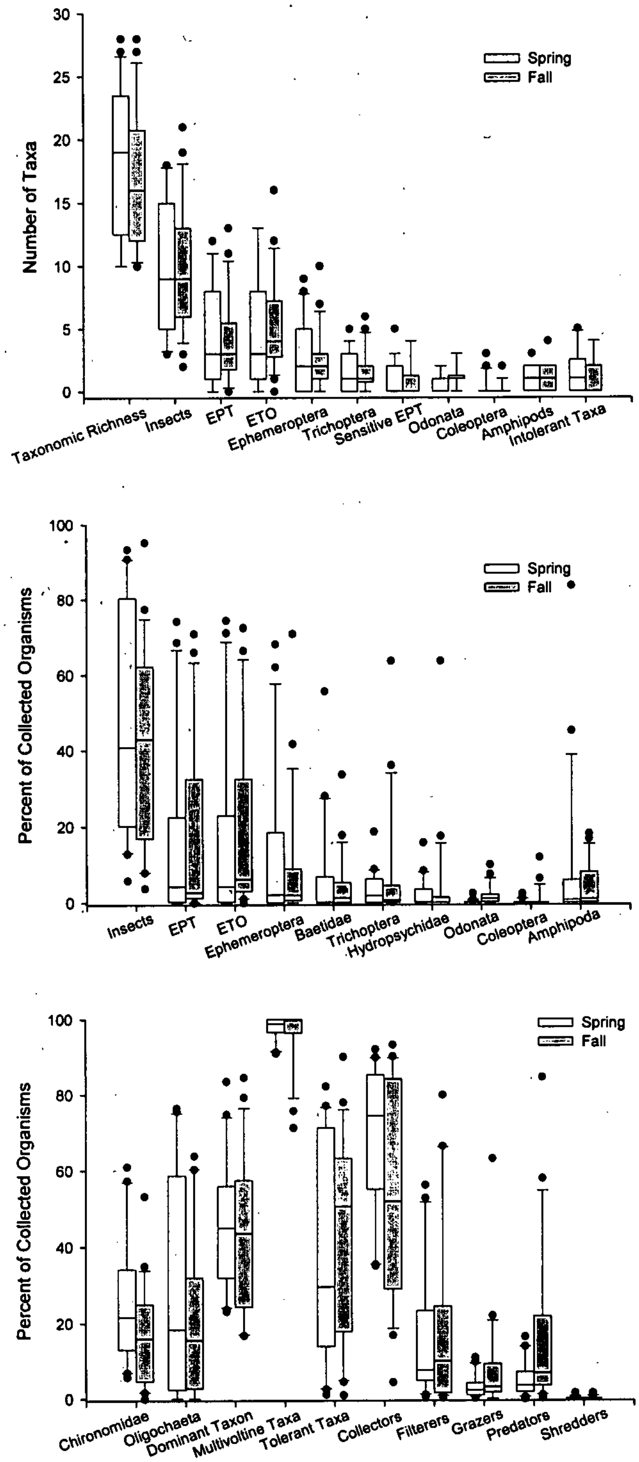


Figure 4. Distributions of benthic macroinvertebrate community metrics during the spring and fall 2002 sampling events. Horizontal lines on bars are medians, bars 75th and 25th percentiles, vertical lines 90th and 10th percentiles and dots outliers.

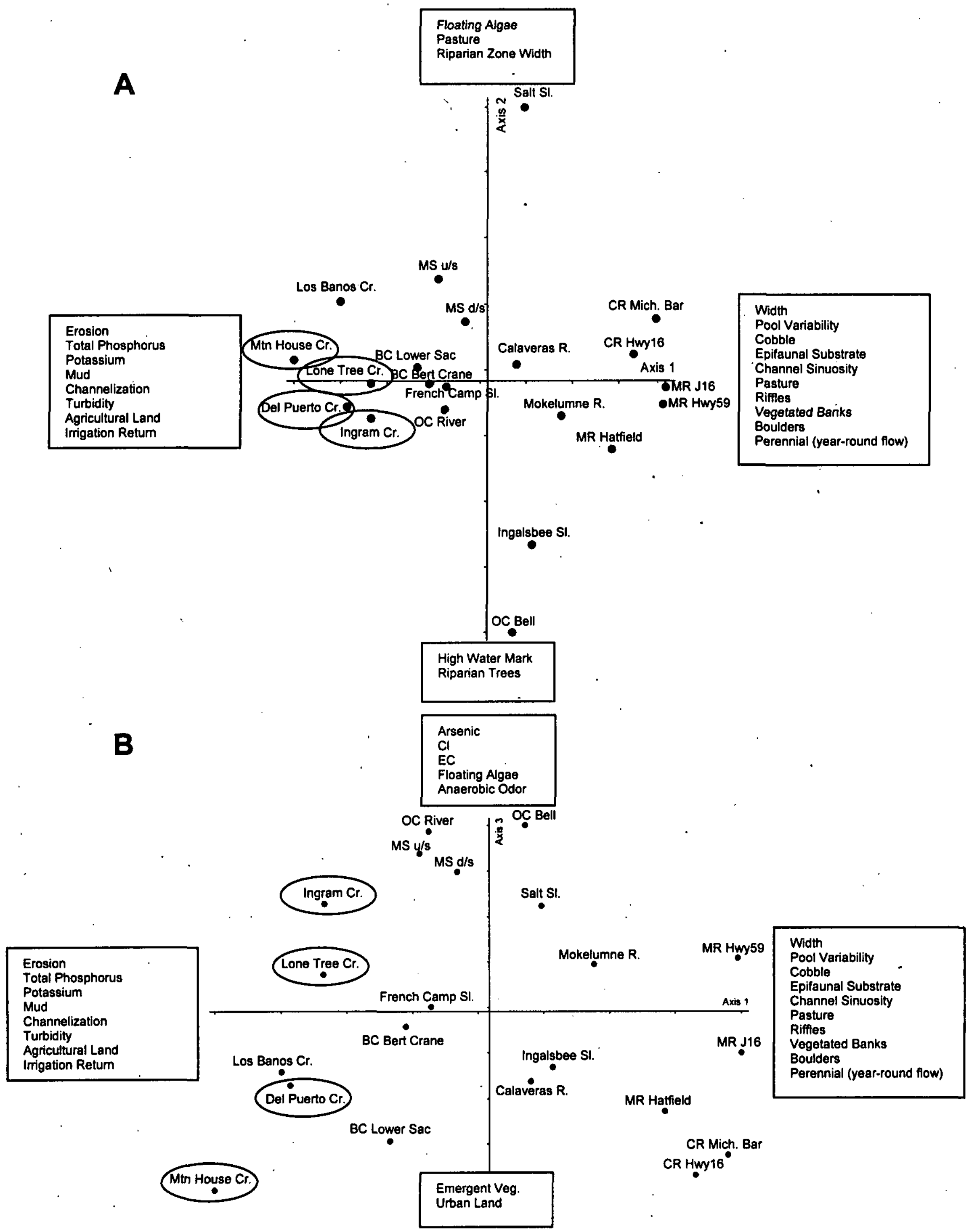


Figure 5. Nonmetric Multidimensional Scaling (NMS) ordination of benthic macroinvertebrate samples at sites in the San Joaquin River watershed sampled 5/13/2002 – 5/23/2002. Boxes at the ends of each axis show environmental variables significant correlated with the axes ($P < 0.05$). Circled sites showed a near total absence of insects. A: Axes 1 and 2. B: Axes 1 and 3.

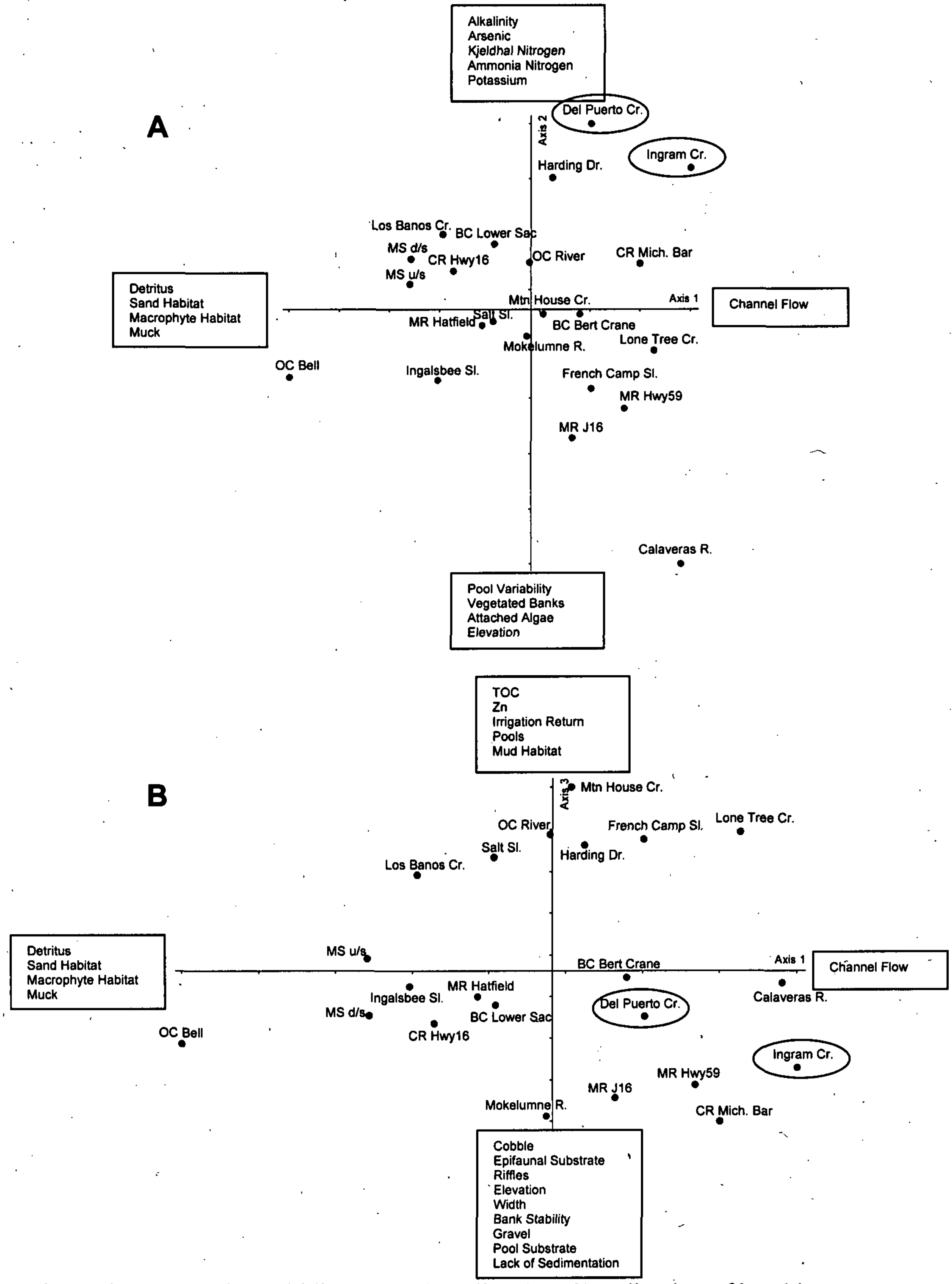
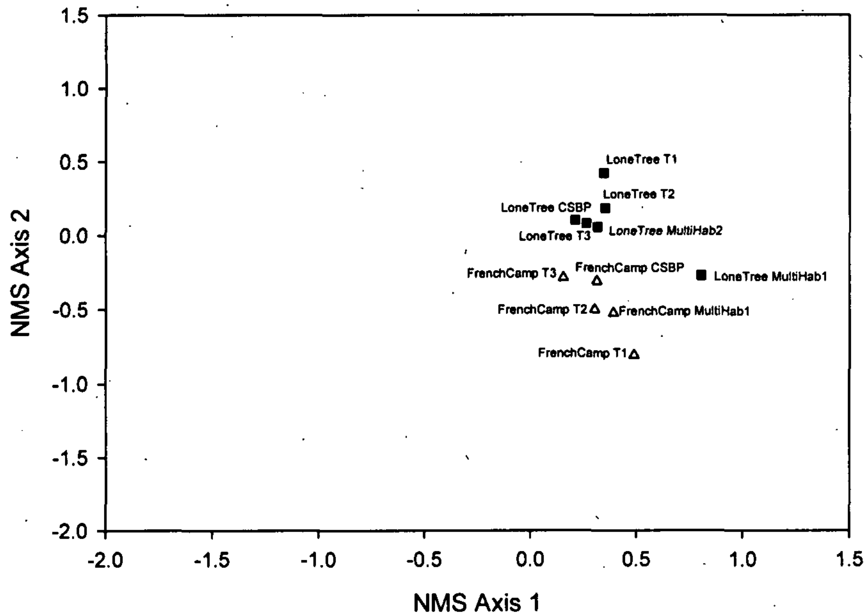


Figure 6. Nonmetric Multidimensional Scaling (NMS) ordination of benthic macroinvertebrate samples at sites in the San Joaquin River watershed sampled 9/30/2002 – 10/23/2002. Boxes at the ends of each axis show environmental variables significant correlated with the axes ($P < 0.05$). Circled sites showed a near total absence of insects. A: Axes 1 and 2. B: Axes 1 and 3.



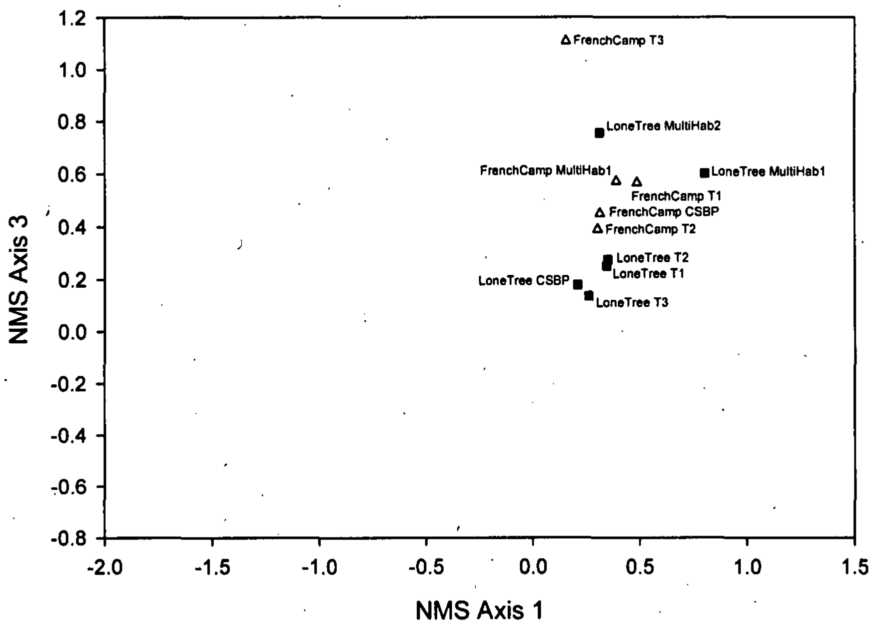


Figure 7. Predicted NMS scores of benthic macroinvertebrate samples collected simultaneously by CSBP, CSBP transect (T1, T2, T3), and multi-habitat protocols during the fall 2002 sampling event. These plots illustrate the variability of the multi-habitat method and provide a comparison of CSBP and multi-habitat results. Grey points depict site NMS scores of sites where no duplicate or CSBP samples were collected.