99D 111

4.5 PSP Cover Sheet (Attach to the front of each proposal)

Proposal Title: Using Ecological Health and Integrity Indicators to Effectively Monitor the Exposure and Effects of Contaminants to Target Species in the Sacramento River, San Joaquin River and the Delta

Applicant Name: Minghua Zhang

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Amount of funding requested: $ 200,391 for 2 years

Indicate the Topic for which you are applying (check only one box).

- ☐ Fish Passage/Fish Screens
- ☐ Habitat Restoration
- ☐ Local Watershed Stewardship
- XX Water Quality
- ☐ Introduced Species
- ☐ Fish Management/Hatchery
- ☐ Environmental Education

Does the proposal address a specified Focused Action? X yes ____ no

What county or counties is the project located in? Delta region

Indicate the geographic area of your proposal (check only one box):

- ☐ Sacramento River Mainstem
- ☐ Sacramento Trib: ____
- ☐ San Joaquin River Mainstem
- ☐ San Joaquin Trib: ____
- ☐ Delta: ____
- ☐ East Side Trib: ____
- ☐ Suisun Marsh and Bay
- ☐ North Bay/South Bay: ____
- XX Landscape (entire Bay-Delta watershed)
- ☐ Other: ____

Indicate the primary species which the proposal addresses (check all that apply):

- ☐ San Joaquin and East-side Delta tributaries fall-run chinook salmon
- ☐ Winter-run chinook salmon
- ☐ Late-fall run chinook salmon
- ☐ Delta smelt
- ☐ Splittail
- ☐ Green sturgeon
- XX Migratory birds
- XX Other: Terrestrial target species
- ☐ Spring-run chinook salmon
- ☐ Fall-run chinook salmon
- ☐ Longfin smelt
- ☐ Steelhead trout
- ☐ Striped bass
- ☐ All chinook species
- ☐ All anadromous salmonids

Specify the ERP strategic objective and target (s) that the project addresses. Include page numbers from January 1999 version of ERP Volume I and II:

This proposal addresses the ERP objectives in ERP Vol. I, pages of 3,4,6, 178-179, 420-421, 451-490, 501-509; and ERP Vol. II. pages of 18-46.

Indicate the type of applicant (check only one box):

- ☐ State agency
- ☐ Public/Non-profit joint venture
- ☐ Local government/district
- ☒ University
- ☐ Federal agency
- ☐ Non-profit
- ☐ Private party
- ☐ Other: ______________________________

Indicate the type of project (check only one box):

- ☐ Planning
- ☐ Monitoring
- ☒ Research
- ☐ Implementation
- ☐ Education

By signing below, the applicant declares the following:

1.) The truthfulness of all representations in their proposal;

2.) The individual signing the form is entitled to submit the application on behalf of the applicant (if the applicant is an entity or organization); and

3.) The person submitting the application has read and understood the conflict of interest and confidentiality discussion in the PSP (Section 2.4) and waives any and all rights to privacy and confidentiality of the proposal on behalf of the applicant, to the extent as provided in the Section.

Minghua Zhang

Printed name of applicant

Minghua Zhang

Signature of applicant

UNIVERSITY OF CALIFORNIA, DAVIS

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410 Mrak Hall, One Shields Avenue
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April 14, 1999

CALFED Bay-Delta Program Office
1416 Ninth Street, Suite 1155
Sacramento, CA 95814

Proposal Title: "Using Ecological Health and Integrity Indicators to Effectively Monitor the Exposure and Effects of Contaminants to Target Species in the Sacramento River, San Joaquin River and the Delta"
Principal Investigator – Minghua Zhang

Dear Colleague:

It is a pleasure to present for your consideration the referenced proposal.

It is our understanding that for purposes of determining applicant category, The Regents will be classified as "State" thereby resulting awards will only include the terms identified in Attachment D of the 1999 Proposal Solicitation Package as "Terms and Conditions for State (CALFED) Funds" and "Standard Clauses-Interagency Agreements".

The University takes exception to clauses pertaining to Substitution, Rights in Data and Indemnification as detailed in Attachment D. On behalf of The Regents of the University of California, we hereby reserve the right to negotiate said clauses as detailed in the Proposal Solicitation Package should this proposal result in a subsequent award.

Please call on the principal investigator for scientific information. Administrative questions may be directed to me or to Petrina Ho by telephone, facsimile or electronic mail at the numbers specified above. We request that correspondence pertaining to this proposal and a subsequent award be sent to the Office of Research and to the principal investigator.

Sincerely,

Sandra M. Dowdy
Contracts & Grants Analyst

Enclosures

April 12, 1999

DAVIS VISIONING GROUP
3010 Loyola Drive
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(530) 756-6856

Dr. Minghua Zhang
Department of Land, Air & Water Resources
University of California, Davis
Davis, CA. 95616

Dr. Shawn Smallwood
Department of Biological Sciences
California State University, Sacramento
Sacramento, CA 95814

Re: Proposed use of the Davis Visioning Group for a CALFED project.

Dr. Zhang and Dr. Smallwood:

The Davis Visioning Group would be pleased to work with you in screening your GIS products for relevancy and effectiveness in communicating to the public and to CALFED administrators. Our group is already working with Dr. Smallwood to ensure the greatest effectiveness of his indicators and GIS maps he is producing to assess the environmental conditions in Yolo County. We believe the Davis Visioning Group is appropriate for the task, because our group is composed of academics, experienced social and environmental activists, and just regular folks. We have been meeting twice a month for over a year, which demonstrates our commitment and intra-group harmony. We feel that it would be well within our interests to help you in achieving CALFED goals. Please feel free to contact us at the above address and phone number, if there are any questions.

Sincerely,

Pamela S. Nieberg

Pamela Nieberg
Coordinator, Davis Visioning Group

Using Ecological Health and Integrity Indicators to effectively Monitor the Exposure and Effects of Contaminants to Target Species in the Sacramento River, San Joaquin River, and the Delta

Principal Investigator: Minghua Zhang, Department of Land, Air, and Water Resources, University of California, Davis, CA 95616. Phone: (530) 752-4953. Fax: (530) 752-5262.
Email: mhzhang@ucdavis.edu

Co-Principal Investigator: K. Shawn Smallwood, California State University, Sacramento
Phone: 530-756-4598 email: puma@davis.com

Collaborators:

Dr. Michael Morrison, Department of Biology, California State University, Sacramento
Dr. Joseph L. Domagalski, US Geologic Survey, Sacramento
Dr. Julie Yamamoto, Department of Animal Science, University of California, Davis
Dr. Larry Wilhoit, California Department of Pesticide Regulations
Ms. Ramona Robison, University of California, Davis
Dr. Yinyan Guo, University of California, Davis
Mr. Stu Townsley, University of California, Davis
Mr. Johnson Ding, University of California, Davis.

Type of Organization and Tax status: University

Tax identification number: 94-6036949

Executive Summary

Through time, human activities in the Sacramento Valley have contaminated the Sacramento River, San Joaquin River, and the Delta with nitrates and pesticides, and human actions have changed the structure and extent of integral parts of the landscape that affect ecosystem functionality. We are prepared to apply ecological indicators to assess the water quality and assemblages of biota within the Sacramento River, San Joaquin River, and the Delta (hereinafter referred to as the study area, Figure 1). One of our goals is to identify the toxic contaminants in the environment that may pose the greatest risks to the target species (Table 1). Another goal is to identify the source distributions of these contaminants and their transport pathways and endpoints in the study area. A third goal is to identify those target species within the study area that are most vulnerable to past and ongoing land uses involving or influencing chemical inputs to the system, based on their spatial patterns of abundance with respect to contaminants; that is, based on their exposure. Our specific objectives would be to apply ecological indicators, GIS (Geographic Information Systems), and existing and derived spatial data in the Sacramento River, San Joaquin River, and the Delta to identify:

(1) The major source distributions, transport pathways, and settlement sites of water-borne contaminants;

(2) The likely and known areas of occupation by the target species, their levels of abundance, and behaviors that add to their exposure vulnerability;

(3) The locations in the study area where the risks of exposures are greatest based on the coincidence of highest target species abundance and the highest concentrations of contaminants, and where monitoring of exposure and effects would be most efficient; and,

(4) Map-based indicators of ecological health (e.g., levels of nitrate and pesticide residue contamination of ground and surface water) and integrity (e.g., degree to which the native biota and key functional aspects of the landscape are intact), which would be useful for prioritizing ecological restoration and land use decisions by policy makers.

To achieve our goals and objectives, we will use GIS, available spatial data, indicators of ecological health and integrity, and appropriate statistics. Indicators of ecological health are composed of available data that are carefully integrated to inform of the risks posed by pesticide contaminants. Indicators of ecological integrity inform of the degree to which functional parts of the landscape are intact from the perspective of the target species. We will explore how these indicators might interact and affect each other, and how these effects can be monitored effectively. Also, we will work with the USGS, the Department of Pesticide Registration, and the Davis Visioning Group, to implement our results by providing policy makers and the public with map-based risks to the target species occurring in the study area. We recognize that our assessment and recommended monitoring program will be more effectively communicated by developing indicators and an approach to map presentation that simplifies the most functionally significant information to the user while also maintaining data quality and reliability.

We propose to develop indicators representing the cumulative effects and aggregated effects of residue concentrations of multiple pesticides and nitrates. Our indicators would have meaning with respect to the statutes of the Food Quality Protection Act (FQPA, 1996) and other laws.

The scope of our project would include all the land areas draining into the Delta, although we would focus more on the areas with the highest levels of human inputs, such as the agricultural, industrial, and residential areas. Our project would cost $ 200,390. It would have no adverse impacts on any third parties.

The AGIS (Agricultural Geographic Information Systems) laboratory at UC Davis focuses its research on pesticide runoff to surface water and leaching to groundwater. the AGIS lab also develops GIS tools for assessing the risks in the environment. This lab is skilled with GIS and modeling, biostatistics, ecology and agronomy. Therefore, this lab is qualified more than any other to assess the exposure risks to target species in the Sacramento River, San Joaquin River, and the Delta, and to develop an efficient monitoring system for effects. We have the needed spatial data, the top-of-the-line software and computer systems, and a published record of successfully applying indicators to problems involving wildlife and agricultural landscapes. We also have a working relationship with the California State University, California Department of Pesticide Regulation, California Department of Food and Agriculture, California Department of Fish and Game, California Department of Water Resources, the Contaminants and Endangered Species Divisions of the US Fish and Wildlife Service, and the Davis Visioning Group. Finally, we have experience researching agricultural production systems (Smallwood 1995, 1996; Smallwood and Geng 1993a,b, 1997; Geng et al. 1995), wildlife ecology (e.g., Smallwood 1994, 1995, 1996, 1997, 1998) and chemical groundwater contamination (Zhang et al. 1998, Zhang et al, 1999).

Our local support is evident in the spatial data sets we have been provided by various resource agencies and by other researchers. Our project is compatible with CALFED objectives, especially because it will provide CALFED with the effective, long-term monitoring program that it needs to restore the ecological health to the Bay-Delta, and to improve water management for beneficial uses. Our project will be monitored for achieving its specific objectives using the structure depicted in Figure 2. Our water quality monitoring program will enable CALFED to assess its entire program's effectiveness at improving the quality of the ecosystem, including both terrestrial and aquatic habitats. Our project will identify those areas within the study area that are most vulnerable to accumulations of water-borne contaminants, and where the target species are most vulnerable to exposure and effects.

Table 1. Target species we sill use to select priority monitoring sites for exposure and effects of toxic contaminants in the study area. These species were listed in ERP, Volume I, pages 178-179.

Species	Priority level in CALFED ERP
Suisun thistle	Priority Group II species
soft bird's-beak	Priority Group II species
Mason's lilaeopsis	Priority Group II species
Delta button-celery	Priority Group II species
California tiger salamander	Priority Group III species
Native anuran amphibians	Priority Group III species
Western spadefoot toad	Priority Group III species
California red-legged frog	Priority Group III species
Giant garter snake	Priority Group III species
Western pond turtle	Priority Group III species
Swainson's hawk	Priority Group II species
California clapper rail	Priority Group II species
California black rail	Priority Group II species
Greater sandhill crane	Priority Group III species
Western yellow-billed cuckoo	Priority Group III species
Bank swallow	Priority Group III species
Suisun song sparrow	Priority Group II species
Western least bittern	Priority Group III species
Least Bell's vireo	Priority Group III species
Littlw willow flycatcher	Priority Group III species
Salt marsh harvest mouse	Priority Group II species
San Pablo California vole	Priority Group II species
Suisun ornate shrew	Priority Group II species
Riparian brush rabbit	Priority Group III species
San Joaquin Valley woodrat	Priority Group III species
Valley elderberry longhorn beetle	Priority Group II species

Figure 1. Study area - Sacramento river, San Joaquin river and the Delta regions.

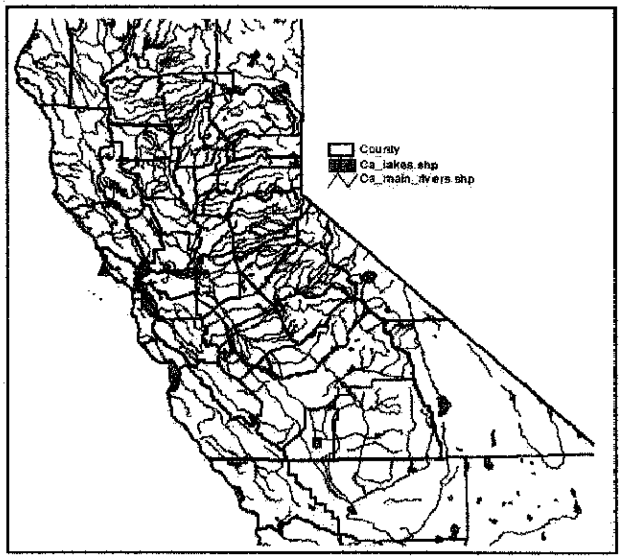


Figure 2. Pathway to compile and integrate existing spatial data that are critical for assessing the ecological health and integrity of large areas.

Collection of available data

- Identify data related to water contaminants and target species in the study area
- Screen existing data for relevance and consistency
- Reference data to source and location
- Where practical, verify existing data with sampling in the field

Derivation of new data (GIS queries, pattern analysis)

- Combine variables and reduce detail
- Reduce variable set to representative factors
- Characterize spatial grain of the landscape
- Identify and use the functionally significant spatial scales

Selection of indicator variables

- Match existing and derived data with scientific principles
- Match data to legal statutes and local values
- Identify functional relationships
- Normalize frequency distributions & improve robustness of indicators
- Conduct sensitivity analysis

Relate ecosystem health & integrity indicators, or spatial patterns of contamination to those of the target species

- Simple map-based presentation of exposure factors
- Recognition of data shortfalls & new field sampling & monitoring needs
- Design monitoring plan
- Suggest restoration and land use strategies to reduce risks (in map-form)

Project Description

Scientists have recently begun developing a hierarchically organized, top-down approach for assessing the ecological resources in large areas. This approach is referred to as the ecological indicators approach. Its origins stem to the Netherlands (Rotmans et al. 1994) and its use in the US includes the EPA (O'Neill et al. 1994, Schultze et al. 1994), USDA Forest Service (USDA 1994,), US Geological Survey (Battaglin and Goolsby 1995), and multiple academic scientists (Rapport et al. 1985, Karr et al. 1986, Bedford and Preston 1988, Hunsaker et al. 1990, Graham et al. 1991, Cairns and McCormick 1992). We also adopted and improved on the approach (Smallwood et al. 1998, Zhang et al. 1998). Using this approach we have gained valuable insight into factors influencing ecological health (Zhang et al. 1998, Zhang et al, 1999) and integrity (Smallwood et al. 1998) across entire counties, and we have produced map output that is readily understandable by policy makers, the public and scientists.

Scientists involved with the ecological indicators approach have developed a methodology for using available spatial data (Figure 2). These methods include data collection, error correcting, aggregating information, expressing particular variables, and integrating the data for making GIS queries leading to hypothesis tests and the derivation of new data. These scientists also systematize the ecological elements of the political jurisdiction under study into component parts and processes. Indicators of sensitivity (i.e., inherent properties of a particular element or process) and vulnerability (i.e., pressures applied to a particular element or process) are compared spatially to project the impacts, and known impacts are used for verification analysis. Furthermore, the indicators approach includes computer intensive uncertainty analysis and sensitivity analysis, where sensitivity in this case refers to the influence of coefficient values on model output.

Our project would provide critical information needed for improving ecosystem water quality, and this information would be presented in a manner that is easily comprehensible to scientists of multiple disciplines and to non-scientists who must make difficult decisions affecting land use and restoration projects. Our project tasks follow largely from the flow chart depicted in Figure 2, and are summarized in Table 2.

Task I-1. We will seek out and acquire data that are relevant to our objectives and that we do not yet have. We will make inquiries about data availability and quality from all the County, State, and Federal natural resource agencies, as well as from the private sector.

Task I-2. Data quality of the existing databases will be examined after we identify the available data sets from Task 1. Limited verification surveys and ground truthing of maps will be conducted once every two months during the first year of the project. Sites for field visits will be chosen systematically from our spatial data sets of the study area. We will extensively cover the study area with field visits, but we will not be able to provide more than reconnaissance-level surveys.

Task I-3. We will estimate the amount of pesticide loads by watershed, by county and by ecoregions to identify the spatial distributions of pesticide loads in the study area. These spatial distributions will also be presented temporally. We will characterize the transport pathways of the pesticides with identified toxic risks in the Delta river systems. We will modify and develop a model of pesticide residues in surface water runoff and of transport in river systems, taking into account the behaviors and degradation process of pesticide residues in surface water systems. This model will help us choose priority monitoring sites for exposure and effects.

Large amounts of diazinon and chlorpyrifos were used in the Central Valley to protect crops from insect pests over the years. Figures 3 and 4 show the amount of diazinon and chlorpyrifos used in each watershed in the Central Valley in 1992 (This version 2.2 California watershed map was from Teale Data

Center and it has not been officially released). The accumulation of these pesticides in the ecosystem, and of other pesticides, has resulted in their runoff into surface water. The pesticide residues in surface water have the potential to affect aquatic and terrestrial species in the ecosystem. With the small percentage of organic matter in the soils of the Central Valley (Figure 5), pesticide residues are likely to runoff with irrigation water. Therefore, there is a potential risk of pesticide residues affecting aquatic and terrestrial species in regions of intensive agricultural production such as the Delta.

It is essential to have a sound monitoring plan for pesticide residues in the ecosystem. To effectively monitor pesticide residues in surface water, an empirical model must be built that will allow us to estimate concentrations of each residue at any point in the system of flowing water (Figure 6). To estimate pesticide residues in the rivers, we need at least the following information: (1) 1/24,000 DEM (digital Elevation Model); (2) detailed stream data including elevation, flow rate, volume, depth and more; (3) chemical properties of the pesticide residues; (4) amounts of pesticide inputs into the system; and (5) local environmental factors.

With these data, we could establish a flow model for the stream network within the study area. Each stream segment could be represented by depth, volume, and flow data for different dates, as well as elevation, flow direction and velocity. Each segment also can be represented by extensive chemical data, each chemical given a decay rate calculated for different weather factors and an absorption rate into the stream bed. Environmental factors such as temperature of the water may influence the degradation of pesticides in the river systems. We also need to know how different chemicals interact with each other, i.e., does 50 ug of pesticide A + 50 ug of herbicide B equal 100 ug of chemical A & B, or something different, such as a secondary reaction? Actual data on pesticide inputs would provide the amounts of chemicals entering the stream in ug/l or lbs/ac. Our data needs may be satisfied by the Pesticide Use Report database at the California Department of Pesticide Regulations, which is provided at the township/range/section resolution. We plan to explore the applications of existing SWAT (The Soil and Water Assessment Tool, Arnold et al., 1995)and BASINS (The Better Assessment Science Integrating Point and Nonpoint Sources, USEPA 1999) to conduct the risk assessment for the pesticide residues runoff to surface water. We also plan to incorporate/modify P-route (US EPA, 1993) pollutant routing model to begin building indicators that will:

1. Represent multiple source point-source pollution;
2. Represent more than one type of point-source pollution at a time;
3. Handle the merging of multiple stream paths;
4. Handle diverging or braided streams;
5. Calculate the interactions between different pesticides and herbicides; and
6. Provide reasonable accuracy – if it cannot portray reality, then it cannot be used.

P-route is a simple model. The inputs are water flow (l/s), chemical concentration (ug/l) and chemical degradation rate and length of stream (m). The initial Upstream Load (UL) is calculated by UL = concentration * flow. The Final Reach Load (FRL) is calculated by FRL = UL * exp (-kT), where k is the degradation rate of the chosen chemical and T is the total reach length from the pollution source in meters. The Final Reach Concentration (FRC) is calculated by the equation: FRC = FRL/F, where F is stream flow. This is then repeated for each reach, or segment, of the stream. The user of the model will split the stream into an even number of segments to run the calculations. The FRC will then be calculated for each segment, where distance is the end of the segment from the source. Thus the distance will be longer for each subsequent segment. Once the FRC has been calculated for each segment, the Average Concentration (AC) can be calculated as $AC = \Sigma(FRC) \div (\text{number of segments})$.

P-route includes a biological module that calculates the percent of the LC50 for the selected species. Less than 100% is below the LC50, whereas above 100% is above the LC50. Some chemicals have no available LC50s estimated for the target species. Others may have LC50s for 1-5 target species. Based on what we know about the P-route model, we can develop a spatial model of pesticide residues travelling in surface water. We plan to develop the spatial model in ArcView with Avenue and mathematical functions built in using Visual Basic as DLLs to interface with ArcView.

With the output from P-route model, we can assess the runoff risks at the watershed scale. SWAT and BASINS can be useful in this watershed scale risk assessment.

Task II-1. The California Natural Diversity Data Base and the Department of Fish and Game keeps track of all reported sightings of rare species. This data base provides some guidance as to where species have occurred recently, and habitat associations can help indicate where the species can potentially occur. Michael Morrison, Shawn Smallwood, Ramona Robison and Johnson Ding all have extensive experience with relating habitat conditions to rare species by searching the published literature and interviewing species' experts. We can identify the habitat conditions of each target species, then crosswalk these conditions to our GIS coverages of soils, vegetation, and hydrology.

Task II-2. We would apply methods that we have used to assess ecosystem health in Tulare County, California, and in the Midwestern US (Zhang et al. 1997, 1998, 1999), and ecological integrity in Yolo County, California (Smallwood et al. 1998). In Tulare County, we mapped the inherent sensitivity and human-influenced vulnerability of groundwater to contamination by nitrates and pesticide residues, and we found good correspondence between our predicted and the actual impacts. Sensitivity, vulnerability and impact were all measured using indicators. In Yolo County, we mapped the known and likely areas of occurrence of 29 legally rare species, based on the records maintained at the California Natural Diversity Data Base and the spatial distribution of likely habitat throughout the County. From these maps, we identified the priority areas for allocating funding to restore and conserve habitat of these species (as mitigation for the Yolo County HCP). Again, indictors were central to the mapping effort, and included indices of soil quality, habitat contiguity and patch sizes, flood zones, diversity of habitats, etc.

Task II-3. We are now working on methods to relate indicators of ecological health to those of ecological integrity, which is timely and appropriate for the CALFED Water Quality Focused Action in the Sacramento River, San Joaquin River, and the Delta. These methods will be presented at the International Conference on Ecosystem Health in Sacramento during August, 1999. They will involve a spatial comparison of indicators representing toxic contaminants and the potential and known levels of abundance of the target species.

Task II-4. Our approach for this project assumes that funding will be limited for monitoring of target species exposure and effects. We would take advantage of the methods we have already developed, and the availability of existing data, to locate potential monitoring sites in priority order. We have spatial data of contaminants in the waters throughout California, hydrology, soils, vegetation cover, land uses, target species occurrences, and other relevant variables. We also would apply transport models through soils and water, and the latest tools used to estimate species occurrences and abundance within fragmented habitat patches. We have research experience with Swainson's Hawk (Smallwood 1995), Giant Garter Snake (Smallwood and Morrison 1997), California Red-legged Frog (Morrison and Smallwood, unpublished data), and Mason's lilaeopsis, Greater Yellow-billed Cuckoo, Bank Swallow and Valley Elderberry Longhorn Beetle (Smallwood et al. 1998). Furthermore, Michael Morrison is on the Recovery Team for the Greater Sandhill Crane, thus providing us with easy access to all the data needed to assess exposure risks of this species.

Task II-5. We will allocate tasks to the collaborators during the appropriate phases of the project, and we will provide quarterly reports of our progress.

Table 2. Tasks, schedules and deliverables of the project.

Task	Schedule	Deliverable
TASK I:		
I-1. Collection of available data \ Literature search	10/1/99-12/31/99	Data dictionary
I-2. Collection of field data on target species	10/1/99-9/30/00	Field reports/GIS maps
I-3. Identify sources, transport pathways, and likely endpoints of contaminants	1/1/00-9/30/00	GIS map output
TASK II:	10/1/99-12/31/00	GIS map output
II-1. Identify known and likely areas of occupancy and abundance of target species		
II-2. Selection of indicator variables	7/1/00-10/31/00	Indicators dictionary
II-3. Relate health and integrity indicators	1/1/01-6/30/01	GIS map output
II-4. Prioritize locations for long-term monitoring of exposure and effects	7/1/01-9/30/01	GIS map output & recommend monitoring options
II-5. Project management	10/1/99-9/30/01	Quarterly progress reports

Figure 3. The amound of Diazinon used in the region by watershed in 1992.

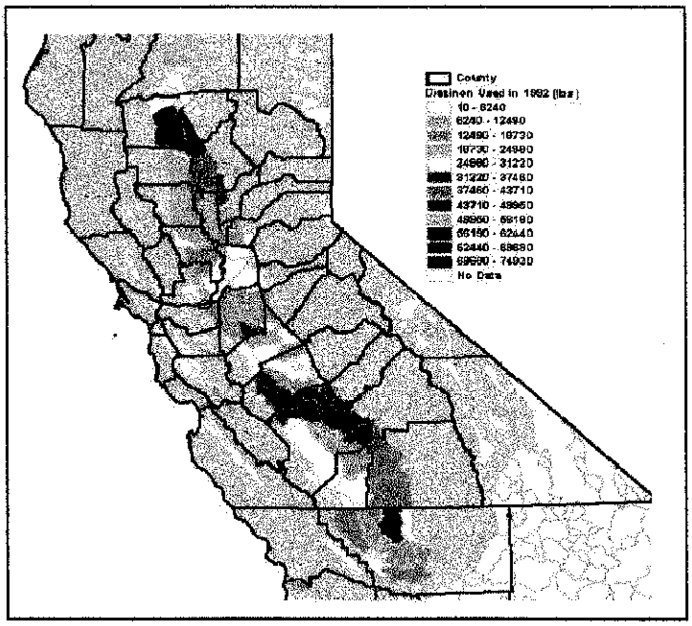


Figure 4. The amount of Chlorpyrifos used in the region by watershed in 1992.

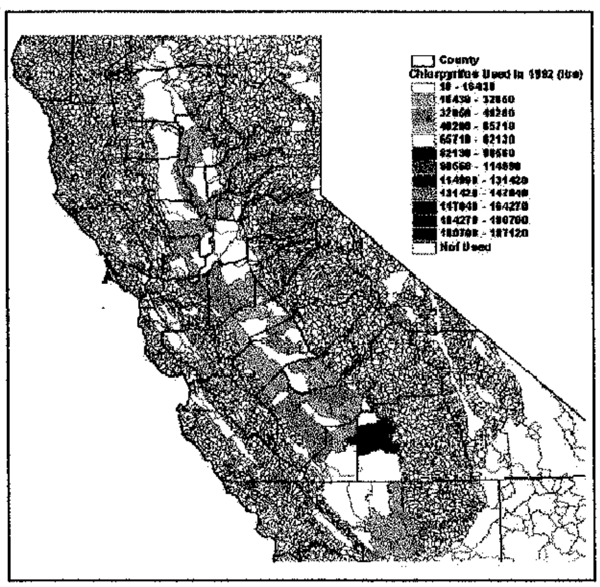


Figure 5. Average percent of organic matter in the region by watershed.

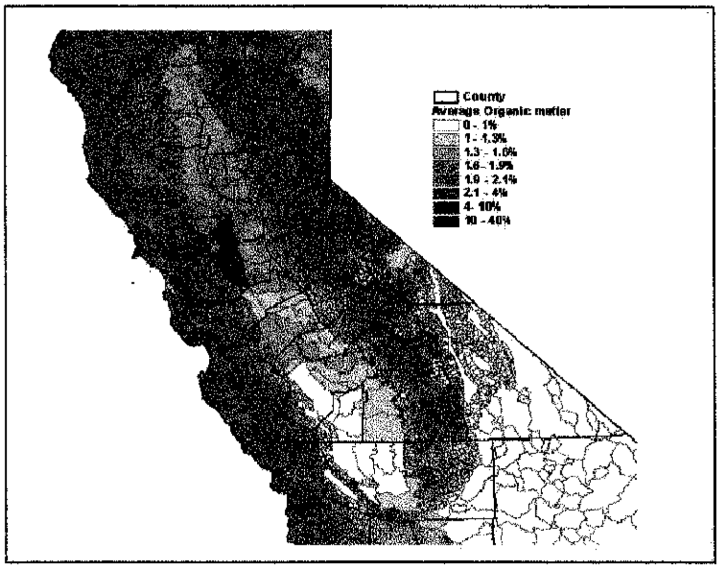
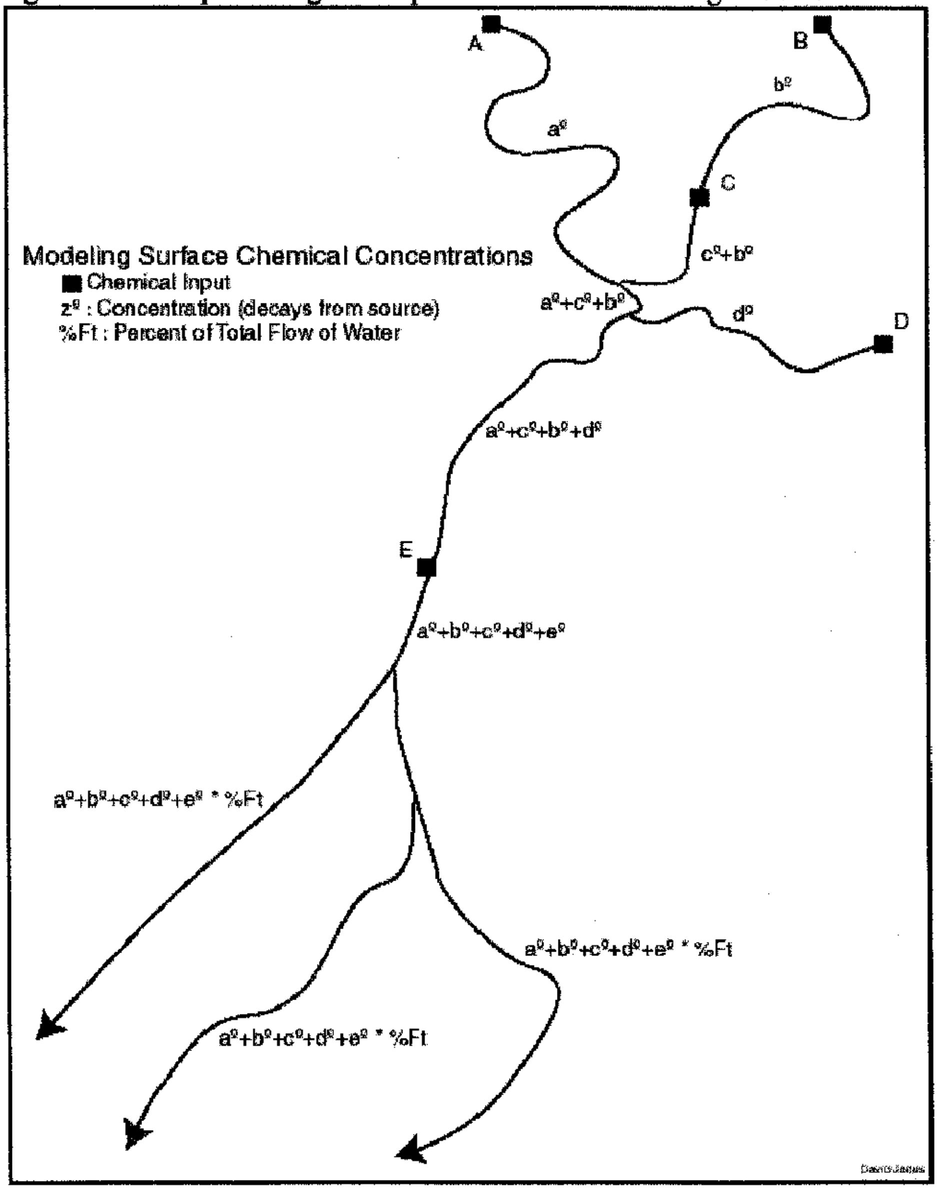


Figure 6. Conceptual diagram of pesticide residues routing in surface water.



Ecological/Biological Benefits

Expanding human populations are increasing the pressures on ecosystems and their biota within California and elsewhere (Meyer and Turner 1992). Agricultural lands have been receiving chemical inputs for crop fertilization and pest control, and these lands are being converted to urban, commercial and industrial uses. Greater proportions of available ground and surface water supplies are being diverted from agriculture to competing uses, and greater proportions are revealing contamination problems from a growing list of compounds. As lands were, and are being, converted, populations or rare plant and animals species are further constrained to using the remaining agricultural lands and remnant habitat patches at the margins of agriculture. Therefore, current trends in land use and land conversions are increasing the pressures on native species, including the pressures related to exposure to hazardous residues from agricultural inputs and urban and industrial effluents. In some cases, target species may be aggregating at locations where chemical contaminants are accumulating, thereby increasing the risks of exposure. These risks vary spatially, depending on the spatial distribution of the contaminants fate and the spatial distribution and behaviors of each species.

Whereas habitat fragmentation has a fairly comprehensive foundation of research documenting its effects on the target species, the effects of contaminants on these species is less well documented. Until focused research has been conducted to identify the effects of various contaminants on the target species, we need to manage and restore the ecosystems of the Bay-Delta with the conservative assumption that the contaminants pose health risks to the target species. Such an approach would be consistent with the recommendations of the National Research Council (1986).

The exposure of target species to water-borne contaminants can be reduced in two ways. One way is to reduce the inputs by identifying and modifying the sources of the contamination or the transport pathways. Another way is to provide the target species with suitable habitat conditions at locations away from those where contaminants are accumulating. Regardless of how effective we are at reducing the chemical inputs, the target species still must have a landscape capable of transporting energy, nutrients and other materials necessary for their existence, as well as cover, movement corridors, and sufficient habitat space to support meaningful levels of social organization. The Bay-Delta study area must be capable of supporting the ecosystem needed for the conservation of the target species (pursuant to the Endangered Species Act and California Environmental Quality Act, for examples). Therefore, to achieve the goals of CALFED, scientists must integrate such disciplines as landscape ecology, ecosystem ecology, wildlife biology, hydrology, toxicology, agronomy and others. Such an integration is not likely to be successful by relying solely on the usual atomistic approach. By using the ecosystem indicators and GIS spatial approach we can accomplish our project objectives while also providing further relevance to CALFED for its other programs of restoration.

Our approach also offers the opportunity to relate indicators of ecological integrity to those of ecological health. In other words, we can examine the relationship between the degree to which important parts of the ecosystem are intact and the level of water contamination. This relationship would bear on our proposed monitoring program, but it also would bear on invasive species. Smallwood (1994) found sites to vary in their invasiveness by exotic species of birds and mammals based on their ecological integrity. As the integrity of a site diminished, the site's invasiveness increased. We can provide CALFED with the opportunity to identify those areas of the Bay-Delta ecosystem where restoration might provide the greatest reductions in exotic species problems, pursuant to one objective of CALFED (Page 420 and pages 451-490, ERP Vol. I). We also can provide CALFED with the opportunity to identify those areas of the Bay-Delta ecosystem where restoration might provide the greatest buffer between habitats of the target species and the locations where toxic contaminants are accumulating in the environment. Finally, we can provide CALFED with the opportunity to identify those areas of the Bay-Delta ecosystem where changes in land use practices or the drainage system can substantially reduce the inputs of contaminants that pose the greatest risks, pursuant to another CALFED objective (Page 421 and 501-509, ERP Vol. I).

Our proposed study would contribute to the goals and objective of the CALFED Ecosystem Restoration Program (ERP), described in Volumes I and II, and presented as attachments to the Environmental Impact Report of January, 1999. For example, our study will contribute an ecological modeling approach that will provide sound scientific understanding of the interrelationships between stressors and ecosystem elements, and taking into account the context, appropriate scales of observation, and interconnectedness of the ecosystem elements (Page 3, ERP Vol. I). We also will provide a suite of priority monitoring sites that will best accommodate an experimental approach to ecosystem management, using the tenets of adaptive management elements (Page 4, ERP Vol. I). Our indicators approach fits the objectives of CALFED very well (Page 6, ERP Vol. I). Furthermore, our project would use the population targets described in pages 18 to 46 of the ERP Volume II, which include recovery of species by establishing new habitat patches and populations and increased population abundance.

Technical Feasibility and Timing

One alternative to our study approach would be to collect new field data. We could carry out an extensive sampling program for the many chemical contaminants that could conceivably occur in the study area and all the target species. This alternative would be very costly, time-consuming, and really unnecessary. Multiple government agencies have already sampled for contaminants in the waters within the study area, such maintain databases such as the surface water monitoring program for pesticide residues and the Pesticide Use Records (PUR) at the California Department of Pesticide Regulations. The PUR database informs of the amounts of pesticides used in the landscape at the resolution of township/range/section. The scientific literature and government reports can provide us with the information we need to map the likely patterns of abundance of the target species. Information shortfalls can also be filled by local experts on the species or by using species that are taxonomically and functionally closely related as surrogates to the target species.

The data we need for carrying out our proposed study have just now become available. Some of these data were around for a long time, but not in digital form and not suitable for integration with the other data for such an analysis as we propose. Also, the methods have only recently become available for conducting the appropriate spatial analyses and for developing and handling indicators of ecosystem health and integrity (Smallwood 1993, Zhang et al. 1998). Risk assessment methods have just been developed for application to spatial data using GIS t higher tiers (Rejesky 1993, US EPA 1998).

Our study methods would not conflict with any CEQA, NEPA, or other environmental compliance documents. We anticipate using existing data and in not manipulating the environment in any way during the course of the study. However, we will conduct some additional searches for certain target species, and in so doing, we will obtain and use all the survey protocols supplied by the California Department of Fish and Game and U.S. Fish and Wildlife Service. If we do additional searches for certain target species, then we may have some difficulty obtaining access to privately-held lands.

Our team has the expertise in spatial modeling and GIS analysis. Stu Townsley is working on spatial modeling and examining scale effects appropriate for the watershed level. Johnson Ding has expertise in the ecology of fishes and birds, and is working toward his Ph.D. at UC Davis. Dr. Yinyan Guo obtained her Ph.D. in agroecology with specialization in biostatistics.

Monitoring and Data Collection Methodology

We have the following software for managing and analyzing existing and derived spatial data: Arc/Info GIS, ArcView GIS, Spatial Analyst, 3D Analyst, ENVI 3.1, Matlab 5.1, Visual Basic, and Visual C++. We also have access to Mathematica. The raw data we currently have to work with include the following:

- Known legally rare species locations in the Natural Diversity Data Base managed by the California Department of Fish and Game;
- Soils and their properties such as organic matter, pH level and textures at scale of 1:24,000;.
- Groundwater quality monitoring data from the US Geological Survey (1970-1995);
- Surface water quality monitoring data from the US EPA (BASINS) and California Department of Pesticide Regulations;
- Pesticide Use Report (PUR) from the California Department of Pesticide Regulations, which includes all the pesticide used on each crop and their acreage in the county at the section level (1990-1995);
- Pesticide residues in groundwater (well inventory) produced by the California Department of Pesticide Regulations (1970-1995);
- New version Calwater 2.2 of Watersheds (not officially released) and rivers and streams and roads on 1:24,000 quadrangle maps provided by the Teale Data Center.

All these data will be summarized and integrated into indices bearing on exposure risks to the target species, using the approach outlined in Figure 2. Indicators derived through the process described in Fig. 2 will be mapped using GIS. These maps will be presented to the Davis Visioning Group for evaluation of the Group's interpretation. We will use the Davis Visioning Group to identify the most effective indicator maps that communicate critical information to policy makers and the public. These maps will then be presented to the responsible government agencies and other interested farming and natural resource organizations.

These steps will help ensure that the data are of the highest quality, their use in indicators are appropriate, and the products effective at communicating otherwise complicated messages to policy-makers and the public. Our progress to these ends will be summarized in our quarterly reports.

Local Involvement

Because our project involves no manipulation of lands within the study area, we have little need for local involvement. We anticipate the need to obtain additional data from local agencies, scientists and naturalists with expertise on certain target species. We also anticipate the need to access lands within the study area to conduct additional searches for certain of the target species.

Probably our greatest need for local involvement will be our need for feedback on our indicators maps. We will need to present our findings to County Governments and citizens groups to assess how well our maps communicate the intended messages, and to let local stake-holders know about the risks posed by contaminants in the water. One citizen group we are prepared to use in this way is the Davis Visioning Group.

Cost

Total Budget ($)

Task	Direct labor hours	Direct salary & benefits	Service contracts	Material & acquisition costs	Miscellaneous and other direct costs	Overhead & indirect costs, State 10% & (Federal 46%)	Total costs State & (Federal)
Task I: I-1, I-2, I-3	3480	77,424		16,500	3,000	8,242 (37,791)	105,166 (134,715)
Task II: II-1, II-2 II-4, II-4, II-5	3480	81,295		4,500	1,000	8,429 (38,624)	95,224 (125,419)
Total	6960	158,719		21,000	4,000	16,671 (76,415)	200,390 (260,134)

Quarterly Budget ($)

Task	Quarterly Budget Oct_Dec99	Quarterly Budget Jan-Mar 00	Quarterly Budget Apr-Jun 00	Quarterly Budget Jul-Sep 00	Total Budget
Task I:	18,132.07	29,011.31	29,011.31	29011.31	105,166
Task	Quarterly Budget Oct-Dec 00	Quarterly Budget Jan-Mar 01	Quarterly Budget Apr-Jun 01	Quarterly Budget Jul-Sep 01	Total Budget
Task II:	16,417.93	26,268.69	26,268.69	26,268.69	95,224
Total	34,550	55,280	55,280	55,280	200,390

Cost-Sharing:

1. A PhD student, Stu Townsley was funded for three year at the University of California Davis to develop a spatial model to understand the spatial distribution of pesticides in surface water systems and address the scale effects ranging from the river segment to the watershed landscape.

2. The University of California at Davis AGIS laboratory will supply basic computer needs and some basic pre-developed GIS data sets and tools that are relevant to pesticides risk assessment and to developing a surface water runoff monitoring program.

Applicant Qualifications

The project leader is Minghua Zhang, who earned her Ph.D. at UC Davis in 1993. Her thesis was on the impacts of agricultural inputs (pesticides and nitrates) to groundwater quality in Tulare County, California. Dr. Zhang was one of the first researchers at UC Davis to use GIS for landscape-scale risk assessment using the ecosystem indicators approach. Dr. Zhang has published 15 professional papers, 8 of which were peer-reviewed. She leads the Agricultural Geographical Information System (AGIS) laboratory in the Department of Land, Air, and Water Resources, and has the title of Adjunct Assistant Professor. She teaches the course titled "Environmental Risk Analysis Using GIS" at UC Davis. She supervises seven students, postdoctoral researchers and post graduate researchers in AGIS lab. Currently, AGIS developed a spatial database to query and retrieve pesticide use report records on any built in fields. This database can facilitate the spatial modeling development. She also works as a GIS specialist in the function of Environmental Fate and Risk Assessment at Zeneca Ag Products, which is a leading agrochemical company. Her work responsibility at Zeneca Ag Products has included technical consultations on pesticide surface water runoff and groundwater leaching and research of product stewardship for Zeneca products. With the funding from Zeneca Ag Products, she also supervises a PhD student to develop a spatial model for predicting pesticide residue in surface water systems at a watershed level.

Shawn Smallwood will lead the analyses of target species and certain aspects of the indicators applications. He earned his Ph.D. at UC Davis in 1990. His thesis was on the ecology of invading species, but he also worked on a statewide monitoring program for mountain lions and other carnivores in California. He served as a Post-Graduate Researcher in the same lab with Dr. Zhang, where he assisted her thesis work. Dr. Smallwood also conducted a two year landscape ecology study of pocket gophers in alfalfa fields in the Sacramento Valley. That study was funded by the US Department of Agriculture. Dr. Smallwood has published 65 professional papers, 32 of which were peer-reviewed. He currently works as a Part-time Faculty member at California State University, Sacramento, where he teaches Mammalogy, Ornithology, and Environmental Issues. He also works as an independent consultant for such clients as the US Fish and Wildlife Service, California Department of Transportation, Southern California Edison, Co., PG&E, and attorneys representing the plaintiffs in two large legal actions directed toward the nuclear weapons industry over the handling of nuclear waste. Dr. Smallwood has developed monitoring programs for mountain lions, funded largely by the California Department of Fish and Game, giant garter snake (a target species), funded by Northern Territories, Inc., and he has monitored Swainson's Hawks (another target species) in the Sacramento Valley for 10 years. He also publishes papers on the Endangered Species Act.

Joseph Domagalski received his PhD in 1988 with a major of Geochemistry at the John Hopkins University. Dr. Domagalski is a Supervisory Hydrologist with the U.S. Geological Survey, Water Resources Division, California District Office in Sacramento. He received a Ph.D. from Johns Hopkins University in 1988 with a concentration in geochemistry. From 1988-93, he worked on pesticide chemistry, fate, and transports for several USGS projects located in the Central Valley and San Francisco Bay. Since 1993 he has managed the USGS National Water-Quality Assessment (NAWQA) project in the Sacramento River Basin. This project includes studies on a variety of water quality problems including pesticides, nutrients, mercury and methyl mercury, and aquatic ecology.

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2. Domagalski J., 1996, Pesticides and pesticide degradation products in stormwater runoff: Sacramento River Basin, California, Journal of the American Water Resources Association, vol. 32, p. 953-964.

3. Domagalski, J., 1997, Results of a prototype surface water network design for pesticides developed for the San Joaquin River Basin, California, Journal of Hydrology, vol. 192, p. 33-50.
4. Domagalski, J., 1997, Pesticides in surface and ground water of the San Joaquin-Tulare Basins, California: Analysis of Available Data, 1996 through 1992, U.S. Geological Survey Water-Supply Paper 2468, 74 p.
5. Domagalski, J., 1998, Occurrence and transport of total mercury and methyl mercury in the Sacramento River Basin, California, Journal of Geochemical Exploration, vol. 64, p. 277-291.
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Michael L. Morrison earned a Ph.D in wildlife ecology from Oregon State University. He then worked 10 years as a tenured faculty member at U.C. Berkeley. He is now an adjunct professor in biological sciences at California State University, Sacramento. Dr. Morrison has authored more than 125 scientific publications, including works on birds, amphibians, reptiles, and mammals. He is expert in analysis of wildlife-habitat relationships, and is the lead author of the graduate-level textbook "Wildlife-habitat relationships: concepts and applications (2nd ed., U. Wisconsin Press, 1998). He is experienced in conducting terrestrial and wetland research and restoration, including numerous projects in the Central Valley of California. He has also reviewed CALFED projects, and is a member of the Sandhill Crane Recovery Team, a species considered to be one of the targets of CALFED ecosystem restoration efforts. Dr. Morrison is the President-elect of the Western Section of the Wildlife Society, and well respected in the community of wildlife biologists.

Ramona Robison has eight years of environmental consulting experience, including many botanical surveys, wetland delineations, analysis, and report preparation. Ramona has worked extensively with rare plants, and is currently a PhD student at UC Davis, working on the invasive exotic weed known as Cape Ivy. Ms. Robison advises The Nature Conservancy on its weed control programs amongst its preserves, and she worked for the Bureau of Reclamation on mapping the locations of exotic weeds along the for use in GIS. Ms. Robison is also the past President and Conservation Chair of the Sacramento Chapter of the California Native Plant Society, and she was the Volunteer Coordinator for the American River Parkway Foundation, which was dedicated to the ecological restoration of the Parkway.

Dr. Julie Yamamoto is a toxicologist by training and majored in Pharmacology and Toxicology, from the University of California, Davis in 1994 with an emphasis on ecological effects of contaminants. Her primary areas of expertise include wildlife toxicology, avian biology, and ecological risk assessment. She is currently a co-investigator at UC Davis on studies of selenium accumulation and reproductive effects in avian species, and a Staff Toxicologist within the Ecotoxicology Unit of the Office of Environmental Health Hazard Assessment (Cal/EPA).

Dr. Julie Yamamoto's recent publications included:
1. Yamamoto, J. T., R. M. Donohoe, D. M. Fry, M. S. Golub, and J. M. Donald. 1996. Environmental estrogens: Implications for reproduction in wildlife. In: A. Fairbrother, L. N. Locke, and G. L. Hoff, eds, *Noninfectious Diseases of Wildlife*. Iowa State University Press, Ames, IA. Pp. 31-51.
2. Stein, R. W., J. T. Yamamoto, D. M. Fry, and B. W. Wilson. 1998. Comparative hematology and plasma biochemistry of American kestrels and red-tailed hawks wintering in California. *Journal of Raptor Research* 32(2):163-169.
3. Yamamoto, J.T., G.M. Santolo, and B.W. Wilson. 1998. Selenium accumulation in captive American kestrels (*Falco sparverius*) fed seleno-L-methionine. *Environmental Toxicology and Chemistry* 17(12):2494-2497.
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Management 63(2):502-511.
5. Santolo, G.M., and J.T. Yamamoto. 1999. Selenium in blood of predatory birds from Kesterson Reservoir and other areas in California.. *Journal of Wildlife Management*: in press.

Dr. Yinyan Guo received her Ph.D. in Agro-ecology. For her Ph.D. thesis, Dr. Guo performed a regional analysis of quality traits in early mature *indica* rice varieties. She has published more than 20 papers in peer reviewed journals. Since last year she has been focusing on analyzing large data sets from a monitoring program for pesticide residues in surface water. She examined and characterized the distribution of chemical residues in water using GIS and statistical methods, and the efficiency of water treatment in reducing chemicals residues. She is well versed in agronomy, ecology and the transport, fate, and other processes of pesticides in surface water.

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Budget

Catagories	Year One	Year Two	Total Project
a. Personnel			
Co-PI, Shawn Smallwood	16545	17372	33917
PI, Minghua Zhang	0	0	0
Postdoctoral Scientist	31590	33170	64760
Research Assistant	14305	15020	29325
TOTAL PERSONNEL	62440	65562	128002
b. Fringe Benefits			
Normal	14984	15733	30717
TOTAL FRINGE BENEFITS	14984	15733	30717
c. Travel			
Scientific Presentation & Field work	3000	1000	4000
TOTAL TRAVEL	3000	1000	4000
d. Equipment			
(GPS and computers)	12000	0	12000
			0
TOTAL EQUIPMENT	12000	0	12000
			0
e. Supplies and Recharges			0
Supplies	2000	2000	4000
Instrument Recharges	0	0	0
TOTAL SUPPLIES	2000	2000	4000
f. Contracts	2500	2500	5000
g. Construction	0	0	0
h. Other	0	0	0
i. TOTAL DIRECT COSTS	96924	86795	183719
j. INDIRECT COSTS (less equipment)	8242	8429	16671
TOTAL INDIRECT COSTS	8242	8429	16671
k. TOTAL PROJECT COSTS	105166	95224	200390
l. TOTAL REQUESTED	105166	95224	200390