Biomass And Toxicity Of A Newly Established Bloom Of The Cyanobacteria Microcystis Aeruginosa And Its Potential Impact On Beneficial Use In The Sacramento−San Joaquin Delta

prepared by Lehman, Peggy W

submitted to Science Program 2004

compiled 2005−01−05 15:02:01 PST

Project

This proposal is for the Science Program 2004 solicitation as prepared by Lehman, Peggy W.

The submission deadline is approximately 26 hours from now.

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Instructions

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Proposal Title	***Biomass and toxicity of a newly established bloom of the cyanobacteria Microcystis aeruginosa and its potential impact on beneficial use in the Sacramento−San Joaquin Delta***	
Institutions	California Department of Water Resources, Sacramento, CA State University of New York, Syracruse, NY University of California, Davis, CA California Office of Environmental Health Hazard Assessment, Sacramento, CA	*List each institution involved, one per line.*
Proposal Document		*You have already uploaded a proposal document. View it to verify that it appears as you expect. You may replace it by uploading another document*
Project Duration	***36 months***	

Is the start date a determining factor to the successful outcome of the proposed effort?
− No.
X Yes. Anticipated start date of this effort: ***2006−06−01***

Select all of the following study topics which apply to this proposal.
− life cycle models and population biology of key species
X environmental influences on key species and ecosystems
X relative stresses on key fish species
− direct and indirect effects of diversions on at−risk species
X processes controlling Delta water quality
X implications of future change on regional hydrology, water operations, and environmental processes
− water management models for prediction, optimization, and strategic assessments
X assessment and monitoring
− salmonid−related projects
− Delta smelt−related projects

Select as many keywords as necessary to describe this proposal (minimum of 3).
X adaptive management
X aquatic plants
− ***benthic invertebrates***
− ***biological indicators***
− ***birds***
− neotropical migratory birds
− shorebirds
− upland birds
− wading birds
− waterfowl
− ***climate***
− climate change
− precipitation
− sea level rise
− snowmelt

X contaminants / toxicants / pollutants
− contaminants and toxicity of unknown origin
X emerging contaminants
− mercury
X nutrients and oxygen depleting substances
X organic carbon and disinfection byproduct precursors
X persistent organic contaminants
− pesticides
− salinity
− sediment and turbidity
− selenium
− trace metals
− ***database management***
− ***economics***
− ***engineering***
− civil
− environmental
− hydraulic
− ***environmental education***
− ***environmental impact analysis***
− ***environmental laws and regulations***
− ***environmental risk assessment***
X fish biology
X bass and other centarchids
X delta smelt
− longfin smelt
− other species
− salmon and steelhead
X splittail
X striped bass
− sturgeon
− ***fish management and facilities***
− hatcheries
− ladders and passage
− screens
− ***forestry***
− ***genetics***
− ***geochemistry***
− ***geographic information systems (GIS)***
− ***geology***
− ***geomorphology***
− ***groundwater***
X habitat
− benthos
X channels and sloughs
X flooded islands
− floodplains and bypasses
− oceanic
− reservoirs
− riparian
− rivers and streams
X shallow water
− upland habitat
− vernal pools
X water column
X wetlands, freshwater
− wetlands, seasonal
− wetlands, tidal
X human health
− ***hydrodynamics***
− ***hydrology***
− ***insects***
X invasive species / non−native species / exotic species
− ***land use management, planning, and zoning***
− ***limnology***

− ***mammals***
− large
− small
X microbiology / bacteriology
− ***modeling***
− conceptual
− quantitative
X monitoring
− ***natural resource management***
− ***performance measures***
X phytoplankton
− ***plants***
X primary productivity
− ***reptiles***
− ***restoration ecology***
− ***riparian ecology***
− ***sediment***
− ***soil science***
− ***statistics***
− ***subsidence***
X trophic dynamics and food webs
X water operations
− barriers
X diversions / pumps / intakes / exports
− gates
− levees
− reservoirs
X water quality management
− ag runoff
− mine waste assessment and remediation
− remediation
− temperature
− urban runoff
X water quality assessment and monitoring
− ***water resource management***
X water supply
− demand
X environmental water account
− water level
X water storage
− ***watershed management***
− ***weed science***
− ***wildlife***
− ecology
− management
− wildlife−friendly agriculture
− ***zooplankton***
− ***administrative***

Indicate whether your project area is local, regional, or system−wide. If it is local, provide a central ZIP Code. If it is regional, provide the central ZIP Code and choose the counties affected. If it is system−wide, describe the area using information such as water bodies, river miles, and road intersections.	
− local	ZIP Code:
X regional	ZIP Code: ***94805*** counties: ***San Joaquin Solano***

	Yolo
− system−wide	

Does your project fall on or adjacent to tribal lands?
No.

(Refer to California Indian reservations to locate tribal lands.)
If it does, list the tribal lands.

Has a proposal for this effort or a similar effort ever been submitted to CALFED for funding or to any other public agency for funding?
No.

If yes, complete the table below.

Status	Proposal Title	Funding Source	Amount	Comments
not funded				

Has the lead scientist or principal investigator of this effort ever submitted a proposal to CALFED for funding or to any other public agency for funding?
Yes.

If yes, provide the name of the project, when it was submitted, and to which agency and funding mechanism if was submitted. Also describe the outcome and any other pertinent details describing the proposal's current status.

Dissolved Oxygen in the lower San Joaquin River 2000−2001 program. This project was funded by CALFED in 2000 and the project was completed.

All applicants must identify all sources of funding other than the funds requested through this solicitation to support the effort outlined in their proposal. Applicants must include the status of these commitments (tentative, approved, received), the source, and any cost−sharing requirements. Successful proposals that demonstrate multiple sources of funding must have the commitment of the non−Science Program PSP related funding within 30 days of notification of approval of Science Program PSP funds. If an applicant fails to secure the non−Science Program PSP funds identified in the proposal, and as a result has insufficient funds to complete the project, CBDA retains the option to amend or terminate the award. The California Bay−Delta Authority reserves the right to audit grantees.

Status	Proposal Title	Funding Source	Period Of Commitment	Requirements And Comments
approved	***Biomass and toxicity of a newly established bloom of the cyanobacteria Microcystis aeruginosa in the Sacramento−San Joaquin River Delta and its potential impact on beneficial use***	***State University of New York, College of Environmental Science and Forestry, Syracuse, NY***	***June 2006 to June 2009***	***dependent on CALFED funding of the project***

Are you specifically seeking non−federal cost−share funds for this proposal?
Yes.

In addition to the general funds available, are you targeting additional funds set aside specifically for collaborative proposals?
Yes.

List people you feel are qualified to act as scientific reviewers for this proposal and are not associated with CALFED.

Full Name	Organization	Telephone	E−Mail	Expertise
Dr. Hans Paerl	***University of North Carolina at Chapel Hill, Institute of Marine Science, Morehead City, NC***	***(919) 726−6841***	***Hans_Paerl@unc.edu***	***phytoplankton***
Dr. Judy Westrick	***Lake Superior State University, Department of Chemistry, 650 W. Easterday Ave., Sault Ste. Marie, MI 49783***	***(906) 635−2165***		***contaminants / toxicants / pollutants, emerging contaminants***
Dr. Kevin Sellner	***Chesapeake Bay Research Consortium, Inc., 645 Contees Wharf Road, Edgewater, MD***	***(410) 798−1283***	***sellnerk@si.edu***	***phytoplankton***

Executive Summary

Provide a brief but complete summary description of the proposed project; its geographic location; project objective; approach to implement the proposal; hypotheses being tested; expected outcomes; and relationship to Science Program priorities. The Executive Summary should be a concise, informative, stand−alone description of the proposed project. *(This information will be made public on our website shortly after the closing date of this PSP.)*

Executive Summary

Biomass and toxicity of a newly established bloom of the cyanobacteria Microcystis aeruginosa in the Sacramento−San Joaquin Delta and its potential impact on beneficial use

Project Purpose: The goals of this research are to 1) determine the impact of the newly established large colonial form of the toxic cyanobacteria (bluegreen algae) Microcystis aeruginosa (Microcystis) on ecosystem structure and function, human and wildlife health and environmental conditions in the Sacramento−San Joaquin River Delta (Delta) and 2) use this information to make recommendations for developing an appropriate monitoring program and to provide information needed for development of effective management strategies for long−term CALFED restoration of water quality and freshwater habitat in the Delta.

These goals will be achieved by an adaptively−managed and hypothesis−driven three−year field and laboratory research program that will determine the distribution, biomass, toxicity, human and wildlife health risks and ecosystem impacts of the bloom of the toxic Microcystis bloom that first appeared throughout the Delta in 1999. This information will be used to quantify the magnitude and direction of mechanistic processes hypothesized to be important in a suite of conceptual models that suggest Microcystis affects 1) drinking water quality through organic carbon production that affects THM production and taste and odor problems and through toxicity by the production of microcystins, powerful hepatotoxins that cause liver cancer in humans and wildlife, 2) ecosystem structure and function through impacts on water quality such as light attenuation and water temperature that affect the quantity and quality of phytoplankton and food web organisms they support, 3) ecosystem structure and function through organic carbon impacts on physical and chemical processes such as visual feeding success, habitat quality and zooplankton vertical migration, and 4) ecosystem structure and function through toxic contaminant impacts on species health and survival that affects biomass and species composition throughout the food web. Additional conceptual models will be refined that address the factors that control Microcystis biomass and toxicity and suggest that Microcystis growth is favored in shallow fresh water habitat in the central Delta. The project goals support the over−arching hypotheses 1) that the organic carbon and toxicity associated with the new large colonial Microcystis bloom changed the ecosystem structure and function in the Delta after 1999 and poses a continuing health threat to both humans and wildlife that will interfere with restoration efforts in the Delta and 2) that information on the spatial and temporal variation of the bloom carbon, its toxicity and toxic pathways in the food web can be used to reduce or manage the harmful impacts of the bloom on Delta beneficial use and restoration.

Questions to be addressed that support these hypotheses include: When and where are the bloom biomass and toxicity highest? How toxic is the Microcystis bloom to humans and aquatic wildlife on acute and chronic time scales? Is the biomass or toxicity increasing over time? What environmental factors control bloom development? How prevalent is the occurrence of Microcystis toxins in the food web and is the toxicity increasing over time? What are the trophic pathways for Microcystis toxins? What is the primary source of the bloom? How could the bloom be controlled or reduced? What is the best way to sample and monitor the bloom?

Project description: The impact of the Microcystis bloom on the Delta ecosystem and its causal factors will be addressed through three tasks. Task 1 is a literature review of library and internet sources that will produce a web−based database containing current information on the acute and chronic effects of the microcystin toxins in the Delta Microcystis bloom on humans and wildlife. This review will focus on determining the health risk associated with the current level of toxicity and bloom biomass on humans and wildlife, levels of microcystins or biomass that create a human and ecosystem threat and possible management strategies. Task 2 is a three year adaptively−managed and hypothesis−driven field program and historical data analysis that will determine the spatial and temporal variability and environmental conditions that influence bloom biomass and toxicity. The field program will include assessment of Microcystis toxins in the food web and pathways of toxin transfer. This task will also include an historical data analysis of the 30−year Interagency Ecological Program Estuarine Monitoring Program (EMP) database to determine factors that contributed to the bloom initiation and development in the late 1990s and any apparent impacts on biological communities and water quality. The field program will be adaptively managed on a yearly basis to focus questions on key habitats or time periods associated with high bloom biomass or toxicity and determine their cause. Task 3 is a fish bioassay that will test the potential chronic impact of Microcystis toxins to fish health and survival from ingestion of microcystins in the Delta bloom at various levels as well as those currently in the food web.

Justification: CALFED − This hypothesis−driven field and experimental research is related to the CALFED Programmatic Record of Decision (ROD) 1) Water Quality Program goals to improve water quality in the Delta by reducing the load of organic carbon, reducing the load of unknown toxins and reducing the impairment from oxygen−demanding substances, 2) Ecosystem Restoration Program goals to improve and increase aquatic habitat, improve ecological function in the Delta and contribute to the recovery of key species and 3) Water storage and use efficiency goals to manage water in wildlife areas and provide reliable good quality water through storage programs as included in the Delta Improvements Package Plan.

The proposal directly addresses the CALFED Science PSP goals to learn about 1) Processes Controlling Delta Water Quality such as improving water quality monitoring, the origin of organic carbon sources and causes of oxygen−demanding substances and 2) Relative Stresses on Key Fish Species, especially plankton feeders such as Delta smelt, including impacts on food quantity and quality, predation processes, contaminant effects and habitat and 3) Assessment and monitoring including phytoplankton and shallow water habitat.

Research need − Microcystis can be a harmful algal bloom (HAB) because it forms surface scums that impede contact recreation sports, reduce aesthetics, lower dissolved oxygen concentration and cause taste and odor problems in drinking water (Carmichael 1995). The Delta Microcystis bloom also contains

toxic compounds called hepatotoxic microcystins that can cause liver tumors and cancer in wildlife and humans (Carmichael 1995; Lehman et al. in press). This bloom first appeared in the Sacramento−San Joaquin River Delta in 1999 and may be an invasive species. Little is known about the spatial and temporal variability of its biomass and toxicity and its impact on beneficial use and ecosystem structure and function in the Delta. A single sampling day funded in 2003 by NOAA and the CA Department of Water Resources determined that the bloom was toxic and widely distributed (Lehman et al. in press). Initial results from a special study funded by the Interagency Ecological Program in 2004 indicated the bloom was again toxic and had the highest biomass in shallow freshwater habitat.

Funding is needed to continue research on the Microcystis bloom in the Delta. No future funding is available due to the State and Federal budget shortfalls. Microcystis is not sampled by the routine Estuarine Monitoring Program because it requires special sampling techniques and sampling at depths and stations outside of the mandated program.

Coordination: This project will be a collaborative effort between the CA Department of Water Resources, State University of New York, California EPA Office of Environmental Health Hazard Assessment and University of California at Davis. Dr. P. Lehman will be the principal investigator and will facilitate completion of an integrated conceptual model and final technical report, compile progress updates and coordinate information exchange with other principal investigators.

Applicant qualifications: Tasks will be conducted by experts from the government and university. CA Department of Water Resources will administer the contracts. The literature review and database will be developed by the CA EPA Office of Environmental Health Hazard Assessment under the direction of Dr. Barbara Washburn, an aquatic toxicologist with expertise in natural toxins. Field monitoring and historical data analysis will be conducted by the CA Department of Water Resources under the direction of Dr. P. Lehman with assistance of the EMP staff. Dr. Lehman is an expert on phytoplankton and water quality in the Delta and completed a journal article on Microcystis in the Delta (Lehman et al. in press). The EMP has sampled water quality and phytoplankton in the Delta since the 1970s, including previous Microcystis sampling. Toxicity testing will be done by Dr. G. Boyer of the State University of New York, an expert on cyanobacterial toxicity. His group has extensive experience in determination of cyanobacterial toxins and routinely analyzes samples for NOAA, CDC, State Departments of Health or Environmental Conservation and private water treatment facilities. Bioassays to determine the chronic toxicity of Microcystis on fish health and survival will be conducted by Dr. S. Teh at the University of California at Davis, an expert in Delta native fish toxicity bioassays.

Schedule: July 2006 through July 2009

Cost: $602,914

Give additional comments, information, etc. here.

Applicant

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All information on this page is to be provided for the agency or institution to whom funds for this proposal would be awarded.

Applicant Institution ***California Department of Water Resources, Sacramento, CA*** *This list comes from the project form.*

Applicant Institution Type ***state agency***

Institution Contact

Please provide information for the primary person responsible for oversight of grant operation, management, and reporting requirements.

Salutation	***Dr.***
First Name	***Peggy***
Last Name	***Lehman***
Street Address	***3251 S Street***
City	***Sacramento***
State Or Province	***CA***
ZIP Code Or Mailing Code	***95816***
Telephone	***916−227−7551*** *Include area code.*
E−Mail	***plehman@water.ca.gov***

Additional information regarding prior applications submitted to CALFED by the applicant organization or agency and/or funds received from CALFED programs by applicant organization or agency may be required.

Personnel

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Instructions

Applicants must provide brief biographical sketches, titles, affiliations, and descriptions of roles, relevant to this effort, of the principal and supporting project participants by completing a Personnel Form. This includes the use of any consultants, subcontractors and/or vendors; provide information on this form for all such people.

Information provided on this form will automatically support subsequent forms to be completed as part of the Science PSP submission process. Please be mindful of what information you enter and how it may be represented in the Task and Budget forms.

Information regarding anticipated subcontractor services must be provided regardless if the specific service provider has been selected or not. If the specific subcontractor has not been identified or selected, please list TBD (to be determined) in the Full Name field and the anticipated service type in the Title field (example: Hydrology Expert).

Please provide this information before continuing to those forms.

Lehman, Peggy W., PhD

*This person is the **Lead Investigator**. Contact information for this person is required.*

Full Name	***Lehman, Peggy W., PhD***	example: Wright, Jeffrey R., PhD.
Institution	***California Department of Water Resources, Sacramento, CA***	*This list comes from the project form.*
Title	***Senior Scientist***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Dr. P. Lehman will be the principle investigator for the project, oversee contract management, integrate progress reports and final report, integrate revised conceptual models and conduct the field monitoring for Microcystis biomass and toxicity and historical data analysis described in Task 2a.	
Qualifications		*You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*
Mailing Address	***Division of Environmental Studies, CA Department of Water Resources, 3251 S Street***	
City	***Sacramento***	
State	***CA***	
ZIP	***95816***	
Business Phone	***916−227−7551***	
Mobile Phone	***916−715−0845***	
E−Mail	***plehman@water.ca.gov***	

Describe other staff below. If you run out of spaces, submit your updates and return to this form.

Technical Assistant

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.

Institution	***California Department of Water Resources, Sacramento, CA***	*This list comes from the project form.*
Title	***technical assistant***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Assist senior environmental scientist with field studies in Task 2a,b	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Scientific Aid

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***California Department of Water Resources, Sacramento, CA***	*This list comes from the project form.*
Title	***Scientific Aid***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Assist senior scientist with field data collection and data analysis in Task 2a,b	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Greg Boyer, PhD.

Full Name	***Greg Boyer, PhD.***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***State University of New York, Syracruse, NY***	*This list comes from the project form.*
Title	***Professor***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Dr. Boyer will conduct toxicity analysis of Microcystis algal tissue, dissolved microcystins in the water column and microcystins in animal tissue in Task 2b	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

Technician

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***State University of New York, Syracruse, NY***	*This list comes from the project form.*
Title	***technician***	*example: Dean of Engineering*

Position Classification	***secondary staff***	
Responsibilities	Assist G. Boyer with algal and food web toxicity analysis in Task 2b	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

Graduate Student

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***State University of New York, Syracruse, NY***	*This list comes from the project form.*
Title	***graduate student***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Assist G. Boyer with algal biomass and food web tissue toxicity analysis in Task 2b	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Undergraduate Student

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***State University of New York, Syracruse, NY***	*This list comes from the project form.*
Title	***undergraduate student***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Assist with laboratory analysis of algal and food web tissue toxicity	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Swee Teh, Ph.D.

Full Name	***Swee Teh, Ph.D.***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Davis, CA***	*This list comes from the project form.*
Title	***professor***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Dr. Teh will direct fish bioassays and histopathology studies to determine the chronic impact of Microcystis toxins on fish health and survival described in Task 3	
Qualifications		***This is only required for primary staff.***

		You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.

Post Graduate Researcher

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Davis, CA***	*This list comes from the project form.*
Title	***post graduate researcher***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Conduct fish bioassay growth and feeding studies, analyze data and assist with reporting in Task 3	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Histopathology Technician

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Davis, CA***	*This list comes from the project form.*
Title	***histopathology technician***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	assist with diet preparation, spawning of splittail, long−term dietary exposure, tissue processing and sectioning for histopathology evaluation by Dr. Teh described in Task 3	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Barbara Washburn, Ph.D.

Full Name	***Barbara Washburn, Ph.D.***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***California Office of Environmental Health Hazard Assessment, Sacramento, CA***	*This list comes from the project form.*
Title	***Staff Toxicologist***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Conduct literature review of the impact of Microcystis toxins found in the Delta on humans and wildlife and develop a web−based literature database file in Task 1	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

Boat Operator

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***California Department of Water Resources, Sacramento, CA***	*This list comes from the project form.*
Title	***Boat operator***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	operate boat during field survey for Task 2a and 2b	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Conflict Of Interest

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Instructions

To help Science Program staff manage potential conflicts of interest in the review and selection process, we need some information about who will directly benefit if your proposal is funded. We need to know of individuals in the following categories:

- Applicants listed in the proposal who wrote the proposal, will be performing the tasks listed in the proposal, or who will benefit financially if the proposal is funded;
- Subcontractors listed in the proposal who will perform some tasks listed in the proposal and will benefit financially if the proposal is funded.

Applicant	California Department of Water Resources, Sacramento, CA
Submittor	Lehman, Peggy W
Primary Staff	Lehman, Peggy W., PhD
Secondary Staff	*technical assistant
Secondary Staff	*Scientific Aid
Primary Staff	Greg Boyer, PhD.
Secondary Staff	*technician
Secondary Staff	*graduate student
Secondary Staff	*undergraduate student
Primary Staff	Swee Teh, Ph.D.
Secondary Staff	*post graduate researcher
Secondary Staff	*histopathology technician
Primary Staff	Barbara Washburn, Ph.D.
Secondary Staff	*Boat operator

Are there other persons not listed above who helped with proposal development?
No.

If there are, provide below the list of names and organizations of all individuals not listed in the proposal who helped with proposal development along with any comments.

Tasks

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Instructions

Utilize this Task Table to delineate the tasks identified in your project description. Each task and subtask must have a number, title, brief description of the task (detailed information should be provided in the project description), timeline, list of personnel or subcontractors providing services on each specific task, and list of anticipated deliverables (where appropriate). When creating subtasks, information must be provided in a way that avoids duel presentation of supporting tasks within the overall task (i.e. avoid double counting). Information provided in the Task Table will be used to support the Budget Form. Ensuring information regarding deliverables, personnel and costs associated with subtasks are only provided once is imperative for purposes of avoiding double counting of efforts within the Budget Form.

For proposals involving multiple institutions (including subcontractors), the table must clearly state which institutions are performing which tasks and subtasks.

Task ID	Task Name	Start Month	End Month	Personnel Involved	Description	Deliverables
1	***Literature database***	***1***	***6***	***Barbara Washburn, Ph.D.***	Prepare literature database of the ecosystem and human health impacts of measured Microcystis toxins in the Delta and organic carbon	Peer−reviewed database on the Office of Environmental Health Hazard Assessment website OEHHA.ca.gov/ECOTOX
2a	***Field study of Microcystis biomass and distribution; historical data analysis***	***1***	***36***	***Lehman, Peggy W., PhD *technical assistant *Scientific Aid *Boat operator***	Conduct field study to determine seasonal and interannual spatial and temporal variability of Microcystis biomass in relation to environmental conditions	Database containing field and laboratory water quality measurements and Microcystis biomass; two peer−review journal publications in collaboration with task 2b describing field studies and historical data analysis; CALFED semi−annual reports and final integrated report; integrated conceptual models for all tasks
2b	***Measurement of Microcystis and food web toxicity***	***1***	***36***	***Greg Boyer, PhD. *technician *undergraduate student***	Conduct laboratory analyses of algal and food web tissue toxicity	Database containing all laboratory data; Two peer−reviewed journal articles in collaboration with task 2a; CALFED semi−annual progress reports
3	***Fish bioassay***	***1***	***36***	***Swee Teh, Ph.D. *post graduate researcher *histopathology technician***	Conduct laboratory fish bioassay studies to determine the chronic impact of Microcystis toxins on fish health and survival	Database containing all results from laboratory bioassays; Two peer−review publications; CALFED semi−annual progress reports and a final task summary report

Budget

This proposal is for the Science Program 2004 solicitation as prepared by Lehman, Peggy W.

The submission deadline is approximately 26 hours from now.

Proposal updates will be disabled immediately after the deadline. All forms, including the signature form, must be completed, compiled and acknowledged in order to be eligible for consideration and review. Allow at least one hour for Science Program staff to verify and file signature pages after they are received.

Instructions

All applicants must complete a budget for each task and subtask. The Budget Form uses data entered in the Task Form, thus tasks should be entered before starting this form. Failure to complete a Budget Form for each task and/or subtask will result in removal of the application from consideration for funding.

CBDA retains the right to request additional information pertaining to the items, rates, and justification of the information presented in the Budget Form(s).

Supporting details on how costs were derived for each line item must be included in the justification section for each item. The cost detail for each item should include the individual cost calculations associated with each line item to provide the basis for determining the total amount for each budget category.

Following are guidelines for completing the justification section of this form:

Labor (Salary &Wages)

Ensure each employee and associated classification is correctly identified for each task and subtask. This information will automatically be provided once the Staff Form has been completed. Provide estimated hours and hourly rate of compensation for each position proposed in the project.

Employee Benefits

Benefits, calculated as a percentage of salaries, are contributions made by the applicant for sick leave, retirement, insurance, etc. Provide the overall benefit rate and specify benefits included in this rate for each employee classification proposed in the project.

Travel

Travel includes the cost of transportation, subsistence, and other associated costs incurred by personnel during the term of the project. Provide purpose and estimated costs for all travel. Reoccurring travel costs for a particular task or subtask may be combined into one entry. The number of trips and cost for each occurrence must be clearly represented in the justification section for reoccurring travel items of this nature.

Any reimbursement for necessary travel and per diem shall be at rates specified by the California Department of Personnel Administration for similar employees (www.dpa.ca.gov/jobinfo/statetravel.shtm).

Equipment

Equipment is classified as any item of $5,000 or more and has an expected life of three years or more. Equipment purchased in whole or in part with these grant funds must be itemized. List each piece of equipment and provide a brief description and justification for each.

Supplies

Provide a basic description and cost for expendable research supplies. Costs associated with GIS services, air photos, reports, etc. must be listed separately and have a clear justification associated with each entry. Postage, copying, phone, fax and other basic operational costs associated with each task and subtask may be combined unless the cost associated with one particular service is unusually excessive.

Subcontractor Services

Subcontractor services (Professional and Consultant services) include the total costs for any services needed by the applicant to complete the project tasks. Ensure the correct organization is entered in the Personnel Form so that it appropriately appears on the Budget Form. The applicant must provide all associated costs of all subcontractors (i.e. outside service providers) when completing this form. Applicants must be able to demonstrate that all subcontractors were selected according to an applicant's institutional requirements for the selection of subcontractors (competitive selection or sole source justification).

CBDA retains the right to request that a subcontractor provide cost estimates in writing prior to distribution of grant funds.

CBDA retains the right to request consultant, subcontractor, and/or outside service provider cost estimates in writing prior to distribution of grant funds.

Indirect Costs (Overhead)

Indirect costs are overhead expenses incurred by the applicant organization as a result of the project but are not easily identifiable with a specific project. The indirect cost rate consists of a reasonable percentage of all costs to run the agency or organization while completing the project. List the cost and items associated with indirect costs. (These items may include general office expenses such as rent, office equipment, administrative staff, operational costs, etc. Generally these items are represented by the applicant through a predetermined percentage or surcharge separate from other specific costs of items necessary to complete a specific task or subtask.)

If indirect cost rates are different for State and Federal funds, please identify each rate and the specific items included in the calculation for that rate.

Task 1, Literature Database: Labor	**Justification**	**Amount**
Barbara Washburn, Ph.D.	***528 hr @ 39.77 per hr (year 1)***	***21000***
Task 1, Literature Database: Benefits	**Justification**	**Amount**
Barbara Washburn, Ph.D.	***528 hr @11.81 per hr (year 1)***	***6235***
Task 1, Literature Database: Travel Expenses	**Justification**	**Amount**
Task 1, Literature Database: Supplies And Expendables	**Justification**	**Amount**
Task 1, Literature Database: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		
Task 1, Literature Database: Equipment	**Justification**	**Amount**
Task 1, Literature Database: Other Direct	**Justification**	**Amount**
Task 1, Literature Database: Indirect (Overhead)	**Justification**	**Amount**
Office Space Etc.	***528 hours @17.35 (year 1)***	***9160***
	Task 1 Total	$36,395
Task 2a, Field Study Of Microcystis Biomass And Distribution; Historical Data Analysis: Labor	**Justification**	**Amount**
Lehman, Peggy W., PhD	***1848 hrs @41.87 per hr (year 1 through 3 equally split)***	***82903***
***Technical Assistant**	***396 hrs @ 41.87 per hr (year 1 through 3 equally split)***	***16581***
***Scientific Aid**	***3168 hrs @ 13.45 per hr (year 1 through 3 equally split)***	***42610***
***Boat Operator**	***396 hrs @ 41.87 per hr (year 1 through 3 equally split)***	***16581***
Task 2a, Field Study Of Microcystis Biomass And Distribution; Historical Data Analysis: Benefits	**Justification**	**Amount**
Lehman, Peggy W., PhD	***1848 hrs @ 9.30 per hr (year 1 through 3 equally split)***	***18414***
***Technical Assistant**	***396 hrs @ 9.30 per hr (year 1 through 3 equally split)***	***3683***
***Scientific Aid**	***3168 hrs @ 2.99 per hr (year 1 through 3 equally split)***	***9472***
***Boat Operator**	***396 hrs @9.30 per hr (year 1 through 3 equally split)***	***3683***
Task 2a, Field Study Of Microcystis Biomass And Distribution; Historical Data Analysis: Travel Expenses	**Justification**	**Amount**
Other	***sampling per diem; $140/day/person for 3 people two times per year (year 1 through 3 equally split)***	***2520***
Conferences	***3 days at $140/day per diem; transportation cost of $800 each (biannual cyanobacteria conferences year 1 and 3)***	***2440***
Task 2a, Field Study Of Microcystis Biomass And Distribution; Historical Data Analysis: Supplies And Expendables	**Justification**	**Amount**
Other	***misc filters; chemicals; postage and packaging; replacement parts (year 1 through 3 equally split)***	***6000***
Other	***boat operation $50.00 per day for 36 days (year 1 through 3 equally split)***	***1800***
Task 2a, Field Study Of Microcystis Biomass And Distribution; Historical Data Analysis: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		
Task 2a, Field Study Of Microcystis Biomass And Distribution; Historical Data Analysis: Equipment	**Justification**	**Amount**
None	***all equipment is available through the EMP program and Dr. Lehman***	***0***
Task 2a, Field Study Of Microcystis Biomass And Distribution; Historical Data Analysis: Other Direct	**Justification**	**Amount**
Bryte Laboratory Fees	***average of $26.88 per lab test (year 1 through 3 equally split)***	***43200***

Task 2a, Field Study Of Microcystis Biomass And Distribution; Historical Data Analysis: Indirect (Overhead)	**Justification**	**Amount**
	senior scientist, technician and boat operator 2640 hrs @ 26.37 per hr	***73098***
	scientific aid 3168 hrs @ 8.57 per hr	***27150***
	Task 2a Total	$350,135
Task 2b, Measurement Of Microcystis And Food Web Toxicity: Labor	**Justification**	**Amount**
Greg Boyer, PhD.	***3% ; $2616 year1; $2721 year2; $2830 year 3***	***8167***
***Technician**	***$9846 year 1; $10240 year 2; $10650 year 3***	***30735***
***Undergraduate Student**	***$3000 year 1; $3120 year 2; $3245 year 3***	***9365***
Task 2b, Measurement Of Microcystis And Food Web Toxicity: Benefits	**Justification**	**Amount**
Greg Boyer, PhD.	***40.31% for all years; $1055 year 1; $1097 year 2; $1141 year 3***	***3293***
***Technician**	***$3643 year 1 (37%); $3994 year 2 (39%); $4154 year 3 (39%)***	***11790***
***Undergraduate Student**	***3% all years; $90 year 1; $94 year 2 ; $97 year 3***	***281***
Task 2b, Measurement Of Microcystis And Food Web Toxicity: Travel Expenses	**Justification**	**Amount**
Conferences	***$2000 per year; domestic***	***6000***
Task 2b, Measurement Of Microcystis And Food Web Toxicity: Supplies And Expendables	**Justification**	**Amount**
Other	***laboratory supplies and chemicals***	***12000***
Task 2b, Measurement Of Microcystis And Food Web Toxicity: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		
Task 2b, Measurement Of Microcystis And Food Web Toxicity: Equipment	**Justification**	**Amount**
Task 2b, Measurement Of Microcystis And Food Web Toxicity: Other Direct	**Justification**	**Amount**
		1500
Task 2b, Measurement Of Microcystis And Food Web Toxicity: Indirect (Overhead)	**Justification**	**Amount**
	49.9% MTDC	***41483***
	Task 2b Total	$124,614
Task 3, Fish Bioassay: Labor	**Justification**	**Amount**
Swee Teh, Ph.D.	***192 hours @ 44.27 per hr***	***8500***
***Post Graduate Researcher**	***960 hours @ 21.14 per hr***	***20293***
***Histopathology Technician**	***960 hours @ 20.03 per hr***	***19226***
Task 3, Fish Bioassay: Benefits	**Justification**	**Amount**
Swee Teh, Ph.D.	***192 hours @ 12.40 per hr***	***2380***
***Post Graduate Researcher**	***960 hours @ 10.57 per hr***	***7711***
***Histopathology Technician**	***960 hours @ 10.02 per hr***	***7306***
Task 3, Fish Bioassay: Travel Expenses	**Justification**	**Amount**
Task 3, Fish Bioassay: Supplies And Expendables	**Justification**	**Amount**
Other	***includes monthly fish facility fees***	***8000***
Task 3, Fish Bioassay: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		

Task 3, Fish Bioassay: Equipment	Justification	Amount
Task 3, Fish Bioassay: Other Direct	**Justification**	**Amount**
Task 3, Fish Bioassay: Indirect (Overhead)	**Justification**	**Amount**
	UCD overhead of 25% for $73416	***18354***
	Task 3 Total	$91,770
	Grand Total	$602,914

− The indirect costs may change by more than 10% if federal funds are awarded for this proposal.

What is the total of non−federal funds requested?

Executive Summary

Biomass and toxicity of a newly established bloom of the cyanobacteria *Microcystis aeruginosa* in the Sacramento-San Joaquin Delta and its potential impact on beneficial use

Project Purpose: The goals of this research are to 1) determine the impact of the newly established large colonial form of the toxic cyanobacteria (bluegreen algae) *Microcystis aeruginosa* (*Microcystis)* on ecosystem structure and function, human and wildlife health and environmental conditions in the Sacramento-San Joaquin River Delta (Delta) and 2) use this information to make recommendations for developing an appropriate monitoring program and to provide information needed for development of effective management strategies for long-term CALFED restoration of water quality and freshwater habitat in the Delta.

These goals will be achieved by an adaptively-managed and hypothesis-driven three-year field and laboratory research program that will determine the distribution, biomass, toxicity, human and wildlife health risks and ecosystem impacts of the bloom of the toxic *Microcystis* bloom that first appeared throughout the Delta in 1999. This information will be used to quantify the magnitude and direction of mechanistic processes hypothesized to be important in a suite of conceptual models that suggest *Microcystis* affects 1) drinking water quality through organic carbon production that affects THM production and taste and odor problems and through toxicity by the production of microcystins, powerful hepatotoxins that cause liver cancer in humans and wildlife, 2) ecosystem structure and function through impacts on water quality such as light attenuation and water temperature that affect the quantity and quality of phytoplankton and food web organisms they support, 3) ecosystem structure and function through organic carbon impacts on physical and chemical processes such as visual feeding success, habitat quality and zooplankton vertical migration, and 4) ecosystem structure and function through toxic contaminant impacts on species health and survival that affects biomass and species composition throughout the food web. Additional conceptual models will be refined that address the factors that control *Microcystis* biomass and toxicity and suggest that *Microcystis* growth is favored in shallow fresh water habitat in the central Delta.

The project goals support the over-arching hypotheses 1) that the organic carbon and toxicity associated with the new large colonial *Microcystis* bloom changed the ecosystem structure and function in the Delta after 1999 and poses a continuing health threat to both humans and wildlife that will interfere with restoration efforts in the Delta and 2) that information on the spatial and temporal variation of the bloom carbon, its toxicity and toxic pathways in the food web can be used to reduce or manage the harmful impacts of the bloom on Delta beneficial use and restoration.

Questions to be addressed that support these hypotheses include: When and where are the bloom biomass and toxicity highest? How toxic is the *Microcystis* bloom to humans and aquatic wildlife on acute and chronic time scales? Is the biomass or toxicity increasing over time? What environmental factors control bloom development? How prevalent is the occurrence of *Microcystis* toxins in the food web and is the toxicity increasing over time? What are the trophic pathways for *Microcystis* toxins? What is the primary source of the bloom? How could the bloom be controlled or reduced? What is the best way to sample and monitor the bloom?

Project description: The impact of the *Microcystis* bloom on the Delta ecosystem and its causal factors will be addressed through three tasks. **Task 1** is a literature review of library and internet sources that will produce a web-based database containing current information on the acute and chronic effects of the microcystin toxins in the Delta *Microcystis* bloom on humans and wildlife. This review will focus on determining the health risk associated with the current level of toxicity and bloom biomass on humans and wildlife, levels of microcystins or biomass that create a human and ecosystem threat and possible management strategies. **Task 2** is a three year adaptively-managed and hypothesis-driven field program and historical data analysis that will determine the spatial and temporal variability and environmental conditions that influence bloom biomass and toxicity. The field program will include assessment of *Microcystis* toxins in the food web and pathways of toxin transfer. This task will also include an historical data analysis of the 30-year Interagency Ecological Program Estuarine Monitoring Program (EMP) database to determine factors that contributed to the bloom initiation and development in the late 1990s and any apparent impacts on biological communities and water quality. The field program will be adaptively managed on a yearly basis to focus questions on key habitats or time periods associated with high bloom biomass or toxicity and determine their cause. **Task 3** is a fish bioassay that will test the potential chronic impact of *Microcystis* toxins to fish health and survival from ingestion of microcystins in the Delta bloom at various levels as well as those currently in the food web.

Justification: CALFED - This hypothesis-driven field and experimental research is related to the CALFED Programmatic Record of Decision (ROD) 1) Water Quality Program goals to improve water quality in the Delta by reducing the load of organic carbon, reducing the load of unknown toxins and reducing the impairment from oxygen-demanding substances, 2) Ecosystem Restoration Program goals to improve and increase aquatic habitat, improve ecological function in the Delta and contribute to the recovery of key species and 3) Water storage and use efficiency goals to manage water in wildlife areas and provide reliable good quality water through storage programs as included in the Delta Improvements Package Plan.

The proposal directly addresses the CALFED Science PSP goals to learn about 1) Processes Controlling Delta Water Quality such as improving water quality

monitoring, the origin of organic carbon sources and causes of oxygen-demanding substances and 2) Relative Stresses on Key Fish Species, especially plankton feeders such as Delta smelt, including impacts on food quantity and quality, predation processes, contaminant effects and habitat and 3) Assessment and monitoring including phytoplankton and shallow water habitat.

Research need - *Microcystis* can be a harmful algal bloom (HAB) because it forms surface scums that impede contact recreation sports, reduce aesthetics, lower dissolved oxygen concentration and cause taste and odor problems in drinking water (Carmichael 1995). The Delta *Microcystis* bloom also contains toxic compounds called hepatotoxic microcystins that can cause liver tumors and cancer in wildlife and humans (Carmichael 1995; Lehman et al. in press). This bloom first appeared in the Sacramento-San Joaquin River Delta in 1999 and may be an invasive species. Little is known about the spatial and temporal variability of its biomass and toxicity and its impact on beneficial use and ecosystem structure and function in the Delta. A single sampling day funded in 2003 by NOAA and the CA Department of Water Resources determined that the bloom was toxic and widely distributed (Lehman et al. in press). Initial results from a special study funded by the Interagency Ecological Program in 2004 indicated the bloom was again toxic and had the highest biomass in shallow freshwater habitat.

Funding is needed to continue research on the *Microcystis* bloom in the Delta. No future funding is available due to the State and Federal budget shortfalls. *Microcystis* is not sampled by the routine Estuarine Monitoring Program because it requires special sampling techniques and sampling at depths and stations outside of the mandated program.

Coordination: This project will be a collaborative effort between the CA Department of Water Resources, State University of New York, California EPA Office of Environmental Health Hazard Assessment and University of California at Davis. Dr. P. Lehman will be the principal investigator and will facilitate completion of an integrated conceptual model and final technical report, compile progress updates and coordinate information exchange with other principal investigators.

Applicant qualifications: Tasks will be conducted by experts from the government and university. CA Department of Water Resources will administer the contracts. The literature review and database will be developed by the CA EPA Office of Environmental Health Hazard Assessment under the direction of Dr. Barbara Washburn, an aquatic toxicologist with expertise in natural toxins. Field monitoring and historical data analysis will be conducted by the CA Department of Water Resources under the direction of Dr. P. Lehman with assistance of the EMP staff. Dr. Lehman is an expert on phytoplankton and water quality in the Delta and completed a journal article on *Microcystis* in the Delta (Lehman et al. in press). The EMP has sampled water quality and phytoplankton

in the Delta since the 1970s, including previous *Microcystis* sampling. Toxicity testing will be done by Dr. G. Boyer of the State University of New York, an expert on cyanobacterial toxicity. His group has extensive experience in determination of cyanobacterial toxins and routinely analyzes samples for NOAA, CDC, State Departments of Health or Environmental Conservation and private water treatment facilities. Bioassays to determine the chronic toxicity of *Microcystis* on fish health and survival will be conducted by Dr. S. Teh at the University of California at Davis, an expert in Delta native fish toxicity bioassays.

Schedule: July 2006 through July 2009

Cost: $602,914

Proposal

Biomass and toxicity of a newly established bloom of the cyanobacteria *Microcystis aeruginosa* in the Sacramento-San Joaquin Delta and its potential impact on beneficial use

1. Project Purpose

The goals of this research are to 1) determine the impact of the newly established large colonial form of the toxic cyanobacteria (bluegreen algae) *Microcystis aeruginosa* (*Microcystis)* on ecosystem structure and function, human and wildlife health and environmental conditions in the Sacramento-San Joaquin River Delta (Delta; Figs. 1 and 2) and 2) use this information to make recommendations for developing an appropriate monitoring program and to provide information needed for development of effective management strategies for long-term CALFED restoration of water quality and freshwater habitat in the Delta.

These goals will be achieved by an adaptively-managed and hypothesis-driven three-year field and laboratory research program that will determine the distribution, biomass, toxicity, human and wildlife health risks and ecosystem impacts of the bloom of the toxic *Microcystis* bloom that first appeared throughout the Delta in 1999 (Lehman and Waller 2003; Lehman et al. in press). The bloom produces high organic carbon concentration and contains cancer causing substances for humans and wildlife called hepatotoxins that can affect both drinking water quality and ecosystem structure and function. This information will be used to quantify the magnitude and direction of mechanistic processes hypothesized to be important in a suite of conceptual models (Figs. 3 through 6) that suggest *Microcystis* affects 1) drinking water quality through organic carbon production that affects THM production and taste and odor problems and toxicity through the production of microcystins, powerful hepatotoxins that cause liver cancer in humans and wildlife, 2) ecosystem structure and function through

biomass impacts on water quality such as light, dissolved oxygen and water temperature that affect the quantity and quality of phytoplankton and food web organisms they support, 3) ecosystem structure and function through biomass impacts on physical processes such as visual feeding success, habitat quality or zooplankton vertical migration, and 4) ecosystem structure and function through toxic contaminant impacts on species health and survival that affects biomass and species composition throughout the food web. Additional conceptual models will be refined that address the factors that control *Microcystis* biomass and toxicity and suggest that *Microcystis* growth is favored in shallow fresh water habitat in the central Delta.

The project goals support the over-arching hypotheses 1) that the organic carbon and toxicity associated with the new large colonial *Microcystis* bloom changed the ecosystem structure and function in the Delta after 1999 and poses a continuing health threat to both humans and wildlife that will interfere with restoration efforts in the Delta and 2) that information on the spatial and temporal variation of the bloom carbon, its toxicity and toxic pathways in the food web can be used to reduce or manage the harmful impacts of the bloom on Delta beneficial use and restoration.

Questions to be addressed that support these over-arching hypotheses include: When and where are the bloom biomass and toxicity highest? How toxic is the *Microcystis* bloom to humans and aquatic wildlife on acute and chronic time scales? Is the biomass or toxicity increasing over time? What environmental factors control bloom development? How prevalent is the occurrence of *Microcystis* toxins in the food web and is the toxicity increasing over time? What are the trophic pathways for *Microcystis* toxins? What is the primary source of the bloom? How could the bloom be controlled or reduced? What is the best way to sample and monitor the bloom? (Table 1)

2. Project Description

Work Plan

Summary - This hypothesis-based research program will focus on learning about the potential impact of this new large-colonial toxic cyanobacterium on beneficial use in the Delta through three tasks. **Task 1: Literature review and database**. A literature review will identify what is currently known about the potential impact of the toxic microcystins in the bloom on acute and chronic human and wildlife health. This information will be made available to the public as a literature database on the CA EPA Office of Environmental Health Hazard Assessment (OEHHA) website. **Task 2: Field study of *Microcystis* biomass, toxicity, food web transfer and historical data analysis**. A three-year field study program will provide information on the spatial and temporal variation of *Microcystis* biomass and toxicity, microcystin toxicity levels in food web organisms and associated spatial and temporal variation in physical and chemical factors associated with the bloom. Additional analysis of historical data in the 30-year EMP physical,

chemical and biological data base will be used to determine factors that contributed to the initial development of the bloom and subsequent water quality and biological community impacts. **Task 3. Fish bioassay**. Laboratory fish bioassays will determine the impact of chronic exposure to a range of individual toxic microcystins concentrations in the bloom and the combined toxins in the bloom biomass on native fish health and survival.

A more **detailed description** of each task follows below:

Task 1. Literature Review and Database Development
Purpose: The purpose of this task is to develop a literature database on the human and aquatic health impacts of *Microcystis* that will be available to the public via the Office of Environmental Health Hazards Assessment website.

Method: Information will be obtained from the current literature through library and internet sources to assess the potential acute and chronic impact of *Microcystis* toxicity on humans and wildlife. Medline, Aquatic Sciences and Fisheries abstracts and other relevant databases will be searched for articles on conditions that stimulate algal blooms, the forms of microcystin toxins as well as their chemical and physical characteristics, the mechanisms of microcystin toxicity on fish, wildlife and humans; useful techniques for evaluating potential effects; and potential management options. This review will be used to refine the conceptual model of the impact of *Microcystis* on human and wildlife health (Figs. 3, 4, 5 and 6). This task will also produce a literature database for public access that will be posted on www.OEHHA.CA.GOV/ECOTOX that includes similar literature databases. These databases undergo an internal peer review process.

Task 2. *Microcystis* Biomass, Toxicity and Food Web Transfer
Task 2 a. *Microcystis* Biomass, Toxicity and Environmental Conditions Field Study and Historical Data Analysis.
Purpose: The purpose of this study is to determine the spatial and temporal variability of *Microcystis* biomass, toxicity and associated changes in physical, chemical and biological factors. Analyses will be used to refine the conceptual model of environmental factors that control *Microcystis* blooms in the Delta (Fig. 3) and the impact of Microcystis on ecosystem structure and function and human and ecosystem health (Figs. 4, 5 and 6) through an adaptively-managed and hypothesis-driven field program (Table 1).

Field sampling: Field research will be conducted to determine the spatial and temporal variability of the *Microcystis* bloom biomass and toxicity in the Delta and associated environmental conditions in relation to hypotheses needed to refine the current conceptual model on causal factors and humans and ecosystem impacts (Figs. 3 through 6; Table 1). During the first year water samples for biomass and toxicity will be collected semi-monthly sampling at 9 stations throughout the Delta between June and November. Stations will be selected to

represent a broad spectrum of habitats including shallow water habitat, deep river channel, flooded island, beach, emergent vegetation and submerged vegetation. The exact stations and sampling interval will depend on the data analysis of the 2004 research program that will be completed in summer 2005. Vertical profiles with a YSI 6600 sonde will provide information on water quality conditions such as water temperature, pH, specific conductance, dissolved oxygen and turbidity at the station as well as the vertical gradient in chlorophyll *a* fluorescence, an estimate of phytoplankton biomass. Water samples will be collected to measure the chemical conditions at the station and will include nutrients (nitrate, ammonia, orthophosphate, total phosphorus and silica), organic constituents (total and dissolved organic carbon and trihalomethane (THM) formation), anions and cat ions (bromide, chloride, sulfate, magnesium and calcium) and biological community composition (phytoplankton species composition) and biomass (chlorophyll *a* concentration). The presence of dissolved microcystins in the water column will be also be assessed from 1-liter water samples. The growth potential and efficiency of the *Microcystis* among habitats will be assessed through *in situ* dissolved oxygen light and dark bottle primary productivity incubations at different light levels (Vollenweider 1974). Mesozooplankton for zooplankton community analysis will be obtained by a diagonal tow of a Clarke-Bumpus net (154 µm mesh) with an attached Oceanics current meter. Zooplankton samples will be immediately preserved with 5% buffered formalin with Rose-Bengal dye added. This sampling regime will be adaptively managed over the sampling period to address hypotheses that focus on habitats, time periods, environmental conditions and mechanisms that promote *Microcystis* growth and toxicity.

Laboratory analyses: Laboratory water quality analyses will be conducted using Standard Methods (APHA et al. 1998; U.S. EPA 1983) and conducted by the CA Department of Water Resources Chemical Laboratory at Bryte, an EPA certified laboratory. The sampling and laboratory procedures will follow procedures described in a QAMP and QAPP that will be developed for the project.

Data analysis: Data will be analyzed to assess spatial and temporal variability using graphical and tabular display and nonparametric and parametric statistical techniques as appropriate. Nonparametraic analyses will include single comparisons with the Wilcoxon Mann-Whitney-U and Spearman correlation and multiple comparisons with Kruskal-Wallis. Parametric analysis will include principal component analysis.

Analyses will be designed to address questions including: What is the current level of *Microcystis* bloom biomass and toxicity? What habitats contain the highest biomass and toxicity? How does the bloom biomass and toxicity vary seasonally? What environmental conditions are associated with high bloom biomass and toxicity? Is the bloom biomass or toxicity increasing over time? How does bloom biomass and toxicity vary among years or water year types? Does the local phytoplankton and zooplankton community composition vary with bloom biomass or toxicity? (Table 1).

Historical data analysis

Historical Estuarine Monitoring Program and Interagency Ecological Program data from 1970 to present will be analyzed to determine links between the occurrence of the *Microcystis* bloom since 1999 and environmental conditions including water quality conditions, residence time, and flow patterns throughout the impacted Delta region. Historical data will also be analyzed to determine if there have been any changes in the phytoplankton and zooplankton community biomass and species composition since 1999 that could be linked to the appearance of the *Microcystis* bloom and associated water quality conditions. Comparison of *Microcystis* field data and historical monitoring data analyses will be made to refine the conceptual model of factors that control *Microcystis* blooms in the Delta (Fig. 3) and their impact on human and wildlife health and ecosystem function (Fig. 4 and 5).

Data analysis: Patterns in these data will be identified using parametric statistical techniques including cluster analysis, principal component analysis and analysis of variance. Information from these analyses will be displayed graphically and in tabular form.

Analyses will address questions including: Was there a change in the water quality, environmental conditions, or plankton community associated with the appearance of the bloom in the late 1990s? Are there any trends in the water quality, environmental or plankton data since 1999? Can any of the changes in conditions since 1999 be used to better understand the field sampling data results or the reverse? Are there any changes or trends in environmental conditions associated with the bloom that can be used to assist management? What is the best way to monitor the bloom? (Table 1).

Food web toxicity and trophic transfer

The movement of microcystins into the tissues of animals in the food web will be measured at least two times during the season. Animals will initially be collected from four stations in the Delta and will include plankton (micro-, meso- and macro-zooplankton), epibenthic (amphipods), benthic (clams) and open water invertebrates (fish). Methods for collection will include a vertical pump collection for microzooplankton, a diagonal net (154 µm mesh) tow for mesozooplankton, a diagonal net (505 µm) tow for macrozooplankton, hand picking from vegetation and ponar dredge for epibenthos, ponar dredge for benthos and species specific nets or left-over tissue for fish. Whole animals in the case of plankton, epibenthos and benthos and muscle and liver tissue in the case of fish will be immediately frozen until analysis for microcystins. Inland silversides and threadfin shad will be the initial focus of the fish tissue study because of their abundance, wide distribution throughout impacted areas of the Delta, plankton diet and frequent use by predators. The tissue of species that have declined in recent years such as Delta smelt and striped bass will also be tested using fish muscle and liver

tissue obtained from preexisting sampling programs so there will be no impact on take permits.

Adaptive management will again be used to adjust field sampling each year to address hypothesis about toxicity (Table 1) needed to refine conceptual models on toxic impacts on ecosystem structure and function (Fig. 6) including questions that address trophic transfer mechanisms (e.g., animals with high microcystins concentration and predators with highly contaminated prey). Toxicity analyses will be conducted as part of Task 2b described below.

Data analysis: Data will be analyzed to determine spatial and temporal differences using graphical and tabular display and nonparametric and parametric statistical techniques as appropriate. Nonparametraic analyses will include single comparisons with the Wilcoxon Mann-Whitney-U and Spearman correlation and multiple comparisons with Kruskal-Wallis. Parametric analysis will include principal component analysis.

Analyses will be designed to address basic questions about Microcystis food web toxicity including: What is the current level of *Microcystis* bloom toxins in each trophic level of the food web? How does the microcystins content of the food web vary with season and water year? What are the pathways of movement of microcystins into the food web and how does this vary seasonally and among water years? What habitats contain the highest food web toxicity? What environmental conditions are associated with high food web toxicity? Does the local phytoplankton and zooplankton community composition vary with microcystins concentration in the food web? (Table 1).

Task 2 b. *Microcystis* Biomass, Food web and Environmental Water Toxicity
Purpose: The purpose of this task is to determine the toxicity of Microcystis biomass and the concentration of Microcystis toxins in the food web organisms. Results from these analyses will be combined with information gained from Task 2a and 3 to refine conceptual models of the impact of *Microcystis* toxicity on humans and ecosystem structure and function (Figs. 4 and 6).

Algal tissue method - Filters for toxin analysis in *Microcystis* biomass will be extracted by sonication with 10 ml of 50% methanol containing 1 % acetic acid, clarified by centrifugation, and the extract used for analysis of the different toxins. Total particulate microcystins concentration in algal tissue will be initially assessed using the protein phosphatase inhibition assay (PPIA) technique. Assays will be run in 96-well plates containing 0.1 mU enzyme (recombinant protein phosphatase 1A, catalytic subunit, Roche Applied Science), 1.05 mg para-nitrophenyl phosphate (Sigma Biochemical) and 10 µl of sample or microcystin-LR (Sigma Biochemical) using the method of Carmichael and An (1999). The rate of phosphate hydrolysis will be calculated from the change in absorbance at 405 nm over 1 h and compared to the control (no added

microcystin-LR) and standards containing between 6 and 40 µg l^{-1} microcystin-LR. Blanks (no enzyme, no toxin), unknowns, standards, and controls will be run in duplicate. The PPIA assay is an activity based assay whose results correlate well with the biological activity of the total microcystins. Duplicate analysis will also be done using a structure based ELISA assay as part of the routine quality control. For dissolved microcystins, a replicate 1-L water sample is lyophilized to dryness without prior filtration. The dried powder is then extracted with methanol and assayed as described above, and the dissolved microcystin fraction determined by difference.

Samples with the highest levels of total microcystins (> 0.5 µg L^{-1}) will be further analyzed by high pressure liquid chromatography to identify the specific microcystins in the sample. Samples will be separated using a Dupont Ace 4.6 x 250 5µ C18 column and a two-step linear gradient of 30 to 70% acidified acetonitrile to acidified water at 0.8 ml/min (Harada, 1995). Detection will be either mass selective using electrospray ionization (LCMS, Agilent 1100 series MSD) or by UV absorbance using a Water's model 996 photodiode array detector (PDA) between 210 and 300nm. For LCMS, all ions between 900 and 1250 amu will be combined to form the total ion chromatograph and potential microcystins identified on the basis of their molecular ions and retention times. For PDA detection, microcystins will be identified on the basis of having an absorbance maximum at 239 nm in their UV spectrum and their retention times.

Animal tissue method - Zooplankton tissue will be lyophilized and then extracted by sonication with 10 ml of 50% methanol containing 1 % acetic acid, clarified by centrifugation, and the extract used for analysis of toxins. Clam and fish tissue will be extracted using a 50% acidified methanol in a Waring Blender. To determine the efficiency of extraction, representative samples of each tissue type are split and purified microcystin-LR, microcystin-YR, microcystin-RR are added to lyophilized or homogenized tissue. Prior experiments showed that the recovery of toxins from algal samples was greater than 95% of microcystins. In contrast, the recovery of toxins from clam tissue was 50-60% of the added toxins. Tissue samples are will be analyzed using both the PPIA and ELISA assay to eliminate potential false positives. In addition, LCMS will be used to determine the individual microcystin distribution and to find and quantify known microcystin degradation products such as the glutathione derivative. These methods were effective for sampling done in 2003 (Lehman et al. in press).

Task 3. Fish Bioassay
Purpose: The purpose of this experiment is to evaluate the potential chronic impacts of microcystin on growth performance and health status of splittail by a long term feeding study and evaluate the effect by histopathology. The information will be used to refine the conceptual model of *Microcystis* toxicity on humans and the ecosystem (Figs. 4 and 6).

Methods: Diet preparation - Five test diets containing graded levels of microcystins found in the Delta food web zooplankton will be used. The study will

focus on microcystin-LR, one of the most toxic microcystins in the Delta bloom. Demethyl microcystin-LR , the most abundant microcystin in the Delta bloom, will be evaluated once it is characterized or through concentrated algal samples. Splittail responses to diets containing 1 to 5 µg dry *M. aeruginosa* /g dry weight will be determined using the chronic toxicity method described by Teh et al. (2004a). This species is useful because it can be successfully grown in long-term bioassay studies (Teh et al. 2004b) and is a good analogue for other native species. The control diet will be formulated with no supplementation and contain vitamin free casein 310 g kg^{-1}, wheat gluten 150 g kg^{-1}, egg albumin 40 g kg^{-1}, dextrin 299 g kg^{-1}, non-nutritive bulk 35g kg^{-1}, carboxymethyl cellulose 20 g kg^{-1}, cod liver oil:corn oil (1:1) 80 g kg^{-1}, vitamin mix 10 g kg^{-1}, mineral mix 30 g kg^{-1}, choline chloride 4 g kg^{-1}, santoquin 0.19 g kg^{-1}.

Fish and experimental conditions - Splittail juveniles (5-7 g) will be reared from the natural spawning of captive broodstocks at the Center for Aquatic Biology and Aquaculture, University of California, Davis. The experiment will be conducted in an indoor flow-through system with 24 individual tanks (40 fish per tank, 66cm in diameter, 90L water in volume). Prior to the initiation of the experiment, 40 fish will be randomly distributed into each tank and acclimated with basic diet (without microcystin) for 2 weeks. Water temperature will be maintained at 18-20 ^{o}C during the experimental period. The flow rate of individual tanks will be 4 L min^{-1}. The system will be kept under a natural photoperiod. Test diet will be randomly assigned to three replicate tanks. Fish will be fed twice daily (9:00am and 4:00pm) with a daily feeding rate of 3 % body weight (BW). Feces and uneaten feeds in the tanks will be cleaned by siphon 30 minutes after feeding and mortality will be recorded daily. The feeding study will last for 1 year or when 50% mortality rate is observed. All moribund and dead fish will be weighed, measured, and processed for histopathological analysis.

Sample collection - Six fish from each tank will be randomly collected at the end of 10, 20, 40, and 60 weeks of exposure. Each fish will be individually netted, examined for gross deformities, and euthanized with an overdose of 3-aminobenzoic acid ethyl ester (MS-222, Sigma, St. Louis, Missouri, USA). Fish will be measured (total length) and body and liver weighed to determine conditional and liver somatic indices. Livers will be examined grossly for neoplasms and then sub sampled for histopathology evaluation. A sub sample of muscle, liver, and gastro-intestinal tract will also be frozen in liquid nitrogen and stored at -80°C for microcystin analysis by Dr. Boyer (Task 2b).

Health assessment - The condition factor and organo-somatic indices have been used extensively as indicators of the well-being of fish health and population assessments (Schmitt and Dethloff 2000). Gross measurements and weights will be used to determine condition (CI) and hepatosomatic (HSI) indices in fish. CI is a measure of "plumpness" and defined as (body weight in grams)(100) / length in cm^3. HSI is the liver to body weight ratio. Both indices are broad measures of general health. Changes in CI reflect alterations in growth and nutritional status

and changes in HSI reflect sex, sexual maturity, or general health and nutrition. Contaminant-induced alterations of somatic growth will therefore be reflected by these indices. Hepatosomatic (100 X liver weight/body weight) indices have proven to be sensitive and simple indicators of responses when compared in fishes from contaminated versus reference sites. For example, hepatosomatic (HSI) and gonadosomatic indices (GSI) decreased in fishes living in water receiving pulp and paper mill effluent (Jobling et al., 1996).

Histopathology has been recommended as a physiological approach to pollution investigation (Sindermann 1985) and has been used with both fish and aquatic invertebrates for the assessment of contaminant-mediated adverse effects (Adams et al. 1999). Histologic lesions can be examined in a tissue specific manner, allowing identification of target organs for specific xenobiotic compounds (Wester and Canton 1986). Direct histological damage of the liver and gonads has been documented in several studies involving heavy metals, pesticides, and pulp and paper mills effluents (Singh et al. 1994; Teh et al. 1997, 1999, 2004a, 2000b, 2005). Liver will be subjected to histopathology as described in Teh et al. (2004a; 2000b; 2005). Lesions will be qualitatively scored based on severity (e.g., 0= normal or no lesion; 10= mild or less than 10% of the organ is affected, 20= moderate or 10-50% of the liver is affected, and 30= severe or > 50% of the liver is affected).

Feasibility - The proposed research experiment will be done at two locations on the campus of UC Davis: the Center of Aquatic Biology and Aquaculture (CABA) and the Aquatic Toxicology Program laboratory (ATP). CABA is equipped with a 1500 sq. ft. Quonset hut and 800 sq. ft. laboratory. The Quonset hut also has a flow-through freshwater system, supplying 19 ± 2 $^{\circ}$C well water at a rate of up to 400 L/min to 72 small (90 L) and 6 large (700 L) fiberglass tanks. The CABA lab and animals are daily by personnel and continuously by remote sensing.

Data analysis: Data will be analyzed using SAS software. All data will be subjected to one-way analysis of variance (ANOVA) to determine treatment effects on growth, condition factor, HSI, and chemical concentrations in tissues. If significant differences ($p<0.05$) were identified, differences among means will be compared by the Duncan's multiple comparison. Analyses will be used to refine conceptual models of the impact of *Microcystis* toxicity on human and ecosystem structure and function as described in Figs. 4 and 6.

Research Program Feasibility: This research program will be fully implementable once contracts are in place. The tasks will not be limited by weather, delay from other projects, environmental compliance or permitting.

Research Program Expected Products and Outcomes: Products from the project will include a BDAT data base containing all new field and laboratory data with a meta database for Tasks 2 and 3 and a literature database on the OEHHA website for Task 1. Programmatic semi-annual status reports and a final report

will summarize the findings of the project to CALFED. The final report will include a discussion of the current and future impact of *Microcystis* on the Delta and restoration projects and any needed direction for future work. At least three peer reviewed journal articles will be prepared as a result of this project.

This hypothesis-driven field and experimental research project will substantially enhance our understanding of the cyanobacterial bloom of *Microcystis* in the Sacramento-San Joaquin Delta thereby helping us to prioritize our future monitoring and research efforts in regard to the impacts of microcystin biomass and contaminants in the Bay-Delta Ecosystem on human health and ecosystem function. The study will also yield critical information on the long-term impact of microcystin toxicity on at-risk fish species and human health needed to develop long-term restoration management strategies.

Management Plan: Dr. P. Lehman will oversee contract management through the CA Department of Water Resources, be the primary contact, synthesize semi-annual status report and final summary report information, track program progress, and conduct the field sampling program. Project integration will proceed through internet discussions and collaboration among scientists through toxicity analyses conducted by Dr. Boyer on field and laboratory samples prepared by both Dr. Teh and Dr. Lehman. Information from the literature database will be used by all research investigators and information from all tasks will be synthesized to refine conceptual models by Dr. Lehman.

Data Management: All data from the field and laboratory studies will be entered into the Interagency Ecological Program BDAT database in order to allow access to the public, government and stakeholder groups. Citations from the literature review will be listed on the OEHHA website and be linked to the Interagency Ecological Program.

Information Dissemination: Information from this study will be disseminated to the scientific research community through oral and poster presentations at local scientific meetings including the CALFED Science Conference, Interagency Ecological Program Annual Meeting and State of the Estuary Conference and national meetings such as the American Society of Limnology and Oceanography, Estuarine Research Federation and the American Fishery Society. Information will be available to the public in the CALFED final report and the international scientific community through three journal articles.

Schedule: The entire project will run from June 2006 to June 2009. Task 1: June 2006 to Dec 2006. Task 2: June 2006 to June 2009. Task 3: June 2006 to June 2009.

Budget: The cost for the three year project is $602,914. In addition, the State University of New York will add an additional $11,452 in cost share in salary and benefits over the three year period ($3668 year 1; $3815 year 2; $3969 year 3).

3. Project Justification

CALFED justification: This hypothesis-driven field and experimental research on this toxic cyanobacterial bloom in the Delta is related to the CALFED Programmatic Record of Decision (ROD) 1) Water Quality Program goals to improve water quality in the Delta by reducing the load of organic carbon, reducing the load of unknown toxins and reducing the impairment from oxygen-demanding substances; 2) Ecosystem Restoration Program goals to improve and increase aquatic habitat, improve ecological function in the Delta and contribute to the recovery of key species and 3) Water storage and use efficiency goals to manage water in wildlife areas and provide reliable good quality water through storage programs as included in the Delta Improvements Package Plan.

The proposal directly addresses the Science PSP goals to learn about 1) Processes Controlling Delta Water Quality such as improving water quality monitoring, the origin of organic carbon sources and causes of oxygen-demanding substances and 2) Relative Stresses on Key Fish Species, especially plankton feeders such as Delta smelt, including impacts on food quantity and quality, predation processes, contaminant effects and habitat and 3) Assessment and monitoring including phytoplankton and shallow water habitat.

Funding is needed from CALFED to continue research on the *Microcystis* bloom in the Delta because no future Interagency Ecological Program Estuarine Monitoring Program funding is available due to the State and Federal budget shortfalls. *Microcystis* is not sampled by the routine Estuarine Monitoring Program because it requires special sampling techniques and sampling at depths and stations outside of the mandated program.

Research justification: *Microcystis biomass - Microcystis* is a cyanobacteria (bluegreen algae) that can form extensive surface scums (Fig. 2). In some cases, this organism can also form a harmful algal bloom (HAB) through production of potent hepatotoxins. A bloom of a large colonial form of *Microcystis* first appeared throughout the Delta in 1999 and has occurred every year since between June and November (Lehman and Waller 2003; Lehman et al. in press) and may be an invasive species. A single day of sampling in October 2003, indicated the bloom was distributed throughout the Delta as far north as Collinsville on the Sacramento River, as far south as navigation light 13 and 14 on the San Joaquin River and the State Water Project (SWP) and Central Valley Project (CVP) water export facilities on Old River and as far seaward as Martinez (Fig. 1; Lehman et al. in press). This region has been routinely monitored by the CA Department of Water Resources (DWR) and U. S. Bureau of Reclamation (USBR) Estuarine Monitoring Program (EMP) since the 1970s, but *Microcystis* was not found in the Delta during this time (IEP database) and the *Microcystis* genus was not recorded for Delta phytoplankton communities in the Delta between 1975 to 1982 (Lehman and Smith 1991).

Microcystis is an extremely cosmopolitan and common freshwater cyanobacterium that blooms in eutrophic lakes and reservoirs throughout the world including the United States, Canada, Australia, New Zealand, South Africa and Japan (Carmichael 1995; Downing et al. 2001: Paerl 1988; Watanabe 1995). It has also been observed in estuaries including the Neuse River estuary (Paerl 1988) and the Potomac River estuary (Sellner et al. 1993) in the USA, the Swan River estuary in Western Australia (Robson & Hamilton 2003) and the Patos Lagoon Estuary in Southern Brazil (Yunes et al. 1996).

The organic carbon loading from the bloom to the Delta may be high. In October 2003, near the end of the bloom, chlorophyll *a* concentration for the largest *Microcystis* colonies (> 75 µm diameter) alone reached 0.075 µgL^{-1} and reached 554 µg L^{-1} in concentrated 1-minute net tow samples. The chlorophyll *a* concentration of the non-Microcystis phytoplankton community in the region ranged from 1 to 3 µg L^{-1}. In 2004, bi-weekly sampling conducted between July and November at nine stations indicated the chlorophyll *a* biomass of large (> 75 µm diameter) *Microcystis* colonies was 4 times higher in September 2004 than those measured in October 2003 and were highest in shallow freshwater habitat.

Microcystis Toxicity - Blooms of *Microcystis* often form surface scums that impede contact recreation sports, reduce aesthetics, lower dissolved oxygen concentration and cause taste and odor problems in drinking water (Carmichael 1995). Some *Microcystis* blooms also contain hepatotoxic microcystins that cause liver tumors and cancer in wildlife and humans (Carmichael 1995).

The *Microcystis* bloom in the Delta formed a surface scum that contained toxic microcystins (Fig. 2). One surface water sample collected in the Delta in 2000 contained total microcystins concentration of 0.8 and 1 µg nmicrocystin-LR equivalents L^{-1}, near or at the World Health Organization (WHO) advisory level of 1 µg L^{-1} (World Health Organization 1998; Lehman and Waller 2003). All of the algal biomass samples collected on the single sampling day in October 2003 contained microcystins, including the highly toxic microcystin-LR. Ambient total microcystins concentration in the largest colonies reached 0.016 µg L^{-1} and was well below the WHO advisory level, but concentrations in 1-minute concentrated net tow samples reached 119 µg L^{-1}, orders of magnitude above the advisory level. Small quantities of microcystins were also found in animal tissue; 1 to 3.5 µg microcystins (g dry weight)$^{-1}$ in zooplankton tissue and 0.02 µg microcystins (g dry weight) $^{-1}$ in clam tissue (Lehman et al. in press). *Microcystis* is not readily eaten by zooplankton or clams (Sellner et al. 1993), but toxins can bioaccumulate. Tissue of the cladocera *Bosmina* spp. contained microcystins concentration that was 202% higher than in the co-occurring algal tissue (Park & Watanabe 1995).

The impact of *Microcystis* toxicity on humans and wildlife in the Delta is unknown. *Microcystis* in the Delta contained a number of microcystins, each with their own

toxicity. The toxicity of the most abundant microcystin in the Delta bloom, tentatively identified as a demethyl microcystin-LR, is unknown and cannot be ascertained until the molecule is purified and individually characterized. Full characterization of this molecule is in progress (G. Boyer personal communication). Microcystin-LR comprised 9 to 23% of the total microcystins and is a powerful hepatotoxin associated with both acute and chronic liver damage (Kaya 1995). This microcystin is associated with toxicity to birds and fish and is suspected as a cause of human cancer in China and Australia (Carmichael 1995; Kaya 1995). Other microcystins in the Delta bloom include microcystin-WR (7-13%), microcystin-FR (5-8%) and microcystin-RR (0-4%).

The toxicity data available so far for July through August 2004 indicated microcystins concentration in concentrated 1-minute net tows ranged from 0 to >500 µg microcystin-LR equivalents L^{-1}, indicating that another toxic bloom occurred in the Delta in 2004. No information is available on the potential impact to human health and ecosystem structure and function in the Delta.

The potential adverse impact of *Microcystis* on the estuary is large. Water from the northern region is used for drinking water and irrigation and the region is an important recreational area for sport fishing and water contact sports. The estuary is habitat for many anadromous commercial and recreational fish including striped bass and Chinook salmon and is a feeding ground for marine mammals. The estuary also contains many threatened or endangered aquatic organisms including the fish Delta smelt, winter run Chinook salmon and Sacramento splittail. Many of these endangered fish species are declining (California Bay-Delta Authority 2000). Of great concern are the low Delta smelt and striped bass population indices measured over the last four years (www.delta.dfg.ca.gov). These low indices could not be explained by the usual causal factors such as hydrology and *Microcystis* may be a contributing factor.

Fish toxicity - Numerous experimental studies have documented the toxicity of microcystin exposure through gastrointestinal or blood circular systems on fish such as common carp (Fischer and Dietrich 2000; Li et al. 2001), gold fish (Xu et al. 1998), Atlantic salmon (Williams et al. 1997), rainbow trout (Bury et al. 1997; Fischer et al. 2000), channel catfish (Zimba et al. 2001), brown trout (Bury et al. 1997), Northern snakehead (Chen et al.1995), and grass carp (Chen et al. 1995; Zhang et al. 1996). The cyprinids appeared to be more susceptible to microcystin toxic effects than salmonids (Tencala 1995). The above studies were limited to acute toxic experiments, and using an approach based on either oral gavaging, intraperitoneal or dorsal aorta injection, which cannot reflect the uptake route under natural environments. Little is known about the chronic impacts of microcystins except for a study of the effect of microcystins on silver carp through a sub-chronic toxicity experiment (Xie et al. 2004).

The long term health effects of native at-risk fish chronically exposed to microcystins in the Delta is unknown. No study has investigated the impact of

Microcystis on splittail, which declined in population over its habitat in the estuary. Sacramento splittail, a cyprinid endemic benthivore, is now largely confined to the San Francisco Estuary and was listed as threatened species by the U.S. Fish and Wildlife Service. Splittail are opportunistic daytime benthic foragers that feed on opossum shrimp, earthworm, clams, insect larvae, and other invertebrates. Detrital material also makes up a high percentage of their stomach contents (Meng and Moyle 1995). A recent study revealed that splittail are changing their diet preference to consume a large quantity of clams and benthic invertebrates as their major food source (Feyrer et al. 2003). Microcystin exposure via trophic transfer warrants investigation for this species directly and as an analogue for other species in the estuary such as Delta smelt and striped bass that have declined in the Delta for unknown reasons in the past four years.

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Table 1. Questions to be addressed by this research.

Questions	Approach	Analysis
Bloom biomass		
Where is the highest bloom biomass in the Delta and is it associated with any particular habitat type?	Compare chlorophyll a concentration measurements of Microcystis colonies among habitats in the Delta	multiple comparison test such as Kruskal-Wallis
How does the bloom biomass vary with season and water year?	Compare biomass estimates measured at frequent intervals over the season and among water years	multiple comparison test such as Kruskal-Wallis
What enviornmental conditons are associated with high biomass?	Compare biomass estimates with measured water quality conditions, computed flow and residence time and verify with historical data where possible	principal components analysis; correlation analyses
Is shallow water a source or sink of biomass?	Compare growth rate of Microcystis in shallow water habitat with other habitats; Compare timing of onset and decline of bloom among habitats; Compute biomass flux at levee breaks;	single and multiple comparison test such as Wilcoxon Mann-Whitney U and Kruskal-Wallis
How do changes in growth rate and photosynthetic parameters affect bloom biomass?	Compare growth rate measured over the season using light and dark bottle primary productivity measurements with biomass estimates	correlation analysis
How important are dispersal and aggregation mechanisms (e.g. tide) to biomass?	Compare biomass flux with tidal versus river flow (tidally filtered)	compute mass balance from flux computed with biomass and flow estimates
What environmental factors trigger decline (e.g., wind speed and duration; water temperature; daylength and vertical mixing)?	Measure or compute environmental conditions during decline phase of bloom and compare with log-growth phase of bloom	principal component analysis
Does the bloom cause changes in water quality conditions (e.g. light attenuation)?	Compare water quality conditions in adjacent areas with high and low bloom biomass	Wilcoxon Mann Whitney U single comparison tests
Is the bloom asssociated with changes in lower food web species composition and biomass?	Compare phytoplankton and zooplankton species composition and biomass in areas with high and low biomass; Compare historical phytoplankton and zooplankton species composition and biomass before and after the bloom	principal components analysis; cluster analysis; time series analysis; anaysis of variance
What historical environmental conditions may have contributed to the successful invasion/development of this bloom in the Delta?	Conduct data analysis on IEP and EMP 30-year historical database to determine if there were any changes in water quality or biological conditions that preceded or were associated with the appearance of the bloom in 1999	principal components analysis; cluster analysis; time series analysis; correlation
What is the best way to sample bloom biomass in terms of stations and sampling frequency?	Evaluate sampling program to determine stations that best represent changes in bloom source and development	compare variability and biomass from different stations and sampling frequency using cluster analysis and multiple comparison tests

Table 1. Questions to be addressed by this research (continued).

Bloom toxicity		
How does the toxicity vary seasonally and among water years?	Compare toxicity at high frequencies among season and at low frequencies among water years	multiple comparison test such as Kruskal-Wallis
When and where are particulate and disssolved microcystins most concentrated?	Compare measurements of particulate and dissolved microcystins among stations and habitats over season and years	multiple comparison test such as Kruskal-Wallis
How is dissolved microcystins concentrations related to bloom biomass and toxicity?	Compare dissolved microcystins concentrations with chlorophyll a concentration, tissue biomass and microcystins concentration per unit biomass	correlation analysis
What environmental factors are associated with particulate and dissolved toxicity?	Compare concentrations of dissolved and particulate microcystins with environmental conditions	correlation analysis; principal components analysis
How does toxicity vary with growth rate?	Compare measured growth rates with toxicity per unit biomass	correlation analysis
Does organic carbon loading from the bloom affect THM formation and taste and odor problems in drinking water?	Measure change in THM formation with bloom biomass; compare taste and odor issues at SWP with bloom biomass	correlation analysis
What is the best way to assess bloom toxicity?	evaluate amplitude and variability of data from program	
Food web toxicity		
How far have microcystins moved into the food web?	Ccompare microcystins concentration in whole organisms, muscle and liver tissue of organisms at many levels in the food web	graphical; tabular and multiple comparison tests
Does any organism in the food web concentrate microcystins?	Compare microcystins concentration in whole organisms, muscle and liver tissue of organisms at many levels in the food web	multiple comparison tests
What are the pathways of microcystins movement through the aquatic food web?	construct path analysis of potential pathways of microcystins movement based on tissue assay	conceptual model development
Is the Delta bloom an acute or chronic threat to fish survival?	conduct fish bioassay studies to determine the effect of microcystins in the Delta bloom and the Delta bloom biomass itself on short-term fish survival	multiple comparison tests
Is the bloom a chronic threat to fish health?	conduct fish bioassay studies to determine the effect of microcystins in the Delta bloom and the Delta bloom biomass itself on long-term fish health	multiple comparison tests; tabular
Does the toxicity affect food web structure and function?	Compare food web structure among habitats with differing toxicity	principal component analysis; cluster analysis; multiple comparison tests
How does toxicity in the food web vary seasonally and among water years?	Compare microcystins concentration in food web organisms within and among years	
What is the best way to access food web toxicity?	Evaluate food web toxicity data to determine the minimum number of stations, trophic levels and sampling frequency needed to assess the status of toxicity	use cluster analysis; multiple comparisons tests; CV

Figure 1. Map of the Delta showing the distribution of the Microcystis bloom based on October 2003 sampling stations (Lehman et al. in press).

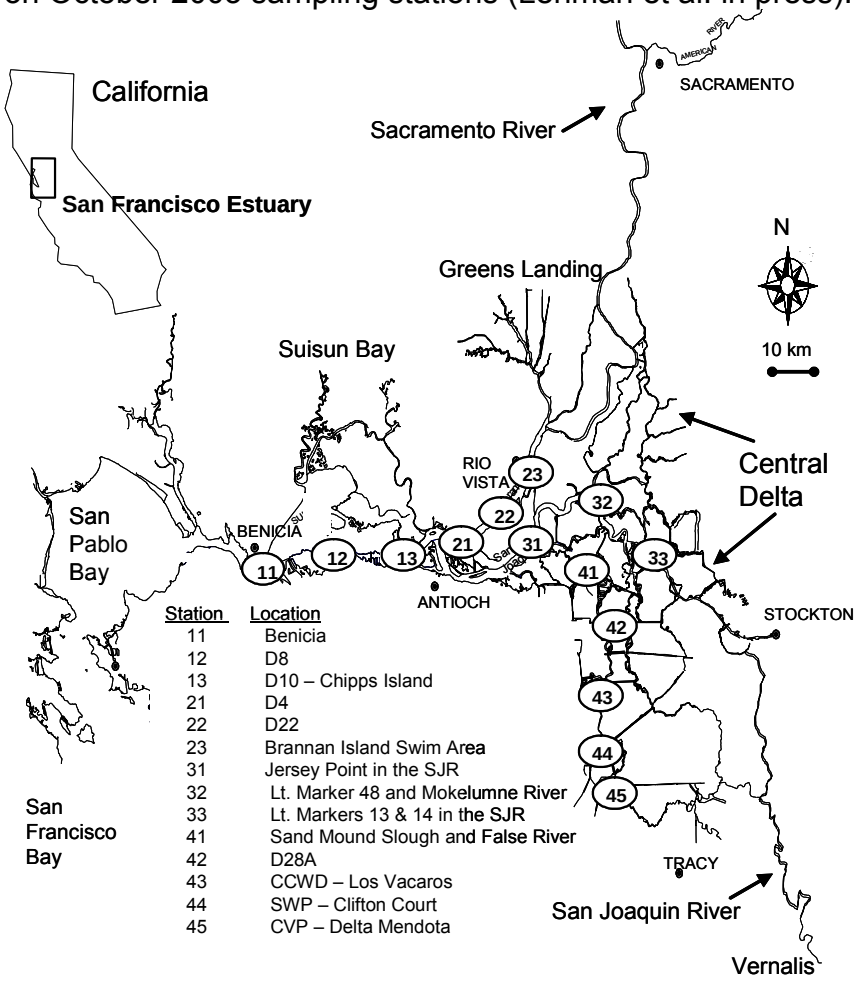


Fig. 2. Microcystis in surface water of the Delta 2003.

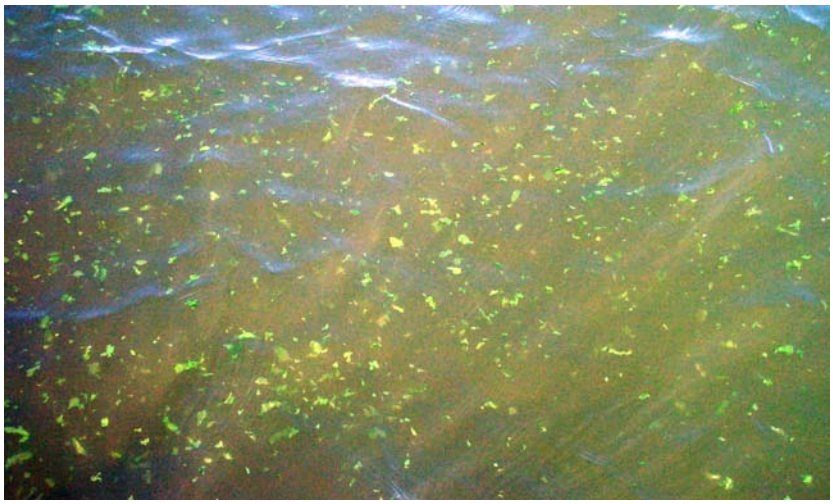


Fig. 3. Conceptual model illustrating the influence of environmental factors on *Microcystis* biomass.

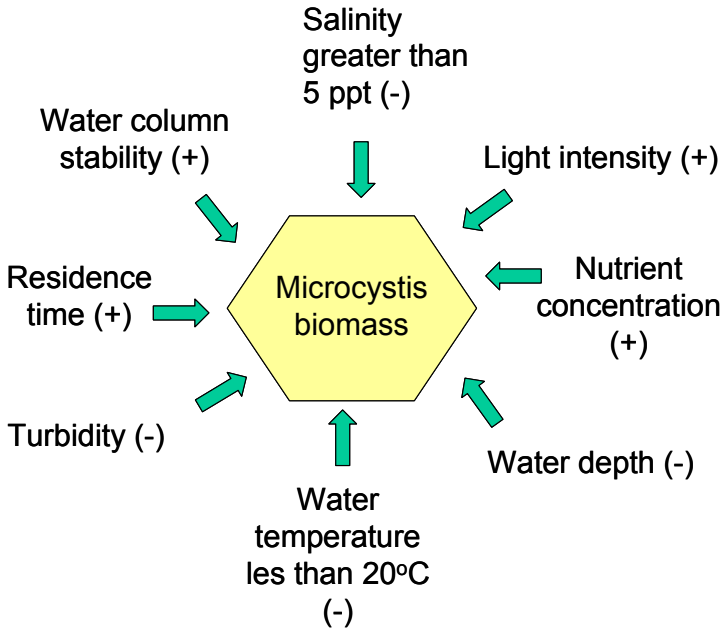


Figure 4. Conceptual model of *Microcystis* Impact on human beneficial use.

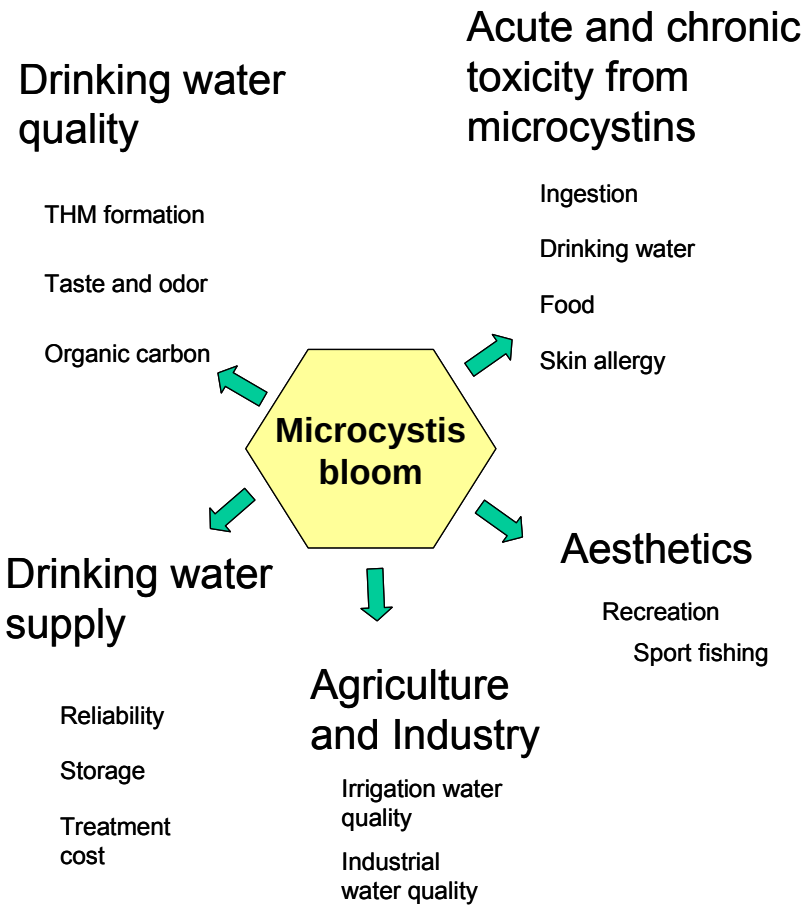


Figure 5. Conceptual model of *Microcystis* impacts on ecosystem structure and function: Part 1. Water quality and organic carbon impacts

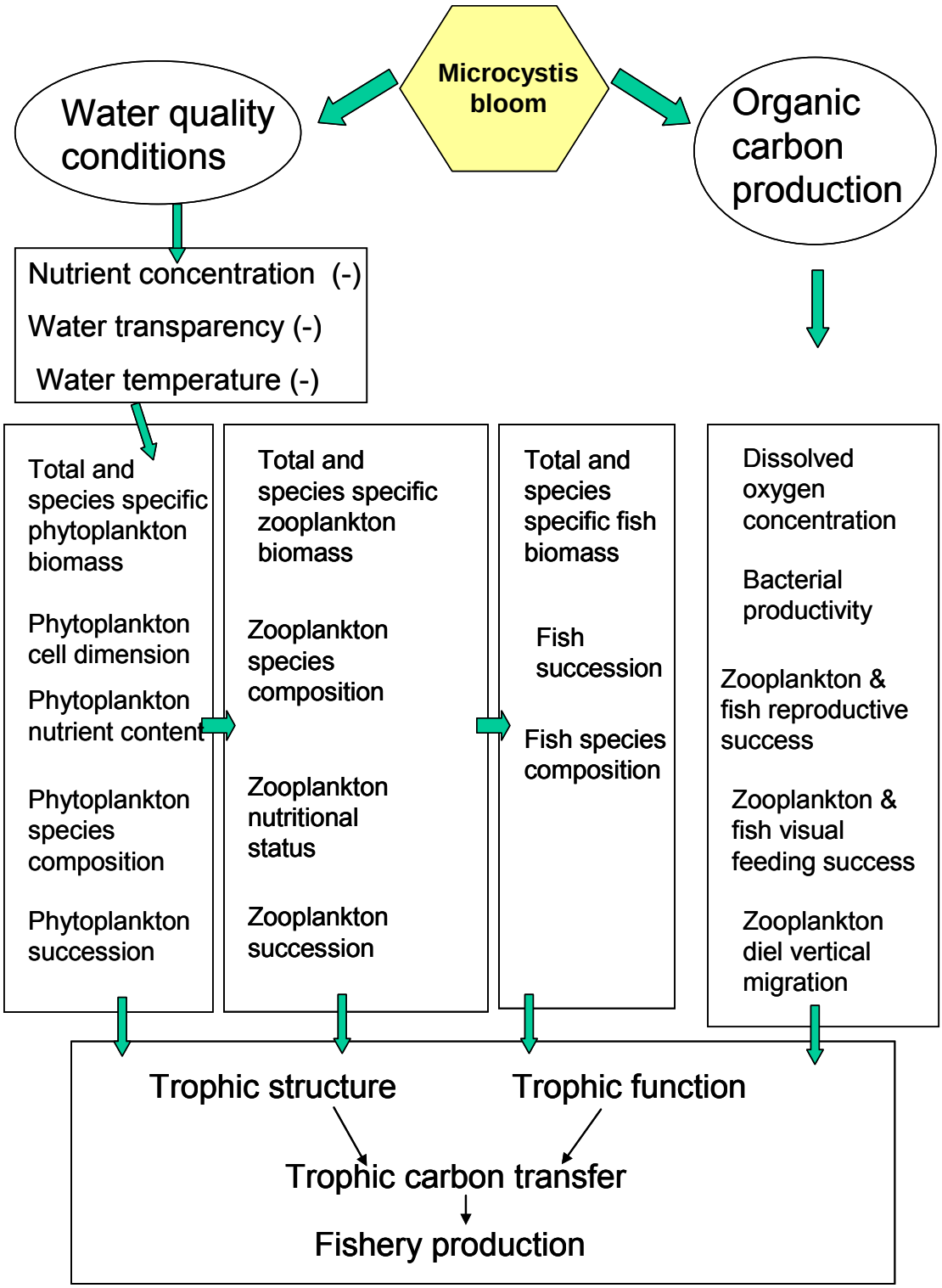
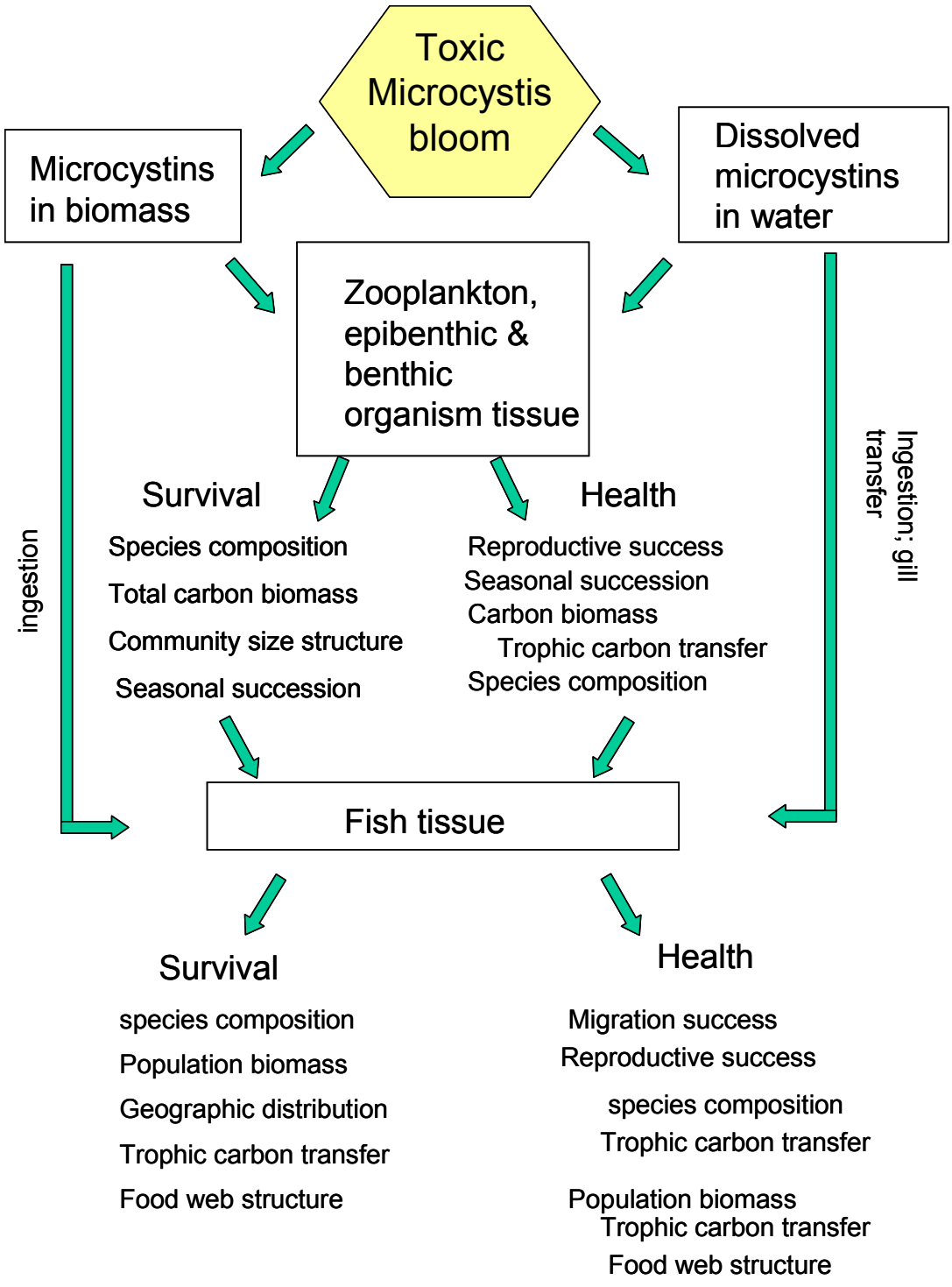


Figure 6. Conceptual model of *Microcystis* impact on ecosystem structure and function. Part 2. Toxicity impact.



Curriculum Vitae
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Education: B.S. Renewable Natural Resources (1972), M.S. Ecology (1974), and Ph.D. Ecology (1979) at University of California, Davis, CA

Research Interests: Research interests include studies associated with phytoplankton biomass, growth rate and species composition, water quality and lower food web dynamics relating to the biological impacts of climate change, eutrophication and wetland restoration in the upper San Francisco Bay region.

Other qualifications: Principal scientist of $860,000 CALFED ERP 200-2001 dissolved oxygen study in the San Joaquin River (completed); Principal and Senior scientist for CALFED and Sacramento-San Joaquin River Interagency Ecological Program grants totaling over $1 m to study phytoplankton growth in the San Joaquin River, carbon production rate and water quality in the Delta, seasonal (Yolo Bypass) and tidal wetlands (Liberty Island) and the distribution and toxicity of toxic bluegreen algae in the Delta; currently conducting CALFED funded primary productivity studies in Liberty Island

Professional Experience:

1986-present Senior Environmental Specialist, California Department of Water Resources, Sacramento, CA
1982-1985 Associate Environmental Specialist, California Department of Water Resources, Sacramento, CA
1980-1981 Instructor, Chapman College, Alameda, CA
1978-1980 Postdoctor and research associate, Land, Air and Water Resources, University of California at Davis, CA
1977 National Research Fellowship, Marine Ecology Lab, Bedford Institute of Oceanography, Nova Scotia, Canada

Selected Journal publications:

Lehman, P. W., T. Sommer and L. Rivard. In review. Phytoplankton primary productivity, biomass and species composition in the Yolo Bypass floodplain, California.

Lehman, P. W., G. Boyer, C. Hall, S. Waller and K. Gehrts. 2005**.** Distribution and toxicity of a new colonial *Microcystis aeruginosa* bloom in the San Francisco Bay Estuary, California. Hydrobiologia (in press).

Lehman, P. W., J. Sevier, J. Giuliannotti and M. Johnson. 2004. Sources of oxygen demand in the lower San Joaquin River, California. Estuaries 27:405-418.

Lehman, **P. W**. 2004. The influence of climate on mechanisms that affect lower food web production in estuaries. Estuaries 27:312-325.

Lehman, P. W. 2000. The influence of climate on phytoplankton community carbon in San Francisco Bay Estuary. Limnology and Oceanography 45:580-590.

Lehman, **P. W**. 2000. Phytoplankton, carbon, cell diameter and species composition in the low salinity zone of northern San Francisco Bay Estuary. Estuaries 23:216-230.

Lehman, **P. W.** 1996. Changes in chlorophyll *a* concentration and phytoplankton community composition with water year type in the upper San Francisco Bay estuary. In J. T. Hollibaugh (ed.), San Francisco Bay: The Ecosystem. Pac. Div., Amer. Assoc. Adv. Sci.

Lehman, **P. W.** 1992. Environmental factors associated with long-term changes in chlorophyll *a* concentrations in the Sacramento-San Joaquin Delta and Suisun Bay, California. Estuaries 15:335-348.

Lehman, **P. W.** and R. W. Smith. 1991. Environmental factors associated with phytoplankton succession for the Sacramento-San Joaquin Delta and Suisun Bay estuary. Estuarine, Coastal and Shelf Science. 32(2):105-128.

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Estuarine Research Federation

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RESEARCH INTERESTS

The chemistry and biochemistry of biologically active natural products from plants and algae including toxins, siderophores, allelopathic agents, and growth regulators. Special interests include the biochemistry of iron in forest and aquatic (marine and freshwater) ecosystems, the chemistry / ecology of marine and freshwater harmful algal blooms, brown tides, and rapid detection methods for toxic cyanobacteria and paralytic shellfish poisoning (PSP) toxins.

EDUCATION:

Ph.D.,	University of Wisconsin - Madison,	1980,	(Biochemistry).
A.B.,	University of California - Berkeley,	1975,	(Biochemistry).
A.S.,	Reedley College (Reedley, Calif.),	1973,	(Chemistry).

PROFESSIONAL EXPERIENCE:

1998-present: Professor of Chemistry, State University of New York, College of Environmental Science and Forestry, (SUNY-CESF) Syracuse NY 13210.

1991-1998: Associate Professor of Chemistry, SUNY-CESF.

1994	Visiting Scientist, Biology Dept., Woods Hole Oceanographic Institute, Woods Hole, MA 02543.
1986-1991	Joint Academic Appointment in the Faculty of Environmental Sciences, SUNY-CESF.
1985-1990	Assistant Professor of Chemistry, SUNY-CESF.
1983-1984	Research Associate, Dept. of Oceanography, Univ. of British Columbia, Vancouver, BC, V6T 1W5
1980-1982	Research Associate, Michigan State University - DOE, Plant Research Labs. East Lansing, MI, 48824
1975-1980	Research Assistant, Department of Biochemistry, University of Wisconsin, Madison, WI, 53706

HONORS:

NRSA predoctoral trainee - Cell & Molecular Biology (1976-79), Life member; Phi Beta Kappa - Alpha (UC-Berkeley Honor Soc.), Life member; Alpha Gamma Sigma (Reedley College Honor Soc.), International Expert for IAEA (International Atomic Energy Agency) on PSP toxins (1999), Participant in EPA's "Creating a Cyanotoxin Target List for the Unregulated Contaminant Monitoring Rule" taskforce (2001), Participant in NOAA – Sea Grant's workshop entitled "Developing a National Plan for Remediation of Harmful Algal Blooms", Steering committee for "National Plan for Marine Biotoxins-2004; Elected as Treasurer and Nominations Chair to the Northeast Algal Society 1999-2005; Recipient; State University of New York Research Foundations 2003 Award for Excellence in the Pursuit on Knowledge.

SELECTED PROFESSIONAL SOCIETIES:

American Society of Plant Physiologists, American Society of Limnology and Oceanography, North East Algal Society, Phycological Society of America, American Littoral Society, American Water Resources Association. International Association for Great Lakes Research, International Society for the Study of Harmful Algal Blooms.

Selected Publications in the last four years:

G. L. Boyer has over 60 publications relating to HPLC, natural products chemistry and plant and algal biochemistry. Selected publications include:

Giner, J-L., X. Li, and G. L. Boyer (2001) Sterol composition of *Aureoumbra legunensis*, the Texas brown tide alga. Phytochemistry, 57:787-789.

Goddard, G. D., and G. L. Boyer (2001) A comparison of HPLC with electrochemical oxidation, HPLC with chemical oxidation, and the mouse bioassay for the analysis of PSP toxins in shellfish. In: "Harmful Algal Blooms 2000", G.M. Hallegraeff, S.I. Blackburn, C.J. Bolch, R.J. Lewis, ed., p. 261-265.

Bates, S. S., C. Leger, M. Satchwell, and G. L. Boyer (2001) The effects of iron on domoic acid production by *Pseudo-nitzschia multiseries*. In: "Harmful Algal Blooms 2000" S.I. Blackburn G.M. Hallegraeff, C.J. Bolch, R.J. Lewis, ed., p. 320-323.

Nichols, D. B., M. F. Satchwell, J. E. Alexander, N. M. Martin, M. T. Baesl, and G. L. Boyer (2001) Iron nutrition in the brown tide algae, *Aureococcus anophagefferens*: Characterization of a ferric chelate reductase activity. In: "Harmful Algal Blooms 2000", G.M. Hallegraeff, S.I. Blackburn, C.J. Bolch, R.J. Lewis, ed., p. 340-343.

Baker, T. R., G. J. Doucette, C. L. Powell, G. L. Boyer, and F. G. Plumley (2003) Characterization of fluorescent compounds from *Pseudomonas stutzeri* SF/PS and *Pseudomonas/Altermonas* PTB-1, bacteria associated with *Alexandrium* spp. and paralytic Shellfish Poisoning. Toxicon 41:339-347.

Giner, J.-L., J.A. Farldos, G.L. Boyer (2003) Unique sterols of the toxic dinoflagellate *Gymnodinium breve* and a proposed defensive function for unusual marine sterols, J. Phycol. 39:1-6

Boyer, G., M. C. Watzin, A. D. Shambaugh, M. F. Satchwell, B. R. Rosen, and T. Mihuc (2003) The occurrence of cyanobacterial toxins in Lake Champlain. In: "Lake Champlain, Partnership and Research in the New Millennium Conference proceedings" T. Manley et al, eds. pp. 241-277.

Satchwell, M. F., and G. L. Boyer (2004) Comparison of three methods for the detection of microcystin cyanobacterial toxins. *In press in*: Proceedings, 10th International Conference on Harmful Algal Blooms (XHAB)

Patchett, E.A. M.F. Satchwell, J. Alexander, and G.L. Boyer (2004) The effects of Iron Limitation on Growth and PSP toxin Production in *Alexandrium fundyense*. *In press in*: Proceedings, 10th International Conference on Harmful Algal Blooms (XHAB).

Lehman, P., G. Boyer, C. Hall, S. Waller, and K. Gerhts (2004) Distribution and toxicity of a new colonial *Microcystis aeruginosa* bloom in San Francisco Estuary, California. Hydrobiology. *In press*

Mihuc, T. B., G. L. Boyer, M. F. Satchwell M. Pellam, J. Visile, and A. Bouchard (2004) Algal Community composition and cyanobacterial toxins in Lake Champlain, NY. Societas Internat Limnol, *In press*

Zou, G., and G. L. Boyer (2004) Synthesis and Properties of different metal Complexes of the siderophore desferriferricrocin. Biometals. *In press*

Rinta-Kanto, J. M., A. J. A. Ouellette, M. R. Twiss, G. L. Boyer, T. Bridgeman, and S. W. Wilhelm (2004) Quantification of toxic Microcystis spp. during the 2003 and 2004 blooms in western Lake Erie using quantitative real-time PCR. Environ. Sci. Technol. submitted.

Hotto, A., M. Satchwell, and G. Boyer (2004) Seasonal Production and Molecular Characterization of Microcystins in Oneida Lake, New York, USA. Environmental Toxicology. submitted.

C.J. Gobler, D. Lonsdale, and G. L. Boyer (2004) A review of the causes, impacts and potential management of harmful brown tides caused by the alga *Aureococcus anophagefferens*. Estuaries, submitted.

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1986-1991 Joint Academic Appointment in the Faculty of Environmental Sciences, SUNY-CESF.

1985-1990 Assistant Professor of Chemistry, SUNY-CESF.

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taskforce (2001), Participant in NOAA – Sea Grant's workshop entitled "Developing a National Plan for Remediation of Harmful Algal Blooms", Steering committee for "National Plan for Marine Biotoxins-2004; Elected as Treasurer and Nominations Chair to the Northeast Algal Society 1999-2005; Recipient; State University of New York Research Foundations 2003 Award for Excellence in the Pursuit on Knowledge.

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Baker, T. R., G. J. Doucette, C. L. Powell, G. L. Boyer, and F. G. Plumley (2003) Characterization of fluorescent compounds from *Pseudomonas stutzeri* SF/PS and *Pseudomonas/Altermonas* PTB-1, bacteria associated with *Alexandrium* spp. and paralytic Shellfish Poisoning. Toxicon 41:339-347. Giner, J.-L., J.A. Farldos, G.L. Boyer (2003) Unique sterols of the toxic dinoflagellate *Gymnodinium breve* and a proposed defensive function for unusual marine sterols, J. Phycol. 39:1-6 Boyer, G., M. C. Watzin, A. D. Shambaugh, M. F. Satchwell, B. R. Rosen, and T. Mihuc (2003) The occurrence of cyanobacterial toxins in Lake Champlain. In: "Lake Champlain, Partnership and Research in the New Millennium Conference proceedings" T. Manley et al, eds. pp. 241-277. Satchwell, M. F., and G. L. Boyer (2004) Comparison of three methods for the detection of microcystin cyanobacterial toxins. *In press in*: Proceedings, 10^{th} International Conference on Harmful Algal Blooms (XHAB) Patchett, E.A. M.F. Satchwell, J. Alexander, and G.L. Boyer (2004) The effects of Iron Limitation on Growth and PSP toxin Production in *Alexandrium fundyense*. *In press in*: Proceedings, 10^{th} International Conference on Harmful Algal Blooms (XHAB). Lehman, P., G. Boyer, C. Hall, S. Waller, and K. Gerhts (2004) Distribution and toxicity of a new colonial *Microcystis aeruginosa* bloom in San Francisco Estuary, California. Hydrobiology. *In press* Mihuc, T. B., G. L. Boyer, M. F. Satchwell M. Pellam, J. Visile, and A. Bouchard (2004) Algal Community composition and cyanobacterial toxins in Lake Champlain, NY. Societas Internat Limnol, *In press* Zou, G., and G. L. Boyer (2004) Synthesis and Properties of different metal Complexes of the siderophore desferriferricrocin. Biometals. *In press* Rinta-Kanto, J. M., A. J. A. Ouellette, M. R. Twiss, G.

L. Boyer, T. Bridgeman, and S. W. Wilhelm (2004) Quantification of toxic Microcystis spp. during the 2003 and 2004 blooms in western Lake Erie using quantitative real-time PCR. Environ. Sci. Technol. submitted. Hotto, A., M. Satchwell, and G. Boyer (2004) Seasonal Production and Molecular Characterization of Microcystins in Oneida Lake, New York, USA. Environmental Toxicology. submitted. C.J. Gobler, D. Lonsdale, and G. L. Boyer (2004) A review of the causes, impacts and potential management of harmful brown tides caused by the alga *Aureococcus anophagefferens*. Estuaries, submitted.

[1.]

CURRICULUM VITAE

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EDUCATION:

Ph.D., Comparative Pathology, (January 1991 - March 1996)
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M.Sc., Human Anatomy, (September 1985 - May 1987)
West Virginia University, Morgantown, USA
B.Sc., Medical Technology, (September 82 - May 1985)
West Virginia University, Morgantown, USA

SPECIALTY: **Research & Environmental Toxicologist/Pathologist**

RESEARCH INTEREST:

Conduct independent research in the fields of biomarker, developmental biology, nutrition, toxicology and pathology. Special emphasis on acute and chronic toxicity and on adverse growth, reproductive and embryonic developmental effects of fish and shellfish populations caused by environmental endocrine disruptors, heavy metals and organic contaminants

Research will include:

1. The culture of native (Delta smelt, Sacramento Splittail, and Sacramento Perch) and surrogate (Medaka) fish models for use in carcinogens, endocrine disruptors and toxicants testing;
2. Design QA/QC & safety protocols for animal care & exposure experiment. Acute and chronic toxicity testing of contaminants and toxicants using native and non-native fish;
3. The long-term, sublethal growth and reproductive effects of fish exposed to contaminant-laden diets (metals or pesticides);
4. Development and use of enzymatic and histopathologic indicators (biomarkers) of exposure and sublethal deleterious effects of environmental pollutants in fish and aquatic invertebrate populations;
5. Development and the application of toxicogenomics in aquatic toxicology testing;
6. Effects of toxicants on quality and quantity of food chain organisms and resultant consequences on the higher trophic organisms.
7. Integrate growth, biochemical and histopathological indicators into an individual health index and extrapolation of this health index to population level effects.

TEACHING EXPERIENCE:

2002-4 Graduate student major advisor for Abimael Leon-Cardona, Ecotoxicology, UC Davis, PhD

2002-4 Davis High School Badminton Coach.

2003-4 Mentor professor for Ms. Uni Leong of the Mentorships for Undergraduate Research in Agriculture, Letters, and Science (MURALS) program at UCD

2002 Lecturer: ECL 298 - #31, Special Summer Session, "Problems in Ecotoxicology" September 16-21, University of California, Davis, CA. Lecture title: "Application of Biomarkers in assessing and evaluating the effects of environmental stressors on aquatic ecosystem health".

2004 Committee member for Diran Tashjian, Ecotoxicology, UC Davis, PhD.

2002 Committee member for Linda Hall, Ecotoxicology, UC Davis, PhD. Thesis

2001 Member of the Graduate Group in Ecology on November 30, 2001.

1997-8 Laboratory instructor in VM432, School of Veterinary Medicine, UC Davis.

PROFESSIONAL COMPETENCE AND ACTIVITY:

A. Participate in CALFED Bay-Delta Program meetings and present research findings.
B. Participate in professional meetings and present research findings.
C. Review research proposals and manuscripts.
D. Member of Society of Environmental Toxicology and Chemistry

SPECIALTY CERTIFICATION:

America Society of Medical Technology (ASMT)
America Society of Clinical Pathologists (ASCP)

HONORS and AWARDS:

Mu Tau Medical Technology (1983)
Mu Tau Scholarship (1984)
Employee of the Month, University of California (1994-1995)
Incentive Award, University of California (1994-1995)

PUBLICATIONS:

1. **Teh, S.J**. Histochemical and histologic analyses in freeze-dried, glycol methacrylate-embedded tissues: Application to chemically-induced neoplasia in aquarium fishes. West Virginia University, Morgantown,WV Thesis, 96 pages. 1987.
2. Hinton, D.E., Couch, J.A., **Teh, S.J**., and Courtney, L.A. Cytological changes during progression of neoplasia in selected fish species.Aquat. Toxicol. 11:77-112. 1988.
3. Hinton, D.E., Laurén, D.J., **Teh, S.J**., and Giam, C.S. Cellular composition and ultrastructure of hepatic neoplasms induced by diethylnitrosamine in *Oryzias latipes*. Mar. Environ. Res. 24:307-310.1988.
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9. **Teh, S.J**. and Hinton, D.E. Detection of enzyme histochemical markers of hepatic preneoplasia and neoplasia in medaka (*Oryzias latipes*). Aquat. Toxicol. 24:163-182. 1993.
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11. Gawlicka, A., **Teh, S.J.,** Hung, S.S.O., Hinton, D.E. and de la Noüe,J. Histological and histochemical changes in the digestive tract of white sturgeon larvae during ontogeny. Fish Physio. Biochem. 14:357-371. 1995.
12. Torten, M., Liu, Z., Okihiro, M.S., **Teh, S.J.** and Hinton, D.E. Induction of ras oncogene mutations and hepatocarcinogenesis in medaka (Oryzias latipes) exposed to diethylnitrosamine. Mar. Environ. Res. 42, Vol. 1-4:93-98. 1996.
13. **Teh, S.J.** Cellular aspects of hepatocarcinogenesis in medaka (*oryzias latipes*): dynamics of histogenesis and gender-related sensitivity. Dissertation. 175 pages. 1996.
14. **Teh, S.J**., Adams, S.M. and Hinton, D.E. Histopathologic biomarkers in feral fish populations exposed to different types of contaminant stress. Aquat. Toxicol. 37: 51-70.1997.
15. **Teh, S.J**. and Hinton, D.E. Gender-specific growth and hepatic neoplasia in medaka (*Oryzias latipes*)**.** Aquat. Toxicol. 41: 141-159. 1998.
16. Olsson, P.E., Westerlund, L., **Teh, S.J.**, Billsson, K., Berg, A.H., Tysklind, M., Nilsson, J., Eriksson, L.O. and Hinton, D.E. Effects of maternal exposure to estrogen and PCB on different life stages of zebrafish (Danio rerio) AMBIO, 28(1): 100-106. 1999.
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18. Koger, C.S., **Teh, S.J.** and Hinton, D.E. Variations of light and temperature regimes and resulting effects on reproductive parameters in medaka (*oryzias latipes*). Biology of Reproduction. 61: 1287-1293, 1999.
19. **Teh, S.J.,** Clark, S.L., Brown, C. and Hinton, D.E. Enzymatic and histopathologic biomarkers as indicator of environmental contaminant exposure and effect in Asian clam (*Potamocorbula amurensis).* Biomarker, V4N6: 497-509, 1999.
20. Villalobos, S.A., Hamm, J.T., **Teh, S.J.** and Hinton, D.E.. Thiobencarb-induced embryotoxicity in medaka (*oryzias latipes*): Stage specific toxicity and the protective role

of chorion. Aqua. Toxicol. 48: 309-326, 2000.

21. **Teh, S.J.**, Miller,C.E. and Hinton, D.E. Hermaphroditism in laboratory culture albino western mosquitofish (Gambusia affinis affinis). Journal of Aquatic Animal Health 12: 78-80, 2000.
22. **Teh, S.J.,** Werner, I., and Hinton, D.E. Chronic Toxicity of Chromium VI in Asian Clam (*Potamocornula* Amurensis). Mar. Environ. Res. 50 (1-5): 295-300, 2000.
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26. Fan, W-M.T, **Teh, S.J,** Hinton, D.E., Higashi, R.M. Selenium Biotransformations into Proteinaceous Forms by Foodweb Organisms of Selenium-Laden Drainage Waters in California. Aquatic Toxicology (Amsterdam) April, 2002. 57 (1-2): 65-84.
27. Deng, D.F., **Teh, S.J.,** Teh, F.C, and Hung, S.S.O. Effect of Diets and Water Temperatures on the Growth of Sacramento Splittail (*Pogonichthys Macrolepidotus*) Larvae. North American Journal of Aquaculture, 64:242-247, 2002.
28. **Teh, S.J.,** Deng, X., Teh, F.C., Hung, S.S.O. Selenium-induced teratogenicity in Sacramento Splittail (*pogonichthys macrolepidotus*). Mar. Environ. Res. 54: 605-608 2002.
29. Tay, K.L., **Teh, S.J.,** Doe, K., Lee, K, and Jackman, P. Histopathologic and histochemical biomarker responses of Baltic clam, *Macoma balthica*, to contaminated Sydney Harbour sediment, Nova Scotia, Canada. Environ. Health Persp. 111 (3): 273-280 2003.
30. **Teh, S.J.,** Wong, C., Furtula, V, and Teh, FC. Lethal and Sublethal Toxicity of Didecyldimethylammonium Chloride (DDAC) in Early Life Stages of White Sturgeon (*Acipenser transmontanus*). Environ. Tox. Chem. 22 (9): 2152-2158 2003.
31. Anderson, M.J., Cacela, D., Beltman, D., **Teh, S.J**., Okihiro, M.S., Hinton, D.E., Denslow, N., Zelikoff, J.T. Biochemical Indicators and Toxicopathic Lesions Assessed in Smallmouth Bass Recovered from a Polychlorinated Biphenyl (PCB) Contaminated River. Biomarker. V8N5: 371-393. 2003.
32. **Teh, S.J.** Histopathologic Biomarkers as Indicators of Biologic Effects of Environmental Contaminants. NorCal SETAC Newsletter. 14-3: 13-15. 2003.
33. **Teh, S.J.,** Zhang, GH., Kimball, T, and Teh, FC. Lethal And Sublethal Effects Of Esfenvalerate And Diazinon On Sacramento Splittail Larvae. In F. Feyrer, L. Brown, J. Orsi, and R. Brown, eds. Early life history of fishes in the San Francisco Estuary and watershed. American Fisheries Society Symposium. Bethesda, Maryland. 2004.
34. Werner, I, **Teh, S.J**., Datta, S., Lu, X.Q., and Young, T. Biomarker Responses In Macoma Nasuta (Bivalvia) Exposed To Sediments From Northern San Francisco Bay. Mar. Environ. Res. 58:299-304, 2004.
35. **Teh, S.J.,** Deng, D.F., Werner, I., Teh, FC, and Hung, S.S.O. Sublethal Toxicity of

Orchard Stormwater Runoff in Sacramento Splittail (*Pogonichthys macrolepidotus*) Larvae. Mar. Environ. Res. 59: 203-216, 2005

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37. **Teh, S.J.,** Deng, X., Deng, D.F., Teh, F.C., Hung, S.S.O., Fan, W-M.T, Liu, J., and Higashi. Chronic Effects of Dietary Selenium on Juvenile Sacramento Splittail (*Pogonichthys Macrolepidotus*).). Environ. Sci. Technol.; 38(22) pp 6085 - 6093.
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39. Deng, X., **Teh, SJ**., Doroshov, S.I., and Hung, S.S.O. Embryonic and larval development of Sacramento splittail *Pogonichthys macrolepidotus*. Submitted to *Environmental Biology of Fishes*.

ACTIVE SUPPORT –

1. Title: Groundwater ambient monitoring and assessment program – Hexavalent chromium and endocrine disrupting chemicals. 09/01/04-06/30/06: $164,094
   Role: Principal Investigator Source: SWRCB
2. Title: Using a Sensitive Japanese Medaka (Oryzias Latipes) Fish Model for Endocrine Disruptors Screening. $399,167.00, 10/01/03 to 9/31/2006,
   Role: Principal Investigator; Source: U.S. Environmental Protection Agency
3. Title: Chronic Toxicity of Environmental contaminants in Sacramento Splittail (*Pogonichthys macrolepidotus*): A Biomarker Approach. $922,598.00; 01/2000 to 01/2005; Role: Co-Principal Investigator; Source: CALFED Bay-Delta Program
4. Title: Integrating Selenium Biogeochemistry and Biological Assimilatory Capacity: Mechanism-Based Management for Selenium in Watersheds. $861,000.00; 6/30/01 to 03/1/2005; Role: Co- Principal Investigator; Source: SWRCB

PAST SUPPORT:

1. CALFED; Project #: Agreement No. B81650. Title: Role of contaminants in the decline of Delta Smelt in the Sacramento-San Joaquin Estuary. $473,000; 01/99-06/2001; Role: Co-Principal Investigator.
2. USEPA; Project# 96NCERQA11. Title: An in vivo model for detection of reproductive effects of endocrine disruptors. $519,729; 10/96 – 11/99; Co-Principal Investigator
3. Source: Department of Boating & Waterways; Project#: 01-105-078. Title: PI is to provide two life stages of Sacramento splittail for acute toxicity study. $106,128.00; 6/28/02 to 12/31/2003. Role: Principal Investigator
4. Source: UC Toxic Substances Research and Teaching Program; Project #: T002. Title: The Application of Toxicogenomics in Aquatic Toxicology Testing. $49,610.00; 6/30/01 to 7/1/2003; Role: Principal Investigator

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EDUCATION

Ph.D. 1991, Nutr. Biochemistry, University of California, Davis. Advisor: Richard A. Freedland, Ph.D., Focus: metabolic effects of estrogen on fish.
M.S. 1987, Animal Science, University of California, Davis. Advisor: Silas S.O. Hung, Ph.D., Focus: role of nutrition on fish reproduction.
B.A. 1970, New York University. Major: English literature

Continuing Education

DNA Manipulations, short course, UC Davis, 1991
DNA Binding Proteins, short course, BETR, Atlanta, 1991
Polymerase Chain Reaction, short course, UC Davis, 1994
Risk Assessment, short course, UC Davis Extension, 1995
Molecular Biomarkers in Toxicology, Society of Toxicology Cont. Ed., 1997.
Markers of Oxidative Stress, Society of Toxicology Cont. Ed., 1998.
Knowledge-Based Risk Assessment from Molecular Mechanisms, Society of Toxicology Cont. Ed., 2000.
Determining the Causes of Biological Impairment: The Stressor Identification Process, NorCal SETAC Short Course, 2003
Landscape & Regional Risk Assessment, SETAC Short Course, 2003
Assessing Ecological Risk at the Watershed Scale, SETAC Short Course, 2003

PROFESSIONAL EXPERIENCE

Staff Toxicologist, OEHHA, Cal EPA, Sacramento, CA 2000-
Focus: ecotoxicology, watershed risk assessment, environmental indicators
Assistant Professor, University of Texas El Paso, El Paso, TX. 1996-2000.
Focus: environmental toxicology (aquatic emphasis)
Adjunct Investigator, NIEHS Marine and Freshwater Biomedical Sciences Center, Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, Miami, FL, 1995-present.
Assistant Research Professor, Dept. of Anatomy, Physiology, & Cell Biology, School of Veterinary Medicine, UC Davis, 1993-1996.
NIEHS Post-doctoral Fellow, NIEHS Marine & Freshwater Biomedical Sciences Center, University of Miami, 1992-1993.
Post-doctoral Associate, Department of Physiological Sciences, School of Veterinary Medicine, UC Davis, 1991-1992.

Research Assistant, Department of Physiological Sciences, School of Veterinary Medicine, UC Davis, 1986-1991; Department of Animal Science, UC Davis, 1984-86.

PUBLICATIONS

J. Florsheim, R. Henly, R. Kattelman, F. Shilling, & B. Washburn. 2004. The California Watershed Assessment Manual and Guide. Internet publication: http://cwam.ucdavis.edu.

D.E. Arrieta, C.C. Ontiveros, W-W. Li, J.H. Garcia, M.S. Denison, J.D. McDonald, S.W. Burchiel, B.S. Washburn, 2003. Aryl hydrocarbon receptor-mediated activity of particulate organic matter from the Paso del Norte airshed along the U.S. Mexico Border. Env. Health Perspect. 111 (10): 1299-1305..

B.S. Washburn, J.J. Moreland, A.M. Slaughter, I. Werner, D.E. Hinton, and B.M. Sanders. 2002. Effects of handling on heat shock protein expression in rainbow trout (Oncorhynchus mykiss). Env. Toxicol. Chem. 21: 557-560.

Moreland, J.J., Arrieta, D.E. & B.S. Washburn. 2000. Effects of estrogen on the stress response in copper exposed PLHC-1 cells. Mar. Env. Research. 50:509-512

Craig, S.R., B.S. Washburn, D.M. Gatlin, III. 1999. Effects of dietary lipids on weight gain, body composition and liver function in juvenile red drum, *Sciaenops ocellatus*. Fish Physiol. Biochem. 21: 249-255.

Washburn, B.S., P.J. Walsh, D.G. Baden, K.S. Rein, D.E. Hinton, K. Tullis, and M.S. Denison. 1997. Brevetoxin, a polyether marine neurotoxin, is a ligand of the Ah receptor. Arch. Biochem. Biophys. 343: 149-156.

Washburn, Barbara Shayne, Carol A. Vines, Daniel G. Baden, David E. Hinton, and Patrick J. Walsh. 1996. Differential effects of brevetoxin and β-naphthoflavone on xenobiotic metabolizing enzymes in striped bass (*Morone saxatilis*). Aq. Toxicol. 35: 1-10.

Washburn, B.S., D.G. Baden, N.J. Gassman, & P.J. Walsh. 1994. Metabolism of brevetoxin by marine teleosts: Tissue distribution and cytochrome P450-dependent enzyme induction. Toxicon 32: 799-805.

Washburn, B.S. J.C. Jiang, S.L. Cummings, K. Dixon, & D.W. Gietzen. 1994. Anorectic responses to dietary amino acid imbalance: effects of vagotomy and tropesitron, Am. J. Physiol 266 (Reg. Integ. Comp. Physiol.): R1922-R1927.

Washburn, B.S., J.S. Krantz, E.H. Avery, & R.A. Freedland. 1993. Effects of estrogen on gluconeogenesis and related parameters in male rainbow trout. Am. J. Physiol 264 (Reg. Integ. Comp. Physiol. 33): R720-R725.

Washburn, B.S., E.H. Avery, M.H. Bruss, & R.A. Freedland. 1992. Effects of estrogen on whole animal and tissue glucose utilization in rainbow trout. Am. J. Physiol 263 (Reg. Integ. Comp. Physiol. 32): R1241-R1247.

Washburn, B.S. 1991. Effects of estrogen on carbohydrate metabolism of rainbow trout. PhD. dissertation, University of California, Davis.

Washburn, B.S., D.J. Frye, S.S.O. Hung, S.I. Doroshov, & F.S. Conte. 1990. The effect of diet on body composition, oogenesis, and reproductive performance of female rainbow trout (*Oncorhynchus mykiss*). Aquaculture 90: 179-195.

AWARDS/HONORS

Paso del Norte Health Foundation Environmental Award
Travel Fellowship, Society of Toxicology
Gordon Conference Fellowship
Phi Sigma, Biological Honor Society
Robert Emrie Smith Research Fellowship
Aquaculture & Fisheries Research Fellowship
Animal Science Fellowship

FUNDING HISTORY

Trace Organic Contaminants of Particulate Matter in the Paso del Norte Airshed, 2000-01. SCERP/US EPA, Role: Co-Principal Investigator, $75,000.

Assessment of Genetic Diversity in Fish and Rotifers in the Rio Grande: A Biomarker of Anthropogenic Stress, 2000-01; CERM/US EPA, Role: Co-Principal Investigator, $38,400.

Role of Genetic Polymorphisms on 1-OH Pyrene Excretion (sub-project), 1999-2000; BEST/Dept. of Defense, Role: Principal Investigator, $35,000.

Biological Effects of Particulate Organic Matter in the Paso del Norte Airshed, NIEHS, 1999-2001. Role: Principal Investigator, $105,000.

Development of an Aquatic Laboratory in the Department of Biological Sciences. 1997-98. NSF Model Institution of Excellence Teaching Enhancement Grant, UT El Paso, Role: Principal Investigator, $40,000.

Methods Development for the Study of the Effects of Airborne Contaminants on Human Health. 1996-1997. University Research Institute, UT El Paso, Role: Principal Investigator, $5000.

Linkage of Stress Proteins to Toxic Alterations: A Laboratory and Field Investigation, 1995-1999; U.S. Environmental Protection Agency, Role: Co-Principal Investigator, $474,500.

Effects of water quality parameters on the reproductive cycle of splittail fish, 1994-95, California Department of Water Resources, Role: Co-Investigator, $ 40,000.

Metabolism of Brevetoxin in Fish, 1993-94, National Marine Fisheries Service Saltonstall-Kennedy Program, Role: Principal Investigator, $ 75,000

PROFESSIONAL AFFILIATIONS

Society of Toxicology
Society of Environmental Toxicology and Chemistry American Fisheries Society
American Association for the Advancement of Science

Biomass And Toxicity Of A Newly Established Bloom Of The Cyanobacteria Microcystis Aeruginosa And Its Potential Impact On Beneficial Use In The Sacramento-San Joaquin Delta: Signature

This proposal is for the Science Program 2004 solicitation as prepared by Lehman, Peggy W.

The submission deadline is approximately 30 hours from now.

Proposal updates will be disabled immediately after the deadline. All forms, including the signature form, must be completed, compiled and acknowledged in order to be eligible for consideration and review. Allow at least one hour for Science Program staff to verify and file signature pages after they are received.

The applicant for this proposal must submit this form by printing it, signing below, and faxing it to +1 877-408-9310.

Failure to sign and submit this form will result in the application not being considered for funding.

The individual signing below declares that:

- all representations in this proposal are truthful;
- the individual signing the form is authorized to submit the application on behalf of the applicant (if applicant is an entity or organization);
- the applicant has read and understood the conflict of interest and confidentiality discussion under the Confidentiality and Conflict of Interest Section in the main body of the PSP and waives any and all rights to privacy and confidentiality1 of the proposal on behalf of the applicant, to the extent provided in this PSP; and
- the applicant has read and understood all attachments of this PSP.

Proposal Title: Biomass and toxicity of a newly established bloom of the cyanobacteria Microcystis aeruginosa and its potential impact on beneficial use in the Sacramento-San Joaquin Delta

Proposal Number: 2004.01-0122

Submitter: Lehman, Peggy W (plehman@water.ca.gov)

Applicant Signature	Date
P W Lehman	1-5-05

Printed Name Of Applicant	Applicant Organization
Peggy W. Lehman	California Department of Water Resources

Help is available: help@solicitation.calwater.ca.gov, +1 877 408-9310

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