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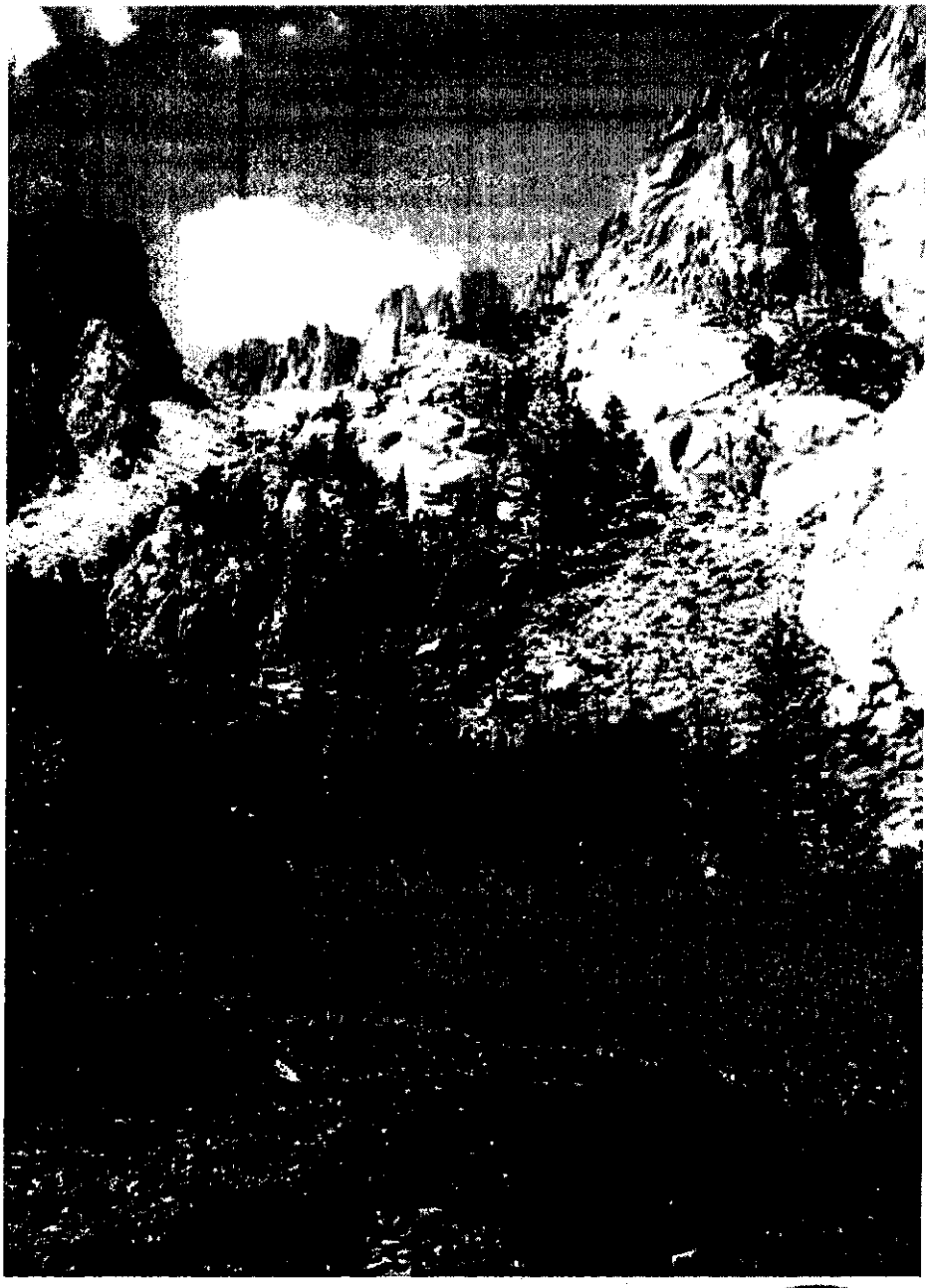
The Status and Future of Biological Assessment for California Streams



California State Water Resources Control Board
Division of Water Quality
January, 2003
Final Report

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Acronym List

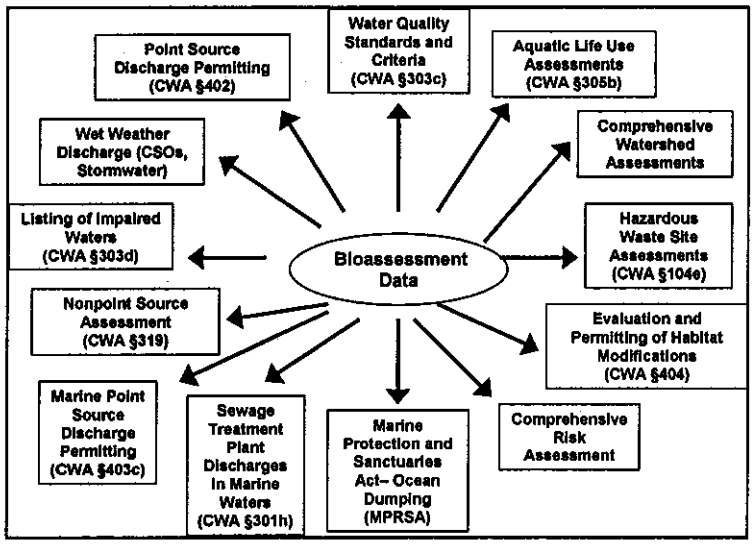
ABL	Aquatic Bioassessment Laboratory
ACCWP	Alameda Countywide Clean Water Program
ANOVA	Analysis of Variance
BLM	Bureau of Land Management
BMI	Benthic Macroinvertebrate
BMPs	Best Management Practices
BP	Basin Plan
BPJ	Best Professional Judgment
CABW	California Aquatic Bioassessment Workgroup
CAMLnet	California Aquatic Macroinvertebrate Laboratory Network
CCAMP	Central Coast Ambient Monitoring Program
CCMAP	Contra Costa Monitoring and Assessment Program
CDFG	California Department of Fish and Game
CSBP	California Stream Bioassessment Procedure
CV	Coefficient of Variability
CWA	Clean Water Act
DFG	California Department of Fish and Game
DWR	Department of Water Resources
EMAP	Environmental Monitoring and Assessment Program
FERC	Federal Energy Regulatory Commission
FRWMP	Feather River Watershed Monitoring Program

GIS	Geographic Information Systems
IBI	Index of Biological Integrity
IMAP	Inventory, Monitoring, and Assessment Program
LSTE	List of Standard Taxonomic Effort
MSE	Mean Squared Error
NAWQA	National Water Quality Assessment
NPDES	National Pollution Discharge Elimination System
NPS	Non-point Source
QA/QC	Quality Assurance/ Quality Control
RBP	Rapid Bioassessment Protocol
REMAP	Regional Environmental Monitoring and Assessment Program
RIVPACS	River Invertebrate Prediction and Classification System
RMAS	Regional Monitoring and Assessment Strategy
RMSE	Root Mean Squared Error
RWQCB	Regional Water Quality Control Boards
SNARL	Sierra Nevada Aquatic Research Laboratory
SWAMP	Surface Water Ambient Monitoring Program
SWRCB	State Water Resource Control Board
TMDL	Total Maximum Daily Load
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WPCL	Water Pollution Control Laboratory

Executive Summary

Biological communities integrate the effects of different pollutant stressors such as excess nutrients, toxic chemicals, increased temperature, and excessive sediment loading and thus provide an overall measure of the aggregate impact of the stressors. Biological communities respond to stresses of all degrees over time and, therefore, offer information on perturbations not always obtained with episodic water chemical measurements or discrete toxicity tests. The central purpose of assessing the biological condition of aquatic communities is to determine how well a water body supports aquatic life.

The diversity and condition of biological communities reflect overall ecological integrity (i.e., chemical, physical, and biological integrity). Therefore, bioassessment results directly assess the status of a waterbody relative to the primary goal of the Clean Water Act (CWA). Biological assessments are crucial to evaluating ecosystem health and provide crucial water quality planning information for managing more complex water quality problems (see graphic listing uses in water quality programs).



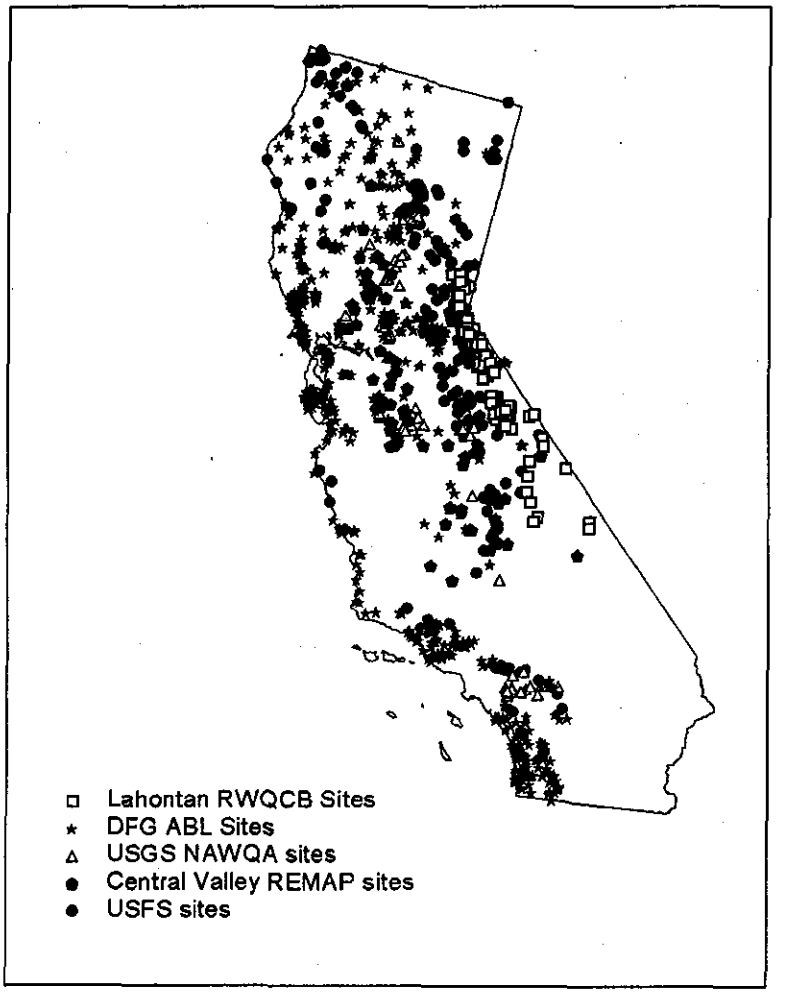
Use of Bioassessment in State Water Quality Programs

The purpose of this report is to document the salient information on the variety of bioassessment programs in California for streams, and to provide recommendations for a universal movement toward a standardized bioassessment program that will serve several entities, especially the SWRCB and RWQCBs. Key findings of this study and report are:

- California has over 200,000 miles of streams and rivers throughout its vast network of mountains and valleys.
- Ranked as the second state in number of stream/river miles (Alaska having the highest number), California is in its infancy in terms of viable biological assessment and monitoring to assess ecological condition.
- The State Water Resource Control Board (SWRCB) and the nine Regional Water Quality Control Boards (RWQCB), who are responsible for implementing water quality standards for California=s surface waters, have only recently begun to apply biological assessment principles to their monitoring programs.
- To date, only a few selected instances in regulatory actions have occurred where biological information was used to support management decisions.
- The broader regulatory initiatives, such as measuring the attainment of Aquatic Life Use

designations as mandated by Section 305(b) of the CWA, has not relied on biological assessments in California.

- The last decade has been an important period of advancement and refinement of stream biological assessment for California.
- As a general data-gathering tool used for problem identification (i.e., not used for regulatory purposes), bioassessments have been conducted at over 3000 sites by a multitude of agencies, universities, and other entities.
- Dissimilarities in techniques and purposes for the bioassessments have precluded a universal comparability and data integration effort.
- Five candidate programs exist in California that have scientifically valid and robust methods, and have similar purposes and scope, which could provide the framework for the implementation of a statewide bioassessment approach.
- This reports documents 36 bioassessment programs, representing 22 government agencies (including tribes), 4 universities, 2 municipalities, and 8 environmental interest groups.
- The method developed by the California Department of Fish and Game (CDFG), known as the California Stream Bioassessment Procedure (CSBP) is the most widely used throughout the state, with more than 2500 sites sampled.



Stream Bioassessment Sites Sampled by Candidate Programs

Recommendations include:

- consideration of multihabitat methods to improve detection of non-chemical perturbations
- continuing to collect replicate bioassessment samples for the purpose of precision estimates, and possibly reducing the number of replicates to two or three as a compromise between statistical power and cost.
- closer interaction between the SWRCB and DFG-ABL and SNARL to consider evaluating its extensive ecological database for proceeding with characterizing reference conditions.
- creating a statewide database of bioassessment data that can accommodate the large quantity of data that will be produced in California.
- combining the resources of a statewide database and CAMLnet in order to provide California with a consistent and standard framework for calibrating biological indicators for use on a statewide basis.
- appointing a full-time SWRCB employee to manage the statewide database and provide technical support to database users throughout California.
- developing viable biological indicators and endpoints for assessing biological condition
- incorporating bioassessment into California's water quality regulatory programs
- making funding available for a concerted, statewide bioassessment program.

Chapter 1 STREAM BIOASSESSMENT: A FRAMEWORK FOR MONITORING

Biological assessments of aquatic communities, also referred to as bioassessments, are rapidly becoming a critical tool for water quality monitoring and are gaining popularity among scientists, resource managers, and decision makers alike. To fully understand the concept of bioassessments, it is important to know not only what they are, but also to understand the rationale for conducting them and how they can be used as a decision-making tool. The following text describes the rationale for conducting bioassessments including; 1) definitions of bioassessment and biocriteria, 2) utility of bioassessment as a decision-making tool, 3) success of bioassessment programs in other states, and 4) limitations. The application of bioassessment in California as well as the objectives of this report are described in this chapter.

1.1 The Role of Bioassessment in Water Quality Determination

State and tribal water resource agencies in the U.S. have developed bioassessment approaches that have added an important dimension of ecological understanding to their already over-burdened and under-funded monitoring programs (Barbour 1997). The central purpose of assessing the biological condition of aquatic communities is to determine how well a water body supports aquatic life (Barbour et al. 1996a). Biological communities integrate the effects of different pollutant stressors such as excess nutrients, toxic chemicals, increased temperature, and excessive sediment loading, and thus provide an overall measure of the aggregate impact of the stressors. Use of information about ambient biological communities, assemblages, and populations to protect, manage, and even exploit water resources has been developing and evolving for the past 150 years (Davis 1995). Despite this long history, it has only been in the last decade that a widely accepted technical framework has evolved for using biological assemblage data for assessment of the water resource (Barbour et al. 1996a).

1.1.1 Definition of Bioassessment and Biocriteria

Biocriteria are narrative descriptions or numerical values adopted into state or tribal water quality standards that can be used to factually and quantitatively describe a desired condition for the aquatic life in waters with a designated aquatic life use. The purpose of biocriteria is to establish standards based on biological characteristics that will protect the designated aquatic life use that can be used to direct water quality management. Biocriteria are developed by biologists and other natural resource scientists using accepted scientific principles to characterize the regional reference conditions for the different water bodies found within a state or tribal nation. Biocriteria depend on bioassessments as the scientific basis for making informed decisions regarding the aquatic resource. Bioassessment, on the other hand, is an evaluation of the condition of a waterbody using biological surveys and other direct measurements of the resident biota (i.e., fish, macroinvertebrates, periphyton). This report will focus primarily on bioassessments using benthic macroinvertebrates.

Bioassessments –
- directly measure the response of a biological community to disturbance and restoration actions.
- establish a benchmark of expected conditions.
- provide indication of impairment from multiple and cumulative stressors.

Biocriteria –
- assist in setting state water quality standards.
- help shift the emphasis of preservation and restoration goals from performance-based standards to impact-based standards.
- assist in setting restoration goals.

1.1.2 Utility of Bioassessment as a Decision-making Tool

Biological assessment provides crucial water quality planning information for managing complex water quality problems. Biological assessment serves four primary functions or uses:

1. Screening or initial assessment of conditions
2. Characterizing the magnitude of impairment
3. Assisting in the diagnosis of causes to impairment
4. Monitoring of temporal trends to evaluate improvements or further degradation

States and tribes are faced with the challenge of developing monitoring tools that are both appropriate and cost-effective, and that will provide comprehensive survey coverage of their water resources (Barbour 1997). The purpose for a water resource agency to establish an effective assessment and monitoring program is fourfold:

1. Assess attainment of water quality standards (per CWA §305[b]) and listing of impaired waters (per CWA §303[d]).
2. Identify causes and sources of impairments to support control strategy development including Total Maximum Daily Loads, or TMDLs, (e.g., use of biological response signatures – see Yoder and Rankin 1995, Simon 2002).
3. Evaluate changes in water quality in response to ongoing management actions to gauge level of success and guide strategy revisions.
4. Involve the public to increase their understanding of the environment, build working relationships and trust, and increase information available on water quality and stressors.

The advent of bioassessment in regulatory programs has provided a more comprehensive and effective monitoring and assessment strategy, which is described in detail in USEPA's Clean

Water Action Plan (USEPA 1998). In many instances of impairment, biological measures are better than chemical measures at reflecting the condition of the aquatic ecosystem (NRC 2001). Consequently, the use of bioassessments and biocriertia in state and tribal water quality standards programs has become a top priority of the U.S. Environmental Protection Agency (USEPA 2000). As such, one of the agency's objectives is to ensure that all states and tribes develop water quality standards and programs that use bioassessment information to evaluate the condition of aquatic life in all waterbodies (USEPA 2000). Furthermore, the development of biological criteria (biocriteria) within regulatory programs to serve as thresholds by which to judge the attainment of designated aquatic life conditions of surface waters is a major focus of states and tribes within the US (Barbour et al. 2000).

1.1.3 Success of Bioassessment Programs in other States

The last decade has been a period of progressive advancement in the development and implementation of bioassessment in the US. In 1989 when the Rapid Bioassessment Protocols were first introduced to state programs (Plafkin 1989), very few states and no tribes had viable bioassessment programs in place. In 1994, twenty states were beginning a biological monitoring program for streams and rivers, and fourteen states had biological programs in place (Davis et al. 1996). However, only eleven were developing or had developed biocriteria based on their monitoring programs. In contrast, by the year 2000, most states had established biological

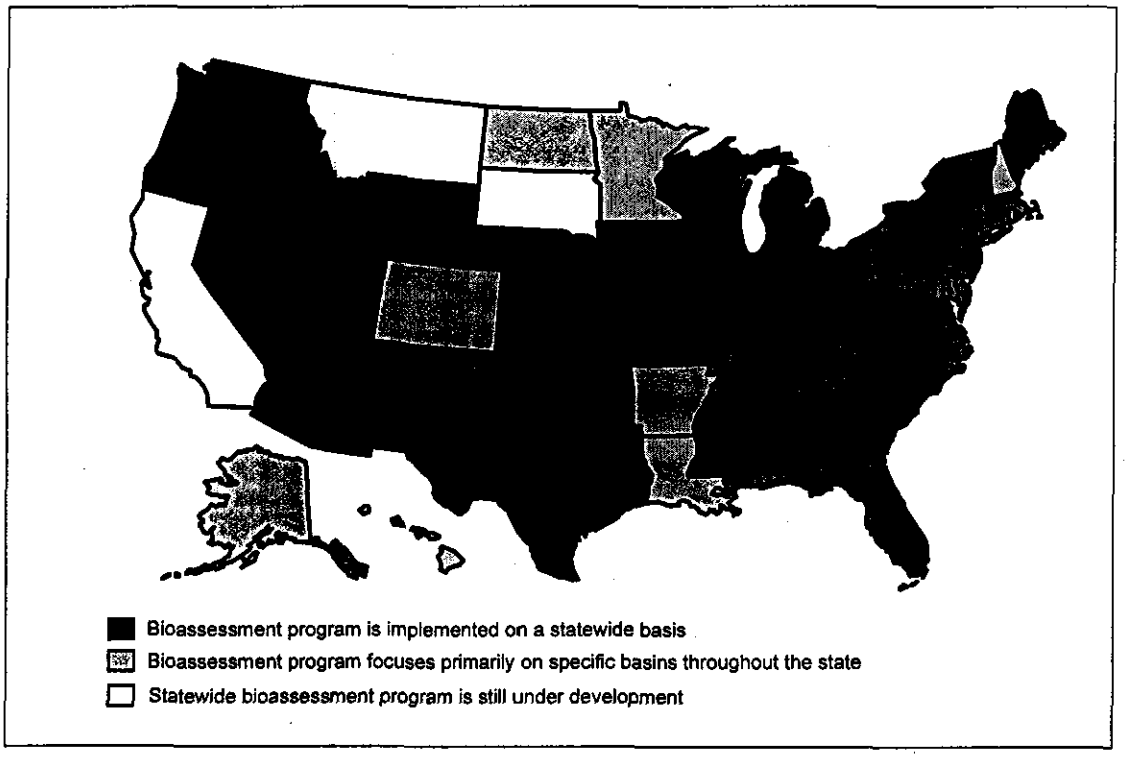


Figure 1. Current status of bioassessment programs (USEPA 2002, Draft).

monitoring programs for streams and rivers, and were developing or had developed quantitative biocriteria. As of 2001, only three states, including California, have yet to establish a concerted bioassessment program (Figure 1), and half of the states have at least 10 % of their streams/rivers assessed for biology (Figure 2). The states and tribes that have been the most progressive in developing biocriteria based on biological assessment include Idaho, Ft. Peck Affiliated Tribes, Maine, Vermont, Maryland, Ohio, Florida, Arizona, and Oregon. The development of bioassessment and biocriteria for bodies of water other than streams or rivers is a more recent phenomenon.

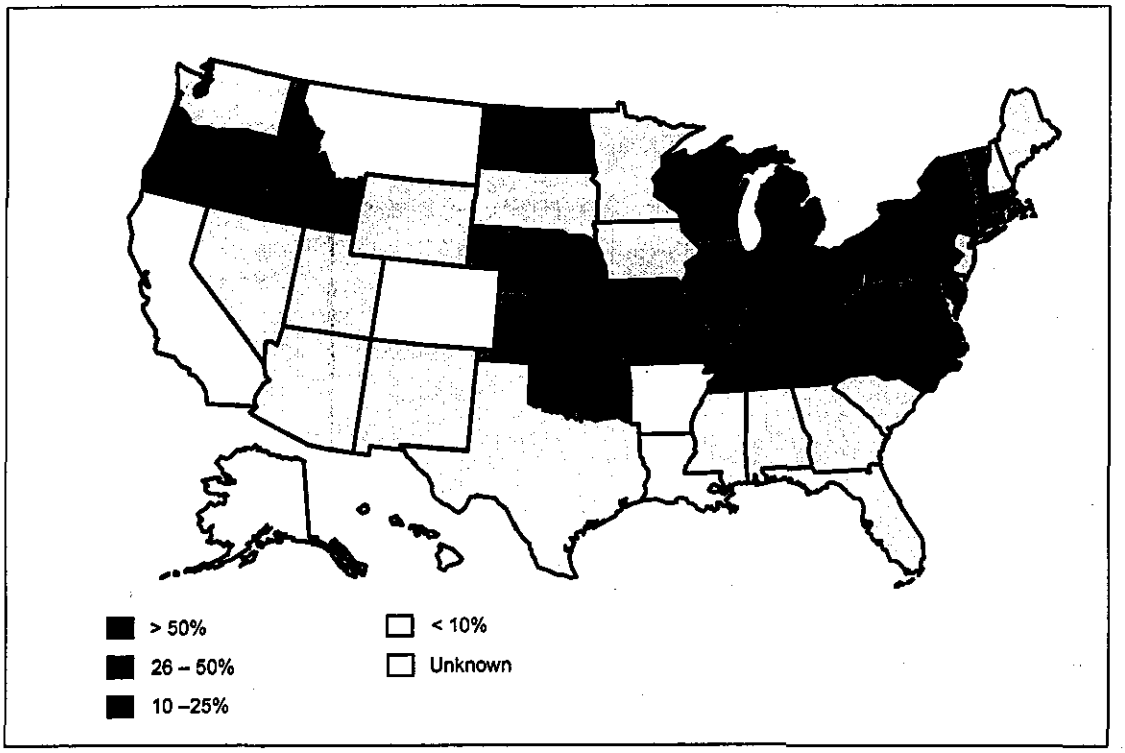


Figure 2. Percent of stream/river miles assessed using bioassessments (USEPA 2002, Draft).

Biocriteria programs begin with the development of a bioassessment framework. Expertise in ecological principles and resource investment by the agency is required to develop this framework and to implement biocriteria. State agencies vary in their investment of resources and effort in this process. In addition, the time frame for development, calibration of a biological indicator for assessment, and implementation is dependent upon resource investment and the ability to gather and compile data. Most states are able to develop the technical framework for bioassessment in less than five years (e.g., Arizona, Florida, Maryland, Wyoming).

1.2 Application of Bioassessment and Biocriteria in California

Historically, the use of bioassessment data in California water regulations and decision-making has not been a high priority. One of the first management actions was in 1993 when the Lahontan Regional Water Quality Control Board (RWQCB 6) required the use of EPA's Rapid Bioassessment Protocols in a fish hatchery permit. Furthermore, in 1993 the California Department of Fish and Game's Water Pollution Control Laboratory in Rancho Cordova began building the infrastructure necessary to develop biocriteria, including an Aquatic Bioassessment Laboratory (ABL) with field and laboratory capabilities large enough to support the bioassessment needs of the State and Regional Boards and other water resource management agencies. In addition, they developed and promoted standardized field and laboratory protocols (California Stream Bioassessment Procedure (CSBP)) for assessing biological integrity in wadeable streams and rivers. Since that time, bioassessment has steadily increased in use in water resource decision-making. Presently, bioassessment is used as an additional tool to NPDES and stormwater permitting to supplement the chemical and toxicological information obtained to address chemical standards. The recent organization of California's Surface Water Ambient Monitoring Program (SWAMP) is providing the impetus to implement a better organized and standardized biological assessment and monitoring program throughout the state. Current concerns over hydroaugmentation and use attainability analyses of targeted waterbodies will foster a greater dependence upon bioassessment information in making informed decisions regarding the protection and restoration of California's streams.

This project is an extension of the SWAMP program and is an attempt to identify and characterize viable bioassessment programs in California's streams. As such, five objectives were articulated for directing this project and resulting report. They are as follows:

1. *Summarize the historical significance of stream bioassessment in California (1992-2000).* Bioassessment development is historically varied and diverse in California. During this period, application of biological survey and assessment techniques was highly oriented toward watersheds and differed among regions of California.

2. *Provide an overview of current statewide bioassessment efforts (2000-present).* With the advent of improved technological advances in bioassessment, certain methods and procedures have come to the forefront as methods of choice for broad-scale assessments.

3. *Highlight candidate programs that can serve as foundations for bioassessment in California.* A few candidate programs encompass the concept and purposes of bioassessment, such that they are viable models for developing a statewide bioassessment approach.

4. *Discuss the future direction of stream bioassessment in California.* Ideally, a single bioassessment approach will emerge that best represents a method that can be used by various agencies and other entities to judge the biological condition, and thus ecological health, of California's streams.

5. *Assist in guidance for database development.* A uniform database to compile and house the multitude of bioassessment data provides a mechanism for integrating ecological data for statewide assessments. The database becomes a central repository where quality control of data integrity and taxonomic standardization can be conducted to ensure comparability.

Chapter 2 Status Of Stream Bioassessment Activities In California

The information presented herein does not constitute a comprehensive overview of all bioassessment activities conducted in California. The information required to complete this section was requested on a volunteer basis; however, only a small fraction of the entities and agencies conducting bioassessments in California responded with sufficient information. On the other hand, the information we collected is indeed representative of a wide range of rigor and interdisciplinary programs, and consequently, it provides a good overall picture of the nature of bioassessment programs throughout California. For more detailed information on specific programs summarized in this section, see Appendix A.

Prior to the 1990's, bioassessment programs were few and far between in California. The only well established long-term bioassessment program in California at this time was that designed and implemented by the California Department of Water Resources (DWR) Northern District. The DWR began collecting bioassessment data circa 1975 and has sampled approximately 100 sites per year. Other than the DWR program, there has been little or no documented information about broad-scale bioassessment programs in California prior to 1992. Historically, the use of bioassessment data in water quality program decisions and management actions has been virtually non-existent. California's State Water Resource Control Board (SWRCB) and RWQCBs have relied primarily on chemical and toxicological information to support management actions.

In the early- to mid-nineties, however, California saw a handful of new bioassessment programs develop across the state. In 1992, the United States Geologic Survey (USGS) began implementation of the first of a series of three broad-scale bioassessment programs in California as part of the National Water Quality Assessment (NAWQA) Program. Also in 1992, the California Department of Fish and Game's Aquatic Bioassessment Laboratory (ABL) began conducting projects covering many different applications of bioassessment throughout the state. Then in 1993, ABL distributed a set of standard protocols for assessing biological and physical conditions of wadeable streams, the California Stream Bioassessment Procedure (CSBP), which is a regional adaptation of the USEPA Rapid Bioassessment Protocols. In 1994, the United States Environmental Protection Agency (USEPA) initiated a broad-scale Regional Environmental Monitoring and Assessment Program (REMAP) bioassessment project in the Central Valley to test the applicability of the national Environmental Monitoring and Assessment Program (EMAP) approach to answer questions about ecological conditions at regional and local scales. In 1995, the Lahontan Regional Water Quality Control Board (RWQCB) began a bioassessment program to monitor the success of remediation efforts at the abandoned Leviathan Mine.

By the year 2000, many had discovered the benefits of conducting bioassessments, and bioassessment programs began sprouting up all over the state, ranging from state agencies to watershed organizations and even volunteer monitoring groups. Coordination among the various groups and agencies collecting bioassessment data began in earnest over the past two years. Consequently, a statewide approach to bioassessment has identified a need, so that differences in results reflect ecological differences, not just differences in methodologies.

2.1 The California Aquatic Bioassessment Workgroup (CABW)

In 1994, DFG, in cooperation with the State Water Quality Control Board and with funding from the U.S. EPA, established the California Aquatic Bioassessment Workgroup (CABW) as a forum for researchers, agency personnel and private consultants working in the field of freshwater biological assessment to communicate and exchange information regarding their work. The three-day meetings provided an opportunity for various state and federal agencies conducting bioassessments in California to update the group on their activities. The State and Regional Boards also discussed ways that they envisioned using bioassessment data in their regulation of water quality. At the first meeting, held in September of 1994, DFG set up a workgroup to review the 1993 edition of the California Stream Bioassessment Procedure (CSBP), assembled a steering committee to produce a Statement of Purpose for the CABW and established an on-going workgroup for defining reference stream criteria.

By the second meeting in 1995, the revisions to the CSBP for wadeable streams and the Statement of Purpose formulated by the steering committee were finalized. The Statement of Purpose outlined four specific objectives of the CABW:

1. Develop consistent, sound methodological approaches to aquatic bioassessment by (a) defining and testing sets of procedures for sampling aquatic communities; (b) establishing reference conditions; (c) developing quality assurance and quality control procedures; and (d) advancing analytical procedures, such as effective use of appropriate metrics and indices.

2. Provide a mentoring and support network concerning technical and professional issues for workgroup participants. The workgroup members envisioned frequent bioassessment workshop where techniques and issues could be presented and participants could network with each other.

3. Facilitate communication by (a) enhancing interagency cooperation; (b) providing an electronics communication platform; (c) disseminating pertinent technical literature; and (d) promoting discussion of findings and bioassessment issues.

4. Promote the incorporation of usable data gathered by volunteer monitoring groups into agency bioassessment programs.

The California Aquatic Macroinvertebrate Laboratory Network (CAMLnet) was formed in 1995 as a workgroup of the CABW with two missions: 1) to provide a forum for sharing technical expertise and experience among laboratories performing bioassessments in California and 2) to serve as a technical advisory body to the CABW and the California State Bioassessment Procedure (CSBP). Although CAMLnet was created as an advisory group to the CABW, its coverage includes all issues related to freshwater macroinvertebrate taxonomy and laboratory procedures. CAMLnet membership consists of private laboratories, tribal, state and federal agencies and university personnel.

One of CAMLnet's major roles is to standardize the levels of standard taxonomic effort used in bioassessments using the CSBP. CAMLnet produced the first edition of the CAMLnet List of Standard Taxonomic Effort (LSTE) in 1999. CAMLnet also sponsors taxonomic workshops to exchange taxonomic expertise, improve taxonomic precision and increase standardization for difficult taxonomic groups.

The objective of the 1996 meeting was to formulate the process for developing biocriteria in California. A workgroup was formed to addressed the regulatory need for California to have a biocriteria program and at the end of the meeting, an informal discussion concluded that implementation of biocriteria would probably be long in coming and that it most certainly would come after all the supporting science was in place. Also at that meeting, DFG distributed the 1996 version of CSBP, introduced, for review, the CSBP for Citizen Monitors and announced that the CAWB web site was up and running.

The CABW continued its annual meetings from 1997 through 1999 providing a forum for updating the attendees on the status of bioassessment in California and presenting examples of bioassessment projects throughout the United States and even Australia. New workgroups were established and others were terminated. The reference stream criteria workgroup ended after three years because the work was dependent on volunteer efforts that were too difficult to support. Many other workgroups met for one or two years to review or gather input for the following issues:

- Identification of funding sources and programs which could promote biocriteria development;
- Review and finalization of revisions of Laboratory and QA/QC Procedures for the 1999 version of the CSBP;
- Formulation of an electronic data processing and storage platform;
- Technical support to citizen monitors and a bioassessment procedure for educational purposes;
- Use of bioassessment in water regulation and FERC re-licensing;
- Use of bioassessment in the California's Stormwater Management Program;
- Use of bioassessment in TMDL development and implementation;
- Assessment of the potential for applying the Rivers Invertebrate Prediction and Classification System (RIVPACS) model to California bioassessment data.

By the year 2000, many bioassessment programs supported by the State and Regional Boards and other water resource agencies needed a forum to present and gather input on their data and interpretation of the results. To accommodate this, DFG changed the seventh and eighth CABW meeting from a three-day workgroup session to two-day platform presentation and panel discussion format. This format was successful in bringing more state and national bioassessment programs to the attention of an expanding audience and providing examples of how bioassessment data was being used in various programs. For the 2002 CABW meeting, DFG returned to the three-day workgroup format consisting of the following sessions:

- The EPA's Environmental Monitoring Program (EMAP) in California and How Water Resource Managers Can Use the Information

- The Use of Bioassessment in Developing and Implementing Total Maximum Daily Loads (TMDLs)
- Developing Biocriteria and How Water Resource Managers Can Use an Index of Biological Integrity (IBI)
- Diagnosing Aquatic Resource Impairment Using Chemical, Toxicological, Physical and Biological Tools

Early in the history of the CABW, the Steering Committee identified the need for professional training in bioassessment. In response, the Sustainable Land Stewardship Institute International (SLSII) adapted a very successful training program for citizen monitors into two three-day workshops aimed at a professional audience. Since 1996, more than three hundred water resource professionals and monitoring coordinators have had extensive training on the concepts of bioassessment in California, use of the CSBP, how to contract public and private laboratories to process bioassessment samples, and how to interpret bioassessment data. The annual CABW meetings and the SLSII bioassessment trainings have been the core elements responsible for introducing the concepts of biocriteria and standardized bioassessment procedures in California.

2.2 Federal Programs

Several federal agencies are currently collecting bioassessment data throughout the State, most of which are large-scale programs. Federal agencies currently collecting bioassessment data are the US Geologic Survey (USGS), the US Environmental Protection Agency (USEPA), the US Forest Service (USFS), and the Bureau of Land Management (BLM). Since all of the agencies collect bioassessment data using candidate methods and are covered more thoroughly in Chapter 3, limited discussion will be afforded to those programs in this section.

Beginning in 1992, USGS has conducted two basin-scale bioassessment projects, and is in the process of conducting a third, as part of the National Water Quality (NAWQA) Program. The San Joaquin-Tulare Basin project was completed in 1995 and the Sacramento Basin Project was completed in 1998. The Santa Ana Basin Project began in 1998 and was not yet completed at the time this report was written (2002).

The US Environmental Protection Agency (USEPA) has conducted a broad-scale bioassessment project throughout the Central Valley as part of their Regional Environmental Monitoring and Assessment Program (REMAP). Biological data were collected for two years (1994-1995) at approximately 87 sites in the Sacramento-San Joaquin River Valley to test the applicability of the nationwide Environmental Monitoring and Assessment Program (EMAP) approach to answering questions about ecological conditions at regional and local scales. USEPA is also collecting bioassessment data in California as part of the EMAP Western Surface Water pilot study, which is a five-year research and monitoring project to assess the ecological condition of streams and rivers throughout the Western U.S. However, because this project has only recently begun and is still several years away from completion, more effort was focused on the completed REMAP study in this report.

The US Forest Service (USFS) has conducted numerous small-scale bioassessment studies throughout the State in the past; however, virtually all bioassessment monitoring has been for

specific projects, with little regional perspective or application. Furthermore, different regional branches often conducted bioassessments using different sampling methods and were not coordinated with other branches. It was not until 2000 that they began a more consistent, standardized, scientifically credible, region-wide effort to address region-wide issues, such as watershed restoration.

2.3 State Agency Programs

Several state agencies have begun to utilize macroinvertebrate bioassessments for a variety of purposes. The California Department of Fish and Game's (CDFG) Aquatic Bioassessment Laboratory (ABL) utilizes bioassessment data in their Enforcement Case Program to measure deleterious effects to biological communities resulting from pollution events. Furthermore, ABL initiates bioassessments for numerous reasons when conducting special studies, such as the Consumnes River Watershed study and the Martinez Creek study. This program will be discussed in much greater detail in Chapter 3.

The State Water Resources Control Board utilizes bioassessment as part of their Federal Energy Regulatory Commission (FERC) Hydroelectric Relicensing and Repair Program to help determine compliance with the Clean Water Act and to assess water quality impacts. Under this program, licensees are requested to use rapid bioassessment to help determine impacts to water quality and beneficial uses. Furthermore, they use bioassessments in conjunction with water quality monitoring to determine the impacts of hydroelectric repair projects.

The California Department of Parks and Recreation has implemented bioassessment as part of their Natural Resources Inventory, Monitoring, and Assessment Program (IMAP) to assess water quality and the condition of aquatic ecosystems in state parks. Additionally, the project aims to assess the bioassessment findings in relation to steelhead and other aquatic organisms inhabiting these streams.

The Department of Water Resources (DWR) has been conducting bioassessments since 1975 as part of their responsibility per the California Water Code to determine the quality of the waters of the State. The primary objectives of their program are to provide long-term background information, to determine water quality based on types and abundance of individual species, and to monitor impact assessment and FERC relicensing of major DWR hydroelectric facilities.

2.4 State and Regional Water Quality Control Board Programs

Several Regional Water Quality Control Boards (RWQCB) have recently implemented bioassessment programs to assess the condition of streams within their jurisdiction. Only in its second year, the San Francisco Bay RWQCB (Region 2) has already collected bioassessment data from 72 sites throughout six watersheds. The primary purpose of this program is to establish screening-level ambient biological and physical monitoring in the region's streams along with chemical and toxicity monitoring, as well as establish reference conditions. Secondary purposes include impact characterization, pre- and post-project characterization, and support of regional efforts at habitat classification.

Since 1998, the Central Coast RWQCB (Region 3) has been using bioassessment as part of their Central Coast Ambient Monitoring Program (CCAMP). In this program, bioassessment is used in conjunction with other water quality monitoring approaches to characterize all watersheds throughout the region and to evaluate the effectiveness of best management practices (BMPs) in the Morro Bay Watershed.

The Los Angeles RWQCB (Region 4) is currently funding a bioassessment project to determine the biological health of streams relative to land use in three watersheds (Malibu, Calleguas, and Santa Clara). The University of California Los Angeles (UCLA) is conducting the project, which began in the Fall 2001 sampling season. Furthermore, Region 4 recently initiated a bioassessment program as part of the Surface Water Ambient Monitoring Program (SWAMP), whereby both site-specific monitoring goals and the regional monitoring goals have been integrated into one ambient monitoring program. The information gathered will be used to identify impaired beneficial uses, as well as potentially in the development of an index of biological integrity.

The Central Valley RWQCB - Sacramento (Region 5) began their stream bioassessment program in Fall 2000. The goal of this project is to provide a first step at identification of aquatic life stressors and associated development of ecological indicators in agriculturally dominated and effluent dominated waterbodies in the Central Valley.

Starting in 1995, the Lahontan RWQCB (Region 6) began collecting stream bioassessment data in order to monitor the success of the remediation efforts at the abandoned Leviathan Mine. In 1999, a more concerted, region-wide bioassessment program was implemented: 1) to establish regional reference conditions, 2) to assess the impacts of human activities on the biological integrity of streams and rivers, 3) to evaluate the effectiveness of restoration efforts, BMP implementation, and permit conditions, and 4) to develop narrative and numeric biocriteria. The primary objective of this program is to incorporate consideration of biological integrity into the many regulatory and watershed management functions of the Lahontan RWQCB. This program will be discussed in much further detail in Chapter 3.

The San Diego RWQCB (Region 9) initiated a bioassessment program in 1998 to support the ambient monitoring program and to provide baseline data on the benthic macroinvertebrate community in regional streams. The bioassessment program will evaluate the biological and physical integrity of targeted inland surface waters, and is designed to meet an obligation to assess the condition of the Region's waters relative to the attainment of water quality standards.

It should be noted that the North Coast RWQCB (Region 1) have also been conducting stream bioassessments throughout their region. However, since they chose not to participate in our report, we are unable to provide any details about their program.

2.5 Countywide Programs

Many counties have also begun utilizing bioassessments in their Clean Water Plans. The Alameda Countywide Clean Water Program (ACCWP) began using bioassessments in 1998 to support stormwater management activities in Alameda County creeks. The Alameda County

Flood Control and Water Conservation District sponsors the program, which focuses on providing watershed characterization, assessment, and trend monitoring data, and on ensuring compliance with NPDES permit requirements.

The Contra Costa Monitoring and Assessment Plan (CCMAP) began using bioassessment in 2001 as part of a long-term strategy that builds on previous special studies and data collection efforts. CCMAP is designed to assess the conditions of watersheds, water bodies, and water quality within Contra Costa County. CCMAP entails further characterization of watersheds and sub-watersheds, and the development of strategically placed monitoring stations where rapid bioassessment data can provide a valuable screening device to determine where water quality and watershed health are degraded or have the potential for degradation.

The Marin County Department of Public Works incorporated bioassessment in the form of a macroinvertebrate survey into the Marin County Stormwater Pollution Prevention Program in 1999. The primary focus of this survey is to provide data on watershed characterization, assessment, and trend monitoring.

The Ventura County Flood Control Department (VCFCD) began conducting bioassessment after the Regional Board inserted the requirement in the NPDES MS4 permit during the permit renewal. The County has created a program under consultation with CDFG and has conducted bioassessment at 12-14 stations throughout the Ventura River Watershed, which is much more extensive than the requirements placed in the MS4 permit. The main purpose of this program is to assess the biological condition of the Ventura County Watershed and to ensure compliance with NPDES permit requirements.

2.6 Municipal Programs

Both the City of San Jose and the City of San Diego began conducting stream bioassessments to assess water quality. The City of San Jose uses bioassessment data to establish a baseline condition of the benthic macroinvertebrate community prior to the release of recycled water into streams. The City of San Diego uses bioassessment data to assist the city's Metropolitan Wastewater and Storm Water Departments in assessing water quality. Furthermore, they also use bioassessment data to determine biological recovery after toxic events, such as sewage spills, and to assist other agencies with their bioassessment needs.

2.7 Watershed Organization Programs

There are over 100 watershed organizations located throughout the state of California, many of which incorporate bioassessments into their watershed protection/restoration strategies. While summarizing each individual program is not possible, we chose to include a few representative examples to indicate how and why bioassessments are being used by watershed organizations.

The Feather River Watershed Monitoring Program (FRWMP) began conducting bioassessments in 1999 with the purpose of obtaining and making available baseline and continuing data from which trends in watershed health can be measured. The FRWMP is a project of the Feather

River Coordinated Resource Management Group, which is a consortium of 21 public and private agencies and land management entities.

The Friends of Deer Creek began collecting bioassessment data in 2000 as part of the Deer Creek Watershed Bioassessment Program. The primary focus of this program is to assess the ambient condition of the watershed and to evaluate stream restoration efforts. Additionally, they provide data to community members and decision makers in order to support watershed protection and restoration.

The McCloud River Preserve began collecting bioassessment data in 1998 at the citizen level, and then in 1999 at the professional level. The primary focus of the program is to document and analyze the aquatic macroinvertebrate community in the McCloud River and to use the information in conjunction with on-going water quality research to provide a baseline review of the state of aquatic resources within the watershed.

The Reeds Creek/Red Bank Creek Watershed Program is a citizen-based bioassessment program overseen by the Tehama County Resource Conservation District. The program focuses on determining the long-tern trends in watershed conditions for Reeds and Red Bank Creeks through volunteer collected macroinvertebrate data. Both volunteers and students have been collecting bioassessment data since 2001.

The Upper Putah Creek Watershed Management Program began collecting bioassessment data in 2000, which is funded by a 319(h) grant administered by the Placer County Resource Conservation District. The program focuses on training and supervising citizen volunteers to monitor impacts to Upper Putah Creek and its tributaries and translate findings into restoration projects for the Stewardship to implement.

The South Yuba River Citizens' League began collecting bioassessment data in 2001 in order to assess ambient water quality throughout the Yuba River Watershed. The program trains volunteers to collect bioassessment data, which are used to educate community members and to provide data to decision makers for supporting watershed protection and restoration.

2.8 Tribal Programs

Several Native American Tribes across the State have recently begun conducting their own bioassessement programs to monitor water quality on Tribal lands. Both the Hoopa Tribe and the Yurok Tribe utilize rapid bioassessments as part of their ambient water quality monitoring programs. The Pit River Tribe, Smith River Rancheria, and several other tribes are still in the development phase of their water quality programs but plan to include bioassessment as part of their monitoring strategies in the near future.

2.9 Other Programs

There are various other programs/projects throughout California that utilize bioassessments, most of which are research oriented. For example, the Santa Clara Valley Project collected macroinvertebrate data from 14 streams in the Santa Clara Valley from May 1997 to October

1998. The primary focus of the project was to establish the relationships between benthic macroinvertebrate assemblage composition and physical and chemical factors associated with an urban environmental setting. Furthermore, the project aimed to develop a baseline data set representing the distribution of benthic macroinvertebrates in the Santa Clara Valley, which can also be used for evaluating the level of field and laboratory effort needed to conduct bioassessments.

Additionally, several universities (i.e., UC Davis, UC Berkeley, UC Santa Barbara, UC Los Angeles) have all been involved in conducting various bioassessment projects. The scope of these projects ranges from students' theses to private consulting projects for Regional Boards. For example, the Tahoe Research Group, which is a cooperative between UC Davis and The Tahoe Conservancy, is conducting a research project to quantify the effects of anthropogenic habitat degradation and restoration on stream insects in the Tahoe basin. The results of the study will provide necessary information for adaptive management land use decisions and for determining the feasibility of using benthic macroinvertebrates as biological indicators in sub-alpine streams.

Some industries, such timber harvesting, have also discovered the utility of bioassessments and began using them to monitor their impacts on the environment. For example, Scotia Pacific Company has been conducting extensive bioassessments over several years as part of their Habitat Conservation Plan requirements.

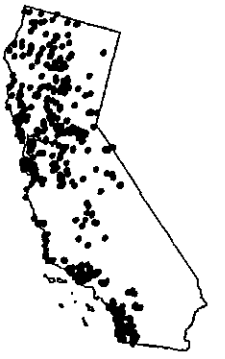
Chapter 3 Status Of Stream Bioassessment Activities In California

A few key programs in California encompass the concept and purposes of bioassessment, such that they are viable models for developing a statewide bioassessment approach. Five candidate stream bioassessment programs were identified in California based on the rigor of their scientific methods and the extent and relevancy of the data collected thus far. To qualify as a candidate program, each bioassessment program must: 1) utilize scientifically credible methods for data collection and processing, and 2) have collected a relatively large set of reliable data across a broad spatial and/or temporal scale. The following bioassessment programs in California meet these criteria: 1) California Department of Fish and Game (CDFG) Aquatic Bioassessment Laboratory (ABL) Program, 2) Lahontan Regional Water Quality Control Board Bioassessment Program, 3) U.S. Forest Service's Pacific Southwest Region Bioassessment Program, 4) U.S. Geological Survey's National Water Quality Assessment (NAWQA) Program, and 5) U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP)/Regional Environmental Monitoring and Assessment Program (REMAP). However, it should be mentioned that the CDFG ABL provides a bioassessment support service to the state and regional boards, as well as other programs and agencies. The ABL provides sampling, taxonomic identification, and training support on a regular basis. The method developed by the ABL, the California Stream Bioassessment Procedure (CSBP) is currently the most widely used stream bioassessment method in California.

3.1 Summary of Candidate Programs

Each of the five candidate programs is summarized based on six major attributes: contact person, sampling method, timeline of sampling, data availability, purpose, and a brief description. More comprehensive summaries outlining key program elements such as habitat selection, sampling gear, sampling method, area sampled, replication, subsampling and enumeration, taxonomic identification, quality assurance procedures, data analysis/metrics, habitat assessment, and purpose for monitoring can be found in section 3.2 - Comparison of Key Elements of Candidate Programs.

3.1.1 California Department of Fish and Game (CDFG) Aquatic Bioassessment Laboratory - California Stream Bioassessment Procedure (CSBP)



The program of the California Department of Fish and Game, Aquatic Bioassessment Laboratory is designed to both investigate pollution events and to support other studies, particularly those of the RWQCBs. CDFG has been instrumental in developing technical resources and conducting numerous bioassessment studies, and in assisting with the design and collection of data for various other bioassessment programs throughout California since 1993.

Contact Person: James Harrington, State Water Quality Biologist, DFG Water Pollution Control Laboratory, 2005 Nimbus Road, Rancho Cordova, Ca 95670 (916) 358-2862 FAX (916) 985-4301 jharring@ospr.dfg.ca.gov

Sampling Method: California Stream Bioassessment Procedure (CSBP) Rapid Bioassessment Protocol (RBP)

Timeline of Sampling: 1992 - present

Data Availability: Approximately 2500 sites statewide.

Purpose of Bioassessment:

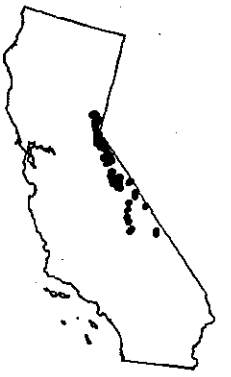
- Enforcement and resource damage assessment
- Use attainability
- Ambient monitoring
- Special studies and research

Description: DFG was the first water resource agency to be asked to assess the condition of a freshwater stream using the U.S. EPA's Rapid Bioassessment Procedure (RBPs) (Plafkin *et al.* 1989). The Lahontan Board requested the assessment in 1993 as part of the NPDES requirement of the DFG Hot Creek Hatchery in Mono County. The request necessitated the need to adapt the RBPs to California and the resulting protocol became the California Stream Bioassessment Procedure (CSBP). Because the CSBP was developed for a point-source assessment, it incorporated the use of replicated sampling of a single, richest habitat. Although not consistent with the RBP, DFG decided on this procedure for the following reasons: a) the immediate need for bioassessment was for point-source assessments, enforcements and diagnosis of known, but undocumented water quality impairment; b) there was no interest, at that time, in using bioassessment as an ambient monitoring tool; and c) the ability to produce a measure of biological metric variability at every monitoring site was deemed necessary to convince water resource managers of the robustness of biological assessments.

The CSBP is a regional adaptation of the U.S. Environmental Protection Agency (EPA) Rapid Bioassessment Protocols (Barbour *et al.* 1999). The CSBP was reviewed and refined by a CABW workgroup in 1994 and 1995 resulting in an updated version in 1996. The CSBP for wadeable streams and rivers has remained consistent over the years and is recognized by the U.S. EPA as California's standardized bioassessment procedure (Davis et al. 1996). Since 1993, the ABL has processed nearly 9000 samples collected using the CSBP at more than 2500 sites throughout California. Thousands of additional CSBP samples have been collected and processed by other entities. In addition to the CSBP for wadeable streams and rivers, as of 2002, there are versions of the CSBP for non-wadeable streams (draft), citizen monitors, lentic environments (California Lentic Bioassessment Procedure), and there is a modification of the CSBP in which samples are composited for sites that are part of an ambient bioassessment program (this CSBP modification has been adopted by the Nevada DEQ).

In addition to the numerous special studies they conduct, CDFG investigates situations where reports of activities or pollution events in the surrounding watershed may have adversely impacted stream integrity and/or stability.

3.1.2 Lahontan Regional Water Quality Control Board Biological Assessment Program – Sierra Nevada Aquatic Research Laboratory (SNARL) Method



The primary objective of this program is to incorporate consideration of biological integrity into the many regulatory and watershed management functions of the Lahontan RWQCB.

Contact Person: Thomas J. Suk, Regional Monitoring Coordinator, California Regional Water Quality Control Board, Lahontan Region, 2501 Lake Tahoe Blvd., South Lake Tahoe, CA 96150. Phone: (530) 542-5419; Email: <sukt@rb6s.swrcb.ca.gov>

Sampling Methods: Prior to 2000, all samples were collected following protocols developed by Dr. David Herbst at the University of California's Sierra Nevada Aquatic Research Laboratory (SNARL). Starting in 2000, the Lahontan RWQCB began using and evaluating three different bioassessment sampling methods: (1) benthic macroinvertebrates, periphyton, and physical habitat assessments following SNARL protocols; (2) California Stream Bioassessment Procedures (CSBP) developed by CDFG; and (3) RIVPACS protocols being used in the Sierra Nevada by the U.S. Forest Service

Timeline of Sampling: 1995 - present

Data Availability: Approximately 350 surveys have been conducted at 200 sites in the Lahontan Region using the SNARL method. At 40 of those 200 sites, sampling was conducted using three methods (e.g., SNARL, CSBP, RIVPACS) to facilitate quantitative comparison of the results provided by each of those three methods. At approximately 30 other sites (throughout the eastern Sierra Nevada) samples were collected using both the SNARL and RIVPACS methods, and at 20 other sites (all in the Walker River drainage) samples were collected using both the SNARL and USEPA-REMAP methods. Most of this data is not yet available, and lab identification and quality assurance procedures are still underway.

Purpose of Bioassessment:

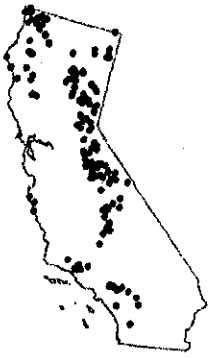
- To establish regional "reference conditions" for benthic macroinvertebrates and periphyton in streams and rivers
- To assess the impacts of human activities on the biological integrity of streams and rivers
- To evaluate the effectiveness of stream & wetland restoration efforts, BMP implementation, and permit conditions
- To develop numeric targets for TMDLs
- To develop narrative and numeric biocriteria

Description: The Lahontan RWQCB began using bioassessment in 1995, in order to monitor the success of remediation efforts at the abandoned Leviathan Mine. A more concerted (i.e., region-wide) bioassessment program was begun in 1999, for the multiple purposes outlined above.

The current regional-scale effort is focused on developing reference conditions (based on benthic macroinvertebrates and periphyton) for the eastern Sierra "ecoregion," which covers six major watershed basins (e.g., Truckee River, Tahoe Basin, Carson River, Walker River, Mono Basin, Upper Owens River). Streams in this ecoregion were stratified based on stream order, and minimally impaired sites were selected from each class of streams. Sampling has been conducted during the summer reference period (i.e., late June to early September), using protocols developed by Dr. David Herbst of the University of California's Sierra Nevada Aquatic Research Laboratory. As of this writing (i.e., 2001), the effort has focused on data collection and lab identifications; analyses of the data for biocriteria are pending. Several project-specific reports have also been generated (Upper Truckee, Leviathan, Squaw sediment TMDL)(Herbst 2002a, Herbst 2002b, Herbst 2002c).

The Lahontan RWQCB, via contract with the University of California (SNARL), is also using bioassessment data to: (1) evaluate the effectiveness of several stream & wetland restoration projects (e.g., Upper Truckee River, Bagley Valley); (2) evaluate the effectiveness of BMP implementation (e.g., Upper West Walker River, Bridgeport Valley); (3) monitor the success of remediation efforts at Leviathan Mine; (4) verify and/or assess the effectiveness of regulatory permits (e.g., fish hatcheries, Grover Hot Springs State Park); and (5) develop targets based on benthic macroinvertebrates for sediment TMDLs (e.g., Squaw Creek, Heavenly Valley Creek).

3.1.3 U.S. Forest Service - Pacific Southwest Region (California) Bioassessment Program



The focus of this program is on establishing reference conditions by collecting macroinvertebrates from a network of both perennial and intermittent wadeable streams throughout the entire state of CA, mainly on Forest Service lands. There are 18 national forests in the region (Angeles, Cleveland, Eldorado, Inyo, Klamath, Lassen, Lake Tahoe Basin Management Unit, Mendocino, Modoc, Plumas, San Bernardino, Sequoia, Shasta-Trinity, Sierra, Six Rivers, Stanislaus and Tahoe)

Contact Person: Joseph Furnish, Ecosystem Conservation Division, 1323 Club Drive, Vallejo, CA 94592

Sampling Method: Hawkins, Ostermiller, and Vinson (1998)

Timeline of Sampling: 2000 - present

Data Availability: Approximately 176 sites in 2000 and 85 sites in 2001 located in the following watersheds: Klamath- North Coastal; Sacramento; Tulare-Buena Vista; San Joaquin; Central Lahontan; Central California Coastal; South California Coastal; North Mojave- Mono Lake.

Purpose of Bioassessment:

- Development of biocriteria and bioassessment protocol
- Monitoring of impacts from timber harvest, grazing and mining activities
- Ensure compliance with the Clean Water Act
- TMDL implementation
- Reference site characterization

Description: The primary effort has been on establishing reference conditions by collecting macroinvertebrates from a network of both perennial and intermittent wadeable streams, which can serve as the basis for monitoring biological condition and determining whether water quality has been degraded compared to reference conditions. Reference conditions will be based on development of a predictive RIVPACS (River InVertebrate Prediction And Classification System) model. Standard EPA metrics will also be considered for use if it is determined that they are sensitive to disturbances at the site and watershed (approximately 10,000-50,000 acre) scale.

3.1.4 U.S. Geological Survey: National Water Quality Assessment (NAWQA) Program

The U.S. Geological Survey (USGS) implemented the National Water-Quality Assessment (NAWQA) Program to describe the status of and trends in the quality of the nation's surface water and ground water and to provide scientific understanding of the natural and human-induced factors that affect water quality.

Contact Person: Larry Brown, Placer Hall, 6000 J St, Sacramento, CA 95819-6129

Sampling Method: USGS NAWQA

Timeline of Sampling: San Joaquin-Tulare Basins 1992-95; Sacramento Basin 1995-98; Santa Ana Basin 1998-Present.

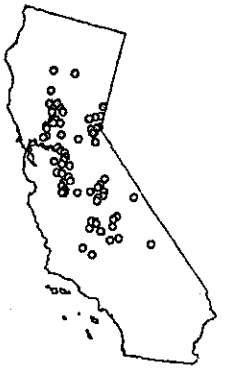
Data Availability: 17 sites in San Joaquin-Tulare Basins; 23 sites in Sacramento Basin; and 4 sites in Santa Ana Basin.

Purpose of Bioassessment:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams
- Describe how water quality is changing over time
- Improve our understanding of the primary natural and human factors affecting water quality

Description: Since 1991, the NAWQA program has been collecting and analyzing data and information in more than 50 major river basins and aquifers across the nation. The goal is to develop long-term consistent and comparable information on streams, ground water, and aquatic ecosystems to support sound management and policy decisions. Three major river basins in California were assessed as part of this program: 1) Sacramento Basin, 2) San Joaquin-Tulare Basins, and 3) Santa Ana Basin.

3.1.5 U.S. Environmental Protection Agency Central Valley Regional Environmental Monitoring and Assessment Program (REMAP)



The Central Valley REMAP project focuses on assessing the biological integrity of agriculture-dominated waterbodies located throughout California's Central Valley, which comprises more than 48,000 miles of surface water and 16 percent of the land area of California.

Contact Person: Peter Husby, USEPA Region 9 Laboratory, 1337 S. 46th St.; Bldg. 201, Richmond, CA 94804

Sampling Method: USEPA EMAP, Lazorchak and Klemm (1994)

Timeline of Sampling: 1994-1995

Data Availability: Approximately 87 sites in the Sacramento-San Joaquin Valley, covering approximately 24,000 square miles.

Purpose of Bioassessment:

- Support State of CA bioassessment and monitoring
- Assess the biotic condition of surface waters in a highly modified agriculturally influenced ecosystem.
- Determine variability of aquatic organisms in natural and man-made conveyances within the Central Valley.

Description: REMAP was initiated to test the applicability of the EMAP approach to answer questions about ecological conditions at regional and local scales. Using EMAP's statistical design and indicator concepts, REMAP conducts projects at smaller geographic scales and in shorter time frames than the national EMAP program. EMAP is a research program to develop the tools necessary to monitor and assess the status and trends of national ecological resources. EMAP's goal is to develop the scientific understanding for translating environmental monitoring data from multiple spatial and temporal scales into assessments of ecological condition and forecasts of the future risks to the sustainability of our natural resources. The objectives of REMAP are to: 1) evaluate and improve EMAP concepts for state and local use, 2) assess the applicability of EMAP indicators at differing spatial scales, and 3) demonstrate the utility of EMAP for resolving issues of importance to EPA Regions and States.

3.2 Comparison of Key Elements of Candidate Programs

A series of key elements were identified and compared among the five candidate programs. More specifically, a comparison matrix was assembled and the following elements were listed and compared: habitat selection, sampling gear, sampling method, area sampled, replication, replication as quality assurance/quality control (QA/QC), subsampling and enumeration, taxonomic level of identification, QA procedures, data analysis/metrics, and habitat assessment (Table 1). Data availability/mode of storage, written protocol availability, purpose of monitoring, and additional comments were also included but not compared in any detail as they provide very little useful information for what we are trying to accomplish in this section. Furthermore, wherever possible, the precision of each method was calculated for comparison.

3.2.1 Major Similarities and Differences Among Methods

Although all of the programs collect benthic macroinvertebrate samples to measure water quality, each has a unique goal, or question, that they are trying to address. Therefore, these differences in program goals often translate into differences in program methods. Conversely, similarities in program goals often lead to similarities in the methods. The following section briefly describes the similarities and dissimilarities of eight bioassessment method elements: habitat selection, sampling gear, collection method, area sampled, replication, subsampling and enumeration, taxonomic identification, and habitat assessment.

Habitat Selection

Most of the candidate programs focus the majority, if not all, of their sampling effort on riffle or fast-water habitats. Both CSBP and SNARL methods focus all of their sampling effort on riffle habitat. In addition to the riffle (or richest-targeted) habitat sample, USGS NAWQA also takes a separate multi-habitat sample whereby all habitats present in the reach are sampled with a proportional amount of effort going to each habitat based on occurrence in the reach. The USFS takes a similar approach in that, in addition to fast-water habitat sampling, it also collects a 10-minute qualitative sample whereby the 10-minute sampling period is apportioned so that each of the habitat types is sampled roughly in proportion to their occurrence.

The USEPA EMAP approach is slightly different from all other programs in that the amount of sampling effort is not subdivided based on habitat type, but rather the entire reach is subdivided by a number of cross-sectional transects and a sampling location is selected for each transect. Therefore, whatever habitat type is present at the selected point will be sampled. Samples collected from riffle and run habitats are composited into one sample and samples collected from pool and glide habitats are composited into another.

Table 1. Comparison of Key Elements for California Stream Bioassessment Programs

	USEPA Central Valley R-EMAP	US Forest Service	Dept. Fish & Game (CSBP)	SNARL/Lahontan	USGS (NAWQA)
Habitat Selection	• Reach determined as 40 times the wetted width with a minimum reach length of 150 meters and maximum length of 500 meters.	• Fast-water (Almost always riffles, runs may also be sampled), four consecutive areas within the sample reach. • Reach length may vary from about 200-500 meters	• Stream reach selected which contains at least 5 riffles within the same order and relative gradient. • If no riffles are present, or less than five within a reasonable distance, EMAP selection method is used as default.	Riffles within 150 m study reach.	• All habitats in selected reach (QMH sample) • "Richest-targeted sample" (RTH sample) with riffles being the priority habitat and woody debris sampled when riffles not available.
Sampling Gear	Rectangular net 50 cm wide, 500 µm mesh.	Surber sampler (0.09 m^2), 500 µm mesh, 1-meter long net to prevent backwashing	30 cm wide D-shaped kick net (500 µm mesh)	30 cm wide D-frame net (250 µm mesh)	• RTH: .5 m x .25 m net with 425 µm mesh. • QMH: standard d-frame net with 210 µm mesh.
Collection Method	• Samples collected at 9 evenly spaced transects within reach. • Composited as riffle/run or glide/pool, 0-9 samples per composite.	• Fixed area sample is composed of 8 Surber samples (4 riffles x 2 samples from each riffle) • 10-minute qualitative sample from all major habitats present.	One composite of 3 samples is collected from the upstream third of 3 randomly chosen riffles.	Each sample is a composite of 3 samples taken from each of 5 randomly selected riffles.	• RTH: composite of samples from 5 locations within riffles. . • QMH: equal effort in all habitats present in entire reach. Time variable (usually 1 hr).
Area Sampled	• Area per sample is ~ 0.5 m^2 • Area per composite is variable depending on proportion of habitat type sampled.	• Total area sampled per fixed area composite = 0.72 m^2 • Total area sampled for fixed time samples variable.	Total area sampled per composite = 0.54 m^2 Total area sampled per site = 1.62 m^2	Total area sampled per composite = 0.27 m^2 Total area sampled per site = 1.28 m^2	• RTH: Total area sampled per composite = 1.25 m^2 • QMH: Total area sampled variable
Replication	• No site replicates.	• No site replication using the same methods.	3 randomly-selected samples taken at each site	5 randomly-selected riffles from each site	Limited replication.
Replication as QA/QC	• Same season, different team revisits (2 sites) • Next year revisits (10 sites).				• Replication limited to a subset of 4-6 sites • 3 samples are collected at each site

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Table 1. Comparison of Key Elements for California Stream Bioassessment Programs (continued)

	USEPA Central Valley R-EMAP	US Forest Service	Dept. Fish & Game (CSBP)	SNARL/Lahontan	USGS (NAWQA)
Data Availability and Mode of Storage	Obtained Excel spreadsheets for Central Valley 1994 & 1995 macroinvertebrate data (no habitat data)	Data are available from the NAMC and eventually will be deposited into the USFS corporate database system of the Natural Resource Information System (NRIS).	Access database (Cal EDAS). Much data still in Excel.	Obtained 4 Excel spreadsheets: Upper Truckee River 1998-2000, Leviathan Mine Watershed 1999, Leviathan Spring 1995/1997, Leviathan Fall 1998)	Obtained Excel spreadsheets for Sacramento River Basin 1996-1998 invertebrate data (no habitat data)
Written Protocols Availability	Lazorchak and Klemm, 1994.	Hawkins et al. 1998	Yes	http://www.swrcb.ca.gov/rwqcb6/QAPP/QAPP_Index.htm	http://water.usgs.gov/nawqa/protocols/doc_list.html
Comments		• Analysis tools not fixed, intend to use both multimetric and multivariate approaches. • Approximately 170 prospective reference sites sampled during FY2000 to develop a RIVPACS model.	• Calibration with RIVPACS and EMAP • More than 8000 samples to date	• Calibration with CSBP & RIVPACS underway. • Analysis tools not fixed, intend to use both multimetric and multivariate approaches. • Approximately 225-250 streams sampled to date (1996-2000). • About 25-50 of these are monitored annually or even seasonally.	Program is in support of the National Water Quality Assessment Program and does not include continuous (annual sampling). Intensive sampling typically only occurs for a year or two.
Purpose for Monitoring	• Support State of California bioassessment and monitoring. • Assess the biotic condition of surface waters in a highly modified agriculturally influenced ecosystem. • Determine variability of aquatic organisms in natural and man-made conveyances within the Central Valley.	• Development of biocriteria & bioassessment protocol • Monitoring of impacts from timber harvest, grazing and mining activities • Ensure compliance with the Clean Water Act • TMDL implementation	• Enforcement and resource damage assessment • Use attainability • Ambient monitoring • Special studies and research • Develop and promote bioassessment methodologies • Test and troubleshoot methods	• Biocriteria development and assessment & monitoring. • Livestock grazing stream restoration • Acid Mine Drainage stream restoration monitoring. • TMDL development for sediments. • Reference condition sampling	In support of National Water Quality Assessment Program, a water quality program. Biological assessments are included as a measure of ecological health of streams.

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Table 1. Comparison of Key Elements for California Stream Bioassessment Programs (continued)

	USEPA Central Valley R-EMAP	US Forest Service	Dept. Fish & Game (CSBP)	SNARL/Lahontan	USGS (NAWQA)
Subsampling And Enumeration	• Random subsampling to 300 organism count/identification	• Composite samples are divided into equal-sized proportions and all organisms are removed from each sub-sample until a minimum of 500 specimens (early data was 300) have been obtained from a complete sort of 1 or more subsamples. • Big/rare specimens are also removed from the entire remaining sample during a 10-minute examination.	• 300 organisms for ID. • All organisms in grid are counted for abundance	• Subsampling using rotating drum splitter • Minimum count of entire split = 250 organisms, (actual range = 300-500) • Big/rare organisms are also removed	• Field splits conducted when sample volume is >0.75 L. • Field processing can result in 4 sample components: large-rare, main-body, elutriate, and split-sample. • Samples are split until composite volume is ≤ 0.75 L.
Taxonomic Level of ID	• Lowest taxon possible • Genus, species, or species group (including Chironomids and Mites).	• Insects are primarily identified to the genus level. • Chironomidae are identified to the sub-family level. • Non-insect invertebrates identified to various levels depending on available keys.	• Insects are primarily identified to the genus level. • Chironomidae are identified to the sub-family level. • Non-insect invertebrates identified to various levels depending on available keys.	• Lowest taxon possible • Genus, species, or species group (including Chironomids and Mites).	• Most insects to species or genus. • Other organisms variable.
QA Procedures	• Field: revisit by different team - same year (2 sites) and second year revisit on 10 sites • Vouchers and reference collection maintained • Lab: sorting checks 10%; ID checks 100%.	• Field: instrument calibration. • National Aquatic Monitoring Center (NAMC) procedures for sample processing. • Vouchers and reference collection maintained at NAMC.	• Field: crew members trained for sampling consistency, and audits • Lab: sorting checks 100%; ID checks 10-20%, bioassessment validation 10-20% • Internal and external QC, 10% each	• Field: instrument calibration, crew training. • Vouchers and reference collection maintained • Lab: sorting checks 20%; ID checks 100%. • Lab training and corrective actions.	• All identifications by qualified experts • 10 % internal QC • External vouchers
Data Analysis/ Metrics	Various including many alternatives for use in screening environmental correlation.	No standard procedure has been designated. RIVPACS will be utilized to develop a model to determine the level of impact to the biological assemblage at a site. Benthic-IBI may also be used depending on performance.	Developed own multimetric and multivariate approach.	Various including many alternatives for use in screening and environmental correlation.	No established metrics or endpoints used. Analysis emphasizes multivariate gradient analyses.
Habitat Assessment	Quantitative surveys of 11 transects (intensive) and full reach (water and sediment chemistry, thalweg, width, depth, velocity, substrate, etc.	1) Densiometer shade measurements, 2) wetted width, 3) mean depth (n=3 measures x 10 transects= 30), 4) substrate- Wolman'pebble count, 5) conductivity, 6) alkalinity, 7) Gradient, 8) Habitat Types (Montgomery-Buffington channel classes)	EPA method and additional: • Canopy • Quantitative substrate • Pebble count • Substrate consolidation • Depth & width • Velocity	Quantitative surveys of 15 transects (intensive) and full reach (chemistry, width, depth, velocity, substrate, etc.)	Detailed habitat measurements at various scales (basin, segment, reach, transect). Protocols now call for 11 habitat transects within each reach.

Habitat Selection

Most of the candidate programs focus the majority, if not all, of their sampling effort on riffle or fast-water habitats. Both CSBP and SNARL methods focus all of their sampling effort on riffle habitat. In addition to the riffle (or richest-targeted) habitat sample, USGS NAWQA also takes a separate multi-habitat sample whereby all habitats present in the reach are sampled with a proportional amount of effort going to each habitat based on occurrence in the reach. The USFS takes a similar approach in that, in addition to fast-water habitat sampling, it also collects a 10-minute qualitative sample whereby the 10-minute sampling period is apportioned so that each of the habitat types is sampled roughly in proportion to their occurrence.

The USEPA EMAP approach is slightly different from all other programs in that the amount of sampling effort is not subdivided based on habitat type, but rather the entire reach is subdivided by a number of cross-sectional transects and a sampling location is selected for each transect. Therefore, whatever habitat type is present at the selected point will be sampled. Samples collected from riffle and run habitats are composited into one sample and samples collected from pool and glide habitats are composited into another.

Sampling Gear

The majority of candidate programs prefer to use D-frame or rectangle frame kicknets to collect samples; however, net mesh size is variable among programs. Most of the methods prefer a net with a mesh size around 500 μm. For example, both CSBP and USFS methods use 500 μm mesh netting, while USEPA EMAP and USGS NAWQA (RTH sampling) use 595/600 μm and 425 μm, respectively. On the other hand, SNARL prefers 250 μm mesh netting, and USGS NAWQA (QMH sampling) uses 210 μm mesh netting.

The only obvious difference in sampling gear, other than mesh size, is USFS method's use of a Surber sampler. All other programs use either a D-frame net or rectangle frame kicknet to collect samples. CSBP, SNARL, and NAWQA (QMH) methods all use D-frame nets. Both EMAP and NAWQA (RTH) methods use rectangle frame kicknets.

Collection Method

Perhaps the largest difference between programs lies in the collection method used by each. All of the programs take one or more composite samples from each site, but the make up of and method of collecting each composite is quite variable. For a detailed description of each programs' sampling method see Appendix B.

Area Sampled

The area sampled per composite is quite variable ranging from 0.27 m^2 for the SNARL method to 1.25 m^2 for NAWQA (RTH) method. However, composites using the EMAP method may sample up to 4.5 m^2, but the area sampled varies based on habitat selection. The total area sampled per reach, not including fixed time or QMH sampling, ranges from 0.72 m^2 for the USFS method to 4.5 m^2 for the EMAP method.

Replication

Only three of the five methods collect valid site replicates as part of their sampling programs. Both the CSBP and SNARL methods routinely collect replicate samples at every site (i.e., three and five, respectively), whereas NAWQA collects replicate samples at a subset of 4-6 sites per study. USFS collects no replicates samples, and EMAP only collects QA/QC replicates using same season, different team revisits and same team, different year revisits.

Subsampling and Enumeration

Both the count and method of subsampling is highly variable among all programs. NAWQA uses both a qualitative visual sort method and a quantitative fixed-count method of subsampling; however, the organism count varies based on the data quality objectives of the study. Both the CSBP method and the EMAP method subsample to 300 organisms, but the remaining programs use subsampling methods based on composite sample splits and identifying the entire split to within a range of organisms. For example, USFS divides the composite into equal-sized portions and all organisms are removed until a minimum of 500 specimens have been obtained from a complete sort of one or more subsamples. The SNARL method uses a similar subsampling strategy whereby the composite sample is split until the minimum count of the entire split is 250 organisms.

Taxonomic Identification

Most of the programs identify insects to the lowest taxon possible, which is usually the genus and/or species level. However, USFS and CSBP identify Chironomid midges to the sub-family level. Non-insect invertebrate identification is variable, usually depending upon available taxonomic keys.

Habitat Assessment

Habitat assessment tends to be highly variable among programs in terms of rigor and detail of measurements. EMAP, NAWQA, and SNARL collect quantitative measurements at multiple (11-15) transects throughout the study reach, utilizing a relatively comprehensive habitat assessment approach. On the other hand, CSBP and USFS utilize more rapid habitat assessment techniques (visual-based for most measures) to characterize physical habitat semi-quantitatively.

3.2.2 Comparison of Performance Characteristics for Bioassessment Methods

Although water quality programs have distinct goals for conducting bioassessments and require different levels of effort in sample collection, taxonomic identification, and data analysis, discrete methods may yield comparable data for certain objectives despite these differences in effort. If discrete methods are similar with respect to the quality of data they produce, it is possible to use the results together. In other words, determining the performance characteristics of individual methods enables agencies to share the results of bioassessments by providing an estimate of the level of confidence in assessments from one method to the next (Barbour et al. 1999). The best way to determine the quality of data produced by a method is through the use of

data quality objectives. Data quality objectives (DQOs) are qualitative and quantitative expressions that define requirements for data precision, bias, method sensitivity, and range of conditions over which a method yields satisfactory data (Klemm et al. 1990).

The documentation of performance characteristics for all methods is known as the performance-based method system (PBMS – see ITFM 1995), which is essentially a system that permits the use of any method of sampling and analysis that meets established requirements for DQOs (Diamond et al. 1996, NWQMC 2001). The basic elements of a PBMS approach include method precision (repeatability of measurements), bias (skewness of measurements), sensitivity (detection limit), and accuracy (proximity to the analytical truth).

For the PBMS approach to be useful, three basic assumptions must be met (ITFM 1995):

1. DQOs must be set that realistically define and measure the quality of the data needed; reference (validated) methods must be made available that meet those DQOs;
2. there must be proof that the method yields reproducible results that are sensitive enough for the program; and
3. the method must be effective over the prescribed range of conditions in which it is to be used.

Key Performance Characteristics
- Precision
- Sensitivity

For bioassessments, the above assumptions imply that a given method for sample collection and analysis produces data of known quality, including precision, the range of habitats over which the collection method yields a specified precision, and the magnitude of difference in data among sites with different levels or types of impairment (Diamond et al. 1996). Calculating the performance characteristics for a given bioassessment method is essential to understanding the robustness of the method for reliably determining the condition of the aquatic ecosystem. A method that is very labor intensive and requires a great deal of specialized expertise, and, in turn provides a substantial amount of information, is not necessarily the most appropriate if it is not very precise and repeatable. A less rigorous method may be less sensitive to detecting perturbation or have more uncertainty in its assessment. All of these attributes are important to minimizing Type I and II error in bioassessment. The ultimate question resides in a firm balance between cost and resolution, i.e., is more information better (more cost) or is a limited amount of the right information best (less cost). A knowledge of method precision, sensitivity, bias, and accuracy helps with this decision. For purposes of this discussion, the key performance characteristics are precision and sensitivity to establish a basis for understanding the CSBP and SNARL methods comparison presented later in his section.

Establishing DQOs for a bioassessment method helps to evaluate the adequacy and robustness of a method. For example, we may establish the following DQOs:

DQO 1. We want to be able to detect a 20% change, e.g., five categories of condition on a 100-pt scale for a calibrated biological index.

DQO 2. We want the method to have a discrimination efficiency of greater than 75%, i.e., the method is calibrated so that only 25% or less ($\beta = 25\%$) of the *a priori* determined sites of reference and degraded would be misclassified.

Using these two example DQOs, we establish the following hypothetical scenario.

Hypothetical Scenario

To conduct an analysis of the performance of a bioassessment method, or several methods, five steps can be identified: 1) compare the relative variability of the various methods from both reference and degraded sites – *DQO 1*, 2) evaluate sensitivity or discrimination efficiency – *DQO 2*), 3) evaluate precision, 4) evaluate bias and accuracy, and 5) evaluate ability to make a correct assessment – *DQO 2*. In this hypothetical example, we compare three methods used side-by-side to collect bioassessment data.

Step 1 (Characterization of sites). The first step toward evaluating a method's performance as a bioassessment tool, is to collect or assemble data from both reference and degraded sites. Having a population of reference sites as well as a population of data collected from known degraded sites is essential for determining both the relative performance using different levels of biological condition as well as determining sensitivity or discrimination efficiency. Box-and-whisker plots are used to plot data for a given biological indicator (e.g., a metric or index) from each of the three methods (Figure 1). These plots illustrate the amount of variability measured in a population of sites (in both reference and degraded categories). For this example, we will say that methods 1 and 2 have tight enough ranges in variability to allow us to meet the first DQO, i.e., an ability to detect a 20% change.

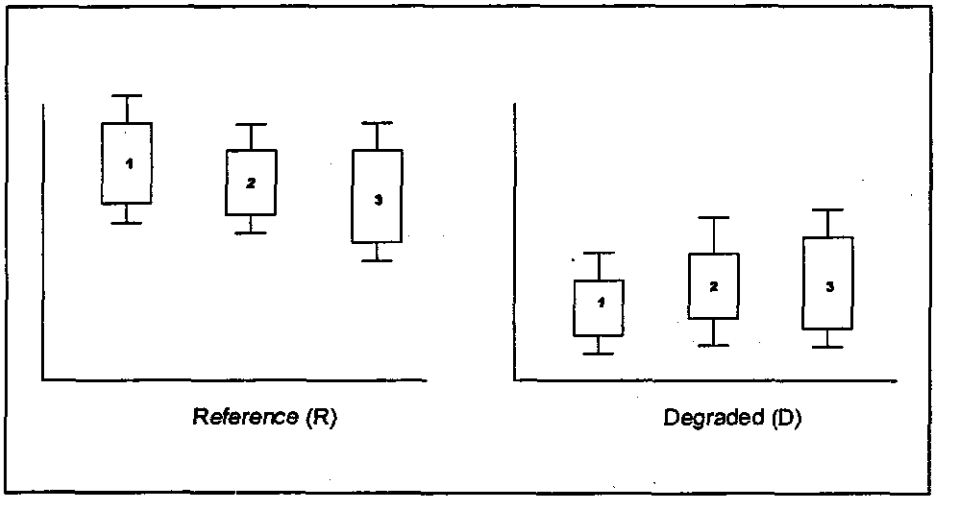

Figure 1. Box-and-whisker plots showing the distribution of data collected from reference and degraded sites using three separate methods (1, 2, and 3). Boxes illustrate population attributes (via percentile distribution, i.e., 25% - 75%) and whiskers provide a sense of variability.

Step 2 (Sensitivity). The second step is to evaluate the sensitivity of each method, or ability to discriminate between reference and degraded sites. By examining the reference and degraded box and whisker plots side-by-side, it is possible to determine the sensitivity of a given method. The reference and degraded plots are paired to show the amount of overlap, or lack thereof (Figure 2). The more overlap between plots the less sensitive the method, and vice versa. In this example, method one is the most sensitive because there is no overlap between plots, and method three is the least sensitive because it has the most overlap of the interquartile ranges. Method 1 meets the second DQO of having greater than 75% discrimination efficiency.

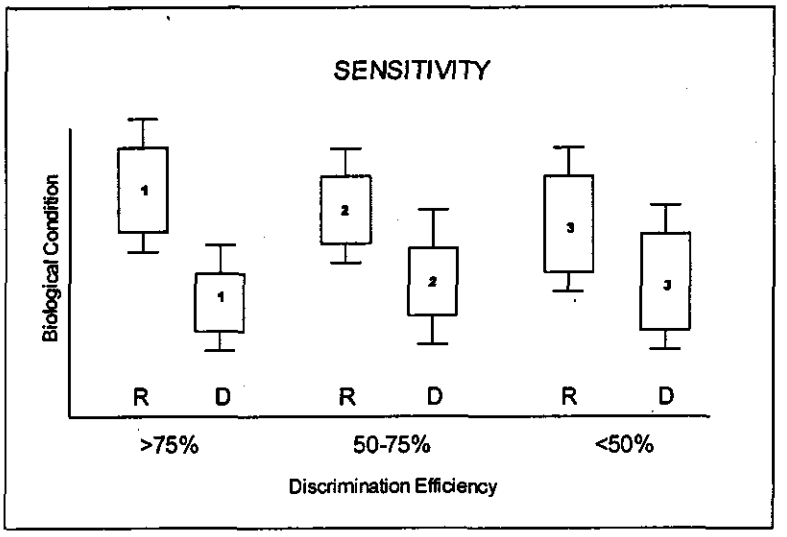

Figure 2. Box-and-whisker plots illustrating the ability of each method to discriminate between reference (R) and degraded (D) conditions. Method one discriminates greater than 75% of the sites correctly; method two can only discriminate between 50 and 75% of the sites correctly; and method three is least sensitive, discriminating less than 50% of the sites.

Step 3 (Precision). The third step is to evaluate the method precision, or repeatability of measurements, using all sites (i.e., reference and degraded) in the population. Repeated samples (replicates or duplicates) are required to calculate the standard deviation from the mean. This can be illustrated by graphing the mean value for a given metric or index and incorporating error bars to show the standard deviation (Figure 3). In this example, method two is the most precise because it has the smallest standard deviation around the central tendency (mean), and method three is the least precise because it has the largest deviation around the mean.

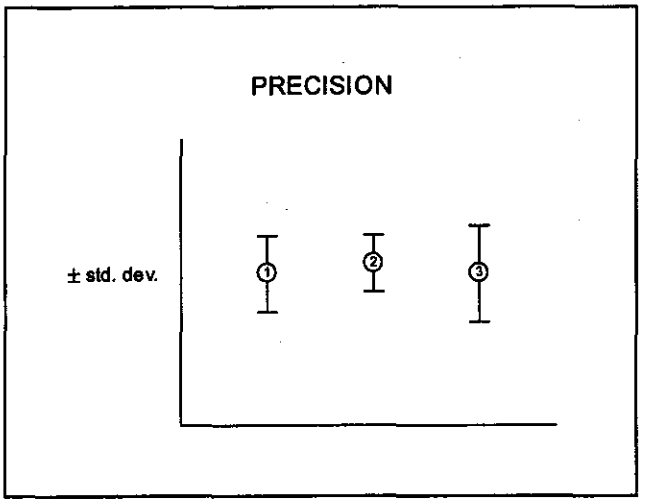

Figure 3. Graph illustrating the precision of each method for a given measure using means and standard deviations.

Step 4 (Bias and Accuracy). Although not treated here, bias and accuracy are often determined for various components of bioassessment, such as laboratory subsampling and taxonomic identification. In the laboratory setting, it is relatively easy to determine the accuracy of sorting as well as the bias of sorters and taxonomists through the implementation of simple QA/QC plans. For example, after organisms are identified, they can be sent to another independent taxonomist for confirmation of taxonomic identifications. Bias would be a consistent mis-identification that could be ascertained through QC checks. Additionally, after a sample is sorted, an assigned QC officer can resort the sample to determine the percentage of "missed" specimens. Bias might be in always missing midges, or very small specimens, for example. While both bias and accuracy can be determined at various stages in the bioassessment process, it is often unclear how these characteristics can be calculated for the overall assessment where "truth" is determined by an impairment threshold.

Step 5 (Site assessment). The fifth and final step is to evaluate the influence of the performance characteristics on making a correct assessment. By examining the performance characteristics of the three methods in relation to a fixed impairment threshold, we can determine a level of confidence in each index value (Figure 4.) In this example, we use the three methods at one site and their measurement precision and discriminatory efficiency to illustrate how a site assessed as impaired by all three might be evaluated. For Method 1, we have high discrimination efficiency and moderate precision. Because the value of the site and its error bars (precision) fall below the impairment threshold, we have a high level of confidence that this site is in fact impaired. Method 3 is the least precise and least discriminatory, and thus, our confidence that this site is impaired is low. For Method 2, which has the highest precision, the site would likely be assessed as impaired. However, the discrimination efficiency of Method 2 indicates that we only assess between 50 and 75% of our sites correctly. In this case, sites that are slightly

impaired, i.e., near the threshold, would benefit from additional, supplemental data (e.g., complementary water or habitat quality data, a follow-up biosurvey, etc.).

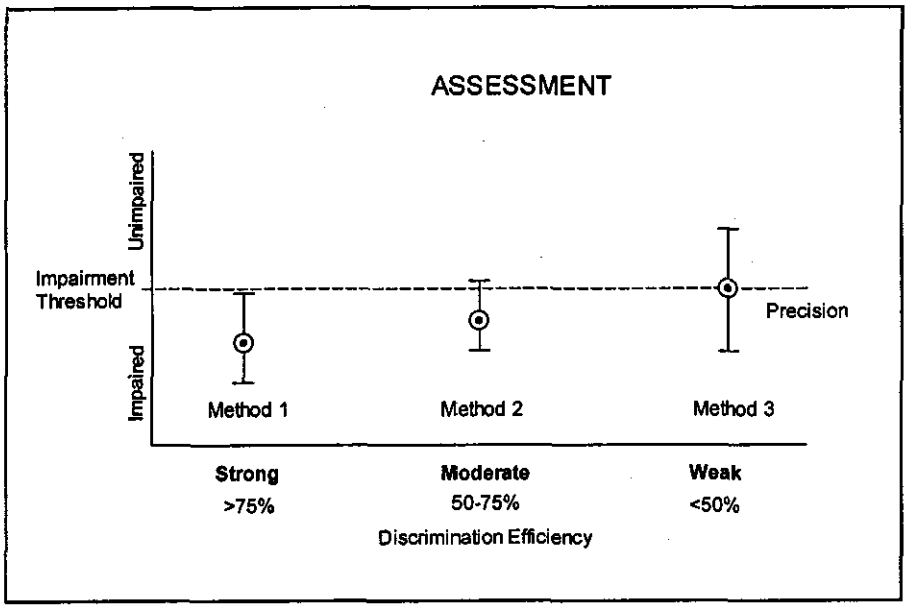

Figure 4. Graph illustrating the ability of a method to yield a correct assessment based on a combination of precision and sensitivity (or discriminatory efficiency) and the value of the assessed site in relation to the impairment threshold.

Comparison of CSBP and SNARL Methods

Due to the paucity of data provided to us at the time of this report, only one performance characteristic, method precision (i.e., measurement error within a site), could be evaluated for two candidate methods, CSBP and SNARL. It should be mentioned, however, that there are a few caveats with this precision comparison. First, the populations sampled using each method were quite different from each other. The SNARL method sampled primarily high elevation streams (5,000-7,500 feet) in the Sierra Nevada Mountain Range, whereas the CSBP collected samples across a wide variety of locations and across multiple ecoregions, primarily in lower elevation streams. Because variability is a combination of both natural variability and measurement error, greater variability does not necessarily imply greater measurement error when two distinct populations are sampled. Consequently, a side-by-side comparison would help to minimize the influence of natural variability and allow a more accurate comparison of measurement error between these two methods. Secondly, the net mesh size used in the SNARL method and CSBP is very different, 250 µm and 500 µm respectively. This difference can introduce a good deal of variability in the results because of organism selectivity (bias) associated with each method. However, it is uncertain as to whether this would significantly affect the comparison of precision estimates and requires further research. Thirdly, it is uncertain what types of sites (i.e., impacted, reference, etc.) and in what proportions these types of sites make up the datasets that were analyzed. Different types of sites may introduce more

natural variability among replicates than others, and thus, could affect the precision estimate for that method. With this simple comparison, we provided estimates that the SNARL method may be more precise, except for the caveats cited previously. We do not know if the higher precision is either ecologically or statistically significant, and if so, whether cost implications justify the increased precision. However, this exercise demonstrates one of the steps necessary for adequately comparing methods.

As a focus of this methods comparison, sampling precision was evaluated using the root mean square error (RMSE) to measure variability. RMSE, also called the standard error of estimate, is an estimate of the standard deviation of a population of observations. The RMSE was calculated for eight common biological metrics used by both the CSBP and SNARL methods. RMSEs ranged from 0.72 to 11.78 for CSBP and from 1.03 to 7.78 for SNARL for the eight metrics (Table 2). The RMSE was lower for CSBP than for SNARL for the richness metrics (i.e., total number of taxa, EPT taxa, and components of the EPT – Ephemeroptera, Plecoptera, and Trichoptera). However, the reverse was true for the composition and tolerance metrics (i.e., %EPT, %Tolerant organisms, and %Dominance). The relative spread of the values for the two methods is illustrated when the mean and standard deviation for each metric are graphed (Figure 5). The SNARL method recorded a higher mean for each metric. However, the standard deviation was generally lower for the CSBP method.

Table 2. Comparison of ANOVA results between CSBP and SNARL methods.

Metric	CSBP			SNARL			RPD RMSE	Difference CV
	RMSE	*MEAN*	*CV*	*RMSE*	*MEAN*	*CV*		
Total Number of Taxa	3.21	16.72	19.23	3.76	27.09	13.9	15	5.4
EPT Taxa	1.59	6.45	24.71	1.85	11.1	16.67	15	8.04
Ephemeroptera Taxa	0.72	2.97	24.44	1.03	6.77	15.26	35	9.18
Plecoptera Taxa	1.09	2.83	38.54	1.26	4.33	28.99	10	9.55
Trichoptera Taxa	1	2.82	35.65	1.16	5.73	20.22	15	15.43
%EPT	11.29	42.21	26.76	9.5	63.32	15	17	11.76
% Tolerant Organisms	11.24	22.37	50.23	5.4	11.32	47.7	70	2.53
%Dominance	11.78	43.45	27.12	7.78	36.16	21.52	41	5.6

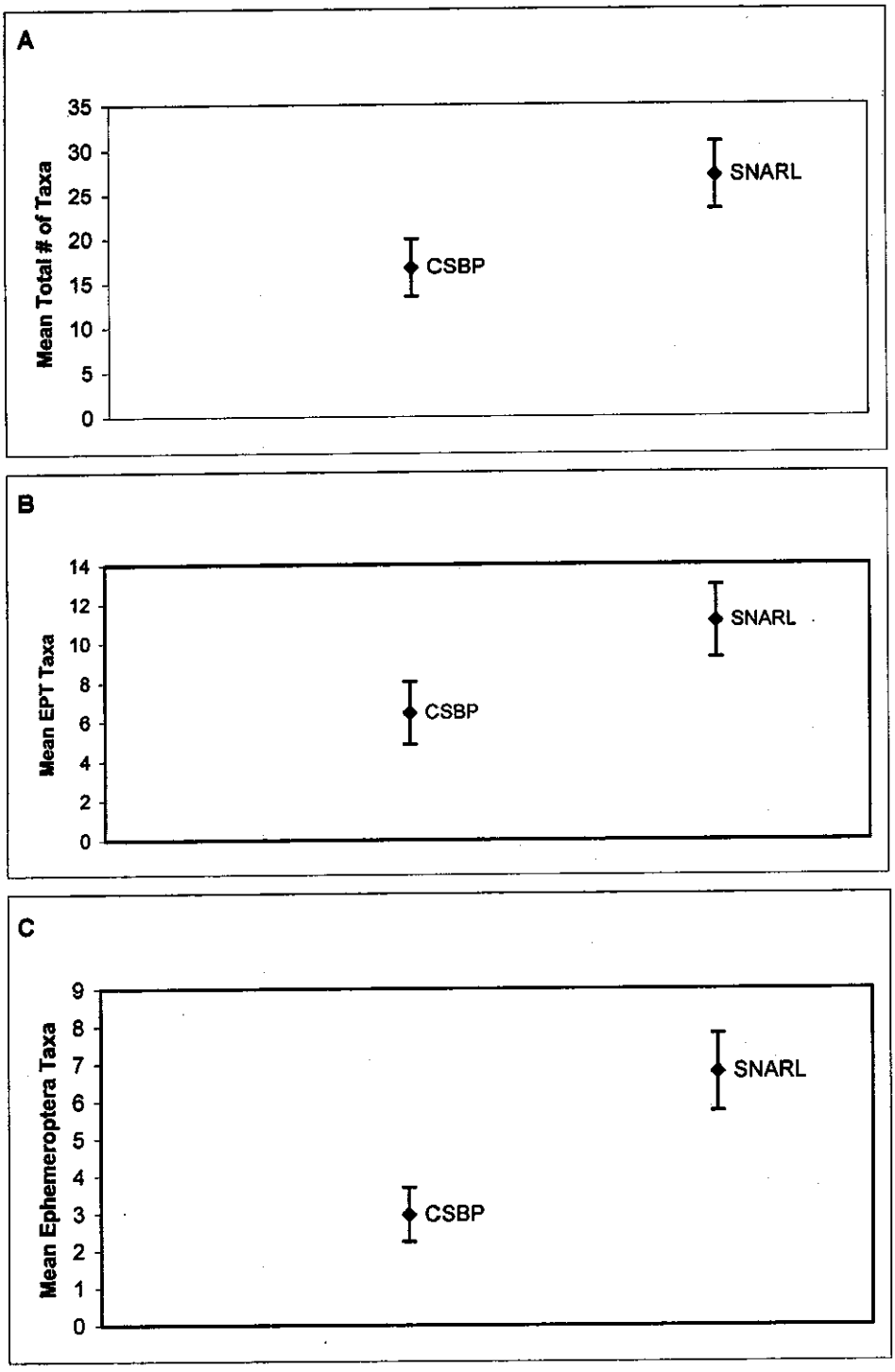

Figure 5. Comparison of precision (mean ± 1 s.d.) between the CSBP and SNARL methods for representative biological metrics for richness (graphs a-e), composition (f-g), and tolerance (g-h).

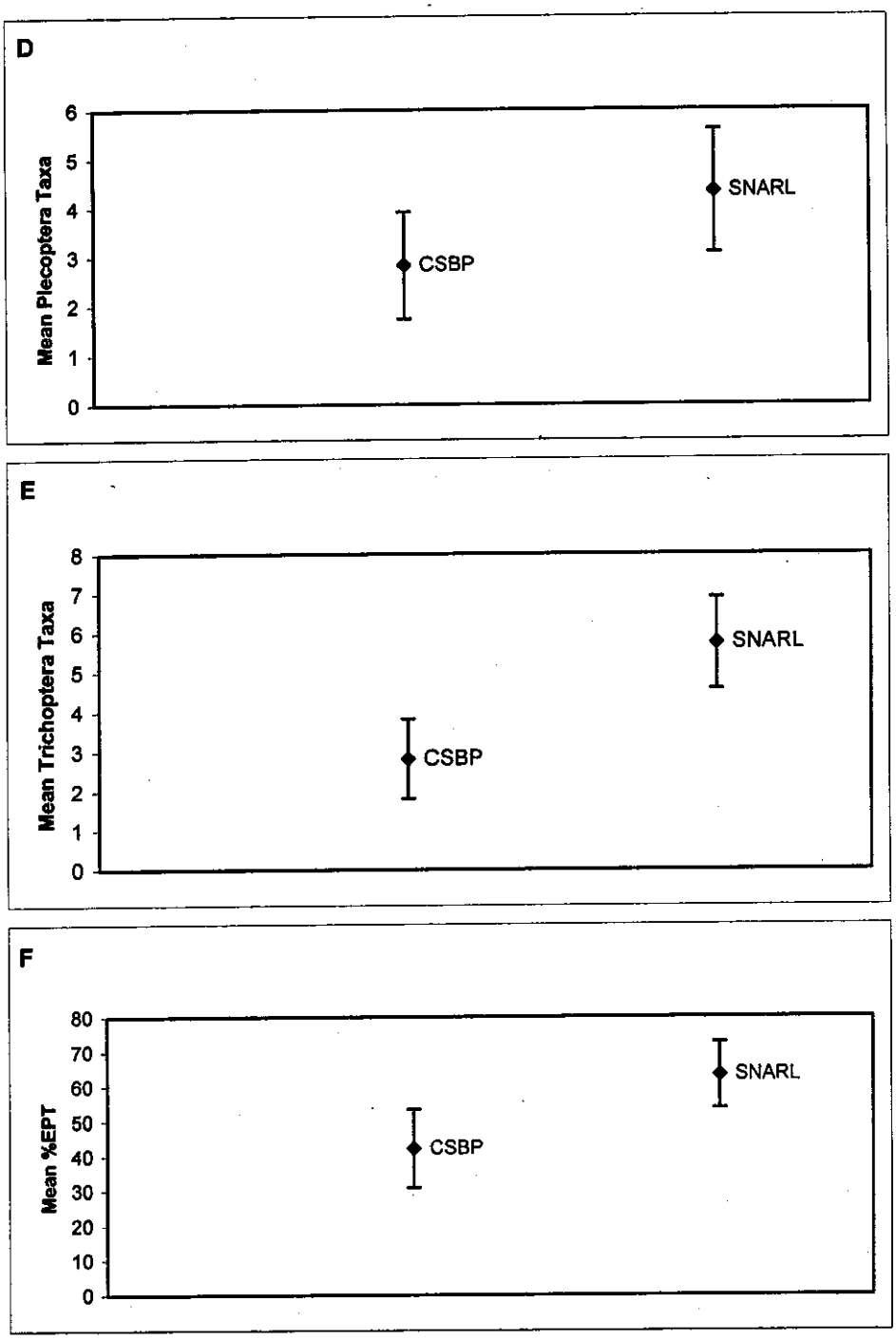

Figure 5 (continued). Comparison of precision (mean ± 1 s.d.) between the CSBP and SNARL methods for representative biological metrics for richness (graphs a-e), composition (f-g), and tolerance (g-h).

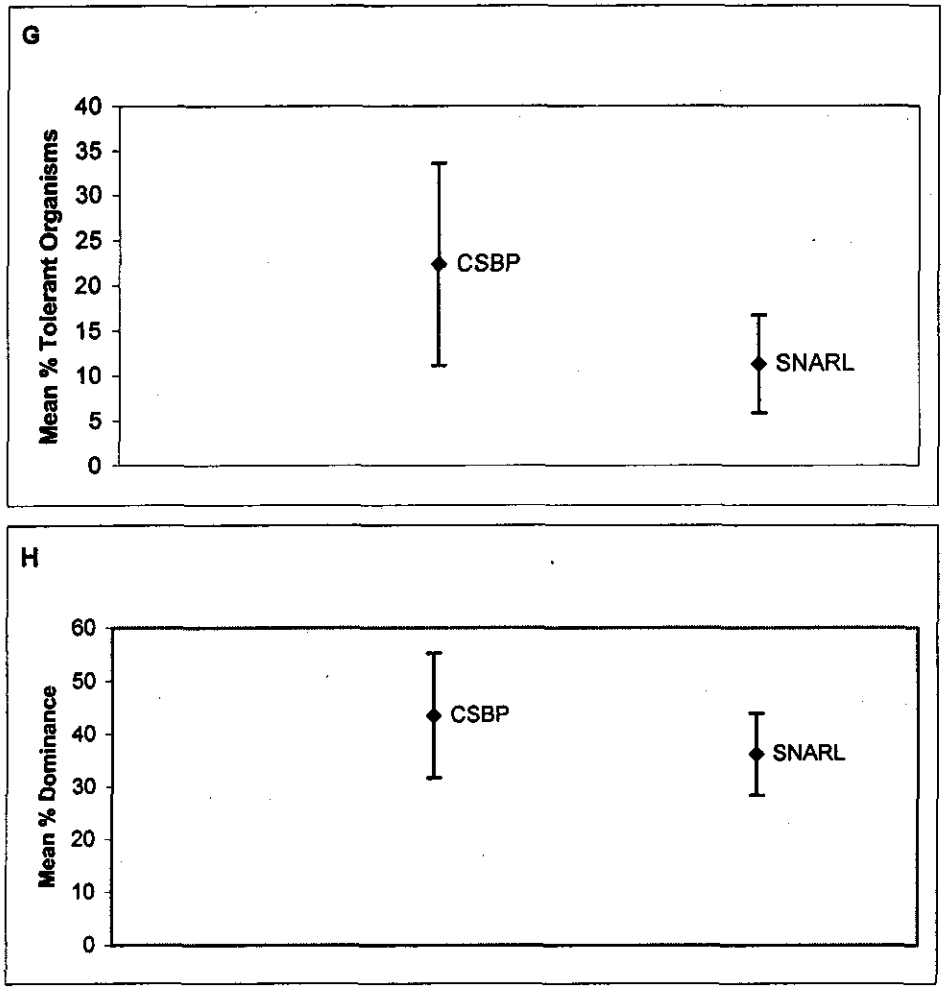

Figure 5. Comparison of precision (mean ± 1 s.d.) between the CSBP and SNARL methods for representative biological metrics for richness (graphs a-e), composition (f-g), and tolerance (g-h).

Because various components of these methods were vastly different, the coefficient of variation (CV) was calculated to evaluate the variation adjusted for the mean of each metric. The values of the CV were lower for the SNARL method for all eight metrics. However, because there are no calibrated indexes and impairment thresholds established for these methods, we do not know whether the lower CVs for the SNARL are ecologically significant. As a point of discussion, we can draw from our DQO 1 established as part of our hypothetical example. Although the difference in the CV values between the two methods never exceeded 20%, the majority of the individual metrics for each method did exceed 20% (our initial DQO from the hypothetical example). It should be noted that our DQO 1 is established for a calibrated index and not individual metrics. However, the precision for overall index scores are often more precise than for individual metrics (Stribling et al., in review). For example, Stribling et al. found that for

three separate data sets (Maryland DNR, Prince George's County DER, Wyoming DEQ), the overall index score was consistently more precise than for any of the individual metrics, with one exception. Still, overall index precision cannot be easily speculated given the precision of only a few individual metrics. One critical step would be to develop a biological index for each method, and then compare the overall index precision to get a better understanding of which method is more precise. Depending on the outcome, another critical step would be to calculate a power cost efficiency (PCE) analysis (Barbour and Gerritsen 1996) to evaluate the cost implications of the added precision that might be realized from a more rigorous method.

Conclusions

From this simple comparison study with an incomplete data set, the results are inconclusive about the performance of the CSBP method vis-à-vis the SNARL method, and vice versa. However, Dr. David Herbst of the University of California Sierra Nevada Aquatic Research Laboratory has conducted a side-by-side comparison of these two methods along with a third method, USFS, also referred to as RIVPACS. Data analyses are ongoing and the results should be available near the beginning of 2003 (Herbst and Silldorff 2003). Furthermore, CDFG-ABL is currently conducting a side-by-side comparison of the CSBP, RIVPACS, and USEPA EMAP methods using a slightly larger dataset (approximately 240 sites from all over the state). This study is ongoing and the results are not yet available. We recommend that the results of these comparisons be sought and considered by anyone who is interested in the performance characteristics of these methods. In order to foster a valid scientific comparison of the performance and cost-effectiveness of a method, or multiple methods, several pieces of information must be made available:

- a data set of both known degraded and qualified reference conditions
- repeated samples (replicates or duplicates) to calculate the standard deviation from the mean (from both degraded and reference sites)
- DQOs from the QA/QC plan
- costs associated with the different levels of subsampling (for cost efficiency calculations)
- number of subsamples required to detect differences in the data
- discrimination (i.e., power) that is required to detect differences in the data.

A case example of how the Florida Department of Environmental Protection (DEP) examined the performance characteristics of their collection and assessment methods can be found in Appendix C.

3.3 Integrating Disparate Programs

The integration of discrete programs is primarily dependent on the results of the performance characteristic characterization. If it is evident that the quality of data is comparable among programs, then it is possible to integrate results of assessments among programs. Essentially, it is the quality and detail of data that defines the level of integration of disparate programs.

However, there are several elements that widely differ among the programs and may hinder the integration of actual biological data:

- Mesh size that retains/excludes certain organisms
- Level of subsampling & enumeration
- Sampling area and method
- Taxonomic resolution

Although there is a certain amount of disparity among all the candidate programs in each of these elements, most will likely allow a certain level of integration provided that the DQOs yield comparable data. This could ultimately lead to an integrated set of reference sites, which could be used to characterize reference conditions all throughout California. The features or attributes proffered by these candidate programs for integrating ecological information include:

- Candidate reference sites
- Identification of impaired sites or sites at risk
- Characterization of watersheds and stream reaches
- Quality ratings for water resource management
- Taxonomic distribution list and statewide records

3.4 Recent Initiatives in Bioassessment

A few recent and notable bioassessment initiatives in California include the development of 1) an Inter-laboratory Quality Assurance/Quality Control (QA/QC) Program, 2) the CalEDAS Database, 3) an Index of Biological Integrity (IBI), and 4) a standardized methodology of reference site selection for wadeable streams.

3.4.1 Inter-laboratory Quality Assurance/ Quality Control Program

Bioassessment data are being collected in California at a rapidly increasing rate. Since there will be much more taxonomic identification work than can be managed by a single laboratory, the standardization of laboratory techniques and taxonomic data is critical to sharing data analyzed by different laboratories.

In 1999, DFG-ABL instituted an inter-laboratory quality assurance/quality control (QA/QC) program for taxonomic identification. There are two main goals of an external QA/QC program, 1) to assess the quality of taxonomic data and its impacts on bioassessment metrics and 2) to assure that taxonomic data from different sources can be included in a common database. The QA/QC procedures are designed to help ensure compatibility of data among different macroinvertebrate laboratories and to ensure taxonomic consistency and high quality of taxonomy for all laboratories involved.

The DFG QA/QC procedure compares each taxonomic identification and groups of all discrepancies into two categories, 1) identification discrepancies, and 2) relative taxonomic effort discrepancies. Identification discrepancies are instances in which the two laboratories do

not agree on the identification of a particular taxon. Relative taxonomic effort discrepancies are cases in which the original taxonomic determination is less or more precise than that of the QC laboratory. Although these differences in taxonomic effort are not as obvious as disagreements over identification, they can have a very strong impact on metrics calculations and often make up the majority of differences in the taxa lists of different laboratories. In addition to taxonomic discrepancies, the procedure evaluates differences in enumeration by the two laboratories. Small differences are a common occurrence in QC analysis and should not be a cause for concern unless the discrepancies are large.

The current external QA/QC program only involves assessment of taxonomy and enumeration; it does not include checks of subsampling procedures. A QA/QC protocol for sub-samples may be included in future programs, but at this point, it is considered the internal responsibility of each laboratory.

3.4.2 CalEDAS Database Development

As bioassessment has become increasingly more included in California's water quality management programs, the amount of biological community data and associated physical and chemical data collected around the state has grown at a rapid pace. The benefits of being able to manage and manipulate this data in a consistent way are immense; these data will ultimately provide the basis for fully exploiting bioassessment's potential as a water quality management tool.

Since 1998, DFG-ABL has been developing a Microsoft Access® database for managing its own bioassessment datasets. CalEDAS is a modification of the EDAS® (Environmental Data Analysis System), which was developed by Tetra Tech, Inc. for the USEPA. The main taxonomic table in CalEDAS (the Benthic Master Taxa List) is based on the CAMLnet List of Standard Taxonomic Effort. DFG-ABL uses CalEDAS in all laboratory aspects of its bioassessment program (from sample log tracking to data analysis) and is currently updating the database with older datasets produced in MS Excel spreadsheets. Although the DFG does not provide technical support for this database, the ABL is willing to share working copies of the database in its current form with other laboratories.

3.4.3 Standardization of Reference Site Selection for Wadeable Streams

Variation is fundamental to biological communities and measures of biotic integrity based on these communities vary accordingly. Most bioassessment techniques account for variation through the use of reference sites. Since practical considerations limit our ability to find "undisturbed" or even "minimally disturbed" sites, most reference condition approaches seek to identify a compromise, the "least disturbed condition". Once candidate reference reaches have been identified, these can be used to characterize the range of biotic conditions expected for minimally disturbed sites.

For both the Russian River and San Diego IBI, the relatively subjective technique of "best professional judgment" (BPJ) and some semi-quantitative selection criteria were used for

selecting reference sites. These early studies have demonstrated the need for a framework for interpreting community data that can be applied in a standardized manner throughout the state.

At the February 2001 Western EMAP Reference Condition workshop in Phoenix, AZ, the workgroup drafted an approach to identifying reference sites that provides a strong framework for standardizing reference site methodologies. In May 2000, the DFG and Dr. David Herbst of SNARL collaborated to develop a quantitative approach to selecting reference sites in California. The basic approach uses landscape analysis tools (i.e., Geographic Information Systems, GIS) to identify areas within the region of interest that have minimal impacts (target areas). Field reconnaissance is then used to identify suitable stream reaches within these target areas, resulting in a pool of reference sites for the region of interest. The procedure consists of the following five steps:

1. Preliminary Organization and Prioritization
   a. Identify the region of interest and classes of streams to be evaluated
   b. Develop a list of land use disturbances of interest

2. Use GIS to Select Areas with Minimal Impact
   a. Divide the region of interest into areas that will serve as the basic reporting units of GIS analysis
   b. Summarize potential land use impacts for each area
   c. Determine impact scores using statistical properties of their distributions
   d. Use impact scores to identify regions with minimal disturbance: target areas

3. Ground Truthing
   a. Stage I– rapid reconnaissance.
   b. Stage II–identify ownership and obtain access permission.
   c. Stage III–intensive habitat scoring and selection of reference sites for sampling.

4. Sampling of Biotic Communities
   a. Sample a subset of the pool of reference sites for benthic invertebrates and analyze the data to define the range of biological metric values in the pool of reference sites.
   b. Reference sites may be sampled for other measures of stream or riparian health (e.g. fish/algal communities, water column chemistry, toxicity, etc.)

5. Iterative Refinement of the Reference Pool
   a. Refine the reference site pool based on biological, chemical and physical habitat data collected at each site.
   b. Eliminate or add candidate reference sites as land use changes occur.

This quantitative approach to selecting reference sites will be used by SNARL for developing an IBI in the eastern Sierras for the Lahontan Regional Board and by ABL for all other regions of California. For all past projects, where BPJ was used to select reference sites, this approach will be applied to assess the accuracy of BPJ selections. Currently, the ABL is using this quantitative approach for selecting reference sites in the Sierra Nevada Foothills Ecoregion and Central

Valley streams for the Central Valley Regional Board and the Sacramento River Watershed Program.

3.4.4 Development of an Index of Biological Integrity (IBI) for California

While there are many potential methods for evaluating biotic condition from community data, most approaches in the United States use a combination of multimetric and multivariate techniques. In multimetric techniques, a set of biological measurements ("metrics"), each representing a different aspect of the community data, is calculated for each site. An overall site score is calculated as the sum of individual metric scores. Sites are then ranked according to their scores and classified into groups with "good", "fair" and "poor" water quality. This system of scoring and ranking sites is referred to as an Index of Biotic Integrity (IBI) and is the end point of a multi-metric analytical approach recommended by the EPA for development of biocriteria (Davis and Simon 1995). The original IBI was created for assessment of fish communities (Karr 1981), but was subsequently adapted for BMI communities (Kearns and Karr 1994).

The first demonstration of a California regional IBI was applied to the Russian River watershed in 1999 (Harrington 1999). The Russian River watershed drains the third largest area in California, sustains an important anadromous salmonid population and is subject to a wide range of land uses including a variety of agricultural, timbering and urban development land uses. This demonstration IBI was based on a conceptual model described by the U.S. Environmental Protection Agency for development of numeric biocriteria. Benthic macroinvertebrates (BMI) were collected from 35 reaches within 21 tributary streams and the main stem of the Russian River during the fall 1995 and spring 1996 and 1997 using the CSBP. Although there was no indication of strong seasonal variability in the BMI communities, it was recommended that the index period for the Russian River tributary streams be in the spring. Since the original IBI was developed, samples have been collected annually (1998-2001) from the original sites and some additional locations.

As the Russian River IBI was being developed, DFG began a much larger project for the San Diego Regional Board. After a pilot project conducted on the San Diego River in 1995 and 1996, the San Diego Regional Board contracted DFG to help them incorporate bioassessment into their ambient water quality monitoring program. The initial sampling strategy was designed to gather a baseline of information to support several project goals:

- To include biological information in the San Diego RWQCB's ongoing water quality monitoring programs
- To create a species list of BMIs known from the region
- To establish a biological classification of different stream types in the region
- To identify potential reference sites for the San Diego regional bioassessments
- To determine the best index period for sampling BMI communities
- To select appropriate metrics for southern California stream bioassessments

During 1997 through 2000, data was collected from 93 locations distributed throughout the San Diego region. Most of the initial sampling sites were chosen to supplement chemical data

collected from long-term sampling locations, but some were established as reference sites based on "best professional judgment". In 2001, a new set of sites were chosen and sampled to further establish reference conditions in the San Diego region. The results of this sampling event were combined with the results of earlier sampling events to establish a preliminary IBI for the San Diego region. In July 2002, a final report was presented as a working IBI for the San Diego region.

Data from several sites sampled for the Los Angeles Regional Board were applied to the San Diego IBI with promising results. With additional refinement, the IBI developed for the San Diego region might be appropriately applied to all Southern California and perhaps Central Coastal wadeable streams and rivers. In 2002 and 2003, testing of impaired and potential reference steams will be conducted on data sets developed throughout this region using the CSBP.

The framework for developing an IBI for the Sierra Nevada Foothills Ecoregion and Central Valley streams will be available in 2004 and 2005, respectively. An IBI for wadeable coastal streams in northern California is being developed for the North Coast Regional Board. This IBI should be available in 2004 and will incorporate sites from the Russian River IBI that comply with the new quantitative approach to selecting reference sites, in addition to new sites throughout the region. Since this region extends from the Oregon border to south of San Francisco Bay, sites chosen by the San Francisco Regional Board will be tested and perhaps incorporated into Northern California Coastal IBI.

Chapter 4 INSTITUTIONAL/POLICY CONSIDERATIONS

In order for any state to effectively implement a bioassessment program, it is important to consider not only the technical issues, but the state's legal and policy framework as well. For example, some states rely on "technical addenda" to their water quality control plans that contain sampling protocols and/or numeric biocriteria that can be updated with relative efficiency as new information becomes available, but unfortunately, this may not be an option for California at the present time.

4.1 California's Regulatory Framework

Pursuant to its Porter-Cologne Water Quality Control Act (California Water Code Section 13000 *et seq.*), the State of California relies on a State Water Resources Control Board (SWRCB) and nine Regional Water Quality Control Boards (RWQCBs) to implement water quality regulatory programs. In general, the SWRCB adopts statewide plans and policies, and the RWQCBs adopt and enforce region-specific standards. The RWQCBs may adopt standards for regional or localized areas that are more protective of water quality than required by the SWRCB's plans and policies, but the RWQCBs may not adopt standards that are less protective than those adopted by the SWRCB.

Given the large size and diversity of California, and the de-centralized framework for adoption of region-specific standards, it is anticipated that the implementation of bioassessment will need to be appropriately tailored to the regional setting, and biocriteria will need to be developed and, over time, adopted by the RWQCBs.

4.2 California's Standard-Setting Process

The water quality standards setting process in California appears to be more rigorous and time-consuming than in many other states, and once standards are incorporated into a water quality control plan, or "basin plan" (BP), those standards cannot be modified in any way without repeating the entire standard-setting process.

California law also requires that the specific sampling protocols, supporting data, and methods for calculating compliance with standards be specified at the time that standards are adopted. This makes it impossible to modify the sampling methods (for example, if more cost-effective methods become available), or to modify biocriteria (for example, as more data becomes available regarding natural variability) without going through the entire standard-setting process. The rigidity of the standard-setting process will create some key hurdles to implementing biocriteria in California.

Given the difficulty of amending water quality standards in California, the state needs to be relatively certain that any biocriteria, whether narrative or numeric, are both protective of water quality and beneficial uses of water, and also accurate enough so that "false positives" will not occur to any great extent. For example, once biocriteria are adopted, streams found to violate

those criteria could be listed as "impaired," triggering requirements for mandatory development of Total Maximum Daily Loads (TMDLs).

Options for California include the following:

1. Wait many years before incorporating any numeric or narrative biocriteria into the BPs.
   This would be the most conservative approach to avoiding "false positives," but would abdicate the state's responsibility under the Clean Water Act to protect and restore the biological integrity of the state's waters. While the USEPA currently does not require that biocriteria be included in state water quality control plans, this may become a requirement in the not distant future, and the state would be wise to diligently proceed with developing a bioassessment program even if this option is relied upon in the short-term.

2. Focus on narrative biocriteria.
   The USEPA has prepared guidance to assist the states in developing narrative biocriteria (USEPA 1992). California could potentially proceed with refining aquatic life uses and developing narrative biocriteria, without specifying mandatory methods or numeric criteria. The numeric information to support decisions based on the narrative criteria could be developed, specified, and refined over time, outside of the water quality control plans. While this may be the best approach available to the SWRCB and RWQCBs at this time, refining the aquatic life uses and developing narrative biocriteria would require significant resources, which the agency does not appear to have available at this time.

3. Revise state law(s) to allow technical addenda outside of the BPs.
   Biological systems are more variable than the chemical and physical properties that were the basis of California's water quality regulatory scheme. In recognizing this fact, California could consider revisions to state law(s) to allow numeric biocriteria to be developed and continually updated, outside of the normal water quality standard-setting process, in order to reflect new biological information. Such an approach would apparently require legislation at the state level.

4.3 Budgetary and Other Considerations

At this time, there appears to be little statewide, programmatic funding for a concerted bioassessment program in California. The SWRCB has no staff positions dedicated to bioassessment. Efforts to implement bioassessment in California have primarily been led by the RWQCBs, using a variety of ephemeral funding sources.

In order to effectively implement a bioassessment program in California, it should be recognized that there are common resource needs throughout the state. Some of the key resource needs are summarized below:

Statewide Coordination

The SWRCB should strive to establish an institutional infrastructure to facilitate on-going coordination of the many different bioassessment efforts throughout California. This would ideally include at least one full-time staff position at the SWRCB dedicated to coordinating

bioassessment programs at the SWRCB and RWQCBs, as well as funding for bringing together relevant experts, on a regular basis, to address issues related to taxonomy, tolerance values, reference site selection, standard-setting, etc.

Reference Site Selection

In order for the state's bioassessment program to be most meaningful and defensible, the state should strive toward objective procedures for selecting reference sites, where possible. This would include the use of Geographic Information Systems (GIS) to allow identification and selection of "minimally-impaired" reference sites based on objective criteria. Staff experienced with the use of GIS are needed, as well as funding for the computer hardware and software needed to perform GIS analyses. Where minimally impaired reference sites are lacking, funding would be needed to review historic literature and convene panels of experts to develop reference conditions based on best professional judgment.

Refinement of Tolerance Values

A fundamental tenet of bioassessment is that some organisms are tolerant to certain types of stress or pollution, while others are very sensitive to stress or pollution. For bioassessment to be most powerful, the tolerance values assigned to each class of organisms (whether species, genus, family, etc.) need to be meaningful and should be based on objective evidence. There is a need for research to refine tolerance values for some classes of organisms found in California.

Determination of Index Period

The "index period" refers to the time of year or "season" that bioassessment samples are collected. In order for data to be comparable between years, it is important that samples be collected in the same index period. However, in a state as large and diverse as California, it is probable that the most appropriate index period will vary from region to region. A degree-day model could be developed to assist in the selection and refinement of the most appropriate index period for the various regions of California.

Chapter 5 RECOMMENDATIONS

It is beneficial to the State of California and its affiliated agencies and environmental interest groups to consider standardization and methods consistency of bioassessment and biomonitoring throughout its vast watershed network. The benefits include data sharing, conformity in evaluating ecological status, implementation of scientifically based management decisions, maximizing limited technical resources, statewide calibration of biological indicators, and broadscale application and linkage to regulatory activities. From a technical standpoint, the endorsement of consistent methods will provide development of a statewide reference condition and indicator calibration that will, in turn, provide cost efficiencies and enhance program effectiveness for watershed protection and restoration goal-setting.

Our recommendations are structured into areas such as (1) candidate methods, (2) replication, (3) reference condition, (4) calibration of biological indicators, (5) physical habitat assessment, (6) database management, and (7) institutional/policy issues.

5.1 Candidate Methods

Of the five candidate methods, the CSBP is the most widely used throughout the state. Data from multiple collections at more than 2500 sites are available from streams throughout California. A method similar in performance to the CSBP is that developed by SNARL. While the sampling precision of the SNARL method is somewhat more robust than that of the CSBP, both methods are similar enough in results to be considered equally effective in assessing biological condition. Both methods, and those of most of the other candidate programs, focus on cobble substrate (i.e., riffle habitat) as the primary habitat type for collection. It is generally thought by stream ecologists that the riffle habitat is the most productive habitat, where present, and that the macroinvertebrate assemblage of the riffle or other cobble substrate contains the most diverse and sensitive fauna with respect to water quality. Both EMAP and NAWQA methods have endorsed a more multihabitat approach that accounts for techniques that are more representative of stream reach characteristics, and not just site-specific conditions relevant to a single riffle. We recommend that a multihabitat feature be added to the methods to enable a more pertinent evaluation of multiple stressors, such as both chemical (water quality) and non-chemical (habitat-induced) perturbations. Adding a multihabitat component may be in the form of the EMAP method or the NAWQA Qualitative Multihabitat method, or even a variation of the CSBP method to enable advancement to current methodologies rather than radical modifications. Current collaborative efforts between CSBP and EMAP lend themselves to adopting an EMAP sampling methodology. The important aspect of method development is to maintain continuity and data integrity of existing ecological data as methods refinement is adopted into a water resource program. This can be done, in the simplest of techniques, by documenting the biological condition of sites and prioritizing along a disturbance gradient. Changes in condition from one method to another are evaluated for influential factors related to methods changes. Specific considerations for adopting a multihabitat approach are to provide a framework for characterizing regional reference conditions that are parceled out from a statewide network of candidate reference sites, and to enable a characterization of natural variability associated with a

composite of habitat types expected to be present in California streams.

5.2 Replication

For bioassessment purposes, replication is important to identify the performance characteristics, namely sampling precision, of a method, and to strengthen a judgment of the biological condition of a site where uncertainty exists from the results. Most state water resource agencies follow a sequential decision process whereby a composited sample (i.e., composited from a variety of habitats or microhabitats within a habitat) from a method with known precision is used to assess the biological condition. If the results indicate that the judgment of biological condition may be in error because the precision of the method is insufficient, then additional data or other information is needed to confirm the assessment. Therefore, replication, albeit considered pseudoreplication by most biostatisticians, is needed at sites where judgment of biological condition is contentious or uncertain and also to establish precision estimates of the method and investigators. The collection of replicates as a routine procedure is a good practice, but cost considerations may prevent a wide scale implementation of such a procedure. At a minimum, 10% of collections should be replicated. Furthermore, sites that are likely to be in the intermediate portion of the biological condition gradient (i.e., neither considered of reference caliber nor severely impaired status) would benefit from replication, depending on the precision of the method. The exact number of replicates should be decided by a technical workgroup. Factors to be considered are overall objectives and cost implications. Most states take duplicates (Barbour et al. 1999) because the objective is method precision, and two replicates are all that are needed. A precedent has been established in California for three and five replicates (CSBP and SNARL, respectively) to be taken. Our analyses indicate that the two techniques are relatively similar and that cost implications may be a factor. We recommend that replication be continued in California bioassessments for the purpose of precision estimates. We also support a reduction in replicates to two or three as a compromise between statistical power and cost.

5.3 Reference Condition

Regardless of methods, either the identification of candidate reference sites or the elimination of degraded stream reaches from consideration as reference should be possible from the volume of data acquired from around the state in the various monitoring programs. Compilation of the locations and watersheds that contain candidate reference sites can be used as a basis to conduct a land use characterization that will detail the extent of potential disturbance from human activities. Once these candidate sites are delineated on maps and land use overlays, data gaps should be identified and addressed. Data gaps would also include an identification of the kind of methods and collecting techniques. For this subsequent step, only biological data from consistent methods can be used to avoid introducing sampling bias in the results. It may be necessary to schedule some targeted sampling to procure the comparable data. The reference condition is the expected or best idea of the structure and function of the aquatic community, and it also reflects a partitioning of the natural variability into homogeneous classes or groups. This analysis is usually done via multivariate analyses. The DFG-ABL and SNARL are collaborating in an effort to identify and characterize reference sites in California. This effort is extremely important for establishing a benchmark for bioassessments. We recommend that the SWRCB interact closely with DFG-ABL and SNARL and consider evaluating its extensive ecological

database to proceed with characterizing reference conditions.

5.4 Calibration of Biological Indicators

Through the endorsement of a statewide database (i.e., CCAMP), SWRCB is compiling all available and viable biological data. The centralization of biological data through this process will provide a means to reconcile differences in certain technical issues, such as sampling and sample processing documentation practices, taxonomic discrepancies, and metric or biological attributes used in different indices. Of particular interest to calibrating a statewide indicator is the CSBP data, which comprise over 8000 data points. The refinement of existing biological indicators can be done using this comprehensive data source. Using a standard of lowest common denominator for methods and level of taxonomy, and following upon the reference condition development, a benthic macroinvertebrate indicator could be developed for use in assessing biological condition and in producing restoration goals for impaired streams. The creation of the California Aquatic Macroinvertebrate Laboratory Network (CAMLnet) was formed in 1995 as a technical advisory body to facilitate the standardization of freshwater macroinvertebrate taxonomy and laboratory procedures. We recommend that the combination of the central database and CAMLnet be used to provide California with a consistent and standard framework for calibrating biological indicators for use on a statewide basis.

5.5 Physical Habitat Assessment

While conducting physical habitat assessments in conjunction with biological assessments is an important feature to any bioassessment program, it is not within the scope of this document to develop any recommendations in regards to physical habitat assessment methods currently used by the candidate programs. It should be noted, however, that further refinements to current physical habitat assessment methods are being explored.

5.6 Database Management

While the CalEDAS database model currently used by DFG works well at the laboratory scale, it will not able to store all the bioassessment data for California. There is, therefore, a strong need for a statewide database of bioassessment data that can accommodate the large quantity of data that will be produced in California. Ongoing statewide efforts of SWAMP, the SWIM II database and the U.S. EPA's STORET database may eventually meet this need, but neither of these is currently ready to handle the bioassessment data. There are currently no provisions for creating a repository for all California bioassessment data. Once a common database is agreed upon (i.e., SWIM II, SWAMP), it is our recommendation that the SWRCB consider appointing a full-time employee to manage the database and provide technical support to database users throughout the State.

5.7 Institutional/Policy Issues

The State of California should decide among the available options for effectively incorporating bioassessment into its water quality regulatory programs (see Section 4.2). Furthermore, the State of California should strive to make funding available for a concerted, statewide bioassessment program. Funding is needed for: (1) establishing a full-time bioassessment coordinator at the SWRCB; (2) ensuring on-going bioassessment sampling and analysis at the RWQCBs; (3) organizing and facilitating workshops where relevant experts can address issues related to taxonomy, tolerance values, reference site selection, standard-setting, etc.; (4) developing and maintaining the capability to conduct GIS exercises to select reference sites; and (5) meeting other common needs such as contracts for refinement of tolerance values and specification of appropriate index periods (see Section 4.3).

Literature Cited

Barbour, M.T. 1997. The re-invention of biological assessment in the U.S. *Human and Ecological Risk Assessment.* 3(6):933-940.

Barbour, M.T. and J. Gerritsen. 1996. Subsampling of benthic samples: A defense of the fixed-count methods. *Journal of the North American Benthological Society.* 15(3):386-391.

Barbour, M.T., J.M. Diamond, C.O. Yoder. 1996a. Biological assessment strategies: Applications and Limitations. Pages 245-270 *in* D.R. Grothe, K.L. Dickson, and D.K. Reed-Judkins (editors). *Whole effluent toxicity testing: An evaluation of methods and prediction of receiving system impacts,* SETAC Press, Pensacola, Florida.

Barbour, M.T., J. Gerritsen, G.E. Griffith, R. Frydenborg, E. McCarron, J.S. White, and M.L Bastian. 1996b. A framework for biological criteria for Florida streams using benthic macroinvertebrates. *Journal of the North American Benthological Society.* 15(2): 185-211.

Barbour, M.T., J. Gerritsen, and J.S. White. 1996c. Development of the stream condition index (SCI) for Florida. Prepared for Florida Department of Environmental Protection, Tallahassee, Florida.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish.* Second Edition. U.S. Environmental Protection Agency; Office of Water; Washington, D.C. EPA 481-B-99-002.

Davis, W.S. 1995. Biological assessment and criteria: Building on the past. Pages 15-29 *in* W.S. Davis and T.P. Simon (editors). 1995. *Biological assessment and criteria: Tools for water resource planning and decision making.* Lewis Publishers, Boca Raton, Florida.

Davis, W.S., B.D. Snyder, J.B. Stribling, and C. Stoughton. 1996. *Summary of State biological assessment programs for streams and rivers.* U.S. Environmental Protection Agency, Office of Planning, Policy, and Evaluation, Washington, D.C. EPA 230

Diamond, J.M., M.T. Barbour, and J.B. Stribling. 1996. Characterizing and comparing bioassessment methods and their results: A perspective. *Journal of the North American Benthological Society.* 15:713-727.

Harrington, J. M. 1999. California Stream Bioassessment Procedure. California Department of Fish and Game, Aquatic Bioassessment Laboratory. Rancho Cordova, Ca.

Herbst, D.B. 2002a. *Biomonitoring on the Upper Truckee River using aquatic macroinvertebrates: baseline data for 1998-2000.* Report to the Lahontan Regional Water Quality Control Board.

Herbst, D.B. 2002b. *Bioassessment monitoring of acid mine drainage impacts in streams of the Leviathan Mine watershed for Spring and Fall 2000.* Report to the US Forest Service, Humboldt-Toiyabe National Forest.

Herbst, D.B. 2002c. *Development of biological water quality targets for assessment of total maximum daily load (TMDL) of sediment in the Squaw Creek watershed (Placer County, CA).* Report to the Lahontan Water Quality Control Board.

Intergovernmental Task Force on Monitoring Water Quality (ITFM). 1995. *The strategy for improving water-quality monitoring in the United States: Final report of the Intergovernmental Task Force on Monitoring Water Quality.* Technical appendixes. U.S. Geological Survey, Reston, Virginia.

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. *Fisheries* 66:21-27.

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

Klemm, D.J. and J.M. Lazorchak. 1995. *Environmental monitoring and assessment program — surface waters: Field operations and methods for measuring the ecological conditions of wadeable streams.* Environmental Monitoring Systems Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio. EPA/620/R-94/004.

Klemm, D.J., P.A. Lewis, F. Fulk, and J.M. Lazorchak. 1990. Macroinvertebrate field and laboratory methods for evaluating the biological integrity of surface waters. *Environmental monitoring and assessment program — surface waters: Field operations and methods for measuring the ecological conditions of wadeable streams.* Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio. EPA/600/4/90/030.

Lazorchak, J.M., Klemm, D.J., and D.V. Peck (editors) 1998. *Environmental Monitoring and Assessment Program – Surface Waters: Field Operations and Methods for Measuring the Ecological Condition of Wadeable Streams.* EPA/620/R-94/004F. U.S. Environmental Protection Agency, Washington, D.C.

National Research Council (NRC). 2001. *Assessing the TMDL Approach to Water Quality Management.* National Academy Press, Washington, D.C.

National Water Quality Monitoring Council (NWQMC). 2001. *Towards a definition of a performance-based approach to laboratory methods.* Methods and Data Comparability Board, National Water Quality Monitoring Council, Technical Report 01-02, US Geological Survey, Water Information Office, Reston, VA

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. *Rapid bioassessment protocols for use in streams and rivers: Benthic macroinvertebrates and fish.* U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington, D.C. EPA 440-4-89-001.

Simon, T.P. (Ed.). 2002. *Biological response signatures: Patterns in biological indicators for assessing freshwater aquatic assemblages.* CRC Press, Boca Raton, FL.

U.S. Environmental Protection Agency (USEPA). 1992. *Procedures for initiating narrative biological criteria.* Office of Science and Technology, Washington, DC. EPA 822-B-92-002.

USEPA. 1998. *Clean water action plan: Restoring and protecting America's waters.* U.S. Environmental Protection Agency, Office of Water, Washington, D.C. EPA-840-R-98-001.

USEPA. 2000. *Stressor identification guidance document.* U.S. Environmental Protection Agency, Office of Water, Office of Research and Development, Washington, D.C. EPA-822-B-00-025.

USEPA. 2002. *Summary of Biological Assessment Programs and Biocriteria Development for States, Tribes, Territories, and Interstate Commissions - Streams and Wadeable Rivers.* U.S. Environmental Protection Agency, Office of Water, Washington, D.C. DRAFT.

Yoder, C.O. and E.T. Rankin. 1995. Biological response signatures and the area of degradation value: New tools for interpreting multimetric data. Pages 263-286 *in* W.S. Davis and T.P. Simon (editors). 1995. *Biological assessment and criteria: Tools for water resource planning and decision making.* Lewis Publishers, Boca Raton, Florida.

Appendix A

Program/Project Summaries

Appendix A PROGRAM/PROJECT SUMMARIES

This section includes all program/project summary survey responses received from numerous water quality agencies, entities, etc. in California. The survey was sent to dozens of groups across the state; however, only a small proportion responded with complete information while several more groups responded with incomplete information.

Alameda Countywide Clean Water Program - Bioassessment in Alameda County Creeks

The primary focus of this program is to provide watershed characterization, assessment, and trend monitoring using rapid bioassessments. The Alameda Co. Flood Control and Water Conservation District sponsor this program.

Contact Person: Arleen Feng Alameda County PWA, 951 Turner Court, Room 300, Hayward, CA 94545 (510) 670-5575 arleen@acpwa.mail.co.alameda.ca.us

Sampling Method: California Stream Bioassessment Procedure (CSBP) Rapid Bioassessment Protocol (RBP)

Timeline of Sampling: 1998 - Present

Data Availability: 3-4 sites in 1998-2000, 10 in 2001. Watersheds: San Lorenzo Creek (1998-2001); Sausal Creek, Mission Creek, Sabrecat Creek (2001)

Purpose of Bioassessment:

- watershed characterization, assessment, trend monitoring
- NPDES permitting
- ambient water quality monitoring
- establishing reference conditions
- supporting habitat classification
- stream restoration

Description: ACCWP's stormwater management activities include this project to provide understanding of relatively small, highly urbanized watersheds, and develop macroinvertebrate community indicators as tools to assist local municipal watershed managers. Selection of sampling watersheds and sites was based on a) representation of different portions of urbanized Alameda County; b) availability of publicly owned reaches that could be accessed; c) relatively strong opportunities for / interest in restoration activities. Related volunteer monitoring with "streamside" educational protocol is ongoing in Sausal Creek.

California Department of Fish and Game (CDFG) Enforcement Case Program

CDFG investigates situations where reports of activities or pollution events in the surrounding watershed may have adversely impacted stream integrity and/or stability. The California Stream Bioassessment Procedure (CSBP) is used to measure deleterious effects to the biological community resulting from the pollution event.

Contact Person: Angie L. Montalvo (916) 358-4398, CDFG Aquatic Bioassessment Laboratory 2005 Nimbus Road, Rancho Cordova, CA 95670

Sampling Method: California Stream Bioassessment Procedure (CSBP) Rapid Bioassessment Protocol (RBP)

Timeline of Sampling: Wine Creek (May 2000 – Present), East Walker River (Oct 1999-Present), Slug Canyon Creek (Sept 2000), Weber Creek (Mar 2001- Present), Cherokee Creek (Aug 2001), Goose Creek (Apr 2001) Hangtown Creek (Sept 1998), F-1 Line Zone Flood Control Channel (Oct 2001)

Data Availability: Wine Creek (6 sites), East Walker River (39 sites), Slug Canyon Creek (6 sites), Weber Creek (15 sites), Cherokee Creek (3 sites), Goose Creek (3 sites) Hangtown Creek (5 sites), F-1 Line Zone Flood Control Channel (3 sites)

Purpose of Bioassessment: Investigation of pollution spills can be enhanced by measuring the biological and physical/ habitat condition of the receiving waters. Bioassessment can contribute to an enforcement case by documenting injury resulting from a spill of a known pollutant or can stand alone as evidence of a pollution event when chemical analysis is unavailable. Bioassessments are particularly helpful when a pollution event is reported some time after it occurs (thus preventing the collection of timely chemical samples) and when dealing with chemical spills where the substance rapidly dissipates, become diluted or flows as a pulse downstream. Bioassessments may be the only enforcement tool available for physical/habitat destruction, and for spills of substances with low or no toxicity values (sediment, nutrients and elemental metals), but which cause eutrophication or smother benthic communities in the water body.

Description: Under the CDFG 5650 Code Enforcement Case Program, each case is treated as an individual project, which addresses a specific problem of concern. Each project or case is categorized into a classification system based on pollution type: sediment, petroleum, chemical, and other. Benthic macroinvertebrate (BMI) sampling (as well as standard physical habitat, flow, gradient, and ambient chemistry) is conducted in a similar manner for each case (one or more control sites, one site at or near the spill/impacted area, and one or more sites downstream from the spill/impacted area). Often, additional follow-up/ recovery sampling will occur up to 3 years following a pollution event. The results of the bioassessments are used in a court of law to prosecute responsible parties for damages and to recovery departmental costs associated to the case.

California Department of Water Resources (Northern District) Bioassessment Program

The primary objectives of this program are to provide long-term background information, to determine water quality based on types and abundance of individual species, and to monitor impact assessment and FERC relicensing of major DWR hydroelectric facility.

Contact Person: Jerry Boles, Department of Water Resources, 2440 Main Street, Red Bluff, CA 96080 (530) 529-7326 bolesj@water.ca.gov

Sampling Method: DWR professional classic method – multiple sites (three riffles/three cross sections/three samples per cross-section); sort entire sample; identify to genus/species – rely on mathematical metrics as well as biology of insects to determine impacts/water quality.

Timeline of Sampling: 1975-Present

Data Availability: Over 100 sites per year throughout Northern California

Purpose of Bioassessment:

- Support State of CA bioassessment and monitoring
- Assess the biotic condition of surface waters in a highly modified agriculturally influenced ecosystem.
- Determine variability of aquatic organisms in natural and man-made conveyances within the Central Valley.

Description: DWR's long time bioassessment program has historically used classic, professional methods employing a frame to delineate sampling area and collecting downstream from frame in a kick net. Entire sample is sorted and identified. Purposes of program are to provide long-term background information, determine water quality based on types and abundance of individual species, impact assessment, and FERC relicensing of major DWR hydroelectric facility. CSBP sometimes used when we only want cursory assessment of organisms and actual species population information is not that important.

Central Coast Ambient Monitoring Program

The Central Coast Ambient Monitoring Program is conducting watershed characterization monitoring for the Central Coast Regional Water Quality Control Board, using a 5-year rotational strategy. It has been in place since 1998 and covers Santa Cruz, San Benito, Monterey, San Luis Obispo, Santa Barbara, and portions of San Mateo, Santa Clara, and Ventura counties in central California.

Contact Person: Karen Worcester, 81 Higuera Suite 200 San Luis Obispo, CA 93401

Sampling Method: California Stream Bioassessment Procedure (CSBP), Harrington (1996); some sites with protocols modified for low gradient streams

Timeline of Sampling: Ambient monitoring 1998 – Present, 5-year watershed rotational strategy (April – May sampling period); Morro Bay 1993-Present (although they missed a few years); Coastal confluence monitoring 1999-Present.

Data Availability: Morro Bay, 10-15 sites; Pajaro Watershed, 8 sites; Salinas Watershed, 13 sites; Santa Maria Watershed,10 sites; Santa Barbara Coast,12 sites; 28 coastal confluence sites.

Purpose of Bioassessment:

- Conducted as part of ambient assessment along with conventional water quality, sediment chemistry, and tissue bioaccumulation data
- Also evaluation of the effectiveness of BMPs in the Morro Bay watershed

Description: Bioassessment is used in conjunction with other water quality monitoring approaches to characterize condition. Approximately thirty sites are selected along the main stem at the primary discharge point of the watershed, above major tributary inputs, and at the lower ends of major tributaries. For the purposes of site selection a "major tributary" is defined as a watercourse which drains a minimum percentage of the rotation area or which is the major watercourse that drains a Hydrological Area, Hydrological Subarea, or watershed of special concern. Some sites are also located above and below areas of significant human activity, including urban development, agriculture, and point source discharges. Site selection is constrained by site accessibility, since conventional monitoring is done on a monthly basis. Benthic invertebrate sites are located upstream of conventional water quality sites, but out of the immediate influence of bridges. Other sampling activities are conducted at a subset of conventional water quality sites.

Another program component includes monitoring of coastal confluences, where rivers meet the ocean. This monitoring is conducted continuously, rather than in 5-year rotation. Benthic invertebrate samples have been collected at these sites for three years in a row, at approximately thirty sites. Data from this program will be assessed in the near future for its effectiveness at detecting water quality impairment.

The Morro Bay National Monitoring Program has approximately 10 sites, which have been monitored for six years in order to detect changes from implementation of Best Management Practices. Sites are primarily upstream and downstream of cattle exclusion areas.

Central Valley Regional Water Quality Control Board (Sacramento) - Surface Water Ambient Monitoring Program (SWAMP)

The primary focus of this project is to provide insight into the condition of the aquatic community beneficial uses in agriculturally dominated and effluent dominated waterbodies of the Central Valley.

Contact Person: Robert Holmes, 3443 Routier Rd., Ste. A, Sacramento CA 95827-3003 (916) 255-0749 holmesr@rb5s.swrcb.ca.gov

Sampling Method: California Stream Bioassessment Procedure (CSBP) Rapid Bioassessment Protocol (RBP)

Timeline of Sampling: Fall 2000 – Present. Spring & Fall index periods

Data Availability: Approximately 36 sites in the Sacramento River Watershed.

Purpose of Bioassessment:

- Watershed characterization, assessment, trend monitoring
- Research
- Ambient water quality monitoring

Description: The goal of this project is to provide a first step at identification of aquatic life stressors and associated development of ecological indicators in agriculturally dominated and effluent dominated waterbodies in the Central Valley.

Chicarita Creek Bioassessment Study for the Friends of Los Penasquitos Canyon Preserve, Inc.

The purpose of the Chicarita Creek Bioassessment Study is to assess impacts on the Chicarita Creek due to point-source discharge violations.

Contact Person: Andre Macedo, City of San Diego, Environmental Monitoring & Technical Services Division, 14103 Highland Valley Road, Escondido, CA. 92025 (858) 538-8193, amacedo@sandiego.gov

Sampling Method: California Stream Bioassessment Procedure (CSBP) Rapid Bioassessment Protocol (RBP)

Timeline of Sampling: May 2001-Present

Data Availability: 4 sites in the Los Penasquitos Watershed

Purpose of Bioassessment:

- Point-source/incident

Description: The study of this creek is funded by a fine assessed against a discharge violator. There had been no pre-event samples available of this site.

Contra Costa Monitoring and Assessment Plan (CCMAP)

The Contra Costa Monitoring and Assessment Plan (CCMAP) focuses on assessing the biological integrity of watersheds in Contra Costa County (Northern California) to reduce pollutants from entering the municipal separate storm sewer system (MS4) and protect beneficial uses of its water bodies.

Contact Person: Chris Sommers, Contra Costa Clean Water Program, 255 Glacier Dr., Martinez, CA, 94553

Sampling Method: California Stream Bioassessment Protocol (CSBP) (Harrington 1999)

Timeline of Sampling: 2001-Present

Data Availability: Currently 10 sites in Alhambra Creek watershed (16 sq. miles)

Purpose of Bioassessment:

- To comply with the Program's Joint Municipal NPDES Permits;
- To collect baseline information necessary to identify and reduce and/or eliminate stormwater pollutants in the County;
- To prioritize sub-basins within individual watersheds, allowing direction for future studies to determine types and sources of stormwater pollutants adversely affecting beneficial uses;
- To begin identifying specific land uses that may be contributing to decreases in biological integrity;
- To contribute valid data to a Bay/State-wide data set intended to characterize watersheds and possibly create an Index of Biological Integrity (IBI) for the region.

Description: The Contra Costa Monitoring and Assessment Plan (CCMAP) is a long-term strategy, which builds on previous special studies and data collection efforts. CCMAP is designed to assess the conditions of watersheds, water bodies, and water quality within Contra Costa County. CCMAP entails further characterization of watersheds and sub-watersheds, and the development of strategically placed monitoring stations where rapid bioassessment data can provide a valuable screening device to determine where water quality and watershed health are degraded or have the potential for degradation. The Program intends to conduct bioassessments in approximately 6-8 watersheds in the next four years.

California Department of Parks and Recreation Natural Resources Inventory, Monitoring, and Assessment Program (IMAP)

A pilot project began in 2001 for Wilder Ranch State Park near Santa Cruz, where four streams were sampled to assess water quality and the condition of aquatic ecosystems, with an intent that this data would serve as baseline measures for future monitoring.

Contact Person: Roy Woodward, Inventory, Monitoring & Assessment Program, P.O. 942896 Sacramento, CA 94296-0001 (916) 651-6940, rwoodw@parks.ca.gov

Sampling Method: California Stream Bioassessment Procedure (CSBP), Harrington (1996)

Timeline of Sampling: Spring (May-June) and Fall (Sept. – Nov.) 2001. Future sampling of the streams may take place depending on available funding.

Data Availability: Currently 11 sites have been sampled. Spring 2001 data is now available. Fall 2001 data will become available by February 2002.

Purpose of Bioassessment:

- Assess water quality and the condition of aquatic ecosystems
- Establish baseline measures for future monitoring

Description: A small full-time staff at Sacramento HQ supports field staff in all 266 state park units with collection and compilation of data for wildlife, vegetation, and physical resources (e.g. water quality, soils, caves, air quality). A pilot project began in 2001 for Wilder Ranch State Park near Santa Cruz, where four streams, Wilder Creek, Peasley Creek, Majors Creek, and Baldwin Creek have been sampled for water chemistry and macroinvertebrates. These are small, short perennial coastal streams that are mostly contained within Wilder Ranch State Park.

State park ecologists collected the macroinvertebrate samples. Richard Bottoroff, a contractor, performed the macroinvertebrate identifications. Water chemistry was taken with a portable sampling device, and habitat was characterized using the CDFG technique. Under a separate contract, steelhead were counted, red-legged frogs were counted, and fish and aquatic organism habitat was assessed. The final report for the project will assess the findings in relation to steelhead and other aquatic organisms in these streams and will be prepared by June 30, 2002.

Dry Creek Conservancy Watershed Monitoring Program

Physical, chemical, and biological assessment and monitoring of the aquatic resources of the watershed.

Contact Person: Gregg Bates

Sampling Method: Grab samples, benthic macroinvertebrate collection, fish surveys

Timeline of Sampling: Seasonal, and periodic

Data Availability: Data is currently being organized and put into data bases

Purpose of Bioassessment:
- Assess condition of streams
- Identify negative impacts
- Suggest management solutions

Description: None provided.

Feather River Watershed Monitoring Program

The purpose of the program is to obtain and make available baseline and continuing data from which trends in watershed health could be measured. The Feather River Watershed Monitoring Program is project of the Feather River Coordinated Resource Management Group.

Contact Person: Leslie Mink, Watershed Coordinator, or Jim Wilcox, Project Manager, Feather River Coordinated Resource Management Group, c/o Plumas Corporation P.O. Box 3880 Quincy, CA 95971 phone: 530-283-3739; fax: 530-283-5465; email: leslie@plumascounty.org Or plumasco@psln.com

Sampling Method:
Three riffles suitable for sampling are identified, beginning at the downstream extent of the survey segment. Identified riffles are composed of large gravel to cobble size substrate where the water surface is turbulent. Care is taken to not disturb the sample sites prior to sampling. *This is the first measurement taken at each survey segment.*

Once the three riffles are identified, measurements are taken from bottom to top (downstream to upstream) beginning at the farthest downstream riffle. A tape is placed parallel to the longest upstream-downstream axis and the length of the riffle is measured. The riffle is divided into equal segments of length. Three segments are randomly selected for sampling using a random numbers sheet. One of three lateral sampling locations (1/4, 1/2, 2/3 width from the right edge of suitable habitat) is randomly selected at each of the *three selected segments.*

Once the sampling locations have been selected, a D-net with a one-foot wide opening and a mesh size of 0.5mm is placed perpendicular to the flow, and adjusted as necessary to prevent flow under the net frame. An area upstream of the net that is one foot wide by two feet long is chosen for sampling.

Samples are sent to: The Buglab, Dept. Fish and Wildlife, Utah State University, Logan,UT 84322-5210.

Timeline of Sampling: Samples are usually collected once every two years; samples have been collected during the Summer 1999 and 2001.

Data Availability: Biological samples are collected at 19 of the 21 sites, which are strategically located at low-gradient "response" reaches near mouths of the major sub-watersheds; samples are still being processed and are not expected to be completed until summer 2002, however, data will be available on our website at feather-river-crm.org

Purpose of Bioassessment:

- To evaluate the effectiveness of stream restoration efforts
- To assess trends in watershed health
- To accompany other watershed data such as geomorphic data including permanent cross-sections, longitudinal profiles, bedload, bank stability, water temperatures, and flows, water quality, fish populations, etc.

Description:

The Feather River Coordinated Resource Management group has been in existence since 1985, and is a consortium of 21 public and private agencies and land management entities. Our primary mission is watershed restoration, which we successfully implement across jurisdictional boundaries. Since 1985, we have implemented over 40 restoration projects. Project monitoring has been an integral part of our program. In the late 1990's we realized the need for monitoring on a watershed scale. This type of monitoring will help us evaluate the impact of our projects on a larger scale, and allow an observation of trends in the health of the Feather River watershed.

Federal Energy Regulatory Commission Hydroelectric Relicensing and Repair

The SWRCB has authority to issue Clean Water Act (CWA) section 401 water quality certifications for hydroelectric facilities undergoing relicensing. To help us determine compliance with the CWA and Basin Plan we have been requesting that rapid bioassessment be completed to help assess water quality impacts.

Contact Persons: Russ Kanz (916) 341-5341, Sharon Stohrer (916) 341-5397; State Water Resources Control Board, P.O. Box 2000, Sacramento, CA 95812-2000

Sampling Method: California Stream Bioassessment Procedure

Timeline of Sampling: Completed during the relicensing process. Usually a single sampling program with limited follow-up. We are also requiring bioassessement to determine impacts of repair projects. A number of rivers have been completed with more planned.

Data Availability: PG&E –Stanislaus River (44 sites), Pit River (16 sites), Mokelumne River (26 sites), Feather River (?? sites), Fordyce Creek (?? sites): El Dorado Irrigation District – SF American River (?? sites)

Purpose of Bioassessment:

- Assess impacts to water quality

Description: Hydroelectric projects licensed by the FERC undergo relicensing every 30-50 years. Currently in California there are a large number of facilities either being relicensed, or will be relicensed soon. The State Water Resources Control Board has the authority to issue Clean Water Act (CWA) section 401 certifications for these facilities. The CWA 401 certification requires an assessment of the impacts to beneficial uses. We have been requesting that the licensees use rapid bioassessment to help determine impacts to water quality/beneficial uses. We also use bioassessment in addition to water quality monitoring to determine the impacts of hydroelectric repair projects. Upcoming projects include Southern California Edison relicensing – Upper San Joaquin River sampling (planned for 2001-2002) and PacifiCorp relicensing – Klamath River sampling (planned for 2002).

Hoopa Valley Environmental Protection Agency Water Quality Monitoring Program

Our primary goals are to use rapid bioassessment as a tool to sample all streams that have been damaged by fires and logging and to protect domestic water sources.

Contact Person: Forrest Blake, 1348 Hoopa, California 95546

Sampling Method: California Stream Bioassessment Procedure (CSBP) citizen monitoring method

Timeline of Sampling: Continuous monitoring of annual events

Data Availability: Available on the EDAS program

Purpose of Bioassessment:

- To make sure our streams are safe for our people

Description: We have continuous data recorders on our creeks as well as high flow stations. We feel that bioassessments are just one more component to our Water Quality Monitoring Program.

Los Angeles Regional Water Quality Control Board – Surface Water Ambient Monitoring Program (SWAMP)

Primary purpose is to design a distinctive monitoring program for each watershed based on its unique characteristics and based on what data exists and what data gaps are present. Because each watershed is treated individually, the approach to each watershed is different. For example, in the Santa Clara River watershed, a random design based on EMAP was employed because the watershed covers an extensive area and little is known about the watershed. The goal was to obtain an overall picture of the health of the watershed. On the contrary, Calleguas Creek watershed encompasses a much smaller area and a multitude of data exists. Therefore staff chose a directed sampling program to address each major tributary and stream within the watershed and chemical analyses where chosen based on the data that already existed. Further information can be obtained in the SWAMP Workplan document for fiscal years 2000/01, 2001/02, and 2002/03, edition date June 30, 2002.

Contact Person: Tracy Vergets, 320 W. 4th Street, Suite 200, Los Angeles, California, 90013; (213) 576-6661; tvergets@rb4.swrcb.ca.gov

Sampling Method: California Stream Bioassessment Procedure (CSBP) Rapid Bioassessment Protocol (RBP)

Timeline of Sampling: 2001-Present

Data Availability: currently 17 sties in the Santa Clara River sampled in 2001; 30 more to be sampled in 2002; 13 sites sampled in Calleguas Creek in 2001; 45 sites to be sampled in Santa Monica Bay WMA in 2003 with repeat sampling at 6 of the best stations in 2004 & 2005; 12 stations to be sampled in the Dominguez Channel and LA/LB Harbor Watershed in 2003.

Purpose of Bioassessment:

- Ambient water quality monitoring
- Establish reference conditions
- Watershed characterization, assessment, trend monitoring
- Determine attainment of beneficial uses
- Assess biological integrity of surface waters
- Detect biological responses to pollution
- Identify probable causes of impairment not detected by chemical or physical water quality analysis

Description:

The overall goal of the Site-Specific Monitoring portion of SWAMP is to develop site-specific information on representative sites or water bodies that are (1) known or suspected to have water quality problems and (2) known or suspected to be clean. This portion of SWAMP is focused on collecting information from sites in water bodies of the State that could be potentially listed or delisted under Clean Water Act Section 303(d). This workplan has been developed to implement the Site-Specific Monitoring Requirements of SWAMP per State Board directive. However, in Region 4, both the Site-Specific Monitoring goals and the Regional Monitoring goals have been integrated into one ambient

monitoring program. The scope encompasses the regional goals, while still obtaining site-specific information.

Per AB 982, monitoring is required in each hydrologic unit of the State at least once every five years. Region 4 proposes to visit each hydrologic unit one year ahead of the WMI schedule for targeted watersheds, which rotate on a five-year cycle. In this strategy, data will be gathered, analyzed, and interpreted in time to use the following year during NPDES permit renewals and other ongoing activities within the targeted watershed. Ultimately, the information from these analyses will be used in the water quality assessment for the targeted watershed. Other uses of this data include, but are not limited to, development of the 305(b) report and 303(d) List of Water Quality-Limited segments, TMDL development, and NPDES permit renewals.

The sampling and analysis will be used to assess the ambient conditions of the watersheds in Los Angeles and Ventura counties, and will further delineate the nature, extent, and sources of toxic pollutants, which have been detected or are suspected to be problematic for this region and its individual watersheds. Where applicable, a triad approach (benthic community analysis, water chemistry, and toxicity testing) is being used. In addition, bioaccumulation tests, historically funded through the statewide Mussel Watch and Coastal Fish Contamination Programs, are being conducted in order to address possible human health concerns (contaminants in edible fish tissue) and ecological concerns (benthic community impacts), which may result if the contaminants at a site are bioavailable for uptake by organisms. These bioaccumulation tests will help to demonstrate the bioavailability of contaminants at these stations and may identify impaired beneficial uses. There is also a large focus on bioassessment, which historically has been overlooked. The bioassessment performed will follow the California Stream Bioassessment Protocol developed by CDFG, which focuses on the benthic macroinvertebrate assemblage and a physical habitat assessment. The information gathered will be used in trend analysis, identifying impaired beneficial uses, as well as potentially in the development of an index of biological integrity.

Lahontan Regional Water Quality Control Board: Biological Assessment Program

The primary objective of this program is to incorporate consideration of biological integrity into the many regulatory and watershed management functions of the Lahontan RWQCB.

Contact Person: Thomas J. Suk, Regional Monitoring Coordinator, California Regional Water Quality Control Board, Lahontan Region, 2501 Lake Tahoe Blvd., South Lake Tahoe, CA 96150. Phone: (530) 542-5419; Email: <sukt@rb6s.swrcb.ca.gov>

Sampling Methods: The Lahontan RWQCB is using and evaluating three different bioassessment sampling methods: (1) benthic macroinvertebrates, periphyton, and physical habitat assessments following protocols developed by Dr. David Herbst at the University of California's Sierra Nevada Aquatic Research Laboratory (SNARL); (2)

California Stream Bioassessment Procedures (CSBPs) developed by the California Dept. of Fish and Game; and (3) RIVPACS protocols being used in the Sierra Nevada by the U.S. Forest Service

Timeline of Sampling: 1995 - present

Data Availability: Approximately 350 surveys have been conducted at 200 sites in the Lahontan Region using the UC-SNARL method. At 40 of those 200 sites, sampling was conducted using three methods (e.g., UC-SNARL, CSBPs, RIVPACS) to facilitate quantitative comparison of the results provided by each of those three methods. At approx. 30 other sites (throughout the eastern Sierra Nevada) samples were collected using both the UC-SNARL and RIVPACS methods, and at 20 other sites (all in the Walker River drainage) samples were collected using both the UC-SNARL and USEPA-REMAP methods. Most of this data is not yet available, and lab identification and quality assurance procedures are still underway.

Purpose of Bioassessment:

- To establish regional "reference conditions" for benthic macroinvertebrates and periphyton in streams and rivers
- To assess the impacts of human activities on the biological integrity of streams and rivers
- To evaluate the effectiveness of stream & wetland restoration efforts, BMP implementation, and permit conditions
- To develop numeric targets for TMDLs
- To develop narrative and numeric biocriteria

Description: The Lahontan RWQCB began using bioassessment in 1995, in order to monitor the success of remediation efforts at the abandoned Leviathan Mine. A more concerted (i.e., region-wide) bioassessment program was begun in 1999, for the multiple purposes outlined above.

The current regional-scale effort is focused on developing reference conditions (based on benthic macroinvertebrates and periphyton) for the eastern Sierra "ecoregion," which covers six major watershed basins (e.g., Truckee River, Tahoe Basin, Carson River, Walker River, Mono Basin, Upper Owens River). Streams in this ecoregion were stratified based on stream order, and minimally-impaired sites were selected from each class of streams. Sampling has been conducted during the summer reference period (i.e., late June to early September), using protocols developed by Dr. David Herbst of the University of California's Sierra Nevada Aquatic Research Laboratory. As of this writing (i.e., 2001), the effort has focused on data collection and lab identifications; analyses of the data are pending.

The Lahontan RWQCB, via contract with the University of California (SNARL), is also using bioassessment data to: (1) evaluate the effectiveness of several stream & wetland restoration projects (e.g., Upper Truckee River, Bagley Valley); (2) evaluate the effectiveness of BMP implementation (e.g., Upper West Walker River, Bridgeport

Valley); (3) monitor the success of remediation efforts at Leviathan Mine; (4) verify and/or assess the effectiveness of regulatory permits (e.g., fish hatcheries, Grover Hot Springs State Park); and (5) develop targets based on benthic macroinvertebrates for sediment TMDLs (e.g., Squaw Creek, Heavenly Valley Creek).

The Lahontan RWQCB, via contract with the University of California (SNARL), is also conducting a comparison of three common bioassessment methods (e.g., UC-SNARL, CSBP, RIVPACS). Sampling was conducted using all three methods at forty (40) sites during the summer of 2000. The objective of this study is to evaluate the potential strengths and weaknesses of the various methods for use by the RWQCB.

Development of narrative and numeric biocriteria is a long-term goal of this project, and will be subject to available funding.

McCloud River Preserve Aquatic Macroinvertebrate Monitoring Program

The primary focus of this program is to document and analyze the aquatic macroinvertebrate community in the McCloud River and to use this information in conjunction with on-going water quality research to provide a baseline view of the state of the aquatic resources within the watershed.

Contact Person: John Crandall, McCloud River Preserve, P.O. Box 409, McCloud, CA 96057 (530) 926-4386

Sampling Method: California Stream Bioassessment Procedure (CSBP), Harrington (1996)

Timeline of Sampling: started in 1998 at citizen's level, 1999-2001 at professional level

Data Availability: All years data available (taxa and metrics) plus brief write-up for each year.

Purpose of Bioassessment:

- Assess water quality and the condition of aquatic ecosystems
- Establish baseline measures for future monitoring

Description: None provided.

San Diego Regional Water Quality Control Board: Biological Assessment Program

The primary objectives of this project are to introduce biological information to the San Diego Regional Water Quality Control Board's ambient monitoring program and to provide baseline data on the benthic macroinvertebrate BMI community in regional streams.

Contact Person: Linda Pardy, 9174 Sky Park Court, Suite 100 San Diego, CA 92123

Sampling Method: California Stream Bioassessment Procedure (CSBP), Harrington (1996)

Timeline of Sampling: May 1999 – Present

Data Availability: Approximately 48 sites

Purpose of Bioassessment:

- To include biological information in the San Diego RWQCB's ongoing water quality programs
- To create a species list of BMIs known from the region
- To establish a biological classification of different stream types in the region
- To identify potential reference sites for the San Diego regional bioassessments
- To determine the best index period for sampling BMI communities
- To select appropriate metrics for southern California stream bioassessments
- To assist with 305(b) assessments, 303(d) listings, development of TMDLs, assessments of nonpoint sources (NPS), and assessments of effectiveness of NPS management measures.
- To develop biocriteria

Description:

The bioassessment program will evaluate the biological and physical integrity of targeted inland surface waters in the San Diego Region and is designed to meet an obligation to assess the condition of the Region's waters relative to attainment of water quality standards. Information developed will be used for the Section 305(b) Water Quality Assessment, the Section 303(d) list of impaired water bodies, development of Total Maximum Daily Loads (TMDLs), assessments of nonpoint sources, and assessments of effectiveness of nonpoint source management measures. Information will also be used to define issues, set priorities, and evaluate effectiveness of actions under the Watershed Management Initiative.

This ambient bioassessment program will put initial emphasis on biological community structure monitoring. Only after the biological information indicates impairment will samples be chemically analyzed. It is assumed that municipal storm water co-permittees, the Regional Water Board, and citizen volunteer monitoring groups will be responsible for biological monitoring. The program will be in concert with the San Diego Region's *Watershed Management Plan.*

The Regional Water Board will use the information gained from these bioassessments to identify areas of stream impairment and most likely causes. For the coastal lagoons identified as impaired, the bioassessments will help to identify those areas of the influent streams, which are most significant contributors of pollutants. With the accompanying data on water column and sediment chemistry provided by various sources, the Regional Water Board can initiate a scientifically based TMDL development for each of the impaired streams and coastal water bodies.

In addition, the program will produce a workable IBI using a modified approach outlined by the USEPA. Ultimately, the results of this bioassessment program will be used to develop biocriteria, which will serve as the standard against which future assessment results are compared.

San Francisco Bay Regional Water Quality Control Board - Surface Water Ambient Monitoring Program (SWAMP)

Primary purpose is to establish screening-level ambient biological and physical monitoring in the region's streams along with chemical and toxicity monitoring, as well as establish reference conditions. Secondary purposes include impact characterization, pre- and post-project characterization, and support of regional efforts at habitat classification.

Contact Person: Steve Moore and Karen Taberski, 1515 Clay St., #1400, Oakland, CA 94612 (510) 622-2439; (510) 622-2424; smm@rb2.swrcb.ca.gov; kmt@rb2.swrcb.ca.gov

Sampling Method: California Stream Bioassessment Procedure (CSBP) Rapid Bioassessment Protocol (RBP)

Timeline of Sampling: 2001-Present; Spring Index Period (Mar- May)

Data Availability: 72 sites in 2001; 49 sites in 2002 3rd year: estimated 45 sites in 2003. Watersheds sampled: 2001 - Lagunitas Cr., Walker Cr., Suisun Cr., San Pablo Cr., Wildcat Cr., Arroyo Las Positas, San Leandro Cr.; 2002 - San Gregorio Cr., Pescadero Cr., Butano Cr., Stevens Cr., Permanente Cr.; 2003 - Petaluma R., San Antonio Cr. (Marin), San Mateo Cr., Mt Diablo Cr., Kirker Cr.

Purpose of Bioassessment:

- Ambient water quality monitoring
- Establish reference conditions
- NPDES permitting
- Point-source/incident monitoring
- Watershed characterization, assessment, trend monitoring
- Support habitat classification
- Stream restoration monitoring

Description: The three components that make up the Board's Regional Monitoring and Assessment Strategy (RMAS) include: 1) SWAMP funding from the State Water Resources Control Board for Regional Board-lead activities (these activities will concentrate on monitoring watersheds, lakes/reservoirs and bays and estuaries other than San Francisco Bay and will include other Regional Board programs such as State Mussel Watch, the Toxic Substances Monitoring Program and the Coastal Fish Contamination Program), 2) partner-lead watershed monitoring programs that are being conducted by

local agencies/groups and are of similar goals, structure and scope as the Regional Board-lead activities and 3) the San Francisco Estuary Regional Monitoring Program (RMP), funded by dischargers. Specific objectives of the Regional Board-lead SWAMP-funded monitoring program are to: 1) identify reference sites, 2) identify impacted sites or waterbodies in order to determine if beneficial uses are being protected, 3) identify the cause of impacts (i.e., sediment, specific chemical contaminants, temperature), 4) determine if these impacts are associated with specific land uses and 5) evaluate monitoring tools in watersheds in order to develop a program that uses the best environmental indicators to achieve the purposes of the program. Data developed in this program will be used for evaluating waterbodies for the Clean Water Act Section 305b report and the 303d list. Data will include physical, chemical, and biological information.

Santa Clara Valley Project

The primary focus of this project is to examine the factors influencing the development of bioindicators based on lotic macroinvertebrate assemblages in urban environmental settings. Little is known of the specific factors found in urban environmental settings that affect macroinvertebrate distributions. Determining the natural and anthropogenic factors that most influence the distribution of macroinvertebrates is a necessary step prior to developing bioindicators based on resident macroinvertebrate assemblages found in urban streams.

Contact Person: Dr. James L. Carter, US Geological Survey, 345 Middlefield Road Mail Stop 465, Menlo Park, CA, 94025

Sampling Method: Two macroinvertebrate collection methods were used. First, a semi-quantitative method that consisted of compositing 5 - 0.1 m^2 collections made from riffle habitats. Each of the 5 collections per sample was systematically located. Second, a multi-habitat collection made by collecting macroinvertebrates from all habitats in a reach (=1 pool/riffle sequence). Collecting effort was partitioned based on the percentage composition of various invertebrate habitat types found in the sampled reach. All collections were made using a D-frame kicknet fitted with a 500 µm mesh.

Timeline of Sampling: Samples were collected in May 1997 and September/October 1998.

Data Availability: 85 sites from 14 streams in the Santa Clara Valley area. These include:

San Francisquito Ck	Ross Ck.	Saratoga Ck.	Arroyo Calero
Guadelupe River	Coyote Ck.	Corte Madera Ck.	Guadelupe Ck.
Los Gatos Ck.	Penitencia Ck.	Los Trancos Ck.	Alamitos Ck.
Stevens Ck.	Barret Ck.		

Purpose of Bioassessment:

- Develop a baseline data set representing the distribution of benthic macroinvertebrates in the Santa Clara Valley area.

- Development of a macroinvertebrate dataset for evaluating the level of field and laboratory effort needed to conduct bioassessments.
- Establish the relationships between benthic macroinvertebrate assemblage composition and physical and chemical factors associated with an urban environmental setting.

Description:

Fourteen streams were Sampling locations were +/- equidistant, with sites set at approximately 2 km intervals. Eighty-five sites were sampled in total. The downstream limit of sampling was either the point of assumed or observed intermittent flow or where there appeared to be a tidal influence. The upstream limit was approximately 300 m. Sampling at all sites for both types of invertebrate collections occurred during May 1997 and for riffle collections only during September/October 1998.

Depth and velocity were measured at each riffle subsample location (5 locations per riffle). At each riffle DO, temperature, conductivity, and pH were measured at the time of invertebrate sampling. Qualitative estimates of riparian vegetation, instream algal and macrophyte cover also were made. Quantitative measures of channel morphology and pebble counts were made at each site. Lastly, dissolved nutrients and trace metals were measured at each site.

For more information see:

Carter, J. L., and S. V. Fend. 2000. The Distribution and Abundance of Lotic Macroinvertebrates during Spring 1997 in Seven Streams of the Western Santa Clara Valley area, California. U.S. Geological Survey, Open-File Report 00-346.

Carter, J. L., and S. V. Fend. 2000. The Distribution and Abundance of Lotic Macroinvertebrates during Spring 1997 in Seven Streams of the Santa Clara Valley area, California. U.S. Geological Survey, Open-File Report 00-68.

Tecolote Creek and Alvarado Creek Bioassessment Studies

The purpose of the Tecolote Creek and Alvarado Creek Bioassessment Studies is to assess impacts due to a sewage spill.

Contact Person: Andre Macedo, City of San Diego, Environmental Monitoring & Technical Services Division, 14103 Highland Valley Road, Escondido, CA. 92025 (858) 538-8193, amacedo@sandiego.gov

Sampling Method: California Stream Bioassessment Procedure (CSBP) Rapid Bioassessment Protocol (RBP)

Timeline of Sampling: May 2000-Present

Data Availability: 3 sites in 2000, 4 sites in 2001, and 5 sites in 2002 located in the San Diego Watershed.

Purpose of Bioassessment:

- Point-source/incident

Description: None provided.

Truckee River Aquatic Monitors Bioassessment Program

The primary purpose of this program is to obtain data for watershed characterization, assessment, and trend monitoring in addition to educating the public and decision makers. Secondary purposes include ambient water quality monitoring, pre- and post-project monitoring, and establishing reference conditions in the watershed.

Contact Person: Jill Wilson, 2501 Lake Tahoe Blvd., South Lake Tahoe, CA 96150 (530) 542-5449 jwilson@rb6s.swrcb.ca.gov

Sampling Method: California Stream Bioassessment Procedure (CSBP) Rapid Bioassessment Protocol (RBP)

Timeline of Sampling: 1999-Present

Data Availability: Approximately 3-5 per year throughout the Truckee River Watershed

Purpose of Bioassessment:

- Ambient water quality monitoring
- Establish reference conditions
- Watershed characterization, assessment, trend monitoring
- Support habitat classification
- Stream restoration monitoring
- Education

Description: TRAM is an all-volunteer group that follows the CSBP protocol to collect samples. Sampling occurs within the Truckee River Watershed from the Lake Tahoe outlet to the California state line. Most samples are sent out for professional identification. However, during the winter the group does do some of its own identification at the CSBP citizen's level.

UCLA/Los Angeles Regional Water Quality Control Board Biological Assessment Project

The purpose of this project is to determine the biological health of streams relative to land use in three southern California watersheds (Malibu, Calleguas, and Santa Clara) using modifications to existing protocols. This work was conducted by University of California Los Angeles and

funded by Los Angeles Regional Water Quality Control Board with the goal of collecting data that would be used in the generation of nutrient TMDL's for southern California watersheds, but in so doing, new methods were explored for determining the relationship between human influences and the biological health of streams.

Contact Person: Steven F. Lee M.S. and Rich Ambrose, Ph.D. UCLA. Department of Environmental Health Sciences, 46-059 CHS Building, Los Angeles, CA 90095-1772

Sampling Method: Combination of CSBP (Harrington and Born, 2000) and modified USEPA REMAP, Lazorchak and Klemm (1994) methods.

Timeline of Sampling: Fall, 2001 season

Data Availability: ~40 sites throughout three Southern California watersheds (Malibu, Calleguas, and Santa Clara). Data are public and will be available through LARWQCB sometime in the middle of 2002.

Purpose of Bioassessment:

- Determine the health of biological communities relative to human land use, incorporating new methodologies and metrics
- Collect data for use by Los Angeles RWQCB in the generation of nutrient TMDL's.

Description: Benthic invertebrates were collected according to CSBP methods to keep data comparable to other state agency bioassessment work, but then a modified EMAP-type protocol was superimposed over the riffle/reach to collect data on stream morphology, physical habitat, riparian vegetation, fish and fish habitat etc. Site selection involved targeted reaches rather than a probabilistic approach. The reach length and the number of transects were reduced, but with expanded data taken at each transect. We feel this was appropriate because 1. we targeted more homogeneous sites and 2. these southern California stream reaches tend to be more homogeneous in general. In addition, data for percent cover of macroalgae, vascular macrophytes, and diatoms, macroalgae biomass, and light meter measurements were added to the protocol. Streamside riparian vegetation data were enhanced with focus on cover of native and introduced species. More extensive data were taken alongside the benthic invertebrates including light meter readings, macroalgae, macrophyte, and diatom data, and substrate type including percent composition, embeddedness, and consolidation.

Upper Putah Creek Citizen Based Watershed Management Program

The Stewardship will organize, train and supervise citizen volunteers to monitor impacts to Upper Putah Creek and its tributaries from sediment and other non-point pollution sources and translate findings into restoration projects for the Stewardship to implement.
Funded by a 319(h) grant administered by Placer County Resource Conservation District.

Contact Person: Dwight Holford, Project Coordinator, Box 27 Middletown, CA 95461-0027 707-987-2600 showmums@jps.net

Sampling Method: California Stream Bioassessment Procedure (CSBP), Harrington and Born 2000

Timeline of Sampling: 2000-2002

Data Availability: March 2002

Purpose of Bioassessment:
- Support CA State bioassessment program
- Train citizen monitors
- Establish bioassessment program in the Upper Putah Creek Watershed
- Produce restoration projects
- Establish base for biocriteria in watershed

Description:
A team of citizen monitors has been established, led by a Ph.D. scientific advisor. By the end of this 319(h) project they will have surveyed the upper third of the watershed. A restoration project for St. Helena Creek will be proposed. They are helping other watershed groups establish bioassessment programs. They are also involved in education/outreach programs.

U.S. Environmental Protection Agency Central Valley Regional Environmental Monitoring and Assessment Program (REMAP)

The Central Valley REMAP project focused on assessing the biological integrity of agriculture-dominated waterbodies located throughout California's Central Valley, which comprises more than 48,000 miles of surface water and 16 percent of the land area of California and is one of the nation's most productive agricultural areas.

Contact Person: Peter Husby, USEPA Region 9 Laboratory, 1337 S. 46th St.; Bldg. 201, Richmond, CA 94804

Sampling Method: USEPA EMAP, Lazorchak and Klemm (1994)

Timeline of Sampling: 1994-1995

Data Availability: Approximately 87 sites in the Sacramento-San Joaquin Valley, covering approximately 24,000 square miles.

Purpose of Bioassessment:
- Support State of CA bioassessment and monitoring

- Assess the biotic condition of surface waters in a highly modified agriculturally influenced ecosystem.
- Determine variability of aquatic organisms in natural and man-made conveyances within the Central Valley.

Description: REMAP was initiated to test the applicability of the EMAP approach to answer questions about ecological conditions at regional and local scales. Using EMAP's statistical design and indicator concepts, REMAP conducts projects at smaller geographic scales and in shorter time frames than the national EMAP program. EMAP is a research program to develop the tools necessary to monitor and assess the status and trends of national ecological resources. EMAP's goal is to develop the scientific understanding for translating environmental monitoring data from multiple spatial and temporal scales into assessments of ecological condition and forecasts of the future risks to the sustainability of our natural resources. The objectives of REMAP are to: 1) evaluate and improve EMAP concepts for state and local use, 2) assess the applicability of EMAP indicators at differing spatial scales, and 3) demonstrate the utility of EMAP for resolving issues of importance to EPA Regions and states.

U.S. Forest Service - Pacific Southwest Region (California) Bioassessment Program

The primary focus is on establishing reference conditions by collecting macroinvertebrates from a network of both perennial and intermittent wadeable streams throughout the entire state of CA, mainly on Forest Service lands. There are 18 national forests in the region (Angeles, Cleveland, Eldorado, Inyo, Klamath, Lassen, Lake Tahoe Basin Management Unit, Mendocino, Modoc, Plumas, San Bernardino, Sequoia, Shasta-Trinity, Sierra, Six Rivers, Stanislaus and Tahoe)

Contact Person: Joseph Furnish, Ecosystem Conservation Division, 1323 Club Drive, Vallejo, CA 94592

Sampling Method: Hawkins, Ostermiller, and Vinson (1998)

Timeline of Sampling: 2000 - present

Data Availability: Approximately 176 sites in 2000 and 85 sites in 2001 located in the following watersheds: Klamath- North Coastal; Sacramento; Tulare-Buena Vista; San Joaquin; Central Lahontan; Central California Coastal; South California Coastal; North Mojave- Mono Lake.

Purpose of Bioassessment:

- Development of biocriteria and bioassessment protocol
- Monitoring of impacts from timber harvest, grazing and mining activities
- Ensure compliance with the Clean Water Act
- TMDL implementation
- Reference site characterization

Description: The primary effort has been on establishing reference condition by collecting macroinvertebrates from a network of both perennial and intermittent wadeable streams, that can serve as the basis for monitoring biological integrity and determining whether water quality has been degraded compared to reference condition. Reference condition will be based on development of a predictive RIVPACS (River InVertebrate Prediction And Classification System) model. Standard EPA Metrics will also be considered for use if it is determined that they are sensitive to disturbances at the site and watershed (approximately 10,000-50,000 acre) scale.

U.S. Geological Survey: National Water Quality Assessment (NAWQA) Program

The U.S. Geological Survey (USGS) implemented the National Water-Quality Assessment (NAWQA) Program to describe the status of and trends in the quality of the nation's surface water and ground water and to provide scientific understanding of the natural and human-induced factors that affect water quality.

Contact Person: Larry Brown, Placer Hall, 6000 J St, Sacramento, CA 95819-6129

Sampling Method: USGS NAWQA

Timeline of Sampling: San Joaquin-Tulare Basins 1992-95; Sacramento Basin 1995-98; Santa Ana Basin 1998-Present.

Data Availability: 17 sites in San Joaquin-Tulare Basins; 23 sites in Sacramento Basin; and 4 sites in Santa Ana Basin.

Purpose of Bioassessment:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams.
- Describe how water quality is changing over time, and
- Improve our understanding of the primary natural and human factors affecting water quality.

Description: Since 1991, the NAWQA program has been collecting and analyzing data and information in more than 50 major river basins and aquifers across the Nation. The goal is to develop long-term consistent and comparable information on streams, ground water, and aquatic ecosystems to support sound management and policy decisions. Three major river basins in California were assessed as part of this program: 1) Sacramento Basin, 2) San Joaquin-Tulare Basins, and 3) Santa Ana Basin.

Studies in the San Joaquin-Tulare Basins NAWQA Study Unit focus on the status of and the processes influencing the quality of surface water, ground water, and aquatic ecology. The Study Unit is located in central California and includes the San Joaquin Valley, the eastern slope of the Coast Ranges and the western slope of the Sierra Nevada.

In 1994, the Sacramento River Basin study unit team began planning assessment activities. The basin was subdivided into six physiographic subunits and nine ecological subunits that were determined to be the most influential natural factors affecting water quality. Stream sampling began in 1995 and lasted until April 1998. Much of the data collection focused on the Sacramento Valley and Klamath Mountain subunits, but ecological sampling also included the Cascade Mountains and Sierra Nevada subunits. Hundreds of water-quality characteristics were measured in different media during this time, including ground water, stream water, streambed sediments, and aquatic biological tissues. Fish, invertebrate, and algal communities and stream habitat also were sampled or assessed. In addition, spatial data such as geology, land use, hydrography, and other watershed characteristics were compiled into a geographic information system (GIS) to support the assessment. After April 1998, the project entered a period of less frequent sampling called the low-intensity phase.

The Santa Ana Basin study began in 1997. Study planning and analysis of existing data was done during the first 2 years of the study. After that 2-year planning period, surface- and ground-water and biological data were collected intensively for 3 years (termed the high-intensity phase). A low-intensity phase will follow for 6 years, during which water quality is monitored at a limited number of sites and areas that were sampled during the high-intensity phase. This combination of high- and low-intensity monitoring phases allows the NAWQA Program to examine long-term trends in water quality and aquatic ecology.

Ventura River Bioassessment Monitoring Program

The main purpose of this program is to assess the biological condition of the Ventura County Watershed and to ensure compliance with NPDES permit requirements.

Contact Person: Darla Wise, County of Ventura Flood Control Department, (805) 645-3942

Sampling Method: California Stream Bioassessment Procedure (CSBP), Harrington (1996)

Timeline of Sampling: Annual sampling Fall 2001- Present,

Data Availability: 15 sites

Purpose of Bioassessment:

- Assess biological health in the watershed
- Ensure compliance with NPDES permit requirements

Description: Bioassessments are conducted as part of an overall program to assess water quality for stormwater monitoring throughout the Ventura County Watershed. In addition to collecting biological samples, they also look at conventional

water quality
parameters. They also have a group of volunteers who collect water quality samples on a monthly basis at the bioassessment sites. Recently acquired a Water Sonde and anticipate monitoring nutrients (nitrate, nitrite and ammonia) chlorophyll a in addition to basic water quality parameters. Also plan to monitor fecal coliform and streptrococcus bacteria in future monitoring efforts.

Yurok Tribe Water Quality Program

The primary focus of this program is to provide ambient water quality data for the Klamath River watershed.

Contact Person: Kevin McKernan, PO Box 355 Orick, CA 95555
(707) 834-2536 / kevinmck@reninet.com

Sampling Method: California Stream Bioassessment Procedure (CSBP) Rapid Bioassessment Protocol (RBP)

Timeline of Sampling: 2001– Present. Spring & Fall index periods

Data Availability: 30 sites in the Klamath River Watershed.

Purpose of Bioassessment:

- ambient water quality monitoring
- research
- point-source/incident
- watershed characterization, assessment, trend monitoring
- establish reference conditions
- stream restoration
- education

Description: Sites include mainstem Klamath River during low flow conditions, bio-metrics used to support ambient physical and chemical monitoring. Sites in Lower Klamath tributaries support ambient physical and chemical monitoring, watershed trends, presence/absence of forest herbicide impacts.

Appendix B

Candidate Methods

Appendix B CANDIDATE METHODS

This section includes the complete information on the key program elements (i.e., habitat selection, sampling gear, sampling method, area sampled, replication, subsampling and enumeration, taxonomic identification, quality assurance procedures, data analysis/metrics, habitat assessment, and purpose for monitoring), which is summarized in Chapter 3.

California Department of Fish and Game - Aquatic Bioassessment Laboratory

DFG was the first water resource agency to be asked to assess the condition of a freshwater stream using the U.S. EPA's Rapid Bioassessment Procedure (RBPs) (Plafkin *et al.* 1989). The Lahontan Board requested the assessment in 1993 as part of the NPDES requirement of the DFG Hot Creek Hatchery in Mono County. The request necessitated the need to adapt the RBPs to California and the resulting protocol became the California Stream Bioassessment Procedure (CSBP). Because the CSBP was developed for a point-source assessment, it incorporated the use of replicated sampling of a single, richest habitat. Although not consistent with the RBP, DFG decided on this procedure for the following reasons: a) the immediate need for bioassessment was for point-source assessments, enforcements and diagnosis of known, but undocumented water quality impairment; b) there was no interest, at that time, in using bioassessment as an ambient monitoring tool; and c) the ability to produce a measure of biological metric variability at every monitoring site was deemed necessary to convince water resource managers of the robustness of biological assessments.

The CSBP is a regional adaptation of the U.S. Environmental Protection Agency (EPA) Rapid Bioassessment Protocols (Barbour *et al.* 1999). The CSBP was reviewed and refined by a CABW workgroup in 1994 and 1995 resulting in an updated version in 1996. The CSBP for wadeable streams and rivers has remained consistent over the years and is recognized by the U.S. EPA as California's standardized bioassessment procedure (Davis et al. 1996). Since 1993, the ABL has processed nearly 9000 samples collected using the CSBP at more than 2500 sites throughout California. Thousands of additional CSBP samples have been collected and processed by other entities. In addition to the CSBP for wadeable streams and rivers, as of 2002, there are versions of the CSBP for non-wadeable streams (draft), citizen monitors, lentic environments (California Lentic Bioassessment Procedure), and there is also a modification of the CSBP in which samples are composited for sites that are part of an ambient bioassessment program (this CSBP modification has been adopted by the Nevada DEQ).

1) *Habitat selection:* Riffle habitat is the only habitat sampled using this method. A stream reach is chosen that contains at least five riffles within the same order and relative gradient. If no riffles are present, or less than five within a reasonable distance, the reach is determined as 40 times the wetted width with a minimum reach length of 150 m and a maximum length of 500 m.

2) *Sampling gear:* All samples are collected using a D-frame kicknet with 500 µm mesh netting.

3) *Sampling method:* CSBP utilizes separate point and non-point source sampling designs when conducting ambient bioassessments. When sampling for point source discharges, at least one riffle in the unaffected upstream portion of the reach and one or more riffles in the affected portion of the reach are sampled; one sample is collected from three randomly chosen transects in each riffle. On the other hand, when sampling for non-point source discharges, one sample is collected from the upstream third of 3 randomly chosen riffles.

Point Source Design

Step 1. A measuring tape is placed along the bank of the entire riffle selected. Each meter or 3 foot mark represents a possible transect location. Three transects perpendicular to the flow are selected from all possible meter marks along the measuring tape using a random number table.

Step 2. Three locations are chosen along the transect where the samples are to be collected. If the substrate is fairly similar and there is no structure along the transect, the three locations will be on the side margins and the center of the stream. If there is substrate and structure complexity along the transect, the three locations are selected to best reflect it.

Step 3. Starting downstream, collections are made by placing the D-frame kick-net onto the substrate and disturbing a one by two foot portion of substrate upstream of the kick-net to approximately 4-6 inches in depth. Large rocks are scrubbed by hand under water in front of the net. A consistent sampling effort (approximately one to three minutes) is maintained at each site. The 3 collections within the transect are combined to make one "composite" sample.

Step 4. The contents of the kick-net are placed in a standard size 35 sieve (0.5 mm mesh) or white enameled tray. The larger twigs, leaves and rocks are removed by hand after carefully inspecting for clinging organisms. The sampled material and label are placed in a jar and completely fill with 95% ethanol.

Step 5. Proceeding upstream, repeat Steps 2 and 3 for the next two randomly chosen transects within the riffle.

Non-point Source Design

Step 1. Three of the five riffles within the selected reach are randomly chosen using a random number table.

Step 2. A measuring tape is placed along the bank of the entire riffle selected. One transect is selected from all possible meter marks along the top third of the riffle using a random number table.

Steps 3-6. Follow steps 2-5 for point source sampling.

4) *Area sampled:* The total area sampled per composite sample, or transect, is 0.54 m^2. Since there are 3 transects sampled per site, the total area sampled at each site is 1.62 m^2.

5) *Replication:* Three replicate composite samples are collected from each site.

6) *Subsampling and enumeration:*

Step 1. The contents of the sample jar is emptied into the # 35 sieve (0.5 mm mesh) and thoroughly rinsed with water.

Step 2. Once the sample is rinsed, debris larger than 2 inch is removed. Green leaves, twigs and rocks are also discarded.

Step 3. The cleaned material is placed into a plastic tray marked with equally sized, numbered grids (approximately two by two inches). Do not allow any excess water into the tray. The moist, cleaned debris is spread on the bottom of the tray using as many grids necessary to obtain an approximate thickness of 2 inch.

Step 4. Randomly chosen grids are removed and sorted until 300 macroinvertebrates are counted. The specimens are placed in a clean petri dish containing 70% ethanol/5% glycerin. The remaining organisms in the last grid are counted but are not included with the 300 used for identification.

7) *Taxonomic identification:* 300 specimens from each sample are identified to the standardized level (genus and/or species) using appropriate taxonomic keys. Identified specimens are placed in individual glass vials for each taxon. Each vial contains a label with taxonomic name, bioassessment laboratory number, stream, county, collection date and collector's name. The voucher collection is labeled and returned to the Sample Depository.

8) *Quality assurance procedures:*

QA for Collecting Macroinvertebrate Samples

The following procedures are implemented to help field crews collect unbiased and consistent macroinvertebrate samples:

1. Most sampling reaches should contain riffles that are at least 10 meters long, one meter wide and have a homogenous gravel/cobble substrate with swift water velocity. However, there are approved modifications of the CSBP when these conditions do not exist.
2. A DFG biologist or project supervisor trains all field crews in the use of the macroinvertebrate sampling procedures described in the CSBP. Field personnel are to review the CSBPs before each field season.
3. During the training, crew members practice collecting BMI samples as described in the CSBP. The 2 ft^2 area upstream of the sampling device is delineated using the measuring tape or a metal grid and the collection effort is timed. The method is practiced repeatedly until each crew member has demonstrated sampling consistency. Throughout the sampling season, sampling effort is timed and sampled area is measured for approximately 20% of the sampling events.

QA for Measuring Physical/Habitat Quality

The following procedures will help to standardize individual observations to reduce differences in scores:

1. A DFG biologist or a project supervisor trains field crews in the use of the EPA physical/habitat assessment procedures. Field personnel are to review these procedures before each field season.
2. At the beginning of each field season, all crew members are to conduct a physical/habitat assessment of two practice stream reaches. The first stream reach is assessed as a team and each of the 10 physical/habitat parameters described in the EPA

procedure is discussed in detail. The second stream reach is assessed individually and when members are finished, the 10 parameters are discussed and discrepancies are resolved.

3.Crews or individuals assessing physical/habitat quality are to frequently mix personnel or alternate assessment responsibilities. At the end of each field day, crew members are to discuss habitat assessment results and resolve discrepancies.

4.The Project Supervisor randomly pre-selects 10 - 20% of the stream reaches where each crew member will be asked to assess the physical/habitat parameters separately. The discrepancies in individual crew member scores should be discussed and resolved with the Project Supervisor.

QA for the Laboratory

The CSBP uses the following procedures in the bioassessment laboratory to ensure that quality data is produced:

Subsampling - The Subsampling Technician systematically transfers organisms from the sample to a collection vial then transfers the processed sample debris (remnant) into a Remnant jar. At least 10% of the Remnant samples are examined by the QA Taxonomist for organisms that may have been overlooked during subsampling. For subsamples containing 300 or more organisms, the Remnant sample should contain fewer than 10% of the total organisms subsampled. The Remnant for samples containing fewer than 300 organisms should contain fewer than 30 organisms.

Taxonomic Identification and Enumeration - The QA Taxonomist checks at least 10% of the samples for taxonomic accuracy and enumeration of individuals within each taxon. The same sample numbers that were selected randomly for the subsampling quality control should be used for this procedure. Misidentifications and/or taxonomic discrepancies as well as enumeration errors are noted on the laboratory benchsheets. The Laboratory Supervisor determines if the errors warrant corrective action.

Organism Recovery - During the sorting and identification process organisms may be lost, miscounted or discarded. Taxonomists will record the number of organisms discarded and a justification for discarding on the laboratory benchsheets. Organisms may be discarded for several reasons including: 1) subsampler mistakes (e.g. inclusion of terrestrial or semi-aquatic organisms or exuviae), 2) small size (< 0.5 mm), 3) poor condition or 4) fragments of organisms. The number of organisms recovered at the end of sample processing is recorded and a percent recovery determined for all samples. Concern is warranted when organism recoveries fall below 90%. Samples with recoveries below 90% are checked for counting errors and laboratory benchsheets are checked to determine the number of discarded organisms. If the number of discarded organisms is high, then the technician that performed the subsampling is informed and re-trained if necessary.

Corrective Action - Any quality control parameter that is considered out of range is followed by a standard corrective action that includes two levels. Level I corrective action includes an investigation for the source of error or discrepancy derived from the quality control parameter. Level II corrective action includes checking all samples for the error derived from the quality control parameter but is initiated only after the results of the Level I process justify it. The decision to initiate Level II corrective action and

reanalyze samples or conduct quality control on additional samples is made by the Laboratory Supervisor.

Interlaboratory Taxonomic Validation - An external laboratory or taxonomic specialist is consulted on a regular basis to verify taxonomic accuracy. External validation can be performed on selected taxa to help the laboratory taxonomists with problem groups of BMIs and to verify representative specimens of all taxa assembled in a reference collection.

Bioassessment Validation - The CSBP recommends at least 10% bioassessment validation where whole samples of 300 identified specimens are randomly selected from all samples either for a particular project or for all samples processed within a set time period such as each 6 months or a year. The labels are removed from the vials and replaced with a coded label that does not show the taxonomic name of the specimens. The validation laboratory or specialist is to identify and enumerate all specimens in each vial and produce a taxonomic list. There will inevitably be some disagreements between the bioassessment and the external laboratory on taxonomic identification. These taxa should be re-examined by both parties and a resolution reached before a final QA report is written.

9) *Data analysis/Metrics:* The CSBP analysis procedures are based on the EPA=s multi-metric approach to bioassessment data analysis. A taxonomic list of the macroinvertebrates identified in each sample is generated for each project along with a table of sample values and means for the biological metrics listed in the table below. Variability of the sample values are expressed as the CV. Significance testing is used for point source sampling programs and ranking procedures are used to compare sites sampled using the non-point sampling design.

10) *Habitat assessment:* Physical/habitat parameters are assessed using a ranking system ranging from optimal to poor condition. This rapid ranking system is derived from the procedures outline in the "Revised Rapid Bioassessment Protocols for use in Streams and Rivers" (Barbour et al. 1999), and relies on visual evaluation and is inherently subjective. The following ten parameters are evaluated and ranked: 1) epifaunal substrate/available cover, 2) embeddedness, 3) velocity/depth regimes, 4) sediment deposition, 5) channel flow status, 6) channel alteration, 7) frequency of riffles (or bends), 8) bank stability, 9) vegetative protection, 10) riparian vegetative zone width. In addition to EPA RBP habitat measures, the CSBP also evaluates measures cover, quantitative substrate, pebble count, substrate consolidation, depth and width, and velocity.

11) Purpose for monitoring:

- Enforcement and resource damage assessment
- Use attainability
- Ambient monitoring
- Special studies and research

United States Forest Service Pacific Southwest Region (California) Bioassessment Program

The US Forest Service uses a method developed at Utah State University by Charles Hawkins, Jeff Ostermiller, and Mark Vinson. The invertebrate protocols were modified from the designs used by the states of Oregon and Washington and the Bureau of Land Management's National Monitoring Center.

1) *Habitat selection:* Sampling is done at the first fast-water (e.g., riffles, runs) habitat encountered at the site and will continue upstream for the next three fast-water habitat units. If no fast-water habitats occur, eight constant area samples are taken from shallow, slow-water habitat units.

2) *Sampling gear:* All samples are collected using a Surber sampler ($0.09m^2$) with 500 µm mesh netting and a one meter long net to prevent backwashing.

3) *Sampling method:* Two types of samples are collected at each site: 1) a series of eight fixed area samples taken from four fast-water habitat units and 2) a single 10-minute qualitative sample taken from all major habitat types approximately in proportion to their occurrence.

   Fixed Area Samples
   Net placement within each habitat unit is determined by generating two pairs of random numbers between 0 and 9. The first number in each pair (multiplied by 10) represents the percent upstream along the habitat unit's length. The second number in each pair represents the percent of the stream's width from bank left. This process is repeated to locate the second sampling location. Samples are taken where the length and width distances intersect. If it is not possible to take a sample at one or both of these locations, additional random numbers are drawn. Invertebrates are collected from within the $0.09m^2$ area in front of the sampler starting from the upstream edge of the sampling plot and working downstream. Large stones are rubbed and inspected to ensure that all organisms are dislodge and collected. After removing all large stones, small substrates (i.e., sand or gravel) are disturbed to a depth of approximately 10 cm by raking and stirring until no additional organisms or organic matter is being washed into the net.

   10-Minute Qualitative Samples
   The area is visually appraised and the proportion of different habitat types is estimated. The 10-minute sampling period is apportioned so that each of the habitat types is sampled roughly in proportion to their occurrence.

4) *Area sampled:* The total area sampled per fixed area composite is $0.72m^2$. The total area for the fixed time sample is highly variable.

5) *Replication:* There are no replicate samples collected using this method.

6) *Subsampling and enumeration:* The following is a step-by-step description of how quantitative benthic macroinvertebrate samples are processed:

Step 1. The sample is poured through an appropriately sized 250 µm sieve. If the sample contains a lot of sand and gravel, the organic matter will need to be decanted. The entire sample is then poured from the sieve into a bucket partially filled with water. The bucket is swirled so that the organisms and organic matter become suspended in the water column and the heavier sand and gravel falls to the bottom. The water and floating organisms are carefully decanted back through the sieve. Water is continually added to the bucket and decanted until no organic matter remains in the bucket. When finished, the remaining material in the bucket is closely examined and any caddis flies, snails, clams, or other animals that remain are picked out. These organisms are added to those on the sieve.

Step 2. The sample on the sieve is rinsed under the faucet to wash additional fine particles and silt away.

Step 3. The sieve is then placed in an enamel pan or bucket that is partially filled with water and the sample is "floated" so that it becomes level within the sieve. Once leveled, the sieve is carefully removed from the enamel pan. An appropriately sized separator bar is placed into the sieve to split the material in the sieve in half.

Step 4. A coin is flipped to determine which half of the sample is to be processed (heads = right or top, tails = left or bottom). The portion of the sample to be processed is kept in the sieve, and the other half is transferred into a cup using a spoon or rinsed into the cup using an alcohol filled squeeze bottle. The cup is covered with ParaFilm and the portion or split of the sample is written on the lid, e.g., 50%. If it appears that less than 50% of the sample will be sorted, the sieve is placed back in the enamel pan and the material is re-floated to level it, and repeat the same process described above until it appears that approximately 500 organisms remain in one-half of the sieve. Once a split is started it must be finished to its entirety.

Step 5. The material to be sorted is placed little-by-little into a petri dish and all organisms within the petri dish are removed under a dissecting microscope at 7-20x magnification. As the organisms are removed, they are counted and separated into different taxonomic orders. Some representative individuals of the following groups are removed from the sample but not counted as part of the 500 bugs:

- eggs
- exuviae, molt skins
- adult insects – terrestrial or aquatic
- empty snail shells
- brooding juveniles, e.g., small amphipods
- zooplankton
- Collembola

All worms are put in the non-insect vial, but are not counted as part of the 500 bugs. Additional portions of the sample (splits) are sorted until at least 500 organisms are found. The target is to sort between 500 and 550 bugs. If 600 organisms are exceeded, the entire sample must be redone.

Step 6. When 500 bugs have been removed, the entire sample is spread evenly throughout a large white enamel pan. The pan is systematically searched for 10 minutes, and any organisms that have not been found in the split samples thus far are removed. These bugs are placed into a separate vial labeled "B/R" for "Big/Rare".

7) *Taxonomic identification*: Insects are primarily identified to the genus level, Chironomidae are identified to the sub-family level, and non-insect invertebrates are identified to various levels depending on available keys.

8) Quality assurance procedures: Not Avaliable.

9) *Data analysis/Metrics:* No standard data analysis procedure has been designated at this time. RIVPACS will be utilized to develop a model to determine the level of impact to the biological assemblage at the site.

10) *Habitat assessment:* Site evaluations are conducted to determine the suitability of reference sites and the degree or type of degradation occurring within test sites. Three major categories are evaluated: Riparian, bank, and channel.
Riparian – 1) vegetative condition, 2) percent historic floodplain remaining intact, 3) anthropogenic activity within the floodplain, 4) alteration of the vegetation within the floodplain, and 5) erosional deposition into stream from surrounding hillslopes.
Bank – 1) percent of streambank with deep, binding root mass, and 2) percent of stream with active lateral cutting.
Channel – 1) siltation, and 2) large woody debris. Additional measures are taken at each site for channel shade, width, depth, substrate, stream slope, dominant erosional habitat type, and dominant depositional habitat type.

11) *Purpose for monitoring:*
- Development of biocriteria and bioassessment protocol
- Monitoring of impacts from timber harvest, grazing and mining activities
- Ensure compliance with the Clean Water Act
- TMDL implementation

United States Geologic Survey - National Water Quality Assessment

The USGS National Water Quality Assessment (NAWQA) program uses a benthic macroinvertebrate sampling method developed by Thomas F. Cuffney, Martin E. Gurtz, and Michael R. Meador and revised method for characterizing stream habitat developed by Faith A. Fitzpatrick, Ian R. Waite, Patricia J. D'Arconte, Michael R. Meador, Molly A. Maupin, and Martin E. Gurtz. However, prior to 1998, when most of the California data was collected, NAWQA used a stream habitat assessment method developed by Michael R. Meador, Cliff R. Hupp, Thomas F. Cuffney, and Martin E. Gurtz.

1) Habitat selection: Two types of samples are collected at each site: 1) qualitative multi-habitat (QMH) sampling and 2) richest targeted habitat (RTH) sampling. For QMH samples, all habitat types present in the reach are selected. Semi-quantitative RTH sampling focuses on sampling a habitat supporting the faunistically richest community of benthic invertebrates, usually a fast-flowing, coarse-grained riffle. When riffles are not available, woody debris is sampled.

2) *Sampling gear:* The primary sampling gear used to collect QMH samples is a D-frame kick net equipped with a 210 µm mesh net. RTH samples are collected using a 0.5 m by 0.25 m rectangular frame net equipped with a 425 µm mesh net.

3) *Sampling method:* Two types of samples are collected at each site: 1) qualitative multi-habitat sampling (QMH) and 2) richest targeted habitat (RTH) sampling.

Qualitative Multi-habitat

QMH sampling effort is variable because it depends on the types of habitats present and their abundance within the sampling reach. A D-frame kick net is used to collect samples by kicking, dipping, or sweeping in a manner appropriate for the instream habitat type being sampled. When possible, equal sampling effort is applied to each habitat type within the sampling reach. This is usually accomplished by dividing the available 1-hour sampling time equally among the instream habitat types. The D-frame kick net collections are supplemented with visual collections and, where appropriate, with seines to collect highly-motile invertebrates. Visual collections involve manually collecting large rocks, coarse organic debris, clay from stream margins, root wads, and macrophytes or other substrates, and visually locating and removing any associated organisms.

Richest Targeted Habitat

The rectangular frame net is held perpendicular to the direction of flow and pressed tightly against the stream bottom. Benthic invertebrates are collected from an area of approximately 0.25 m^2 immediately upstream of the net. If 50 percent or more of a rock lies within the sampling area, it is removed and held in front of the net opening, and attached organisms are dislodged into the net by gently brushing the surface of the rock with the hand and then with a fingernail brush. After a rock is brushed, it is examined to determine if any closely adhering organisms are present. Such organisms are removed from the rock surfaces using forceps and placed into a separate vial holding the large-rare sample component. This sample component contains large organisms that can interfere with sample splitting and rare organisms that might be lost during sample splitting. After the large rocks (fist size and larger) are removed, the sampling area is dug to a depth of about 0.1 m. Any remaining organisms are dislodged into the net by kicking the substrate within the sample area for a period of 30 seconds. The material collected in the net is then transferred to an appropriate container, usually a 19-L (5-gal) plastic bucket or dishpan, for further field processing. Subsequent elements of the composite sample are added to this container and then processed, or the separate elements may be processed and then composited. A minimum of five samples, apportioned within and among examples of the targeted instream habitat type, are composited into a single RTH sample. Examples of the targeted habitat type are collected from across the length and width of the sampling reach.

4) *Area sampled:* The total area sampled per RTH composite is 1.25 m^2. The total area sampled for the QTH sample is variable.

5) *Replication:* More intensive sampling is conducted at a subset of four to six sites to assess spatial variability among reaches and short-term temporal variability at a site. At these sites, three sampling reaches are established to represent environmental conditions associated with the basic fixed site. One sampling reach is sampled in each of 3 successive years to estimate short-term temporal variability. Two additional sampling reaches are sampled in 1 year to assess the magnitude of reach-to-reach variability.

6) *Subsampling and enumeration:* Samples are field processed to reduce the volume of each sample component so that it fits in to a 1-L sample container with ample room for preservative. Sample volume reductions are accomplished by removing large debris, elutriating to remove inorganic sediments, and then splitting the elutriated samples. Field processing can result in the production of four sample components from each composite sample: large-rare, main-body, elutriate, and split-sample components.

   Field processing begins with the removal of large rocks and organic debris, such as leaves, twigs, and roots, from the sample. These materials are discarded after all attached invertebrates have been removed. The remaining material is examined for large, rare organisms that can be lost during subsequent sample splitting. These large-rare organisms are removed and placed in a separate, labeled container that is identified as the "large-rare" sample component. All organisms that are picked from the sample by hand prior to sample splitting are added to the large-rare sample component.

   The remaining sample material is elutriated onto an appropriately sized sieve (425-Φm mesh for semi-quantitative samples and 212-Φm mesh for qualitative samples) to separate the lighter organic material from the heavier sand and gravel. Elutriation is usually accomplished by placing the sample in a deep bucket filled about one-fourth to one-half with water. The contents of the bucket are stirred by hand to suspend as much material as possible. The bucket is picked up, swirled, and then gently decanted onto an appropriate sieve. The elutriation process is repeated until it appears that only sand and gravel remain in the elutriation bucket. The sand, gravel, and small pebbles remaining in the bucket are visually examined for invertebrates, particularly case-building caddisflies and small mollusks. Invertebrates that are removed during this process are added to the large-rare sample component. Once free of invertebrates, the left-over sand and gravel is retained as a quality-assurance check on the efficiency of elutriation.

   Elutriated material retained on the sieve is quickly examined for large, rare organisms that are added to the large-rare sample component. If, after elutriation and compositing, the volume of material constituting the main-body or elutriate sample component exceeds 0.75 L, that sample component is split in the field. Any debris or large organisms that remain in the sample is removed to simplify the sample-splitting process. Organisms so removed are added to the large-rare sample component, whereas debris is discarded after any attached invertebrates are removed.

   Sample splitting is accomplished by using either a special sieve sample splitter (Mason, 1991) or a sieve diameter splitting method. Once the sample has been split, one half of the sample is randomly selected. If the sample being processed is an elutriate sample, then the half of the sample selected is retained for analysis and the other half is discarded. If the sample being processed is a main-body sample, then the half of the sample selected

is designated as the main-body component and the other half is designated as the "split" sample component. Some particularly large samples may require repeated splitting to obtain suitable volumes (less than or equal to 0.75 L) of main-body, split, and elutriate sample components. If the resulting split-sample component (elutriate, split, or main-body) exceeds 0.75 L, it is split again. Careful records of the number of splits performed and the portion of the original sample retained for analysis are kept and entered on the appropriate field data sheet.

After samples have been processed, they are transferred to appropriately sized plastic sample containers and an internal sample label is filled out and placed in the container. The sample should occupy approximately one-half to three-fourths of the container volume. A solution of 10% buffered formalin is added to bring the total volume to within 2 cm of the top of the jar. The jar is then capped and slowly inverted several times to mix the contents of the jar with the formalin solution and to remove any air trapped in the sample matrix. The jar is then opened and topped off with 10% buffered formalin.

Qualitative Visual Sort Method

The preservative is rinsed from the sample through a sieve that has a mesh size less than or equal to that used in the field. If necessary, the sample is elutriated to separate inorganic and organic detritus. The sample is then size-fractionated by using a 4.75-mm sieve. To ensure consistent and effective sorting, the sample is apportioned evenly among multiple white sorting trays. The number and size of the trays are adjusted so that about 50 percent of the bottom is visible in each tray. Total sorting time is limited to 2 hours. The coarse-size fraction is sorted for about 0.25 hour. The remaining time, about 1.75 hours, is apportioned between the fine-size fraction and any elutriated inorganic debris; however, if the taxonomist determines that the entire sample has been adequately sorted without adding different taxa, and then sorting is terminated at less than 2 hours. This action is approved by a second taxonomist and noted on the bench data sheet. If the volume of the fine-size fraction is such that it cannot be adequately sorted in about 1.75 hours, then the sample is divided directly on a sieve or on an appropriate sub-sampling frame so that at least 25 percent of this fine-size fraction can be sorted. The remaining unsorted remnant is quickly scanned and sorted for distinct taxa.

Each tray is sorted systematically by a taxonomist for mature, undamaged organisms. After one complete pass of the tray, the detritus is redistributed by rocking the tray and sorting continues. BMIs are sorted into gross taxonomic categories and placed into polyseal screw-cap vials that contain 70% ethanol. At least 50 Chironomidae larvae are sorted whenever possible. Visually distinguishing Genus- or Species-level diversity for some BMI taxa is often difficult; therefore, comparable numbers of organisms of these groups are sorted from each tray of each sample. All unique mollusk shells are sorted, even if the body of the organism is not present.

Quantitative Fixed-Count Subsampling Method

The principal objective of the fixed-count method is to identify and estimate the abundance of each BMI taxon sorted from the sample. This method is similar to the USEPA's RBP sample-processing procedure (Barbour et al. 1999; Plafkin et al. 1989).

The fixed count is based on a minimum number of organisms sorted from the sample and is defined by the study's data quality objectives (for example, 100-, 200-, or 300-organism fixed-count target).

Samples containing more organisms than the fixed-count target are subsampled by using a subsampling frame partitioned into 5.1- by 5.1-cm grids. However, uniformly distributing a sample in a subsampling frame is often difficult, and organisms in the sample matrix tend to have a clumped distribution. Therefore, subsampling by simply acquiring a single, very small portion from a subsampling frame could lead to extreme errors in estimating the abundance of taxa in the sample. The method described below uses multiple, randomly selected 5.1- by 5.1-cm portions of the original sample (stage-1 grids) to estimate abundance accurately. Large-rare organisms are sorted from any remaining portion(s) of the sample after the random subsampling is complete.

Total sorting time is limited up to a maximum of 8 hours, depending on the fixed-count target. The time limitation has been implemented to avoid spending too much time on samples that contain few or have exceedingly difficult detritus to sort. A generalized processing procedure is listed as follows:

- The sample is uniformly distributed in a subsampling frame (stage-1 subsampling frame).
- An estimate of the average number of organisms per stage-1 grid is obtained.
- By using the average number of organisms per stage-1 grid, an appropriate processing strategy is selected.
- The grids are randomly selected from either a stage-1 or a stage-2 subsampling frame, and organisms are sorted from each grid.
- Large-rare organisms are sorted from any remaining unsorted portion(s) of the sample.

Three sizes of gridded subsampling frames are used, 12 grid (15.2 cm X 20.3 cm X 3.8 cm), 24 grid (20.3 cm X 30.5 cm X 3.8 cm), and 42 grid (30.5 cm X 35.6 cm X 3.8 cm). The size of the subsampling frame chosen depends on the total sample volume and organism density; frame size increases with sample volume and density. If the volume of a sample is very low but the density of the BMIs is high, the subsampling frame size is dictated by the density of organisms in the sample. Occasionally, the volume of detritus is so small and the BMIs are so depauperate that the use of a sub-sampling frame is not necessary. The primary objective is to choose a frame size for uniform dispersal of the sample.

The mean number of organisms per stage-1 grid is used to determine the appropriate subsampling strategy. This mean is obtained by randomly selecting five grids from the stage-1 subsampling frame and uniformly distributing the material from each grid into separate, appropriately sized, estimation trays. Estimation trays with either 49 or 81 grids can be used to obtain a uniform distribution and density of sample material. The organisms in each of three randomly chosen estimation tray grids are counted and used to estimate the number of organisms in each estimation tray and, hence, each stage-1 grid. Separate estimates are made from each of the five estimation trays. The resulting five

estimates are averaged to give an estimate of the number of organisms in each stage-1 grid. An informed processing decision can be made once the mean number of organisms per stage-1grid has been estimated. Sub-sampling may involve processing multiple randomly selected stage-1 grids from the stage-1 subsampling frame (1-stage sub-sampling) or a further subsampling of three to five stage-1 grids (2-stage subsampling). Numeric criteria are used to determine the appropriate subsampling strategy. Once the appropriate level of subsampling has been achieved, the approximate number of random grids are randomly selected for sorting. Additional grids are randomly selected as needed to reach the fixed-count target.

The contents of each randomly chosen stage-1 or stage-2 grid are sorted separately by using a dissecting microscope with X 10 magnification. All identifiable organisms are sorted. Mollusk shells are only sorted if the animals are present in the shells. Only a portion of colonial organisms, such as Bryozoa or Porifera, is sorted to document its presence in the sample. Vertebrates, exuviae, invertebrate eggs, microcrustaceans, and terrestrial organisms are not sorted. However, terrestrial insects that have an aquatic lifestage are sorted.

Once sorting has begun, the grid is sorted to completion even if numeric or time frame criteria are exceeded. Organisms are enumerated as they are removed from each grid and pre-sorted into categories. Organisms are placed in polyseal capped vials containing 70% ethanol. The sort-time criteria, excluding time required to prepare the sample and estimate grid densities, are 8 hours for a 300-organism fixed-count target and 3 hours for a 100-organism fixed-count target.

Some large-rare taxa may be present but at such low densities that it is unlikely that they will be encountered in the random subsamples. The quantitative sample-processing method accounts for these large-rare taxa by visually sorting them from the unsorted portion of the sample. This sorting is limited to 15 minutes. If inorganic debris is separated from the sample, this debris also is sorted for large-rare organisms.

7) *Taxonomic identification*: The National Water Quality Laboratory (NWQL) Biological Group (BG) provides three levels of taxonomic assessment for BMI samples. These levels include (1) the Standard Taxonomic Assessment (STA), (2) the Rapid Taxonomic Assessment (RTA), and (3) the Custom Taxonomic Assessment (CTA). Each provides a different basic level of taxonomic resolution to address various water-quality and related data-analysis objectives. The STA and RTA are adapted from the U.S. Environmental Protection Agency (USEPA) Rapid Bioassessment Protocols (RBP) (Barbour et al., 1999; Plafkin et al., 1989). The STA represents a taxonomic effort similar to that described in the USEPA RBP III (Barbour et al., 1999; Plafkin et al., 1989) and in many other state biomonitoring protocols. It is currently (2000) the level of resolution used by the USGS NAWQA Program for BMI samples. In general, mollusks, crustaceans and insects are identified to either the Genus or Species level. Aquatic worms are identified to the Family level. Other BMI groups, such as flatworms and nematodes, are typically identified at higher taxonomic levels (for example, Phylum or Class). The RTA represents a taxonomic effort similar to the USEPA RBP II (Barbour et al., 1999; Plafkin et al., 1989). In general, all BMI groups are identified to the Family level, except for

groups such as flatworms and nematodes, which are typically identified at higher taxonomic levels (for example, Phylum or Class). The CTA provides a customer-specified taxonomic effort that is not provided in the STA or RTA.

8) *Quality assurance procedures:* Not available.

9) *Data analysis/Metrics:* Not available.

10) *Habitat assessment:* Habitat is assessed using a first-level reach characterization and a more detailed second-level reach characterization.

First-level reach characterization:
Six transects, as a minimum, are established to collect information throughout the reach with two transects established at or near each boundary. If the reach is established on the basis of the presence of two examples of each of two types of geomorphic channel units, the remaining four transects are established at the middle of each geomorphic channel unit. If the reach is defined on the basis of channel width, then the remaining four transects are evenly spaced throughout the reach. Transects are oriented perpendicular to streamflow.

- Channel width: Measure the channel width along the transect from left edge of water to right edge of water.
- Bank width: Bank width is the distance between the channel bed and the flood plain. This distance is measured with a tape measure or rangefinder.
- Flood-plain width: Flood-plain width is measured as the distance between the significant changes in slope that distinguish the flood plain from terraces and riparian features. If this distance is less than 50 m, it can be measured with a tape measure or rangefinder. However, if the flood-plain width is greater than 50 m, it is determined from maps or aerial photographs, and indicated as greater than 50 m on the form.

For the next 3 items, data are collected at three points along each transect. These points should correspond to the thalweg, and to two locations that are equally spaced along the transect (or three equally spaced locations if no thalweg is apparent).

- Depth: In wadeable reaches, water depth between the water surface and the bed substrate is measured with a wading rod and recorded. In nonwadeable reaches, a sounding line or hydroacoustic depth meter may be necessary to determine depth. When using a hydroacoustic depth meter, the investigator maneuvers the boat along the transect with the meter operating, so as to produce a continuous recording of water depth along the transect. Three depth measurements, one at the thalweg and two at locations equally spaced along the transect, can be determined from the hydroacoustic chart.
- Velocity: In wadeable reaches, record velocity using a Price AA current meter, pygmy meter, or Gurley meter. In nonwadeable reaches, use a velocity meter appropriate for velocity determinations at that site. Velocity is recorded at 60% depth

where depth is less than 1 m. At depths greater than or equal to 1 m, two velocity measurements, one at 20% depth and the other at 80% depth, are recorded.

- Bed substrate: Determine the spatially dominant and subdominant substrates. In turbid wadeable reaches and in nonwadeable reaches, a sample of the substrate is obtained by using an appropriate device such as a shovel, Ponar sampler, or Ekman dredge. In turbid wadeable reaches and in nonwadeable reaches, the presence of boulders and bedrock cannot be determined by sampling. However, in turbid wadeable reaches, the presence of these substrate types can be determined by touch. In nonwadeable reaches where sampling devices cannot yield a substrate sample, acoustic recording of the stream bottom along the transect can detect boulders and bedrock.

- Embeddedness: Embeddedness is measured by rating the percentage of the surface area of the larger-sized particles (by visual estimation) covered by fine sediment. To determine how much of the surface area of large particles is covered in order to provide a rating, select five relatively large (gravel to boulder size) substrate particles at the three sampling points along the transect and examine them on the sides. Note the percentage of each particle's height that was buried in sediment by the extent of discoloration on the particle. The rating is based on the percentage of coverage of fine sediment as determined from the average percentage of coverage for the five particles. In turbid wadeable reaches and in nonwadeable reaches, a sample of the substrate is obtained using an appropriate device such as a shovel, Ponar sampler, or Ekman dredge.

- Canopy angle: From the midpoint of the transect, use a clinometer to determine the angle from the line of sight of the investigator to the tallest structure (for example, tree, shrub, building, or grass) on the left bank (in the general area of the transect). The same procedure is done at the right bank. The sum of these angles is computed and subtracted from 180 degrees.

- Aspect: Record the aspect (0 to 360 degrees) of the downstream flow of the stream using a compass. At the midpoint of the transect, face downstream and point a compass parallel to streamflow.

- Habitat features: Determine the type and amount (two-dimensional area) of all habitat features that are partly or wholly within a 2-m zone on either side of the transect. Habitat features consist of any mineral or organic matter that produces shelter for aquatic organisms to rest, hide, or feed, and include natural features of a stream such as large boulders, woody debris, undercut banks, and aquatic macrophyte beds, as well as artificial structures such as discarded tires, appliances, and parts of automobiles. Habitat features are not counted when they are in insufficient depth (usually less than 20 cm).

- Bar/Shelf/Island: If channel bars, shelves, or islands are present, measure width using a tape measure or rangefinder. Determine the spatially dominant and subdominant substrates along the transect for the bars, shelves, and islands that occur. Also

estimate the percentage of coverage of woody and herbaceous vegetation for the entire bar/shelf/island.

- Bank angle: A clinometer is used to measure the angle formed by the downward-sloping bank as it meets the stream bottom. The angle is determined directly from a clinometer placed on top of a surveyor's rod or meter stick that is aligned parallel to the bank along the transect. The clinometer reading is subtracted from 180 degrees to produce the bank angle. If the height and shape of the bank are such that more than one angle is produced, then an average of three readings is recorded. Both left bank and right bank (facing downstream) angles are recorded.

- Bank height: Determine the left and right distance from the channel bed to the top of the bank. A surveyor's rod and hand level can be used if this distance can be measured directly. If the bank height cannot be measured directly, then it can be estimated. Note that the bottom of the bank is the deepest part of the channel. At large, nonwadeable reaches, topographic maps may be useful in determining bank height.

- Bank vegetation stability: Bank vegetation stability is evaluated using a rating based on four classes that represent percent coverage of the bank surface. The rating includes only that part of the bank that is within 2 m of either side of the transect, to the top of the bank.

- Bank shape: Record the shape of the left and right banks as: concave upward, linear, or convex upward.

- Bank erosion: The types of bank material movement, if present, are noted. These types include mass wasting (debris avalanche, rotational failure, and slab failure), and cut-bank scalloping. Indicate the presence of bank erosion for the left and right banks as: debris avalanche, rotational failure, slab failure, cut-bank scalloping, or none.

- Bank substrate: Determine the spatially dominant and subdominant substrate types that are present in an area of the bank that is within 2 m of either side of the transect, to the top of the bank. This procedure is done for the left and right banks.

- Bank woody vegetation: The point-centered quarter method is used to evaluate density and dominance of bank woody vegetation (Mueller-Dombois and Ellenberg, 1974). Sampling points are established on both banks at the ends of the transect so as to include dominant bank woody vegetation. Four quarters are established at a sampling point at the intersection of two perpendicular lines, one of which is the transect. Trees and shrubs are included in the analysis. Trees are distinguished from shrubs in that trees are at least 2 m high and have a diameter at breast height (dbh) of at least 3 cm. The sampled trees or shrubs are identified to species, and the distance from the sampling point to the nearest tree or shrub in each quarter is measured, along with its dbh. Where bank woody vegetation is growing in narrow strips or rows, the two closest trees or shrubs on either side of the sampling point are measured. Where a single tree or shrub has developed many separate trunks, an average dbh for three trunks is recorded, along with the total number of trunks.

- Photodocumentation: Stream conditions at three transects, including the transects at or near the reach boundaries and one transect representative of reach conditions, are photographed. Semipermanent markers are established at these locations to facilitate taking repeat photographs. Color photographs, preferably slides, are taken that include upstream, transect, and downstream views of the channel and should include a scale reference in the image. The inclination and aspect of the camera lens are important and are measured with a compass. A level camera is preferred to an inclined one because inclination complicates the perspective of the view and makes accurate duplication of repeat photographs difficult. The aspect of the camera is noted by pointing a compass at the central aiming point in the view and recording the compass reading. Photographs are taken facing upstream, facing perpendicular to the channel, and facing downstream, from either the left or right banks.

- Diagrammatic mapping: Draw a schematic or representative map of the reach. The map should include location of geomorphic channel units, habitat features, and bank and flood-plain land use. Indicate the stream type and general shape of the channel.

- Aquatic and riparian vegetation species: Record the species name of all common aquatic (submerged, emergent, and floating) and riparian (bank--herbaceous and woody, and flood plain--herbaceous and woody) species. Be sure to note the five most common for each category.

Second-level reach characterization

A second-level reach characterization also is conducted at all fixed sites. This is a detailed reach characterization and is designed to provide additional quantitative data on geomorphic and hydraulic properties that are critical to the evaluation of temporal changes in the environmental setting and stream habitat. The second-level reach characterization consists of an analysis of hydraulic properties and channel geometry plus additional components tailored to enhance an understanding of temporal changes. The analysis of channel geometry consists of longitudinal profiles of the water surface, flood plain, and channel bed; cross-sectional surveys with levels; a map of the reach; and a quantitative analysis of bed and bank materials. Additional suggested components of the second-level reach characterization include permanent plot vegetation analysis and detailed quantitative mapping of habitat features throughout the reach. Study unit personnel are responsible for developing an appropriate form for recording the second-level reach characterization.

The longitudinal profile of the channel bed is conducted along the thalweg (or the approximate center of the channel if a thalweg is not apparent) on the basis of channel-bed elevations recorded at intervals equal to one channel width. This distance is generally sufficient to determine the mean slope of the reach. The water-surface profile can be determined simultaneously by having the rodman record the water depth at each location and add this value to the channel-bed elevation. Profiles of the flood plain along both banks also are conducted. In nonwadeable reaches, longitudinal profiles of the channel bed are determined using a hydroacoustic depth meter, and water-surface elevations are determined along one bank or both banks.

At a minimum of three locations (both reach boundaries and a location that includes a prominent geomorphic feature), leveled cross-sectional surveys are conducted from left

flood plain to right flood plain. Each cross-sectional survey is plotted, with elevation recorded on the ordinate axis and distance in meters along the abscissa. All surveys are conducted in relation to the reference location. A map of the reach is constructed, indicating the locations of the longitudinal profiles and the cross-sect ional surveys. Cross-sectional surveys of nonwadeable reaches include as much information as can possibly be recorded.

In addition to an analysis of channel geometry, a quantitative analysis of channel substrate particle size is conducted. Pebble counts are conducted to determine bed material particle-size distribution in wadeable reaches. At the three surveyed cross sections, a pebble-count transect is established, and the pebble count is conducted in the following method:

(1) Begin the count at each transect at bankfull elevation on the left bank and proceed to bankfull elevation on the right bank.
(2) Proceed one step at a time, with each step constituting a sampling point.
(3) At each step, reach down to the tip of your boot and, with your finger extended, pick up the first pebble-size particle touched by the extended finger.
(4) To reduce sampling bias, look across and not down at the channel bottom when taking steps or retrieving bed material.
(5) As you retrieve each particle, measure the intermediate axis. If the intermediate axis cannot be determined easily, measure the long diameter and the short diameter of the particle, and determine the average of the two numbers.

Thus, the size distribution of particles is determined and expressed in percentage by number of particles. A count of 100 particles is recommended; however, to determine percentages of particle sizes, 50 or 25 particles can be measured. To obtain a quantitative determination of finer grained bed material, three samples of the bed material are collected along each transect and composited. In addition, samples of the bank substrate material can be collected from one bank or both banks. These samples are returned to the laboratory for sieve analysis.

Permanent plot vegetation analysis is also suggested as a component of the second- level reach characterization. To construct a permanent vegetation plot, select an area at the end of each of the surveyed cross sections. A 20- by 20-m plot is identified by using a tape measure to determine the appropriate distance and a compass to establish 90-degree angles at the corners of the plot. The corners are then marked with semipermanent boundary markers. The edge of the plot nearest the bank edge should be at least several meters from the bank. Sample the vegetation by determining the diameter and species of all trees and shrubs within the plot. Record only living trees and shrubs. If the riparian zone is narrow such that a 20- by 20-m plot cannot be established, then two or more smaller plots are established so that the total area sampled equals 400 m^2. Where herbaceous vegetation is clearly dominant, then a 10- by 10-m square plot is established. At herbaceous vegetation plots, the aerial coverage of up to five species is measured, and the percent coverage of these species within the plot is calculated.

Mapping of all geomorphic channel units and habitat features can also provide critical information needed to evaluate temporal trends in habitat. Though the diagrammatic stream map should indicate the presence of these units and features to approximate scale,

the first-level reach characterization does not attempt to quantify the occurrence of all features throughout the reach. In the second-level reach characterization, the two-dimensional area of all significant geomorphic channel units and habitat features is determined.

11) Purpose for monitoring:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams.
- Describe how water quality is changing over time, and
- Improve our understanding of the primary natural and human factors affecting water quality.

United States Environmental Protection Agency - Environmental Monitoring and Assessment Program

EMAP is a research program to develop the tools necessary to monitor and assess the status and trends of national ecological resources. EMAP's goal is to develop the scientific understanding for translating environmental monitoring data from multiple spatial and temporal scales into assessments of ecological condition and forecasts of the future risks to the sustainability of our natural resources. The objectives of REMAP are to: 1) evaluate and improve EMAP concepts for state and local use, 2) assess the applicability of EMAP indicators at differing spatial scales, and 3) demonstrate the utility of EMAP for resolving issues of importance to EPA Regions and states.

A Regional-EMAP (REMAP) study was conducted in 1994-1995 in Californina's Central Valley, which comprises more than 48,000 miles of surface water and 16 percent of the land area in the State and is one of the nation's most productive agricultural areas. The Central Valley REMAP Project was initiated to assess the biological integrity of agriculture-dominated waterbodies located throughout California's Central Valley. Moreover, USEPA is currently collecting additional bioassessment data in California as part of the EMAP Western Surface Water pilot study, which is a five-year research and monitoring project to assess the ecological condition of streams and rivers across the Western U.S.

Typically, EMAP and REMAP studies use the same sampling methods; however, the Central Valley REMAP study used an earlier method developed by Philip A. Lewis and Donald J. Klemm (see Klemm and Lazorchak 1995), while the Western EMAP study uses a revised method developed by D. J. Klemm, J.M. Lazorchak, and P.A. Lewis (see Lazorchak et al.1998). Only the revised (current) method will be discussed in this section.

1) Habitat selection: Each sampling reach is determined as 40 times the wetted width, with a minimum reach length of 150 m and a maximum length of 500 m. The habitats that are sampled are selected randomly by dividing the reach into 11 equidistant cross-sectional

transects, and randomly sampling at the left third, center, or right third from the interior nine transects. For each reach, riffle and run habitat samples are composited into a single "Riffle" sample whereas pool and glide samples are composited into a single "Pool" sample.

2) *Sampling gear:* The primary sampling gear used to collect samples is a modified 0.5 m by 0.3 m rectangular frame kick net equipped with a 595/600 μm mesh net.

3) *Sampling method:* As mentioned previously, the sampling reach is equally divided into 11 cross-sectional transects. At each of the nine interior transects, a sampling point (left, center, or right) is assigned. Once the first sampling point is randomly chosen, points at successive transects are assigned in order (left, center, right). Habitat type is sampled roughly in proportion to their occurrence.

4) *Area sampled:* The total area sampled per transect is 0.5 m^2, and the total area sampled per site is 4.5 m^2. The area sampled per composite sample is variable based on the distribution of habitats sampled at the site.

5) *Replication:* There are no site replicates collected; however, there are QA/QC replicates whereby a different team samples the same site and next year revisits at several sites.

6) *Subsampling and enumeration:* Random subsampling to 300 organisms.

7) *Taxonomic level:* Identification of all organisms to the lowest possible taxon, usually to genus, species, or species group (including Chironomids and Mites).

8) *Quality assurance procedures:* Not available.

9) *Data analysis/Metrics:* Not available.

10) *Habitat assessment:* See Lazorchak et al. 1998.

11) *Purpose for monitoring:*
- Evaluate and improve EMAP concepts for state and local use
- Assess the applicability of EMAP indicators at differing spatial scales, and
- Demonstrate the utility of EMAP for resolving issues of importance to EPA Regions and states.

University of California Sierra Nevada Aquatic Research Laboratory (SNARL)

1) *Habitat selection:* Only riffle habitat is sampled within a 150 m study reach.

2) *Sampling gear:* The primary sampling gear used to collect samples is a D-frame kicknet with 250 μm mesh netting.

3) *Sampling method:* Five riffles are selected from a random number table along the 150 meter reach. The D-net is used to collect kick samples at ¼, ½ and ¾ of the stream width (always start at the location furthest downstream and work up). Kick an area approximately 30 square centimeters directly above the net (a square area with sides equal to net width) is kicked to disturb the substrate and dislodge organisms. The kicking is maintained for a count of about 10-15 seconds, then the rocks are scrubbed by hand for an additional 10-15 seconds (total 20-30 seconds at each of 3 positions = 1-1.5 minutes). Large rocks or wood debris are removed after washing them in the current into the net following each sample position. For streams less than 1-2 meters wide, the 3 kick samples are taken from both sides and middle above or singly one above another at the random number location (instead of taking all 3 across the stream when widths are greater than 1-2 meters). Because the focus of the method is on sampling across different microhabitat types in the stream including varied depth, current, substrate types – the three composited samples should represent the variety of habitat present. One or two composites may be taken if samples are dense with debris.

   When sampling in pools, only a single collection is taken within the tail zone of the pool (i.e. downstream third of pool zone) by sweeping or brushing the sample area into the mouth of the net. The net is sometimes used to scoop through sample area after the sweep. More than a single area sampled usually produces too much sample volume to process and preserve.

   The net should be quickly dipped into the stream to consolidate the material to the bottom of the D-net. Any remaining large debris is removed. The net is inverted into a bucket with 1/4 to 1/3 full of water. The net is shaken out to collect all the debris and insects. The net is dipped into the stream again to consolidate remaining contents and the net is then inverted into the bucket.

   Lighter material is elutriated with a swirling motion into the other bucket five times. Only a small volume of water is used in each elutriation so the receiving bucket does not overflow. Only rocks and sand should be left in the original bucket. These rocks are emptied into a shallow white pan (or the bottom of the bucket is closely examined). Cased caddisflies/snails are examined for and added to sample if found.

   The debris is then strained through a fine mesh aquarium net supported on one bucket (this may also serve as an elutriation since some sand will have gotten into this debris). The contents of the aquarium net is emptied into a sample container. BioQuip forceps are used to scrape any remaining debris into vial. The container is filled with ethanol to preserve the bugs, and a small volume of rose bengal stain is added.

4) *Area sampled:* The total area sampled per composite is 0.27 m^2, and the total area sampled per site is 1.28 m^2.

5) *Replication:* Five replicate composite samples are collected from each site.

6) *Subsampling and enumeration:* Random subsampling to 300 organisms.

7) *Taxonomic level:* Identification of all organisms to the lowest possible taxon, usually to genus, species, or species group (including Chironomids and Mites).

8) *Quality assurance procedures:* See website for detailed information; http://www.swrcb.ca.gov/rwqcb6/QAPP/QAPP_Index.htm

9) *Data analysis/Metrics:* See website for detailed information; http://www.swrcb.ca.gov/rwqcb6/QAPP/QAPP_Index.htm

10) *Habitat assessment:* 15 transects are spaced at 10 meter intervals along the 150 meter delineated reach length (starting at 0). Bank and channel features are measured (wetted perimeter width, bank cover category, bank angles, and vegetation cover (using densiometer) across each transect and at 5 equal-spaced points within each transect the depth, current velocity (60% depth), and substrate type (size class) are measured. Location of each site (mid-reach) is determined with a GPS unit, and elevation determined from map location (and/or barometer). Slope is measured using a hand-held leveling scope sighted on a stadia rod over a series of intervals over the 150 meter reach length. Sinuosity is determined from the ratio of reach length to minimum linear distance from the bottom to top points of the reach. Percent riparian canopy cover by type (within 1 meter on the bank) is visually estimated for the reach. Temperature, pH, conductivity and turbidity are measured using calibrated field meters. Dissolved oxygen is determined in the field using a standard test kit. Alkalinity, nitrogen, phosphate, and hardness are measured in the lab from field samples. General types of algae present are noted for each reach (algae samples from rock surfaces are also collected and preserved). Photo documentation of each reach is also made at 4 points: mid-stream looking upstream at 0, 50, 100, and at 150 meters looking downsteam.

Reach and Riffle-Pool Delineation

The first step in description of physical habitat is delineation of the 150 meter length of the stream reach along an approximation of the thalweg of the channel. To the extent possible, this measurement should be made by following along the bank contours of the channel, laying out the meter tape (50 m on a reel). This may require crossing the channel or even walking in the stream if bank vegetation cover is too dense – but this should be kept to a minimum to avoid disturbance of benthic habitat. For each 25 meter length a flag should be placed to serve as a monument for marking locations and later measurement of gradient. Over the 150 meter reach delineation, the primary data to be recorded is the position along the meter tape (to the nearest meter) where erosional and depositional habitat types begin and end – riffles and pools, respectively. This data provides an indication of the distribution and length of these major geomorphic units within each reach. The position of these habitat features will also be used to determine where the benthic invertebrate samples are to be taken by using a random number table (0-150) to assign a riffle or pool location to be sampled. Any habitat not assigned to the riffle-pool categories may be regarded as transitional glide or run habitat type. Depending on the criteria for reach selection, the starting point of a reach may be

established to maintain the reach within a certain zone defined by the problem of interest, the gradient, vegetation cover, or accessibility. Selection may also be random, using preliminary map information on the target area.

Bank and Channel Features

Bank features on each transect are identified according to bank cover categories (substrate type, vegetation present and eroded, stable or incised). The intersect of interest is between the water level and an approximation of the bank full height of the channel. Bank angle is also rated categorically as shallow (less than 30 degrees), moderate (30-90) or undercut (>90). Riparian vegetation cover over and next to the channel is determined using a concave mirror densiometer, taped to view the canopy in the facing direction of the measure. There are 17 grid points and vegetation reflected at those grid points is recorded at the left and right banks, and mid-stream facing up- and downstream.

Transect Measures

After measuring stream width (wetted perimeter), the transect is visually divided into 5 equally spaced points (visualize the mid-point as 3, and equally divide the left and right sides into points 1 and 2 and points 4 and 5). At each point, the depth and substrate type at the point of contact are recorded (recorder on bank) using a meter stick. Substrate types are grouped by size class for the mineral type, and also according to algal, vegetation or detrital components present at the point. At 60% depth the current velocity is also measured at each point (also record current meter type used and units). Discharge is calculated later for each of the 5 cells measured (current x cross-section area). Any cobble encountered is also rated according to the volume of rock embedded by fine / sand substrates (a visual estimate, calibrated among observers).

Overall Reach Features

The gradient of the channel is measured using a hand-held leveling scope (5X magnification) to sight off a 5 meter leveling rod. The observer serves as the tripod and so should find a position where both upstream and downstream position of the rod can be clearly observed without moving except to turn the upper body. Most readings will be taken over 25 meter intervals but where possible should be taken over 50 meter intervals to save time. The sum difference in up-down readings over 150 will give the percent slope or gradient. The sinuosity of the channel is measured as the ratio of the 150 meter thalweg stream length to the direct line distance from the top to bottom flags defining the reach. This is done by sighting to the leveling rod held at one end of the reach and walking a direct line of sight to the rod, measuring distance with a reel tape over the distance (a person to hold the tape end facilitates the several walks needed to measure the full distance). Riparian vegetation cover is visually estimated as morphological categories of cover (grass, bush, tree) and type. This provides another measure of shading, riparian development and potential inputs. Algae type present is also qualitatively scored. Notes should also be kept on any aquatic vegetation present.

11) *Purpose for monitoring:*

- Biocriteria development and assessment & monitoring.
- Livestock grazing stream restoration

- Acid Mine Drainage stream restoration monitoring.
- TMDL development for sediments.
- Reference condition sampling

Appendix C

Performance Characteristic Evaluation

Appendix C Performance Characteristic Evaluation

To determine the method precision (i.e., measurement error within a site), we evaluated two data sets from SNARL, one from the Leviathan Mine study and another from the Upper Truckee River, and a large database (CalEDAS) from the California Department of Fish & Game containing CSBP data. The Leviathan Mine data set included a total of seven metrics, which were calculated from 54 sites (Table 1). On the other hand, the Upper Truckee River included a total of 15 metrics, which were calculated from 18 sites (Table 2). Where there were common metrics, the data was combined, and several metrics were calculated from a total of 72 sites (Table 3). The data set using the CSBP method was significantly larger (approximately 360 sites) and was much more widely distributed than the SNARL data; however, details on the exact site distribution across the state were not provided.

An analysis of variance (ANOVA) was conducted to compare the variability among replicates at each site. From the mean squared error (MSE), we calculated the root mean square error (RMSE), which can be used to compare precision between metrics, and the coefficient of variability (CV), which can be used to compare precision among metrics. The RMSE provides an estimate of the standard deviation of a population of observations; however, it is scale dependent, and therefore metrics that are on different scales cannot be directly compared. CV, on the other hand, is a unit-less measure calculated by dividing the RMSE by the mean of the dependent variable, which allows for direct comparison among means and indices. Because the CV takes into account the within site variability relative to the sample mean, it was chosen to be the better indicator of precision when comparing the two methods.

Tables 1 and 2 list ANOVA results of SNARL data from the Leviathan Mine dataset and the Upper Truckee River dataset, respectively. Unfortunately, the same metrics were not calculated for both studies; therefore, in our attempt to combine the datasets, the number of observations is not consistent among the different metrics (i.e., N = 18, N = 72)(Table 3). Table 4 lists the among season variability for data collected in the Upper Truckee River study using the SNARL method.

Table 1. ANOVA results of SNARL Leviathan Mine data (N = 54)

Metric	*MS Error*	*RMSE*	*Mean*	*CV*
Species Richness	12.05	3.47	23.52	14.76
EPT Taxa	2.98	1.73	9.00	19.18
Density (ind./m^2)	212000000.00	14551.03	15653.30	92.96
%Chironomidae	0.01	0.07	0.35	20.88
Ratio EPT/Chironomidae	1.38	1.17	1.34	87.24
Hilsenhoff Biotic Index	0.11	0.33	4.52	7.20
Dominance	0.01	0.08	0.40	20.50

Table 2. ANOVA results of SNARL Upper Truckee River data (N =18)

Metric	*MS Error*	*RMSE*	*Mean*	*CV*
Species Richness*	14.17	3.76	27.09	13.90
EPT TAXA*	3.42	1.85	11.10	16.67
No. EPHEMEROPTERA TAXA	1.07	1.03	6.77	15.26
No. PLECOPTERA TAXA	1.58	1.26	4.33	28.99
No. TRICHOPTERA TAXA	1.34	1.16	5.73	20.22
No. of CHIRONOMIDAE	5.98	2.45	11.22	21.80
No. of Individuals	49468.56	222.42	593.24	37.49
DENSITY* (#/m^2) @30x30 cm area	170000000.	13054.01	17948.72	72.73
%EPT	0.01	0.09	0.63	15.00
%CHIRONOMIDAE*	0.00	0.07	0.31	22.44
Chiro Richness / Chiro Density	0.00	0.00	0.01	62.39
Hilsenhoff Biotic Index*	0.13	0.36	4.26	8.46
%TOLERANT TAXA (7-8-9-10)	0.00	0.05	0.11	47.70
INTOLERANT TAXA (0-1-2)	4.66	2.16	14.41	14.98
DOMINANCE*	0.01	0.08	0.36	21.52
%FILTER-FEEDERS	0.00	0.05	0.08	60.62

Table 3. ANOVA results of combined SNARL data (N =18)

Metric	*MS Error*	*RMSE*	*Mean*	*CV*
Species Richness	19.76	4.44	36.80	12.08
EPT TAXA	4.61	2.15	16.83	12.75
No. EPHEMEROPTERA TAXA	1.07	1.03	6.77	15.26
No. PLECOPTERA TAXA	1.58	1.26	4.33	28.99
No. TRICHOPTERA TAXA	1.34	1.16	5.73	20.22
No. of CHIRONOMIDAE	5.98	2.45	11.22	21.80
No. of Individuals	49468.56	222.42	593.24	37.49
DENSITY (no./m^2) @30x30 cm area	61354347.0	7832.90	24197.34	32.37
%EPT	0.01	0.09	0.63	15.00
%CHIRONOMIDAE	0.01	0.08	0.20	38.18
Chiro Richness / Chiro Density	0.00	0.00	0.01	62.39
Hilsenhoff Biotic Index	0.19	0.44	3.58	12.31
%TOLERANT TAXA (7-8-9-10)	0.00	0.05	0.11	47.70
INTOLERANT TAXA (0-1-2)	4.66	2.16	14.41	14.98
DOMINANCE	0.00	0.06	0.25	25.46
%FILTER-FEEDERS	0.00	0.05	0.08	60.62

Table 5 lists the metrics used to describe the characteristics of the benthic macroinvertebrate communities sampled according to each method. It should be noted that the metrics listed in the table are not part of a biological index for either method, and the metrics calculated for each study does not necessarily remain consistent. Therefore, the suite of metrics listed in this table is not intended to be indicative of the analyses performed for each study.

Table 4. Among season CVs for SNARL Upper Truckee River data.

Metric	*Spring 95*	*Spring 97*	*Fall 98*	*Spring 99*	*Fall 99*
Species Richness	13.79	22.72	13.12	15.02	14.05
EPT TAXA	28.21	20.71	19.02	21.24	14.48
No. of Individuals	50.92	27.83	29.49	36.79	23.59
Density (ind / m^2)	50.92	27.83	35.61	47.55	72.93
%Chironomidae	19.58	24.74	21.13	13.80	21.56
Ratio EPT/Chironomidae	60.05	60.37	84.01	119.34	59.55
Hilsenhoff Biotic Index	4.86	11.50	8.66	6.63	4.90
Dominance	35.64	22.46	19.97	19.02	19.53

* N = 72 for these metrics.

Table 5. Metrics used to by each method to describe characteristics of Benthic Macroinvertebrate communities.

Metric	CSBP	SNARL	Metric	CSBP	SNARL
Taxa Richness	X	1	% Hydropsychidae	X	
EPT Taxa	X	X	% Baetidae	X	
Ephemeroptera Taxa	X	X	% Dominant Taxa	X	X
Plecoptera Taxa	X	X	% Collectors	X	
Trichoptera Taxa	X	X	% Filterers	X	X
Chironomidae Taxa		X	% Scrapers	X	
EPT Index (%)	X	X	% Predators	X	
Sensitive EPT Index	X	2	% Shredders	X	
Shannon Diversity Index	X		Density		X
Hilsenhoff Biotic Index		X	Estimated Abundance	X	X
Tolerance Value	X		Ratio EPT/ Chironimdae		X
% Intolerant Organisms	X		Chironomidae Richness/ Chironomidae Density		X
% Tolerant Organisms	X	X			

Footnotes:

1 Species Richness

2 Number of Intolerant Taxa

Table 6 lists the ANOVA results of the CSBP dataset. Table 7 shows the ANOVA results of both datasets and can be used to compare precision estimates between methods. Because the CSBP data set contained a much larger number of observations (N =300), we decided to standardize the number of observations and compare the results to see if observation size had any significant effect on differences in precision (Table 8). Furthermore, we standardized the number of replicates between the two datasets to see if replicate size had any effect on differences in precision (Table 9).

Table 6. ANOVA results of CSBP data (N = 300)*

Metric	*MS Error*	*RMSE*	*MEAN*	*CV*
TAXA RICHNESS	10.33	3.21	16.72	19.23
EPT Taxa	2.54	1.59	6.45	24.71
Ephemeroptera Taxa	0.53	0.72	2.97	24.44
Plecoptera Taxa	1.19	1.09	2.83	38.54
Trichoptera Taxa	1.01	1.00	2.82	35.65
Chironomid Taxa	0.46	0.68	2.46	27.47
%EPT	127.56	11.29	42.21	26.76
%Chironomidae	71.46	8.45	19.99	42.29
Hilsenhoff Biotic Index	0.63	0.79	5.77	13.70
% Tolerant Taxa	126.30	11.24	22.37	50.23
Intolerant Taxa	0.89	0.94	2.99	31.49
Dominance	138.83	11.78	43.45	27.12

* For plecoptera taxa metric, N = 168

Table 7. Comparison of ANOVA results between CSBP and SNARL methods.

	CSBP			*SNARL*			*% Difference*
Metric	*RMSE*	*MEAN*	*CV*	*RMSE*	*MEAN*	*CV*	
Richness	3.21	16.72	19.23	3.76	27.09	13.9	5.4
EPT Taxa	1.59	6.45	24.71	1.85	11.1	16.67	8.04
Ephemeroptera Taxa	0.72	2.97	24.44	1.03	6.77	15.26	9.18
Plecoptera Taxa	1.09	2.83	38.54	1.26	4.33	28.99	9.55
Trichoptera Taxa	1	2.82	35.65	1.16	5.73	20.22	15.43
Chironomid Taxa	0.68	2.46	27.47	2.45	11.22	21.8	5.67
%EPT	11.29	42.21	26.76	9.5	63.32	15	11.76
%Chironomidae	8.45	19.99	42.29	6.99	31.15	22.44	19.85
Hilsenhoff Biotic Index	0.79	5.77	13.7	0.36	4.26	8.46	5.24
% Tolerant Taxa	11.24	22.37	50.23	5.4	11.32	47.7	2.53
Intolerant Taxa	0.94	2.99	31.49	2.16	14.41	14.98	16.51
Dominance	11.78	43.45	27.12	7.78	36.16	21.52	5.6

Table 8. Comparison of precision estimates between CSBP and SNARL methods where population size is consistent (N = 18)

	CSBP				SNARL			
Metric	MS Error	RMSE	Mean	CV	MS Error	RMSE	Mean	CV
EPT Taxa	1.63	1.28	5.87	21.75	4.61	2.15	16.83	12.75
Ephemeroptera Taxa	0.31	0.56	2.65	21.19	1.07	1.03	6.77	15.26
Plecoptera Taxa	0.63	0.79	0.91	87.45	1.58	1.26	4.33	28.99
Trichoptera Taxa	0.67	0.82	2.04	40.08	1.34	1.16	5.73	20.22
Chironomidae Taxa	0.43	0.65	2.20	29.62	5.98	2.45	11.22	21.80
%EPT	102.42	10.12	47.88	21.14	0.90	9.50	63.32	15.00
%Chironomidae	76.66	8.76	20.10	43.55	0.60	7.74	20.27	22.44
Hilsenhoff Biotic Index	0.43	0.65	4.74	13.74	0.19	0.44	3.58	12.31

Table 9. Comparison of precision estimates between CSBP and SNARL methods where replicate size is consistent (replicates = 3).

	CSBP				SNARL			
Metric	MS Error	RMSE	Mean	CV	MS Error	RMSE	Mean	CV
EPT Taxa	2.54	1.59	6.45	24.71	3.14	1.77	10.66	16.60
Ephemeroptera Taxa	0.53	0.72	2.97	24.44	0.81	0.90	6.70	13.47
Plecoptera Taxa	1.19	1.09	2.83	38.54	1.11	1.05	4.28	24.64
Trichoptera Taxa	1.01	1.00	2.82	35.65	1.24	1.11	5.69	19.59
Chironomidae Taxa	0.46	0.68	2.46	27.47	4.67	2.16	11.00	19.64
%EPT	127.56	11.29	42.21	26.76	0.49	7.03	64.10	10.97
%Chironomidae	71.46	8.45	19.99	42.29	0.53	7.31	32.36	22.58
Hilsenhoff Biotic Index	0.63	0.79	5.77	13.70	0.17	0.41	4.31	9.45

Case Example Defining Method Performance Characteristics

While developing a statewide network for biomonitoring and bioassessment using macroinvertebrate data, Florida Department of Environmental Protection (DEP) rigorously examined performance characteristics of their collection and assessment methods in order to provide better overall quality assurance of their biomonitoring program and to provide defensible and appropriate assessments of the state's surface waters (Barbour et al. 1996b, c). This case example was summarized from Chapter 4 - Performance-Based Methods System in *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers* (Barbour et al. 1999).

Characterizing Sampling Error (Method Precision on a Population of Reference Sites): A total of 56 reference sites were sampled in the Peninsula bioregion. The Florida Stream Condition Index (SCI) score could range from a minimum of 7 to a theoretical maximum of 31 based on the component metric scores. However, in the Peninsula, reference site SCI scores generally ranged between 21 and 31. A mean SCI score of 27.6 was observed with a CV of 12.0%.

Determining Method and Index Sensitivity: Distribution of SCI scores of the 56 reference sites showed that the 5th percentile was a score of 20. Thus, 95% of Peninsula reference sites had a score >20. Accuracy of the method, using known stressed sites, indicated that approximately 80% of the test sites had SCI scores ≤ 20. In other words, a stressed site would be assessed as impaired 80% of the time using the collection method in the Peninsula bioregion in the summer, and an impairment criterion of the 5th percentile of reference sites.

Determination of Method Bias and Relative Sensitivity in Different Site Classes: A comparative analysis of precision, sensitivity, and ultimately bias, was performed for the Florida DEP method and the SCI index. The mean SCI score in the Panhandle bioregion, during the same summer index period, was 26.3 with a CV = 12.8% based on 16 reference sites. Comparing this CV to the one reported for the Peninsula above, it is apparent that the precision of this method in the Panhandle was similar to that observed in the Peninsula bioregion. On the other hand, the 5th percentile of the Panhandle reference sites was an SCI score of 17, such that actual sensitivity of the method in the Panhandle was slightly lower than in the Peninsula bioregion. An impaired

site would be assessed as such only 50% of the time in the Panhandle bioregion during the summer as opposed to 80% of the time in the Peninsula bioregion during the same index period.