

# **Predicting The Effects Of Invasive Hydrozoa (Jellyfish) On Pelagic Organisms Under Changing Salinity And Temperature Regimes**

submitted to Science Program 2006

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lead investigators:

May, Bernie

Moyle, Peter

# Project Information And Executive Summary

## Predicting The Effects Of Invasive Hydrozoa (Jellyfish) On Pelagic Organisms Under Changing Salinity And Temperature Regimes

This is proposal #0026 for the Science Program 2006 solicitation.

Frequently asked questions and answers for this PSP are now available.

The submission deadline for this proposal has passed. Proposals may not be changed.

### Instructions

Please complete the Project Information and Executive Summary Form prior to proceeding to the other forms contained on this website and required to be completed as part of your PSP application submittal. Information provided on this form will automatically support subsequent forms to be completed as part of the Science PSP submission process. Information provided on this form will appear in the Contacts and Project Staff, Task and Budget Summary, and Conflict of Interest forms.

**Proposal Title: Predicting the effects of invasive hydrozoa (jellyfish) on pelagic organisms under changing salinity and temperature regimes**

*This field is limited to 255 characters. All proposal titles must be entered in title case. No abbreviations or acronyms will be accepted.*

### Applicant Information

**Applicant Organization Name: University of California at Davis**

*Please provide the name of the organization submitting the application as follows: Davis, California University of; Fish and Game, California Department of; California Waterfowl Association, etc.*

**Applicant Organization Type:**

**public institution of higher education**

eligibility

Below, please provide contact information for the representative of the applicant organization who is authorized to enter into a contractual agreement with the State of California and who has overall responsibility for the operation, management, and reporting requirements of the applicant organization. (This should be the same individual who signs the signature page.)

Salutation:

First Name: **Kimberly**

Last Name: **Lamar**

Street Address: **1850 Research Park Drive, Suite 300**

City: **Davis**

State or Province: **CA**

Zip Code or Mailing Code: **95616**

Telephone: **530-747-3924**

E-mail Address: **kdlamar@ucdavis.edu**

Below, please provide contact information for the primary point of contact for the implementation of the proposal. This person should be the same individual who is serving as the project Lead Investigator/Project Director.

Salutation: **Dr.**

First Name: **Bernie**

Last Name: **May**

Telephone: **530-754-8123**

E-mail Address: **bpmay@ucdavis.edu**

### Proposal Information

Total Amount Requested: \$430,870

The figure represented above is provided by the total amount requested on your completed Task and Budget Summary Form. The applicant must ensure the amount indicated above is correct and equal to the total amount requested in the budget document uploaded via the Budget and Justification Form for

this project.

Select one primary and up to three secondary topic areas that best apply to this proposal:

**Aquatic Invasive (Exotic) Species** (Primary)

**Trends and Patterns of Populations and System Response to a Changing Environment**

**Habitat Availability and Response to Change**

Select up to five keywords to describe this project.

- *agriculture*
- *agricultural economics*
- *agricultural engineering*
- *agronomy*
- *agro-ecology*
- *benthic invertebrates*
- *benthos*
- *biochemistry*
- *biological indicators*
- *birds*
- *channels and sloughs*
- climate change*
- *conservation or agricultural easements*
- *conservation program management*
- *database management*
- *ecotoxicology*
- *economics*
- *engineering*
- *erosion control*
- *environmental education*
- *evapotranspiration*
- fish biology*
- *delta smelt*
- *salmon and steelhead*
- *other species*
- *otoliths*
- *tagging*
- *fish management and facilities*
- *flooded islands*
- *floodplains and bypasses*
- *forestry*
- genetics*
- *geochemistry*
- *geographic information systems (GIS)*
- *geology*
- *geomorphology*
- *groundwater*
- *human health*
- *hydrodynamics*
- *hydrology*
- *insects*
- *integrated pest management*
- *integrated resource planning*
- invasive species / non-native species / exotic species*
- *irrigation systems*
- *land use laws and regulations*
- *land use management*
- *land use planning and policy*
- *levees*
- *mammals*
- *microbiology / bacteriology*
- *conceptual*
- *quantitative*
- *oceanography*

- *performance measures*
- *phytoplankton*
- *plants*
- terrestrial
- aquatic
- wetland
- *remote sensing / imaging*
- *reptiles*
- *reservoirs and lakes*
- *restoration*
- *riparian zone*
- *rivers and streams*
- *sediment*
- *soil science*
- *statistics*
- *subsidence*
- *sustainable agriculture*
- *trophic dynamics and food webs*
- *water operations (diversions, pumps, intakes, exports, barriers, gates, etc.)*
- X *water quality*
- other
- temperature
- contaminants
- nutrients, organic carbon, and oxygen depleting substances
- salinity
- sediment and turbidity
- *water supply*
- *watershed assessment*
- *watershed management*
- *wetlands*
- *zooplankton*

Provide the geographic coordinates that best describe the center point of your project. (Note: If your project has more than one site, provide a center point that best captures the central location.)

*Example:*    Latitude:        38.575; must be between 30 and 45  
                   Longitude:    -121.488; must be between -120 and  
                                          -130

Help for finding a geographic location.

Latitude: **38.053733**  
 Longitude: **-122.17897**

Provide the number miles radius from the center point provided above, to demonstrate the radius of the entire project.  
 20

Provide a description of the physical location of your project. Describe the area using information such as water bodies, river miles and road intersections.

**Our field research will be conducted at various locations within the San Francisco Estuary. These include brackish water habitats of the Napa and Petaluma Rivers (eg: Johns F. Kennedy Park in Napa, CA, the Turning Basin and Shollenberger Park in Petaluma, CA), Carquinez Straits, Chipps Island, and Suisun Marsh. Laboratory research will be conducted at facilities on the University of California, Davis campus (Center for Aquatic Biology and Aquaculture and Genomic Variation Laboratory).**

Successful applicants are responsible for complying with all applicable laws and regulations for their projects, including the National Environmental Policy Action (NEPA) and the California Environmental Quality Act (CEQA). Projects funded through this PSP that tier off the CALFED Programmatic EIS/EIR must incorporate applicable mitigation strategies described in the CALFED Programmatic Record of Decision to avoid or minimize the project's adverse environmental impacts. Applicants are encouraged to review the Programmatic EIS/EIR and incorporate the applicable mitigation strategies from Appendix A of these documents for their projects.

If you anticipate your project will require compliance of this nature (ie applications for permits, other environmental documentation), provide below a list of these items, as well as the status of those applications or processes, if applicable. If you believe your project will not require these regulatory actions, please provide one or two lines of text outlining why your proposed project will not be subject to these processes. Further guidance is available in The

Guide to Regulatory Compliance for Implementing CALFED Activities.

**This project takes advantage of existing sampling programs and facilities so will have no additional environmental impact. Therefore, it does not require any further permitting or environmental documentation in order to be in compliance with NEPA and CEQA regulations.**

Is this proposal an application for next phase funding of an ongoing project funded by CALFED Science Program?

No. - Yes.

If yes, identify the ongoing project:

Project Title:

CALFED Contract Management Organization:

Amount Funded:

Date Awarded:

Lead Organization:

Project Number:

Have primary staff and/or subcontractors of the project team (those persons listed on the Contacts and Project Staff form) received funding from CALFED for a project not listed above?

- No.  Yes.

If yes, list the projects below: (only list up to the five most recent projects)

Project Title: **Are 'apparent' sex reversed chinook salmon a symptom of genotoxicity**

CALFED Contract Management Organization: **USGS**

Amount Funded: **\$143,735**

Date Awarded: **September 26, 2005**

Lead Organization: **UCDavis**

Project Number: **05WRGR0012**

Project Title: **Restoration of Sacramento perch to San Francisco estuary**

CALFED Contract Management Organization: **GCAP**

Amount Funded: **\$507,432**

Date Awarded: **August 1, 2003**

Lead Organization: **UCDavis**

Project Number: **ERP-02-P34**

Project Title: **Biological assessment of green sturgeon in the Sacramento-San Joaquin watershed**

CALFED Contract Management Organization: **GCAP**

Amount Funded: **\$1,271,272**

Date Awarded: **October 1, 2003**

Lead Organization: **UCDavis**

Project Number: **ERP-02D-P57**

Project Title: **Population genetics of spittail**

CALFED Contract Management Organization: **DWR**

Amount Funded: **\$256,544**

Date Awarded: **December 1, 2002**

Lead Organization: **UCDavis**

Project Number: **4600002763**

Project Title: **Distribution and abundance of shrimp, plankton and benthos in Suisun Marsh: tidal marsh as a refuge for native species**

CALFED Contract Management Organization: **GCAP**

Amount Funded: **\$367,003**

Date Awarded: **September 2003**

Lead Organization: **UCDavis**

Project Number: **ERP-02-P32**

Has the Lead Investigator, the applicant organization, or other primary staff or subcontractors of your project team ever submitted a proposal for this effort or a similar effort to any CALFED PSP?

No. - Yes.

If yes, list the submission below: (only list up to the five most recent projects)

Project Title:  
CALFED Program:  
Date of PSP:

*Note: Additional information on this or prior applications submitted -- or proposals funded -- may be required of applicants.*

List people you feel are qualified to serve as scientific and/or technical reviewers for this proposal and are not associated with your organization or CALFED.

Full Name	Organization	Telephone	E-Mail	Expertise
Dr. Bill Ardren	US Fish and Wildlife Service	(360) 425-6072 ext 339	William_Ardren@fws.gov	genetics
Dr. Claudia Mills	University of Washington	(206) 543-1484	cemills@u.washington.edu	zooplankton
Dr. Jennifer Purcell	Western Washington University	(360) 650-7400	purcelj@cc.wvu.edu	zooplankton
Dr. Ted Sommer	Dept. of Water Resources	(916) 227-7537	tsommer@water.ca.gov	fish biology

Provide additional comments, information, etc. here:

Please note that Drs. Mills and Purcell are hydrozoan experts. The expertise options did not reflect this.

## Executive Summary

Provide a brief but complete summary description of the proposed project; its geographic location; project objective; project type, approach to implement the proposal; expected outcomes; and adaptive management approach and relationship to the Science Program goals. The Executive Summary should be a concise, informative, stand-alone description of the proposed project and be no longer than one page in length. Please note, this information will be made public on our website shortly after the closing date of this PSP.

Pelagic organisms are in serious decline in the San Francisco Estuary (SFE). A potentially important, yet understudied, factor in this decline is the invasion of four predatory hydrozoan species (*Maeotias marginata*, *Moerisia* sp., *Blackfordia virginica*, and *Cordylophora caspia*). Our current level of knowledge regarding the basic biology and ecology of these organisms is alarmingly poor in light of both their possibly negative effect on the SFE ecosystem and the increasing trends in jellyfish blooms around the globe. Our proposed research seeks to investigate the potential effects of these species on the SFE ecosystem, to determine the key factors allowing successful establishment and spread of these species, and to predict future effects and spread of the invasions. This multi-tiered research project involves three independent tasks utilizing genetic analyses, field surveys, and controlled laboratory investigations. First, through the use of genetic analyses, we will identify the species present in all life history forms via the development of molecular tools. In the second portion of this task, we will use molecular techniques to evaluate clonal diversity and mode of reproduction. Hydrozoans are novel

predators in that they can reproduce both asexually and sexually. The capacity to reproduce asexually may confer a strong advantage on these rapidly expanding invasives, therefore it is important to gain a clear understanding of both the nature of clonal diversity and how they are reproducing and spreading. The second task is two-fold and will be accomplished via directed field surveys focused in Suisun Marsh. In the first portion, we will establish a reliable estimation of the current distributions and abundances of invasive hydrozoans and relate these trends to water quality and habitat data. The remainder of this task will involve detailed gut contents analysis to determine patterns of prey selectivity (including predation on larval fishes), temporal feeding behavior, and dietary overlap with planktivorous fishes. The third task will involve a suite of laboratory studies, designed to determine ecophysiological characteristics of these species. We will quantify feeding rates upon zooplankton and larval fish prey for both the medusae and polyp life history stages, as well as evaluate salinity and temperature tolerances and their effect on survival and reproduction. We will integrate the understanding gained from our studies, the available data for the zooplankton and ichthyofaunal communities, as well as the historical and contemporary data on hydrozoan presence and abundance into a predictive model. This tool will evaluate the potential ecological effects of these invasives on the SFE and how the invasions may change under different scenarios of climate change and water management. The expected outcome of this work will be a clearer understanding of the effects of several abundant and novel hydrozoan predators in the system, as well as predicting trends and patterns of the populations in response to a changing SFE environment. We will understand what makes these invasives successful and predict how the invasion may spread and adapt in the years to come. The proposed body of work will address the CALFED Priority Research Topics of aquatic invasive species, trends and patterns of populations and system response to a changing environment, and habitat availability and response to change. It also is an important research component in elucidating the cause of pelagic organism decline in SFE. In addition to providing a predictive model, the information produced will be disseminated to the management and scientific communities through quarterly reports, poster and oral presentations at local and national meetings, as well as submissions to the IEP Newsletter and multiple publications in peer reviewed journals.

# Contacts And Project Staff

This is proposal #0026 for the Science Program 2006 solicitation.

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## INSTRUCTIONS

Use this form to provide titles, affiliations, qualifications, and descriptions of roles of the primary and secondary project staff. Include any consultants, subcontractors and/or vendors. The Lead Investigator or Project Director, as identified in the Project Information and Executive Summary Form, is required to upload a PDF version of their resume. To complete the qualification field of this form, please provide a bulleted list of relevant project/field experience and any publications/reports that support your participation in the proposed project.

Information provided on this form will automatically support subsequent forms to be completed as part of the Science Program PSP submission process. Please note that information you enter in this form will appear in the Task and Budget Summary and Conflict of Interest forms.

Information on subcontractor services must be provided even if the specific service provider has not yet been selected. If the specific subcontractor has not been identified or selected, please list TBD (to be determined) in the last name field and the anticipated service type in the title field (example: Fish Biologist).

Please provide this information before continuing to the Tasks and Deliverables Form.

## Applicant

University of California at Davis  
Kimberly Lamar  
1850 Research Park Drive, Suite 300  
Davis CA 95616  
530-747-3924  
kdlamar@ucdavis.edu

## Lead Investigator/Project Director

Salutation: **Dr.**  
Last Name: **May**  
First Name: **Bernie**  
Title: **Adjunct Professor**  
Organization: **University of California at Davis**  
Responsibilities: **Overall project management (Task 1) and Laboratory portions (Tasks 2 and 4)**  
Resume:

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

Mailing Address: **Department of Animal Science, 1 Shields Avenue**  
City: **Davis**  
State: **CA**  
Zip: **95616**  
Telephone: **530-754-8123**  
E-Mail: **bpmay@ucdavis.edu**

## All Other Personnel

Salutation: **Dr.**  
Last Name: **Moyle**  
First Name: **Peter**  
Title: **Professor**  
Organization: **University of California at Davis**  
Position:

Co-PI

Responsibilities: Overall responsibility for field studies (Task 3).

Qualifications:

EDUCATION 1964 University of Minnesota B.A.-Zoology 1966 Cornell University M.S.-Conservation 1969 University of Minnesota Ph.D.-Zoology

UNIVERSITY POSITIONS 1969 - 1972 Assistant Professor, Biology, California State University, Fresno, CA 1972 - present Assistant to Full Professor, University of California, Davis, CA 1982 - 1987 Chair, Department of Wildlife & Fisheries Biology, University of California, Davis, CA 2002-present Associate Director, Center for Watershed Science UCD

PROFESSIONAL SOCIETIES/ORGANIZATIONS American Fisheries Society (national & local chapters); American Society of Ichthyologists and Herpetologists; Ecological Society of America; Desert Fishes Council; Society for Conservation Biology; AAAS; AIBS

AWARDS Award of Excellence, Western Division, American Fisheries Society (1991); Haig-Brown Award, California Trout (1993); Distinguished Fellow, Gilbert Ichthyological Society (1993); Fellow, California Academy of Sciences (1993); Bay Education Award, Bay Institute (1994); Public Service Award, UCD (1995); Outstanding Educator Award, American Fisheries Society (1995, with J. J. Cech); Streamkeeper Award, Putah Creek Council (1997); Distinguished Ecologist, Colorado State University (2001); Outstanding Mentor Award, UCD (2003); President's Chair in Undergraduate Education, UCD (2003-2006, with J. Mount).

OTHER ACTIVITIES Editorial Boards Environmental Biology of Fishes, Biological Conservation, University of California Publications in Zoology, and Biological Invasions. Expert testimony: Bay/Delta Hearings, State Water Resources Control Board; Congressional hearings, Re-authorization of Endangered Species Act, etc. Head, Delta Native Fishes Recovery Team (1993-1995); Member, Sierra Nevada Ecosystem Project Team (1994-1996); Member, Independent Science Board, CALFED Ecosystem Restoration Program; Vice President, The Natural Heritage Institute; Fisheries Consultant, City and County of San Francisco. Member, National Research Council Committee on Endangered Fishes in the Klamath Basin (2002-2003). Member, Editorial Committee, UC Press; Member, Delta Risk Management Strategy Steering Committee, DWR.

TEACHING Teach basic courses in fish biology, wildlife conservation, fisheries, watershed ecology, and nature/culture. Co-authored (with J. Cech) widely used ichthyology text (5th edition, 2003) and co-edited (with C. Schreck) American Fisheries Society handbook on techniques for working with fish. Active in Graduate Group in Ecology. Steering Committee, Nature and Culture Program.

SELECTED PUBLICATIONS Author or co-author of over 160 peer-reviewed publications, including five books/monographs. Moyle, P. B. and P. J. Randall. 1998. Evaluating the biotic integrity of watersheds in the Sierra Nevada, California. Conservation Biology 12: 1318-1326.

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 2000. Chinook salmon in California's Central Valley: an assessment. Fisheries 25(2):6-20.

Marchetti, M. P. and P. B. Moyle. 2001. Effects of flow regime and habitat structure on fish assemblages in a regulated California stream. Ecological Applications 11: 530-539.

Marchetti, M. P., T. Light, J. Feliciano, T. Armstrong, Z. Hogan, and P. B. Moyle. 2001. Homogenization of California's fish fauna through abiotic change. Pages 269-288 in J.L. Lockwood and M.L. McKinney, editors. Biotic Homogenization. Kluwer/Academic Press, New York.

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 2001. Historical and present distribution of chinook salmon in the Central Valley. Pages 71-176 in R. Brown, ed. Contributions to the biology of Central Valley salmonids. CDFG Fish Bulletin 179.

Moyle, P. B. 2002. Inland Fishes of California. Revised and Expanded. Berkeley: University of California Press 502 pp.

Matern, S. A., P. B. Moyle, and L. C. Pierce. 2002. Native and alien fishes in a California estuarine marsh: twenty-one years of changing assemblages. Transactions of the American Fisheries Society 131:797-816.

Moyle, P. B., P. K. Crain, K. Whitener, and J. F. Mount. 2003. Alien fishes in natural streams: fish distribution, assemblage structure, and conservation in the Cosumnes River, California, USA. Envir.

- Marchetti, M. P., P. B. Moyle, and R. Levine. 2004. Invasive species profiling: exploring the characteristics of exotic fishes across invasion stages in California. *Freshwater Biology* 49:646-661..
- Marchetti, M. P., T. Light, P. B. Moyle, and J. H. Viers. 2004. Fish invasions in California watersheds: testing hypotheses using landscape patterns. *Ecological Applications* 14:1507-1525.
- Marchetti, M. P., P. B. Moyle, and R. Levine. 2004. Alien fishes in California watersheds: characteristics of successful and failed invaders. *Ecological Applications* 14:587-596.
- Moyle, P.B., R. D. Baxter, T. Sommer, T. C. Foin, and S. A. Matern. 2004. Biology and population dynamics of Sacramento Splittail (*Pogonichthys macrolepidotus*) in the San Francisco Estuary: a review. *San Francisco Estuary and Watershed Science* [online serial] 2(2):1-47.
- Crain, P.K., K. Whitener, P.B. Moyle. 2004. Use of a restored central California floodplain by larvae of native and alien fishes. Pages 125-140 in F. Feyrer, L.R. Brown, R.L. Brown, and J.J. Orsi, editors. *Early life history of fishes in the San Francisco Estuary and watershed*. American Fisheries Society Symposium 39, Bethesda, Maryland.
- Hogan, Z. S., P. B. Moyle, B. May, M. J. Vander Zander, and I. G. Baird. 2004. The imperiled giants of the Mekong. *American Scientist* 92: 228-237.
- Moyle P.B. and J. A. Israel. 2005 Untested assumptions: effectiveness of screening diversions for conservation of fish populations. *Fisheries* 30 (5):20-28
- Moyle, P.B. and M. P. Marchetti. 2006. Predicting invasion success: freshwater fishes in California as a model. *Bioscience* 56:515-524.
- Merz, J. F. and P. B. Moyle. 2006. Salmon, wildlife and wine: Marine derived nutrients in human-dominated ecosystems of central California. *Ecological Applications* 16: 999-1009.

*List relevant project/field experience and publications/reports.*

Salutation: Ms.

Last Name: Meek

First Name: Mariah

Title: Graduate Student Researcher

Organization: UC Davis

Position:

primary staff

Responsibilities: Execution responsibilities for genetic and ecological laboratory studies (Tasks 2 and 4).

Qualifications:

**RESEARCH AND PROFESSIONAL EXPERIENCE:** Doctoral Research, University of California-Davis, Davis, CA 6/03-present Investigated the population structure of black rockfish (*Sebastes melanops*) along the west coast using microsatellite genetic markers. Currently researching the invasion biology of 4 species of hydrozoans (*Maeotias marginata*, *Blackfordia virginica*, *Moerisia* sp, *Cordylophora caspia*) in the San Francisco Estuary; including the trophic role of the invasive hydrozoans in San Francisco Estuary, the relative contribution of asexual and sexual reproduction to the invasions, and the physiological tolerances to environmental conditions.

Environmental Scientist, Windward Environmental, Seattle, WA 3/01-7/03 Conducted contaminated sediment assessment and management, natural resource damage assessment, and ecological risk assessment. Collected ecological data for integration with historical data sets and analyzed to evaluate the health of disturbed environments. Designed, managed, and conducted aquatic field studies, including data collection on fish and invertebrate community structure, sediment chemistry analyses, and habitat mapping. Located, evaluated, and ranked potential restoration projects using field studies and habitat equivalency analysis modeling. Produced technical reports for the public and private sectors. Managed complex ecological database. Research Technician, PNCERS, University of Washington (U of WA), Seattle, WA 6/00-10/00 Investigated the use of Willapa Bay, WA and Coos Bay, OR as a rearing environment for various species of crabs and fishes. Conducted bottom trawls to sample crab and fish communities, identified species, and enumerated and measured sampled organisms. Processed and analyzed light trap

samples, which included identification and enumeration of larval and juvenile fish and crab species. Compiled oceanographic data from various sources to be analyzed with collected biological data. Database Coordinator, AK Salmon Prog.-Fisheries Research Inst., U of WA, Seattle, WA 6/99-6/00 Compiled and analyzed data sets investigating the ecology of sockeye salmon. Created and maintained a database for all biological and physical data collected and used by Fisheries Research Inst. Created and maintained a database and library for all published and unpublished documents used and/or produced by Fisheries Research Inst.

Aquatic Ecological Research in Alaska Field Course, U of WA 7/99-12/99 Researched habitat use, behavior, and life history characteristics of sockeye salmon (*Oncorhynchus nerka*) in Alaska. Collected and analyzed data on the abundance, survival, migration, spawning behavior, and habitat use of adult and juvenile sockeye salmon. Developed and completed independent project investigating the effect of juvenile density and lake temperature on age at smoltification.

Howard Hughes Research Intern, U of WA, Seattle, WA 6/98-9/98 Independently designed and completed research project examining shorebird movement and behavior patterns at Big Beef Creek estuary on Hood Canal, WA.

Research Assistant, U of WA, Seattle, WA 3/98-6/98 Researched the trophic ecology and life history of cutthroat trout (*Oncorhynchus clarkii clarkii*) in Lake Washington, WA. Processed stomach samples from cutthroat trout for diet analyses and analyzed scale samples to determine fish age, lake entry, and spawning status.

INVITED TALKS: Annual Alaska Salmon Research Symposium 12/99 "Affects of temperature and density on age and growth rate of sockeye salmon smolts in Lake Iliamna, AK"

*List relevant project/field experience and publications/reports.*

Salutation: Ms.

Last Name: Wintzer

First Name: Alpa

Title: Graduate Student Researcher

Organization: UCDavis

Position:

primary staff

Responsibilities: Execution responsibility for field studies (Task 3) and supervision of undergraduate assistants.

Qualifications:

RESEARCH AND PROFESSIONAL EXPERIENCE Doctoral Research, University of California-Davis, Davis, CA, 9/05-present Researching the interactions between invasive hydrozoans and fishes in Suisun Marsh, including larval fish predation and competition with planktivorous fish species.

IGERT Trainee in Biological Invasions, University of California, Davis, 9/05-present Fellowship to explore the subject of invasive species in an integrative manner; training involves specialized coursework, an internship and a multi-disciplinary group project.

Biological Science Technician, USFWS, Stockton, CA, 7/04-7/05 Monitored the effects of river flow manipulations on the migration patterns of juvenile salmonids; performed fish surveys to note species abundances; identified larval fishes for recruitment studies.

Master's Research, University of South Florida, Tampa, FL, 8/01- 6/04 Studied differences in feeding kinematics between wild largemouth bass and those reared in hatcheries on non-elusive prey. Also, linked these alternate feeding modes to differences in skull development.

Graduate Teaching Assistant. University of Florida, Tampa, FL, 8/01-12/03 Taught and organized undergraduate laboratory courses including: Cellular Processes, Biodiversity, Human Anatomy and Physiology I &II (Outstanding Teaching Assistant Award 2004).

Research Assistant, The Ohio State University, Columbus, OH, 6/00-8/01 Used telemetry to track saugeye movements from reservoir to riverine systems; assisted in fish collections for various projects; conducted research on gizzard shad feeding dynamics and nutrient recycling (research given Best Poster Award, American Fisheries Society Annual National Meeting 2002).

Ecuador Tropical Ecology Program, Boston University, Ecuador, 1/99-5/99 Completed ecology coursework and nine independent field studies in Ecuador; included work in rainforest, coastal, montane, and island ecosystems.

Boston University Marine Program, Boston University, Woods Hole, MA, 8/98-12/99 Completed coursework and three independent aquatic research projects at the Marine Biological Laboratory in Woods Hole.

#### PUBLICATIONS Peer-Reviewed

A. Wintzer and P.J. Motta. 2004. The effects of temperature on the prey capture kinematics of the bluegill sunfish *Lepomis macrochirus*: implications for feeding studies. *Can J Zool* 82: 794-799.

D. Lowry, A. Wintzer, L. Whitenack, M. Matott, D. Huber, M. Dean, and P. Motta. 2005. Aerial and aquatic feeding in the silver arowana *Osteoglossum bicirrhosum*. *Env Biol Fish* 73(4): 453-462.

A. Wintzer and P.J. Motta. 2005. A comparison of prey capture kinematics in hatchery and wild Florida largemouth bass *Micropterus salmoides floridanus*: effects of ontogeny and experience. *J Fish Biol* 67: 409-427.

A. Wintzer and P.J. Motta. 2005. Diet-induced phenotypic plasticity in the skull morphology of hatchery-reared Florida largemouth bass, *Micropterus salmoides floridanus*. *Ecol Freshw Fish* 14: 311-318.

G.W. Kim, A. Wintzer, T.K. Menker, R.A. Stein, J.M. Dettmers, R.A. Wright, and D.R. DeVries. Laboratory, mesocosm, and field studies quantify benthic-pelagic coupling by gizzard shad in aquatic ecosystems. (IN REVIEW)

P. Motta, R. Hueter, T. Tricas, A. Summers, M. Matott, D. Lowry, K. Mara, L. Whitenack, and A. Wintzer. Functional morphology, suction performance, and the enigma of protrusion in the nurse shark *Ginglymostoma cirratum*. (IN PREPARATION)

K. Börk, A. Wintzer, B. Baker, and P.B. Moyle. Field observations of young-of-the-year mountain whitefish (*Prosopium williamsoni*) in the Green River, Colorado and Utah. (IN PREPARATION) Published Abstracts and Theses

A. Wintzer and P.J. Motta. 2004. Ontogeny of prey capture kinematics and feeding structures in wild and hatchery Florida largemouth bass *Micropterus salmoides floridanus*. *J Morph* 260(3): 340.

P. Motta, R. Hueter, T. Tricas, A. Summers, M. Matott, D. Lowry, K. Mara, L. Whitenack, and A. Wintzer. 2004. Functional morphology, suction performance, and the enigma of protrusion in the nurse shark *Ginglymostoma cirratum*. *J Morph* 260(3): 315.

L. Whitenack, D. Lowry, A. Wintzer, M. Matott, D. Huber, M. Dean, and P. Motta. 2004. Behavioural and morphological specializations for aerial prey capture in the silver arowana *Osteoglossum bicirrhosum*. *J Morph* 260(3): 340.

A. Patel 2000. Phenotypic plasticity in the buccal jaws of cichlid hybrids and its implication in the haplochromine cichlid speciation of the African Great Lakes. BA Thesis, Boston University.

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#### MEETING PRESENTATIONS

Wintzer, A. and H. Blalock-Herod. Fisheries monitoring in California's Central Valley: trends from a 10-year data set. American Society of Ichthyologists and Herpetologists Annual Meeting 2005.

Motta, P.J., R.E. Heuter, D.R. Huber, D. Lowry, K. Mara, M.P. Matott, L. B. Whitenack, and A.P. Wintzer. Suction performance and feeding biology of the nurse shark *Ginglymostoma cirratum*. American Society of Ichthyologists and Herpetologists Annual Meeting 2005.

Wintzer, A. and P.J. Motta. Ontogeny of prey capture kinematics and feeding structures in wild and hatchery Florida largemouth bass *Micropterus salmoides floridanus*. International Congress of Vertebrate Morphologists Meeting 2004.

Motta, P., R. Hueter, T. Tricas, A. Summers, M. Matott, D. Lowry, K. Mara, L. Whitenack, and A. Wintzer. Functional morphology, suction performance, and the enigma of protrusion in the nurse shark *Ginglymostomata cirratum*. International Congress of Vertebrate Morphologists Meeting 2004.

Whitenack, L., Lowry, D., A. Wintzer, M. Matott, D. Huber, M. Dean, and P. Motta. Behavioural and morphological specializations for aerial prey capture in the silver arowana *Osteoglossum bicirrhosum*. International Congress of Vertebrate Morphologists Meeting 2004.

Patel, A., D. Lowry, L. Whitenack, M. Matott, D. Huber, M. Dean, A. Barker, and P. Motta. Aquatic and aerial prey capture in the silver arowana *Osteoglossum bicirrhosum*. American Society of Ichthyologists and Herpetologists Annual Meeting 2003.

Patel, A. and P. Motta. Ontogeny of prey capture kinematics in wild and hatchery Florida largemouth bass *Micropterus salmoides floridanus*. F.I.S.H. Meeting 2003.

Lowry, D., A. Patel, L. Whitenack, M. Matott, D. Huber, M. Dean, A. Barker, and P. Motta. Aquatic and aerial prey capture in the silver arowana *Osteoglossum bicirrhosum*. F.I.S.H. Meeting 2003.

Kim, G.W., A.N. Patel, T.K. Menker, J.M. Dettmers, R.A. Wright, D.R. DeVries, and R.A. Stein. Detritus quality and fish density influence gizzard shad growth and survival. American Fisheries Society Annual Meeting 2002.

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Patel, A.N. and P.J. Motta. The effects of temperature on the prey capture kinematics of the bluegill sunfish *Lepomis macrochirus purpureus*. American Society of Ichthyologists and Herpetologists Annual Meeting 2002.

Kim, G.W., A.N. Patel, T.K. Menker, J.M. Dettmers, R.A. Wright, D.R. DeVries, and R.A. Stein. The effects of detritus quality and fish density on growth and survival of gizzard shad *Dorosoma cepedianum*. F.I.S.H. Meeting 2001.

*List relevant project/field experience and publications/reports.*

# Conflict Of Interest

This is proposal #0026 for the Science Program 2006 solicitation.

Frequently asked questions and answers for this PSP are now available.

The submission deadline for this proposal has passed. Proposals may not be changed.

## Instructions

To assist Science Program staff in managing potential conflicts of interest as part of the review and selection process, we are requesting applicants to provide information on who will directly benefit if your proposal is funded. Please provide the names of individuals who fall in the following categories and are not listed in the Personnel Form:

- Persons 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; and/or
- Subcontractors listed in the proposal, who will perform tasks listed in the proposal, or will benefit financially if the proposal is funded.

Applicant  
Submittor  
Lead Investigator/Project Director  
Primary Staff  
Secondary Staff  
Subcontractor

Provide the list of names and organizations of all individuals not listed in the proposal who helped with proposal development along with any comments.

**Last Name First Name Organization Role**

# Task And Budget Summary

This is proposal #0026 for the Science Program 2006 solicitation.

Frequently asked questions and answers for this PSP are now available.

The submission deadline for this proposal has passed. Proposals may not be changed.

## Instructions

Use the table below to delineate the tasks needed to carry out your proposal. Tasks in this form should support the narrative description of your project in your proposal document and the information provided in your detailed budget spreadsheet. Each task and subtask must have a number, title, timeline, list of personnel or subcontractors providing services, and associated budget figure.

When creating subtasks, ensure that each activity is counted only once. Please note, the initial task of your table (Task 1) must present all project management/administrative activities supporting your overall proposal.

For proposals involving multiple agencies or organizations (including subcontractors), the table must clearly state the tasks and subtasks performed by each entity.

Task #	Task Title	Start Month	End Month	Personnel Involved	Description	Task Budget
1	Administration	1	36	May, Bernie	Administration of the grant, ensuring successful execution of hiring, budgeting, semi-annual progress reports, final reports, presentations at local and national meetings, and manuscript presentation.	36,590
2	Genetic Studies	1	36	May, Bernie Meek, Mariah	Develop microsatellite molecular markers, develop methods for species identification of polyp and medusae forms, and determine clonal diversity and contribution of asexual and sexual reproduction to invasive populations	233,056
3	Ecological Field Studies	1	36	Moyle, Peter Wintzer, Alpa	Expand on current knowledge of distribution and abundance of medusae and polyps, examine potential for temporal feeding behavior, perform extensive dietary analyses including predation on larval fishes, and determine diet overlap between hydromedusae and planktivorous fishes	117,695
4	Ecological Lab Studies	1	36	May, Bernie Meek, Mariah	Determine predation rates of medusae and polyps on zooplankton and larval fish prey and evaluate physiological tolerances for temperature and salinity in medusae and polyps	43,529

total budget=\$430,870

# Detailed Budget Upload And Justification

This is proposal #0026 for the [Science Program 2006 solicitation](#).

[Frequently asked questions and answers for this PSP are now available.](#)

**The submission deadline for this proposal has passed. Proposals may not be changed.**

Using the [budget provided via this link as a guide](#), please complete a budget for your proposal in the software of your choice (e.g. Excel). This document must be in a format and software that can be converted to PDF prior to uploading on the web system.

It is incumbent upon the applicant to fully explain/justify the significant costs represented in the attached budget. This information can be provided either in a text document and uploaded below, or included in your proposal text in a clearly defined budget justification section. If it is not abundantly clear to reviewers what project costs are commensurate with which efforts and benefits, the proposal may receive a poor review and denied funding.

Costs for each task described in the Task and Budget Summary Form and each staff or subcontractor described on the Contacts and Project Staff Form, must be included in your budget. The budget for Task One should represent project management activities, including but not limited to cost verification, environmental compliance, data handling, report preparation, project oversight, and public outreach. The total amount of your budget must equal the total amount represented on your Task and Budget Summary Form and the total budget amount represented on your Project Information and Executive Summary Form.

In a separate text document to be uploaded below, identify any cost share and other matching funds available to support your proposed project. If you identify cost share or matching funds, you must also describe them in the text of your proposal (see explanation of "cost share and other matching funds" in Section Two of the solicitation document).

CBDA may request additional information pertaining to the items, rates and justification of the information presented in your budget. Applications without completed budgets will not be considered for funding.

## Uploading The Completed Budget Template

First, convert your completed Budget to a PDF file. Then, use the browse function to locate the PDF version of your document, select the document and click on the upload prompt below.

*You have already uploaded this document. [View it](#) to verify that it appears as you expect. You may replace it by uploading another document*

## Uploading The Completed Budget Justification

First, convert your completed Justification text to a PDF file. Then, use the browse function to locate the PDF version of your document, select the document and click on the upload prompt below.

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## Uploading The Description Of Cost Share/Matching Funds

First, convert your completed Description of Cost Share/Matching Funds text file to a PDF file. Then, use the browse function to locate the PDF version of your document, select the document and click on the upload prompt below.

*You have already uploaded this document. [View it](#) to verify that it appears as you expect. You may replace it by uploading another document*

# Schedule Of Deliverables

This is proposal #0026 for the Science Program 2006 solicitation.

Frequently asked questions and answers for this PSP are now available.

The submission deadline for this proposal has passed. Proposals may not be changed.

Use the table below to delineate the key deliverables and the time necessary to complete them (in months from the date the project's grant agreement is executed). Each Science Program 2006 PSP grant recipient must provide the required minimum deliverables for each project. The required minimum deliverables for each funded proposal are as follows:

- Semi-annual report(s)
- Final Report
- One page project summary for public audience at beginning of project
- One page project summary for public audience upon project completion
- Project closure summary report or copy of draft manuscript
- Presentation at CALFED Science Conference
- Presentations at other events at request of CALFED Science Program staff
- Copy of all published material resulting from the grant

Deliverable	Description	Delivered By: # (In Months From Project Start Date)
Project summary, beginning	One page project summary for public audience at beginning of project	1
Semi-annual report(s)	Report of progress and findings for each task, delivered twice a year	36
Final Report	Report at completion of project discussing culmination of research and findings	36
Project summary, completion	One page project summary for public audience upon project completion	36
Project closure summary report	Summary of project and findings	36
Presentation at CALFED Science Conference	Annual presentation of results to date	36
Regional conference	Presentations of research findings, twice per year	36
International or national conference	Presentations of research findings, twice per year	36
Other presentations	Presentations at other events at request of CALFED Science Program staff	36
Draft Scientific Paper	Methods Note on Marker Development	18
Draft Scientific Paper	Clonal diversity and relative contribution of asexual and sexual reproduction	36
Draft Scientific Paper	Factors influencing abundance and distribution of invasive hydrozoans (medusae and polyps) in the SFE	30
Draft Scientific Paper	Temporal feeding behavior and diet preference in coexistent jellyfishes	36
Draft Scientific Paper	Predation on larval fishes by invasive jellyfishes	36
Draft Scientific Paper	Diet overlap between invasive hydrozoans and planktivorous fishes in the San Francisco Estuary	36
Draft Scientific Paper	Analysis of feeding rates on zooplankton and larval fishes	30
Draft Scientific Paper	Determination of salinity and temperature tolerances	36

If you are unable to provide a Schedule of Deliverables as outlined above, please provide your justification of non-compliance in the text box provided below. The Science Program reserves the right to determine a proposal non-eligible based on an applicants inability to provide the materials requested above.

# Predicting the effects of invasive Hydrozoa (jellyfish) on pelagic organisms under changing salinity and temperature regimes

## PROJECT PURPOSE

Many pelagic species underwent substantial declines between 2002 and 2004 in the upper San Francisco Estuary (SFE). These trends included the lowest numbers of delta smelt and young-of-the-year striped bass on record as well as estimates for threadfin shad and longfin smelt that were close to their historical minima. Additionally, decreases in the abundance of calanoid copepods were noted (IEP 2005). Understanding the potential role of invasive species as drivers for this phenomenon is one of the goals of the Pelagic Organism Decline (POD) management team (IEP 2005, 2006).

A quartet of invasive hydrozoans, *Maeotias marginata*, *Blackfordia virginica*, *Moerisia* sp., and *Cordylophora caspia*, has become established in the brackish waters of the SFE, where they reach seasonally high abundances during medusae blooms (June-November). In Suisun Marsh, for example recorded *Moerisia* densities can reach more than 500 individuals per m<sup>3</sup> (R. E. Schroeter, unpub. data) and “tens of thousands” of *M. marginata* have been collected in the Napa River during July 2003 surveys alone (USACE 2004). In addition, anecdotal reports have noted increasing abundances and distributions (Rees 1999).

Invasive jellyfish and other hydroids have been documented to have severe effects on the ecosystems they invade because many species are voracious predators, consuming large amounts of prey and disrupting planktivorous food webs (reviewed in Purcell and Arai 2001). Jellyfish blooms are increasing globally (Mills 2001) and can directly affect fish populations by devouring massive quantities of eggs and larvae and decreasing fish survival through competition for resources (Purcell and Arai 2001, Purcell et al. 2001, Purcell 2003, Lynam et al. 2006). Preliminary information on diet of hydromedusae in the SFE shows that they feed on a wide variety of planktonic species, including larval fishes (Mills and Sommer 1995, R. E. Schroeter unpub. data). These brackish water hydrozoans are novel predators in the SFE and thus have an especially high likelihood of impacting this system (Moyle and Light 1996a).

The limited, but compelling information regarding these species indicates more attention is necessary to adequately detect their potential impacts on the ecosystem. This informational deficit has already been recognized by the POD management team, which recommended that density data be recorded and existing data analyzed for patterns in distribution and abundance (IEP 2006). This is a promising preliminary step, but the lack of distribution and abundance data from species-specific sampling, coupled with grave deficiencies in our understanding of their most basic biology and ecology, hinder our best efforts to predict their effects. This information is key to understanding the potential role of hydrozoans in fish declines, predicting how the invasions may change and spread under different scenarios of climate change and water regulation, and providing insights into what management decisions should be implemented to reduce their impacts.

The unifying goal of this research program is to gather quantitative ecological information about these understudied invasives in the SFE to best inform management activity. We propose to answer the following questions: What are the potential effects of these species on the SFE ecosystem? What are the key biological and physical factors allowing successful establishment and spread of these

species? How will the impacts and spread of each species invasion change with future conditions? In order to achieve these goals we will:

- Identify what species are present at all life history stages;
- Determine the extant distribution and abundance of polyps and expand upon known distribution of medusae;
- Investigate the genetic diversity and reproductive mechanisms that contribute to the establishment and spread of the invasions;
- Analyze diet composition for potential predation on and competition with fishes;
- Quantify predation rates on zooplankton and larval fishes;
- Evaluate the range of environmental conditions inhabitable by the invading species; and
- Predict how the invasions may expand under scenarios of climate change and water regulation and what future effects on the SFE community may be.

Our research will be divided into four tasks, each with several subtasks. These tasks and their respective hypotheses (as appropriate) are:

Task 1: Project Management

Task 2: Genetic Studies

2.1- Develop a suite of microsatellite markers to be used in Tasks 2.3.

2.2- Develop molecular markers to efficiently and accurately identify species from samples of medusae and polyps collected in San Francisco Estuary.

2.3- Determine the clonal diversity and predominant mode of reproduction (asexual versus sexual) in the invasive populations. Our hypotheses are:

H<sub>1</sub>: Reproduction occurs entirely asexually in each species.

H<sub>2</sub>: Each species contains only a single clonal line.

Task 3: Ecological Field Studies

3.1 – Estimate medusae and polyp densities by field surveys within the SFE. We will also collect water quality and physical habitat data in order to relate these factors to patterns of medusae and polyp distribution and abundance.

H<sub>1</sub>: Distributions and abundances are related to water quality parameters and physical habitat.

H<sub>2</sub>: Distributions and abundances differ between species and life stages.

3.2 – Determine patterns of prey preference in medusae, including that for larval fishes. Field collections will be made during both day and night in order to identify temporal changes in feeding behavior.

H<sub>1</sub>: Medusae actively prey on larval fishes.

H<sub>2</sub>: Medusae selectively prey on zooplankton also preferred by pelagic fishes.

H<sub>3</sub>: Hydromedusan species exhibit differences in temporal feeding behavior.

3.3 – Examine the level of diet overlap between hydromedusae and planktivorous fish species to gauge the possibility for competition between these taxa.

H<sub>1</sub>: Significant dietary overlap occurs between invasive hydromedusae and planktivorous fishes.

H<sub>2</sub>: Planktivorous fishes undergo shifts in diet during medusae bloom periods.

Task 4: Ecological Laboratory Studies

4.1- Quantify food consumption rates in a laboratory setting. This will expand upon

our third task by determining not only what these predators are eating, but also at what rate they are removing prey from the system.

H<sub>1</sub>: Medusae and polyps have consumption rates that can alter abundance of zooplankton species important to fish.

H<sub>2</sub>: Each species has different consumption rates.

4.2- Quantify both survival and reproduction across a spectrum of salinity and temperature conditions to determine how environmental conditions may limit the invaded range.

H<sub>1</sub>: Survival and reproduction is highest at intermediate salinity (5-10‰) and temperatures (15-20°C) and lowest at extreme values (0‰, 16‰, 10°C, and 25°C).

H<sub>2</sub>: There are differences in responses to temperature and salinity conditions among species.

H<sub>3</sub>: There are differences in responses to temperature and salinity conditions between polyps and medusae.

H<sub>4</sub>: Among clone variation in survival and reproduction under different environmental conditions is greater than within clone variation.

## PREVIOUS RESEARCH

All four species of invasive hydrozoans present in the SFE are thought to be native to brackish water habitats of the Ponto-Caspian region (Calder and Burrell 1969). It is likely they were transported to the SFE via ballast water (Rees and Gershwin 2000). *Maeotias marginata* likely arrived in the SFE in the late 1950s; *B. virginica* was first recorded in the area in 1970; and a yet to be identified species of *Moerisia* was first documented in 1993 (Mills and Rees 2000). There are no other documented occurrences of *M. marginata* or *Moerisia* along the west coast and the only other west coast occurrence of *B. virginica* is in Coos Bay, OR (Mills and Rees 2000). *Cordylophora caspia* is the most invasive of the group, establishing populations along both coasts of the United States. It was likely introduced to SFE prior to the 1950s through ballast water or the oyster trade (CRWQCB 2000). All of these species are found in Chesapeake Bay and in brackish water habitats in Suisun Marsh and Bay, Petaluma River, and Napa River (Mills and Rees 2000, Rees and Kitting 2002). Very little previous research has been published on these hydrozoans and most of the existing studies are purely descriptive. R. E. Schroeter, UC Davis, (unpub. data) has made some advances in the understanding of these species in the SFE through data collected on benthic distribution and abundance of *M. marginata* and limited daytime gut content analyses in *M. marginata* and *Moerisia* sp. The published work available is summarized below for each species:

Mills and Sommer (1995) conducted preliminary diet analyses on *M. marginata* collected from Petaluma River. They found gut contents to be primarily barnacle nauplii, copepods, crab zoea, larvae of *Rhithropanopeus harrisi*, copepod nauplii and egg sacs, and tanaids. They also found *M. marginata* to feed on small guppies in the laboratory. Mills and Sommer (1995) conducted very preliminary salinity tolerance tests with medusae. They subjected medusae of *M. marginata* to salinity conditions ranging from 0-30‰, finding that after 48 hours, all medusae in salinities of 0‰ or ≥ 20‰ became inactive and moribund. Limited conclusions, however, can be drawn from these preliminary studies because they did not feed the medusae during the experiment.

There has been effectively no research beyond specimen descriptions conducted on the *Moerisia* species in SFE. Rees and Gershwin (2000) cultured *Moerisia* from SFE in the laboratory and found

them to be very efficient predators, killing and eating *Artemia* nauplii at a fast rate. They were also able to culture polyps of *Moerisia* by spawning mature medusae. They found polyps capable of capturing and consuming *Artemia* nauplii much larger than their own size. They observed that newly settled polyp buds developed and began releasing their own polyp buds within 1-2 weeks, demonstrating very high population growth potential. Ma and Purcell (2005a and b) investigated the effect of temperature and salinity on asexual reproduction and survival in *Moerisia lyonsi* from Chesapeake Bay. They found lower temperatures and higher salinities lengthened development time and decreased asexual reproductive rate and medusa bud production, with the opposite effects observed under higher temperatures and decreased salinity. The authors used only a single clonal line in their experiments and therefore were unable to quantify the level of variation in responses for the population. It is uncertain, however, if this is the same species present in SFE.

Even more limited research has been conducted on *B. virginica*. Mills and Sommer (1995) described the species morphology and also examined the gut contents of 29 individuals. They found prey items to be copepods, copepod nauplii, and barnacle nauplii. Mills and Rees (2000) recorded polyps of *B. virginica* covering the barnacle *Balanus improvisus* in the Napa River.

Despite its broad distribution and success as an invasive, there is also a paucity of data describing *C. caspia* and its ecology. This invasive can modify the habitat substrate by trapping accumulating particulate organic matter in the interstitial microhabitats created by the thick hydroid colonies (Leppakoski et al. 2002). In the Connecticut River, it is found to feed upon larval insects, primarily chironomids (Smith et al. 2002).

#### CRITICAL UNKNOWNNS

Most of the basic ecology of these organisms is largely unknown. Therefore, it is very difficult to assess what affect these invasives are having on the SFE community. Beyond understanding the general hydrozoan life history, there is a lack of knowledge regarding the importance of the polyp versus medusae form in population growth. For example, medusae of a species could be important zooplankton predators in a different part of the system than the polyps. There is very little information on the range of conditions they inhabit in the SFE and even less is understood about conditions they can potentially inhabit. Finally, little is understood about their trophic ecology, including prey preference and rates of feeding. It is imperative to gain an understanding of these basic factors and synthesize these data to determine both how the invaders are affecting the SFE community and how effects may change over time.

Our proposed research will incorporate and expand upon R. E. Schroeter's study and other previous work to address these critical unknownns and fully understand these invasions.

### **BACKGROUND AND CONCEPTUAL MODEL**

#### HYDROZOAN LIFE HISTORY

*Maeotias marginata*, *Moerisia* sp., and *B. virginica* all possess a similar biphasic life history, with an asexual (polyp) and sexual (medusae) form (Figure 1). Polyps asexually reproduce both polyps and medusae. They are sessile and can be colonial, as in *M. marginata*, or solitary, as in *Moerisia*. Medusae are the pelagic stage. They are dioecious and reproduce sexually. They are free-spawners with planula larvae that settle in the benthos to develop into polyps (Kramp 1961). *Cordylophora caspia* is also an asexually and sexually reproducing hydrozoan species; however it exists only in the polyp form and is colonial.

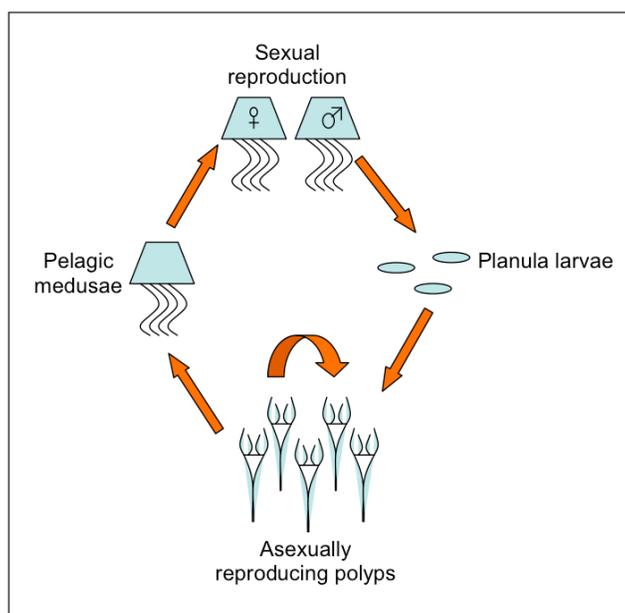


Figure 1: General hydromedusan life history. All invasive hydrozoans in the San Francisco Estuary adhere to this life history strategy except *Cordylophora caspia*, which exists only in polyp form but is capable of reproducing both asexually and sexually (not shown).

#### CONCEPTUAL MODEL

Our conceptual model is summarized below in Figure 2, which depicts the two major factors (distribution/abundance and diet) that we hypothesize are shaping the impact of invasive hydrozoans through predation on and competition with pelagic organisms in SFE. The model is described in detail below.

Distribution and Abundance: Much of our knowledge regarding the distributions of introduced jellyfish in the SFE is based upon the appearance of large medusae as by-catch in agency sampling gear and an initial field survey from 1999 (Rees and Kitting 2002). In the majority of these cases, abundance estimates were impeded as the gear type was not suitable for effective sampling of these species or they were simply not enumerated. Additionally, there is no field derived ecological information currently available for the polyp stages of these hydrozoans. We will integrate data on genetic diversity, reproductive mode, and physiological tolerance to better understand distribution and abundance of invasive hydrozoans in SFE and compare these findings to estimates from proposed field surveys. It is important to recognize that medusae and polyps of each/all species may both be important predators on zooplankton and larval fish and that the cumulative impacts may be more important than the impacts of just one life stage or even one species.

*Genetic diversity and reproductive mode* - Asexual reproduction can confer an advantage during the establishment and spread of an invasive species (Barrett and Richardson 1986). Asexually reproducing species can avoid the demographic constraints of small population size during initial establishment (Lambrinos 2001). Additionally, the potential for preservation of coadapted gene complexes with high phenotypic plasticity and broad tolerance ranges ('general purpose genotypes') is greater under asexual reproduction (Baker 1965, Lambrinos 2001). However, asexually reproducing invasive species may sometimes be less successful compared to those reproducing sexually (e.g., Lambrinos 2001). Low amounts of genetic

variation, due to reduced numbers during invasion, combined with limited recombination and reduced ability to purge deleterious mutations in asexual reproduction may limit a species' capacity to expand and adapt to heterogeneous environments. This may decrease a species' ability to persist in an ecosystem over space and time (Fisher 1930, Sakai et al. 2001, Hughes and Stachowicz 2004). If a population reproduces asexually while maintaining high genetic diversity through multiple clonal lines, it is possible their invasive ability would be increased (Facon et al. 2006). Therefore, it will be very important to understand the level of diversity in the invasive populations in SFE as well as the predominant reproductive mode in order to accurately predict the potential for future spread and success of these invasions. In our proposed research, we will use molecular techniques to determine both genetic diversity of the invading populations and to elucidate what the relative contributions of asexual and sexual reproduction are to the invasions. This work will allow us to understand what life history mechanisms are aiding in the invasions as well as what potential exists for future change and adaptation in the invading populations.

*Physiological tolerance* – It has been suggested that the potential establishment range of many non-native species is limited to a greater extent by tolerances to abiotic conditions than by biotic factors (Moyle and Light 1996b). This may be the case for the invasive hydrozoans because there are no known predators of hydromedusae in the system, and only the non-native shimofuri goby is known to feed on *C. caspia* (Matern and Brown 2005). Additionally, preliminary diet studies indicate a broad prey base. We will investigate differences among *M. marginata* and *Moerisia* sp. and their polyp and medusa lifestages in temperature and salinity tolerance levels. Additionally, we will evaluate variability in tolerance levels both among and within clonal lines. This will allow us to investigate the level of variation due to either each species' plastic ability to respond to various conditions or the contribution of genetic diversity via different clonal lines. It is possible genetic variation may play a more dominant role in determining habitat suitability than phenotypic plasticity. Through this work we will compare the responses among species to varying conditions.

Results will be combined with field survey data. We will perform species-specific sampling within SFE to best determine the present distributions and abundances of both medusae and polyp stages, allowing us to put their level of potential impact into a realistic perspective. Additional abiotic field measurements will allow us to elucidate any importance of such factors as general drivers for distribution and abundance in nature.

Diet: According to the Bad Suisun Bay Hypothesis, invasive species, especially bivalves like the Asian clam, have changed the food web of this ecosystem, reducing prey for fishes (IEP 2006). Jellyfish and other hydrozoans have proven to be important, yet understudied, predators in marine and estuarine systems (Purcell and Arai 2001). We do not currently understand how the invasive hydrozoans in SFE fit into the trophic ecology of the estuary. In order to assess their potential impact, it is important to understand the basic feeding biology of these species.

*Prey preference* - We will perform further detailed gut content analyses to add to those of Mills and Sommer (1995) and R. E. Schroeter (unpub. data) and quantify prey availability in order to estimate patterns of prey preference.

*Temporal feeding behavior* – Both daytime and nocturnal feeding behavior has been documented in hydromedusae (Hamner and Schneider 1986). Yet, all of the previous gut contents studies in

the SFE have involved daytime collections. We will compare feeding of individuals collected during the night to assess whether nocturnal feeding is a significant behavior and whether daytime diet information gathered thus far adequately reflects feeding.

*Feeding rate* – Previous work with jellyfish has demonstrated consumption levels during bloom periods that are so massive that they can control zooplankton populations (Huntley and Hobson 1978, Purcell 1992). The feeding rates for the invasive hydrozoans in the SFE are not known. Therefore, we will perform laboratory based feeding trials on both zoo- and ichthyoplankton to understand the rates at which these prey items can be taken from the system. These rates can then be scaled up to the population-level for an estimate of predation within the estuary.

Predation and Competition: Concerns have been raised over the decline of pelagic, planktivorous fish species in the upper estuary. Negative interactions with non-native species are considered to be a possible factor fueling this phenomenon (IEP 2005). We will examine diet overlap between introduced hydromedusae and key fish species (delta smelt, longfin smelt, threadfin shad, and young-of-the-year striped bass). Additionally, we will determine any diet shift of fishes during times when jellyfish are present, in an effort to gain insight into the potential for competitive interactions between these taxa. Pairing this information with feeding rates and plankton densities will allow us to estimate competition.

Many jellyfish species are known predators on fish eggs and larvae (Purcell 1985). Rees and Kitting (2002) noted that *M. marginata* were able to kill juvenile fishes in laboratory experiments, and R. E. Schroeter (unpub. data) found goby larvae in 6 out of 39 medusae collected in July 2004 from Suisun Marsh. It is important to understand the potential significance of predation on fish larvae because the medusae blooms likely overlap with the larval recruitment of inland silverside, goby sp., threadfin shad, and possibly striped bass, the latter two being key species in the POD. There is also potential that predation on natives occurs in downstream areas, such as the Carquinez Straits, where salinities in March can support early emerging medusae. We will explore the impacts of larval predation via gut content analysis on medusae in this area and Suisun Marsh in conjunction with feeding rates of medusae on larvae, and ichthyoplankton density.

The combination of these factors with abundance and distribution will determine the effects of these invasions on fishes in the SFE. It is important to understand these factors and their interactions in order to manage for a healthy SFE and protect key species. Additionally, it is imperative to determine, not only the current state and impact of interactions among species, but also how those interactions may change under future conditions. There are several predicted major drivers of change in the SFE. These are climate change, water regulation, and future species invasions. The data we will collect lay the groundwork for the development of a model that can predict the impact of invasive hydrozoans on fish species in the SFE under future conditions. The development of this model will be crucial for future management decisions.

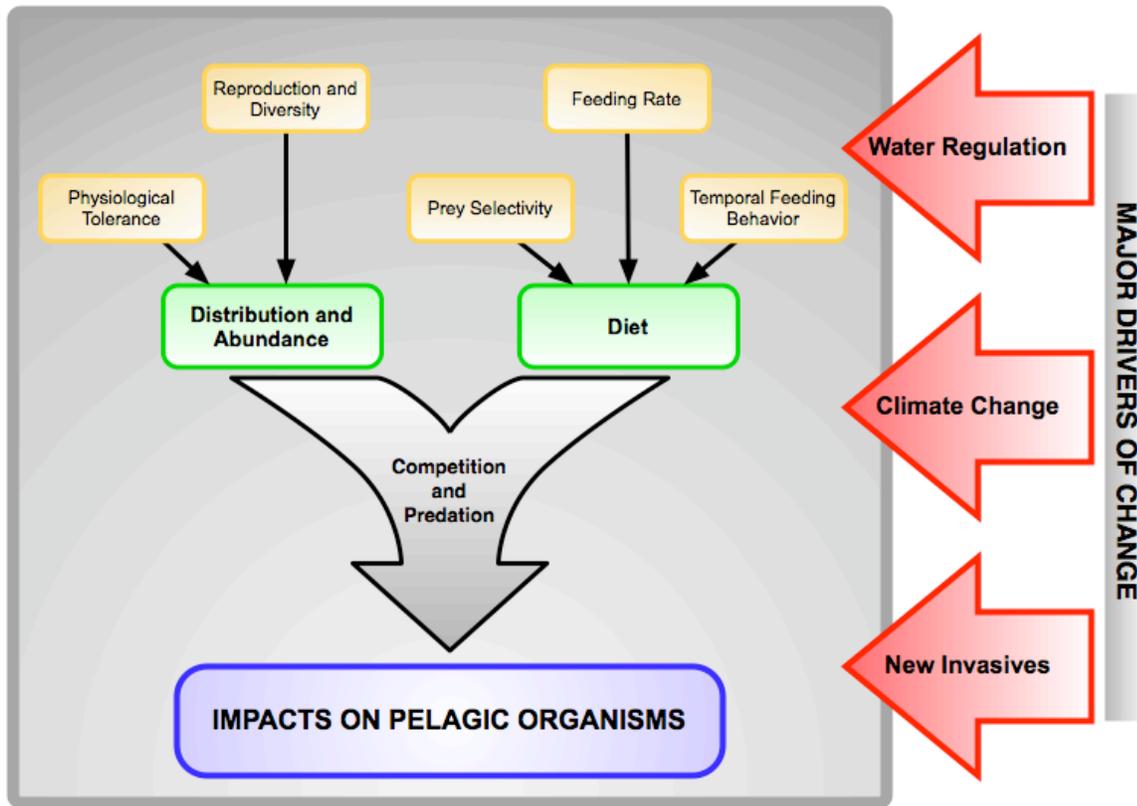


Figure 2: Conceptual model of factors determining invasive hydrozoan impacts on pelagic organisms in the San Francisco Estuary. Major factors driving impacts on pelagic organisms through competition and predation are in green and their respective components are in yellow. Red arrow at right represent major driver of change acting on the SFE system as a whole.

**DESCRIPTION OF PHYSICAL SETTING**

San Francisco Estuary (Figure 3) consists of 1500 km<sup>2</sup> of aquatic habitat, ranging from fresh water in the upper Delta to coastal salinities at the mouth of the Bay (Cohen and Carlton 1998). It receives runoff from a 163,000 km<sup>2</sup> watershed that experiences high annual and seasonal variation in water flow, despite an extensive system of damming, water diversion, and flood control.

The majority of our field sampling will take place within Suisun Marsh because of this area’s importance as a larval fish nursery and its relationship to the POD. This is a brackish water system covering approximately 34,000ha. One-third of the area is formed by a system of tidally influenced sloughs, while the rest is a combination of diked seasonal pools and upland grasslands (DWR 1999, Meng and Matern 2001). Sloughs average between 2-3m in depth, 10-100m in width, and have margins of tules and reeds (Freyer et al. 2003). Suisun Marsh receives the majority of its freshwater from the eastern side of Montezuma Slough, but a series of creeks make additions to various sloughs throughout the system. Saline water is driven into the marsh via tidal action from three southerly-located bays, Suisun, Grizzly, and Honker(Meng and Matern 2001). Salinity levels fluctuate seasonally between 0 and 16‰, with the lowest levels occurring in winter and spring due

to rain and snowmelt. Water temperatures also vary seasonally, typically ranging from 5-25°C (Freyer et al. 2003).

## **APPROACH AND SCOPE OF WORK**

We propose a collaborative program of research that will integrate field and laboratory studies. The primary research focus is to gain basic biological information on invasive hydrozoans in order to understand both what leads the invasions to be successful and how the invasions may be negatively affecting the SFE ecosystem.

### **TASK 1—PROJECT MANAGEMENT**

This research program will be managed as an interdisciplinary collaborative effort between two Primary Investigators, Dr. Bernie May and Dr. Peter Moyle at the University of California, Davis. Dr. Bernie May will be the overall project director and the lead PI for Tasks 2 and 4 and Dr. Peter Moyle will be the lead PI for Task 3. Two doctoral students, Mariah Meek and Alpa Wintzer, will be responsible for executing the research. Weekly meetings will be held among Dr. May, Dr. Moyle, Ms. Meek, and Ms. Wintzer to review progress and make management decisions. All laboratory work will be completed at the University of California, Davis genetic and aquatic facilities. Deliverables will be produced as outlined in Table 1.

### **TASK 2—GENETIC STUDIES**

#### *2.1: Marker Development*

We will extract DNA from several positively identified representatives of *M. marginata*, *Moerisia* sp., *B. virginica*, and *C. caspia*. The extracts will be pooled and four enriched microsatellite libraries produced for tetranucleotide and dinucleotide repeats (CTAT, CTGT, AG, CA) using established methods (Jones et al. 2002). Recombinant clones will be sequenced and nucleotides will be aligned in the program Sequencher (GeneCodes) to screen for microsatellites. Clones containing microsatellites will be selected and primers will be designed from flanking regions using the online software program Primer 3. Initial PCR amplification using primers from candidate microsatellite loci will be conducted for six positively identified individuals from each species. Products will be electrophoresed on 5% polyacrylamide gels and imaged with a Molecular Dynamics 595 Fluorimager to identify polymorphic loci that amplify consistently in one or more of the species of interest. These steps will be repeated until fifteen microsatellites that fit these criteria have been identified for each species. Fluorescently labeled primers will be designed for these loci and they will be optimized for fragment analysis on the BaseStation DNA Fragment Analyzer™ genotyping

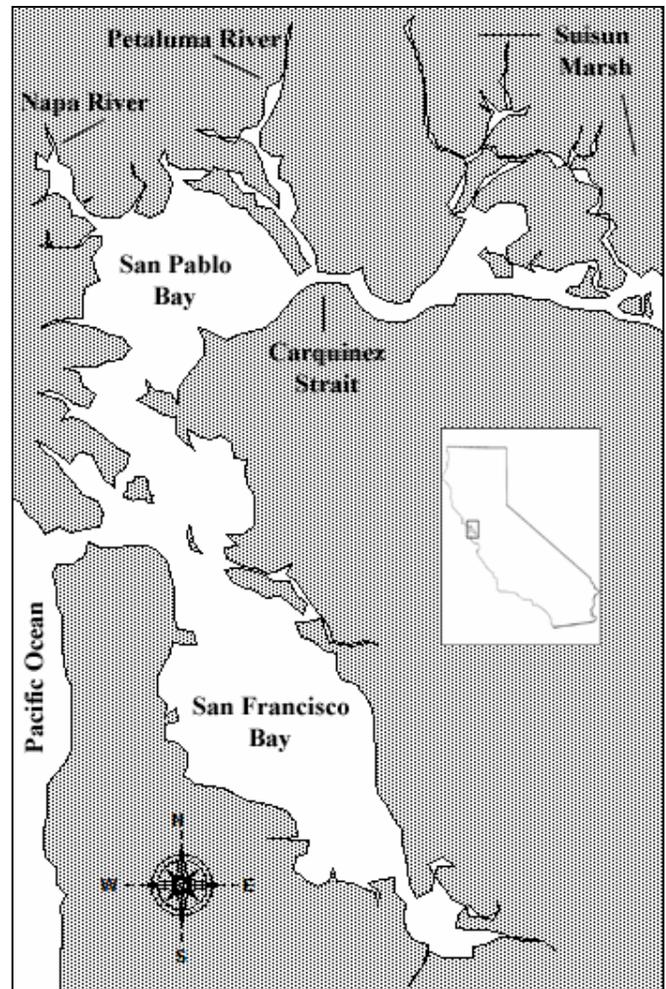


Figure 3: Map of the San Francisco Estuary. The majority of the research proposed will be conducted in Suisun Marsh and Bay.

platform (BioRad) or ABI 3730 capillary sequencer. We will use these markers in the completion of Task 2.3.

### 2.2: *Species Identification*

The first step in studying these potentially important invasives is to develop a quick means of species identification. While the identification of the medusae in this system is relatively straightforward, linking medusae with the corresponding polyps has been difficult and time consuming. Through the use of molecular techniques, we will be able to efficiently and accurately identify large samples of both polyps and medusae to the proper species. Additionally, using molecular techniques, we will determine what species of *Moerisia* is present in SFE. Completion of this task will be highly beneficial to both the rest of our study, to others studying these species in the SFE, and to the scientific community at large.

Single nucleotide polymorphisms (SNPs) are genetic markers that are commonly used to differentiate between closely-related species (Belfiore et al. 2003; He et al. 2003; Itoi et al. 2005). Non-coding DNA regions flanking microsatellite loci developed in Task 2.1 will be screened to identify SNPs that will differentiate between *M. marginata*, *Moerisia* sp., *B. virginica*, and *C. caspia*. Primers will be designed from flanking regions of >250 bp and sequenced in several individuals from each species. Sequences will be aligned in the program Sequencher (GeneCodes) and screened for species specific SNPs. A 5' nuclease TaqMan® SNP Genotyping Assay (Applied Biosystems) will be developed for each diagnostic SNP identified. SNP genotyping of all polyps will be conducted through real-time PCR on a Chromo4™ Real-Time PCR Detector (MJ Research/Bio-Rad Laboratories, Inc.) to establish species identity. We will use these nuclear SNPs, as well as mtDNA, to identify the *Moerisia* organism to the species level. Species determination within Moerisiidae has previously been conducted through the use of morphological characters, such as tentacle number and bell diameter (Kramp 1961). However, this has posed a problem for species identification of *Moerisia* in San Francisco Estuary, as the species present does not clearly fall into the range of morphological characters identified for each described *Moerisia* species (Dr. C. Mills, per. comm.). Therefore, samples from wild *Moerisia* species will be obtained from their native ranges to identify what species of *Moerisia* is present in SFE.

### 2.3--*Relative contribution of asexual/sexual reproduction*

We will collect 30-60 individual samples of both the polyp and medusa phase at each sampling site throughout Suisun Bay for *M. marginata*, *Moerisia* sp, and *C. caspia* (as described in Task 3.1). Polyps for *M. marginata* have yet to be recovered in the SFE. If we are unable to procure any polyps of this species, the following analyses will be conducted on just the medusae form. We will use the 15 polymorphic and rapidly evolving microsatellite markers developed in Task 2.1 to determine the role of asexual versus sexual reproduction in the polyp and medusa populations.

We will determine clonal diversity and the relative contribution of asexual reproduction within each sample by employing the program MGLSim (Stenberg et al. 2003) to estimate clonal diversity and predominant reproductive mode. This program calculates significance values for the likelihood that a multilocus genotype observed more than once in a population is the result of sexual reproduction (Stenberg et al. 2003). We will compare the clonal diversity of the polyp and hydromedusae phase to determine the role of sexual reproduction to recruitment in the polyp phase. We will calculate both the multilocus genotype (clonal) diversity (D) and the clonal evenness (E). We will use a modification of the Simpson Index as used by Ellstrand and Roose (1987) and Novak and Mack (2005) to calculate D:

$$D_{\text{obs}} = 1 - \sum_{i=1}^G (n_i(n_i-1)) / (N(N-1))$$

where  $n_i$  is the number of individuals of genotype  $I$ ,  $N$  is the number of individuals sampled, and  $G$  is the number of multilocus genotypes detected in the population. Values for  $D$  can range from zero (only one multilocus genotype in the population) to 1.0 (every individual sampled contains a unique multilocus genotype). We will calculate evenness to evaluate the distribution of clonal lines throughout the population using the following equation (Ellstrand and Roose 1987 and Fager 1972):

where

$$E = (D_{\text{obs}} - D_{\text{min}}) / (D_{\text{max}} - D_{\text{min}})$$

and

$$D_{\text{min}} = ((G-1)(2N-G)) / (N(N-1))$$

$$D_{\text{max}} = (N(G-1)) / (G(N-1))$$

Values of  $E$  range from zero in populations with only one genotype present to 1.0 when each genotype present is equally represented in the population.

We will analyze our microsatellite data for potential population substructure with the program STRUCTURE (Pritchard et al. 2000). We will remove all repeat copies of multi-locus genotypes to avoid biasing the data. STRUCTURE uses a model-based clustering method to assign individuals to groups in which Hardy–Weinberg equilibrium is realized. If our initial analyses at the sample level determine there are multiple clonal lines present in the population, we will then evaluate clonal diversity and the relative contribution of asexual reproduction in each subpopulation if substructuring exists or on the population as a whole if no substructure exists. Additionally, we will determine the amount of genetic diversity both in the polyp and medusae phase to evaluate whether there is differential recruitment of clonal lines to the medusae population. We will use ARLEQUIN to execute Analysis of Molecular Variance to calculate nucleotide diversity. Microsatellites are ideal for this type of investigation as they evolve rapidly, are distributed throughout the genome, generally don't code for structural genes, and are not thought to be subject to strong selection pressure. This leads to increased polymorphisms. By using 10-15 highly polymorphic loci, we increase the power of our analyses to detect asexual versus sexual reproduction.

After determining the number of clonal lines in each invading population and the relative contribution of asexual versus sexual reproduction to the invasions, the next step of this research will be to evaluate the clonal diversity of the polyp population geographically to determine if the occurrence of clonal lines is homogeneous throughout the invading populations. This will, again, provide us with a metric for the level of diversity found in the invading populations. It is possible that the large scale genetic diversity may be high, while smaller scale diversity may be very low if one clone predominates in large patches. Additionally, if there is differential asexual recruitment based on distance from the edge of the invaded range, we may find either higher or lower clonal diversity at the edge versus the center of the invaded range. The invasion range will be determined through the sampling program outlined in Task 3.

We will use Analysis of Variance (ANOVA) to analyze differences in clonal diversity and reproductive mode among species, locations, and medusae and polyps.

## TASK 3--ECOLOGICAL FIELD STUDIES

### 3.1: *Distribution and Abundance*

Medusae sampling: In 2007 and 2008, we will perform a series of monthly daytime collections in Suisun Marsh during the seasonal bloom period, typically July-October (Rees and Kitting 2002). During this time, we will survey a series of deeper sloughs (Cordelia, Suisun, Nurse, and Montezuma) with 5 minute tows using a midwater trawl (1m x 2.5m mouth, 5m length, 35mm stretch graded to 4mm stretch mesh at the cod end) for collection of large *M. marginata* and a plankton net (0.5m diameter mouth and 500 $\mu$ m mesh) for *Moerisia* sp., *B. virginica*, and small *M. marginata*. Two to four replicate surveys will be performed in each slough, with the number depending upon slough length. A flowmeter will be deployed during tows as a means to calculate volume of water sampled for each net. When possible, medusae will be identified and enumerated in the field. Individuals that are difficult to identify will be brought back to the lab and examined with the aid of a dissecting microscope. The bell widths of up to 30 individuals of each species will also be measured to document size distribution. We will collect water quality parameters, including temperature, salinity, conductivity, dissolved oxygen, and pH at the beginning of each tow using a YSI meter (Model 30). Water clarity will be estimated with a secchi reading. Information about slough average width, maximum depth, and length will be taken from Meng and Matern (2001). This information will be combined with data collected by the UC Davis Suisun Marsh Sampling Program's otter trawl to provide more realistic estimates of distribution and abundance. Additional collections will be made in brackish water habitats of the Napa and Petaluma Rivers using the methodology described above. Monthly samples will also be obtained through USFWS Chipps Island midwater trawl survey as well as with CDFG fish sampling programs when possible (e.g. Suisun, Honker, and Grizzly Bays).

Polyp sampling: Due to the paucity of information regarding all aspects of polyp ecology, this portion of the study will be a preliminary attempt at documenting their distributions and abundances. We will suspend fouling plates made of 0.15m<sup>2</sup> sanded sheet PVC in quadruplicate from various docks in Suisun Marsh beginning in July of 2007 and 2008. At the time of set-up and collection, water quality parameters will be measured as described in the previous section. One plate will be removed from each site at the end of each month, July-October. We will preserve the plates in 95% ethanol and transport them to the lab where hydrozoan polyps will be identified using molecular markers, as described in Task 2.2, and counted. *C. caspia* forms complex branching colonies, making it a difficult subject to assign abundance per unit area. Hence, its abundance will be estimated as a function of weight per area. It is unclear whether polyps prefer fresh or saline conditions (Mills and Sommer 1995), so fouling plates will also be placed around boat launches and docks at John F. Kennedy Park in Napa, CA, the Turning Basin and Shollenberger Park in Petaluma, CA, and Suisun City Marina in Suisun City, CA. Additional plates will be hung at the Carquinez Straits and near Chipps Island. In addition, we will collect three benthic grab samples from each slough surveyed during monthly medusae collections. The densities of any polyps within the samples will be estimated and the types of substrate upon which polyps are attached will be noted.

Canonical Correspondence Analysis will be performed with the CANOCO software program (ter Braak and Smilauer 1998) to examine the relationship between species distributions and abiotic habitat variables. Additionally, Principle Components Analysis will be used to compare differences in jellyfish abundance among sample sites (or water depth) and over time.

### 3.2: Temporal Feeding Behavior on Larval Fish and Zooplankton

During monthly daytime medusae sampling in Suisun Marsh (described above in Task 3.1), up to 30 individuals per species per tow will be preserved in 5% formalin. Non-medusae zooplankton from the 500µm mesh plankton tow will also be preserved in 5% formalin. Finally, an additional 150µm mesh plankton tow will be conducted to collect microzooplankton, and its contents will be preserved. This sampling effort will be repeated during four nights over the seasonal bloom. In the lab, the bell lengths of jellyfish will be measured and gut contents will be identified to the lowest taxon possible and counted. Zooplankton and ichthyoplankton from subsamples of plankton tow collections will be identified and counted. Additionally, medusae will be collected from the Carquinez Straits in March and May. Salinities may allow the earliest medusae appearances here and gut contents will be examined for predation on native fish larvae.

Selection patterns for prey (including larval fishes) by the three jellyfish species will be examined, using Pearre's selectivity index (Pearre 1982), C:

$$C = \pm [((|a_d b_e - a_e b_d| - (n/2)^2) / abde)]^{0.5}$$

where,  $a_d$  is the number of a specific prey type ingested,  $a_e$  is the number of that prey in the environment,  $a$  is the total number of that prey type (ingested + environment),  $b_d$  is the number of all other prey ingested,  $b_e$  is the number of all other prey in the environment,  $b$  is the sum of all other prey ingested and in the environment,  $d$  is the total number of prey ingested,  $e$  is the total number of prey in the environment, and  $n$  is the sum of  $d$  and  $e$ .

A positive value of C indicates a high occurrence of that prey type in the diet, a value of 0 represents no selection, and a negative value indicate a disproportionately low occurrence. All calculated indices will be tested for significance using the  $\chi^2$  statistic.

Taxonomic diversity of prey items within the diets of jellyfish species will be measured by the Shannon diversity index.

$$H' = -\sum p_i \log p_i$$

where, prey species range from  $i \dots n$  and  $p_i$  is the proportion of the total number of prey in the diet that is composed of prey species  $i$ . This value reflects both the dominance and evenness of diet composition (Costello and Colin 2002).

We will examine differences between day and night prey numbers, selection patterns, and taxonomic diversity using ANOVA techniques.

### 3.3: Diet Overlap with Planktivorous Fishes

In an extension of the monthly sampling in Suisun Marsh (as described above in Task 3.1), we will continue surveys year-round during 2007 and 2008. All fishes collected in the midwater trawl will be identified to species and counted. Thirty of each species will be measured to the nearest mm SL. We will return the majority of fishes to the water as quickly as possible, but a subset of up to 10 individuals per species per tow will be retained for gut contents. Collection of delta and longfin smelt will be reduced to 2 individuals per species per tow. These fish will immediately be preserved in 10% formalin and we will open the body cavities of individuals greater than 100mm SL to facilitate the process of diet preservation. Non-medusae zooplankton from the plankton tows will be

preserved in 5% formalin. In the lab, stomach contents will be removed, identified to the lowest taxon practical, and counted. A subset of zooplankton will also be identified and counted.

Please note: We are aware that correlation does not prove causation. This subtask serves as a crucial preliminary exploration and therefore, if significant dietary overlap does occur, a series of field enclosures and/or tank studies will be undertaken to gauge competitive interactions through the condition of fishes kept with varying densities of medusae.

The level of dietary overlap between Suisun Marsh fishes and hydromedusae will be evaluated with Pianka's symmetric niche coefficient (Pianka 1974).

$$\phi_{ij} = (\sum P_{ij}P_{ik})/(\sqrt{(\sum P_{ij}^2 \sum P_{ik}^2)})$$

where,  $P_{ij}$  is the proportion of prey type  $i$  found in the diet of species  $j$  and  $P_{ik}$  is the proportion of prey type  $i$  in the diet of species  $k$  (Freyer et al. 2003). We will also apply this analysis to individual fish species over time to examine the possibility of a diet change during bloom periods.

## TASK 4—ECOLOGICAL LABORATORY STUDIES

### 4.1: Feeding Rates

We will conduct laboratory experiments to determine predation rates on zooplankton and fish larvae for medusae and/or polyps of *M. marginata* and *Moerisia sp.* We will use individuals of average size from either our laboratory cultures outlined in Task 4.2 or collected from the field under Task 3. We will allow the medusae and polyps to acclimate to the container and conditions for 24 prior to beginning the experiment. A single medusae or polyp of average size will then be carefully placed in a 250-2000 ml glass container, containing the average density of zooplankton as in Suisun Marsh using *Artemia* or copepods, as available. Size of the experimental container will depend on the size of the specimens used. Conditions will be as is typical for Suisun Marsh in September during the height of the blooms. After medusae and polyps have fed for 1 hour, medusae/polyps will be removed from 1/3 of the replicates for each medusae/polyp x species combination and fixed in 5% formalin. All remaining live zooplankton will then be removed from the container and fixed in 5% formalin for quantification. Dead zooplankton remaining in the container will also be quantified. We will examine medusae and polyps for zooplankton attached to outer portions of their bodies and add this count to the count of zooplankton found dead but not consumed in the container. We will repeat this procedure for the remaining 2/3 of the replicates after 2 and 4 hours of feeding in order to determine if feeding rate changes over time. This entire process will also be conducted using cultured fish larvae to determine the rate at which each species can consume larval fishes. We will conduct 60 replicates each for the medusae and polyps of each species, as specimens are available. There will be 60 replicate controls for the experiment using the same techniques and density of prey with the exclusion of the hydrozoan predator. These organisms are amenable to rearing under laboratory conditions (Dr. C. Mills and Dr. J. Rees, per. comm.) and will, therefore, make experimental research feasible. Future extensions of this work may include the determination of feeding rates under different temperature and salinity conditions, zooplankton densities, and medusae sizes, as well as repeating this experiment using *C. caspia*.

We will calculate the instantaneous mortality rate ( $Z$ , hours<sup>-1</sup>) owing to predation as

$$Z = ((\ln N_i/N_p) - (\ln N_i/N_c))/T$$

Where  $N_i$  is the initial number of prey,  $N_p$  is the number of prey recovered from the containers with predators,  $N_c$  is the average number of prey recovered from the control containers, and  $T$  is the duration of the experiment in hours (de Lafontaine and Leggett 1988, Elliott and Leggett 1996, Elliott et al. 1997).

Predation rates (prey ingested per predator per hour) will be calculated as

$$I = N_i (1 - \exp(-Z))$$

We will conduct the above calculations both separately for each feeding time ( $T = 1, 2,$  and  $4$  hrs) and by averaging values across times. Predation rates will be compared among feeding times using Analysis of Variance to determine if feeding rate changes with time. We will also use ANOVA to determine if there are significant differences in feeding rates among polyps and medusae and among species.

#### 4.2: Temperature and Salinity Tolerances

We will collect *M. marginata* and *Moerisia sp.* polyps and medusae from the San Francisco Estuary (as outlined in Task 3). We will retain individuals alive and bring them back to the lab where clonal lines will be raised. Polyps will be cultured in the lab and allowed to reproduce asexually, using similar methods to Ma and Purcell (2005a and b), Rees and Gershwin (2000), and Mills and Sommer (1995). Different clonal lines will be detected by sacrificing one of the polyps produced by the parent polyp and conducting genetic analyses using the microsatellites and methods from Task 2.

We will raise four clonal lines of hydromedusae and polyps for both species under several temperature and salinity treatments. We will test the effect of temperature and salinity on survival and reproduction of medusae and polyps using a  $3 \times 3$  full factorial design. Salinity treatments will be 0, 8, and 16‰ salinity. Temperature treatments will be 10, 17, and 25°C. These temperature and salinity treatments represent the natural range of potential conditions experienced by these species in Suisun Bay during the medusae bloom (R. E. Schroeter, per. comm.). We will conduct pilot studies to examine the level of responses to the extreme values of temperature and salinity. We will use the outcomes of the pilot study to adjust the experimental conditions, as necessary, prior to conducting the full experiment. Each replicate will be a 250–4000 ml glass jar (depending on medusae size) holding four polyps or medusae of the same clonal line. The experimental design will be a split plot design with salinity treatments randomized within each temperature treatment as main plots. Temperature treatments will be maintained in a water bath or growth chamber. We will conduct two replicates of salinity treatments within each of two temperature treatment replicates. The experiment will run for ~30 days. Medusae and polyps will be fed *Artemia* or copepods from Suisun Marsh, as available. Each day, we will provide medusae and polyps a standard density of prey as representative of the mean zooplankton availability in Suisun Marsh. We will count any newly formed polyp and medusa buds on each polyp and remove newly liberated medusae and polyps from the jar. We will additionally record survival of polyps and medusae each day and remove any dead individuals from the experiment. Future work may include testing responses at a finer scale of temperature and salinity at the experimental condition extremes, as well as repeating the above described experiments using *C. caspia*.

All data will be analyzed using ANOVA to test for differences in reproduction and survival among temperature and salinity treatments and clonal lines within species. We will also test for differences

in survival and reproduction in temperature and salinity treatments among species as well as any possible interactions among factors.

## DELIVERABLES

Research findings and progress from these tasks will be distributed in quarterly reports, our final report, at presentations during national and local meetings, and in articles submitted to both the IEP Newsletter and peer-reviewed publications (Table 1). In addition, data collected from all midwater trawl surveys will be added to the existing long-term sampling database of otter trawl and seine information from Dr. Peter Moyle’s Suisun Marsh Sampling Program, which is posted on the IEP website. This pairing will lead to further understanding of this system.

Table 1: Tasks with key personnel and deliverables for each.

Task	Description	Key Personnel	Deliverables
1	Project Management	All	<ul style="list-style-type: none"> <li>• Semi-annual Reports</li> <li>• Final Reports</li> <li>• Project Summaries for public (beginning/completion)</li> <li>• Project closure report</li> <li>• Presentations at CALFED Science Conference</li> </ul>
2	Genetic Analyses	May and Meek	<ul style="list-style-type: none"> <li>• Presentations at regional and national/international conferences</li> <li>• Draft scientific paper: Methods note on marker development</li> <li>• Draft scientific paper: Clonal diversity and relative contribution of asexual and sexual reproduction</li> </ul>
3	Ecological Field Studies	Moyle and Wintzer	<ul style="list-style-type: none"> <li>• Presentations at regional and national/international conferences</li> <li>• Draft scientific paper: Factors influencing abundance and distribution of invasive hydrozoans (medusae and polyps) in the SFE</li> <li>• Draft scientific paper: Temporal feeding behavior and diet preference in coexistent jellyfishes.</li> <li>• Draft scientific paper: Predation on larval fishes by invasive jellyfishes</li> <li>• Draft scientific paper: Diet overlap between invasive hydrozoans and planktivorous fishes in the SFE</li> </ul>
4	Ecological Laboratory Studies	May and Meek	<ul style="list-style-type: none"> <li>• Presentations at regional and national/international conferences</li> <li>• Draft scientific paper: Analysis of feeding rates on zooplankton and larval fishes</li> <li>• Draft scientific paper: Determination of salinity and temperature tolerances</li> </ul>

## **FEASIBILITY**

The proposed study is feasible due to the combination of 1) researcher experience, 2) the few contingencies or requirements for completion, and 3) available facilities for research.

1) Dr. Bernie May, the lead PI for this proposal, has been the director of the Genomic Variation Laboratory at UC Davis for the past 11 years and has significant experience in project management. Dr. Peter Moyle, also at UC Davis, has been monitoring the ecology of Suisun Marsh for nearly 30 years and wrote the book (literally) on California fishes. Both Mariah Meek and Alpa Wintzer have specialized training and experience in genetics and trophic ecology, respectively. Management decisions will be made during weekly meetings led by Dr. May.

2) The research outlined in this proposal is not dependent on the outcomes of other projects and is, with the exception of Task 3, independent of natural conditions (i.e. weather). Scientific collection permits (CDFG) and an Animal Use and Care Protocols (Animal Care and Use #12338 UC Davis) have both been obtained. Fish sampling within Suisun Marsh will occur as an extension of the long-term UC Davis monitoring program managed by Dr. Peter Moyle. Take of delta smelt is expected to fall well below the limit set by the IEP for the Suisun Marsh Sampling Program. A minor constraint for this project involves the difficulty in locating and collecting large numbers of medusae of *B. virginica* and polyps of *M. marginata*. This may hinder full-scale investigations of these species and stages. In these cases, the maximum amount of data possible will be utilized.

3) UC Davis has the appropriate genetic laboratories and hydromedusae and plankton rearing facilities required for this project. Genetic analyses will be conducted in Dr. May's fully equipped Genomic Variation Laboratory and hydrozoans will be cultured using the Center for Aquatic Biology and Aquaculture (CABA) facilities at UC Davis.

## **RELEVANCE TO THE CALFED SCIENCE PROGRAM**

This research program will directly address the following three CALFED Priority Research Topic areas and associated questions:

### 1) Aquatic Invasive Species

Our research will add to the understanding of how these predatory aquatic invaders are impacting at-risk species in the SFE and their role in driving ecological processes. It will address the following questions: How are hydrozoan invaders affecting Delta environmental conditions via consumption of zooplankton? What are the key factors allowing successful establishment, distribution, and survival of these invasives? What will the response of these invasives be to possible future conditions?

### 2) Trends and Patterns of Populations and System Response to a Changing Environment

What are possible responses of hydrozoans to different management strategies (water regulation)? How will these responses to different water management strategies impact key fish species? What is the relationship between environmental conditions and hydrozoans?

### 3) Habitat Availability and Response to Change

How will future scenarios affect hydrozoan abundance and distribution and how will this in turn affect key fish species at different geographic and temporal scales?

Our research will include the analysis, integration, and synthesis of existing information on distribution and abundance of the invasive hydrozoan species. Additionally, it will incorporate data on the zooplankton and fish communities. The findings of this research yield a more comprehensive understanding of the system and can be further integrated with current IEP data to form a predictive model. Such a model will allow a direct and tangible method of incorporating past and new data into management practices and policy decisions and will demonstrate both the likely effect these invasives currently have on the system and predict the future impact on the system via scenarios of climate change and water management.

This research program will address the larger CALFED goals of understanding the causes of the pelagic organism decline and management for overall health for the SFE ecosystem. Due to the high likelihood that these invaders are having a negative impact on the SFE community, it is important to understand their basic biology. With this understanding, their level of impact on the system can be determined and the most prudent management decisions made. This work fills the gap left from previous investigations into the cause of the pelagic organism decline.

## **QUALIFICATIONS**

Dr. Bernie May received his PhD in Genetics from the Pennsylvania State University in 1980. He served for 14 years at Cornell University as Director of the Cornell Laboratory for Ecological and Evolutionary Genetics. For the past eleven years he has been the Director of the Genomic Variation Laboratory in the Department of Animal Science at UC Davis. He currently has 11 PhD students working in his laboratory who use a variety of molecular techniques (AFLPs, microsatellites, SSCP, sequencing, microarrays, etc.) to study genomic variation in natural and aquacultural populations. He has published over 150 scientific papers on questions related to genomic structure, linkage of markers to QTLs, population analysis, mixed stock analysis, genomic manipulation, effects of non-indigenous species/populations, effects of toxicants on gene pools, and isolate identification in a wide range of fish, fungi, birds, mammals, plants, and invertebrates. Current target organisms include: salmonids (golden trout, redband trout, Chinook salmon, rainbow trout, cutthroat trout), suckers, tui chub, splittail, delta smelt, Sacramento perch, Shasta crayfish, and sturgeon (lake, green, and white). He is currently a member of the Central Valley Salmonid Technical Recovery Team and annually hosts the CDFG Threatened Trout Committee. Relevant to this work he was the discoverer of the “Quagga” mussel in the Great Lakes, a morphologically similar species to the zebra mussel. He has also published on the temperature and salinity differences between these two invasive invertebrates. Dr. May has prior CALFED funding and extensive experience in project management. He will be the overall supervisor of this project, ensuring that all tasks are accomplished and all promised deliverables are produced.

**For more details see:**

**<http://genome-lab.ucdavis.edu/People/BernieMay/default.htm>**

Dr. Peter B. Moyle has been studying the ecology and conservation of freshwater and estuarine fishes in California since 1969 and has been working on fishes of the San Francisco Estuary since 1976. He has documented the declining status of many native species in California, such as coho and Chinook salmon, and has been active in developing conservation strategies for aquatic species and ecosystems. He also studies the invasions of alien species and works on strategies for reducing

their impacts on native species. He was head of the Delta Native Fishes Recovery Team, a member of the National Research Council's Committee on Endangered and Threatened Fishes in the Klamath River Basin, and a member of the Science Board for the CALFED Ecosystem Restoration Program. He is currently a member of DWR's Delta Risk Management Strategy steering committee. He is author/coauthor of over 160 scientific papers and 5 books. His books include *Inland Fishes of California* (2002) and *Fishes*, the nation's leading fish biology text (5<sup>th</sup> edition, 2004, with J. Cech). He is a professor of fish biology in the Department of Wildlife, Fish, and Conservation Biology, University of California, Davis, where he teaches basic courses in fish biology, watershed ecology, and wildlife conservation. He is also associate director of the new Center for Watershed Sciences and shares the President's Chair in Undergraduate Education with J. Mount, Geology.

**For more details see: <http://wfc.ucdavis.edu/www/faculty/Peter/petermoyle/default.htm>.**

Alpa Wintzer holds a BA from Boston University in Biology with specialization in Marine Science and a MS from the University of South Florida in Zoology. Currently, she is a second year graduate student in Dr. Peter Moyle's lab at the University of California, Davis. Ms. Wintzer is a Fellow in the NSF-IGERT program for Biological Invasions and has been researching various aspects of feeding biology in fishes for the past 6 years. Her publishing record includes 4 peer-reviewed articles with 3 more in preparation. She has given numerous presentations at international, national, and regional scientific conferences. As an employee for both the Aquatic Ecology Laboratory (The Ohio State University) and the USFWS (juvenile salmon monitoring program in Stockton), Ms. Wintzer has gained a high level of field collection experience. In addition, she is trained in regional larval fish identification and diet analysis.

Mariah Meek holds a BS from the University of Washington in Biology and Zoology with a minor in Fisheries Science. Currently, she is a third year doctoral student in Dr. Bernie May's lab at the University of California, Davis and is a National Oceanic and Atmospheric Administration Dr. Nancy Foster Scholar. Ms. Meek has much experience conducting marine and aquatic ecological research, as well as experience using molecular techniques to address ecological questions. She worked for several years as an Environmental Scientist for Windward Environmental, LLC conducting aquatic risk assessment and habitat restoration. Ms. Meek has extensive field and laboratory research experience, working on projects ranging from field investigations into estuaries as rearing environments for larval crabs and fishes to population structure of Pacific coast rockfish species using molecular markers.

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# BERNIE MAY

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## EDUCATION

Ph.D., The Pennsylvania State University, in Genetics--1980

"The salmonid genome: evolutionary restructuring following a tetraploid event."

M.S., University of Washington, in Fisheries--1975

"Electrophoretic variation in the genus *Oncorhynchus*: the methodology, genetic basis, and practical applications to fisheries research and management."

B.S., University of Washington, in Molecular Biology--1973

## EMPLOYMENT

1995 to present Adjunct Professor, Director, Genomic Variation Laboratory, Department of Animal Science, Univ. of California, Davis, CA.

1981-1995 Senior Research Associate and Director, Cornell Laboratory for Ecological and Evolutionary Genetics (CLEEG), Department of Natural Resources, Cornell University, Ithaca, NY.

## RESEARCH INTERESTS

My research over the past three decades has centered around the use of discrete Mendelian data to answer a broad array of biological questions in fungi, fish, plants, invertebrates, birds, and mammals. One of my primary roles has been to provide a genetics perspective to the collaborative projects with which I have been involved. During the past 10 years my laboratory has come to focus primarily on questions in conservation biology regarding the "genetic health" and "genetic integrity" of natural populations of threatened and endangered fish species. Examples of these questions include: How do we identify populations for preservation?, How do we measure loss of genetic variability?, What remnants of native populations remain after extensive stocking with non-indigenous populations?, How different must two populations be for them to be maintained and managed separately? My program also includes a major emphasis on mapping QTLs in aquacultural species and some effort devoted to the use of AFLPs and microsatellites to detect the effects of toxicants on the gene pools of indigenous species. I am currently developing the use of expression technologies as a more suitable technology to examine the effects of toxicants and disease.

## UCDAVIS GRADUATE STUDENT THESIS COMMITTEES

	<u>MS-chair</u>	<u>MS-member</u>	<u>PhD-chair</u>	<u>PhD-member</u>
1997-2006	4	4	9	11
Current	0	3	11	3

## SCIENTIFIC ARTICLES (selected publications from 150+)

- Baerwald, M., V. Bien, F. Feyrer, and B. May. In Press. Microsatellite analysis reveals two genetically distinct Sacramento Splittail (*Pogonichthys macrolepidotus*) populations in the San Francisco Estuary. *Cons. Gen.*
- Chen, Y., S. Parmenter, and B. May. In Press. Introgression between Lahontan and endangered Owens tui chubs, and discovery of toikona tui chub in the Owens Valley, California. *Cons. Gen.*
- Lindley, S. T. E. Mora, R. S. Schick, J. J. Anderson, S. Greene, C. Hanson, A. Low, B. P. May D. McEwan, R. B. MacFarlane, C. Swanson, and J. G. Williams. In Press. Viability of threatened and endangered chinook salmon and steelhead ESUs in the Sacramento-San Joaquin basin. *SF Est. Wtshd. Sci.*
- Papa R., J.A. Israel, F. N. Marzan, and B. May. In Press. Assessment of genetic variation among reproductive ecotypes of Klamath River steelhead reveals differentiation associated with different run-timings. *J. Appl. Ichthy.*
- Sprowles, A.E., M.R. Stephens, N.W. Clipperton, and B.P. May. In Press. Fishing for SNPs: a targeted locus approach for Single Nucleotide Polymorphism discovery in rainbow trout. *Trans. Am. Fish. Soc.*
- Welsh, A. and B. May. In Press. Development and standardization of disomic microsatellite markers for lake sturgeon genetic studies. *J. Appl. Ichthy.*
- Cordes, J.F., M.R. Stephens, M.A. Blumberg, and B. May. 2006. Identifying introgressive hybridization in native populations of California Golden Trout based on molecular markers. *Trans. Am. Fish. Soc.* 135:110-128.
- Ibarra, A.M., J.L. Petersen, T.R. Famula, and B. May. 2006. Characterization of 35 microsatellite loci in the Pacific lion-paw scallop (*Nodipecten subnodosus*) and their cross-species amplification in four other scallops of the Pectinidae family. *Mol. Ecol. Notes.* 6:153-156.
- Lindley, S.T., R.S. Schick, A. Agrawal, M. Goslin, T. Pearson, E. Mora, J. J. Anderson, B.P. May, S. Greene, C. Hanson, A. Low, D. McEwan, R.B. MacFarlane, C. Swanson and J.G. Williams. 2006. Historical population structure of Central Valley steelhead and its alteration by dams. *SF Est. Wtshd. Sci.* 4(1): Article 3.
- Tranah, G.J., and B. P. May. 2006. Patterns of Intra- and Interspecies Genetic Diversity in Klamath River Basin Suckers. *Trans. Am Fish. Soc.* 135:306–316.
- Cordes, J.F., D.L. Perkins, H.L.Kincaid, and B. May. 2005. Genetic analysis of fish genomes and populations: allozyme variation within and among Atlantic salmon from downeast rivers of Maine. *J. Fish Biology.* 67:104-117.
- Williamson, K. and B. May. 2005. Homogenization of fall-run chinook salmon gene pools in the Central Valley of California, USA. *N. Am. J. Fish. Man.* 25:993–1009.
- Williamson, K. and B. May. 2005. Inheritance studies implicate a genetic mechanism for apparent sex-reversal in Chinook salmon. *Trans. Am. Fish. Soc.* 134:1253–1261.
- Baerwald, M.R. and B. May. 2004. Characterization of microsatellite loci for five members of the minnow family Cyprinidae found in the Sacramento - San Joaquin Delta. *Mol. Ecol. Notes.* 4:385-390.
- Cordes, J.F., J.A. Israel and B. May. 2004. Conservation of Paiute cutthroat: the genetic legacy of population transplants in an endemic California salmonid. *CA Fish and Game.* 90-101-118.
- Israel, J.A., J.F. Cordes, M.A. Blumberg, and B. May. 2004. Geographic patterns of genetic differentiation among collections of green sturgeon. *N. Am. J. Fish. Man.* 24:922-931.
- Rodzen, J.A., T. Famula, and B. May. 2004. Estimation of parentage and relatedness in the polyploid white sturgeon *Acipenser transmontanus* using a dominant marker approach for duplicated microsatellite loci. *Aquaculture* 232:165-182.
- Schwartz, R.S. and B. May. 2004. Characterization of microsatellite loci in Sacramento perch (*Archoplites interruptus*). *Mol. Ecol. Notes.* 4:694-697.

- Tranah, G.J., D.E. Campton and B. May. 2004. Genetic evidence for hybridization of pallid and shovelnose sturgeon. *J. Hered.* 95:474-480.
- Beyer, J. and B. May. 2003. A graph-theoretic approach to the partition of individuals into full-sib families. *Mol. Ecol.* 12:2243-2250.
- May, B. 2003. Allozyme variation. In: *Population Genetics: Principles and Applications for Fisheries Scientists*, Ed. E. Hallerman. Amer. Fish. Soc. Pp. 23-36.
- McQuown, E., C.C. Krueger, H.L. Kincaid, G.A.E. Gall, and B. May. 2003. Genetic comparison of lake sturgeon (*Acipenser fulvescens*) populations: differentiation based on allelic frequencies at seven microsatellite loci. *J. Great Lakes Res.* 29:3-13.
- Tranah, G.J., M.J. Bagley, J.J. Agresti, and B. May. 2003. Development of codominant markers for identifying species hybrids. *Cons. Gen.* 4:537-541.
- Whitehead, A., S.L. Anderson, K.M. Kuivila, J.L. Roach, and B. May. 2003. Genetic variation among interconnected populations of *Catostomus occidentalis*: implications for distinguishing impacts of contaminants from biogeographic structuring. *Mol. Ecol.* 12: 2817-2833.
- Rodzen, J.A. and B. May. 2002. Inheritance of microsatellite loci in the white sturgeon (*Acipenser transmontanus*). *Genome* 45:1064-1076.
- Smith, C.T., R.J. Nelson, S. Pollard, E. Rubidge, S.J. McKay, J. Rodzen, B. May, and B. Koop. 2002. Population genetic analysis of white sturgeon (*Acipenser transmontanus*) in the Fraser River. *J. Appl. Ichthy.* 18:307-312.
- Williamson, K. and B. May. 2002. Incidence of phenotypic female chinook salmon (*Oncorhynchus tshawytscha*) positive for the Y-chromosome specific marker OtY1 in the Central Valley. *J. Aquat. An. Health.* 176-183.
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- Spidle, A.P., E.L. Mills, and B. May. 1995. Absence of naturally occurring hybridization between the quagga mussel (*Dreissena bugensis*) and the zebra mussel (*D. polymorpha*). *Can. J. Zool.* 73:400-403.
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<b>BUDGET SUMMARY</b>	<b>Total Amount for Year 1</b>	<b>Total Amount for Year 2</b>	<b>Total Amount for Year 3</b>	<b>Total Amount for All Years</b>
<b>Total Costs for Task One</b>	\$ 11,540.00	\$ 12,165.00	\$ 12,885.00	\$ 36,590.00
<b>Total Costs for Task Two</b>	\$ 93,236.25	\$ 68,593.75	\$ 71,226.25	\$ 233,056.25
<b>Total Costs for Task Three</b>	\$ 14,625.00	\$ 53,290.00	\$ 49,780.00	\$ 117,695.00
<b>Total Costs for Task Four</b>	\$ 13,508.75	\$ 13,687.50	\$ 16,332.50	\$ 43,528.75
<b>Total Costs for Project Tasks</b>	\$ 132,910.00	\$ 147,736.25	\$ 150,223.75	\$ 430,870.00
<b>1/Cost Share</b>	\$ 80,000.00	\$ 40,000.00	\$ 40,000.00	\$ 160,000.00
<b>2/ Other Matching Funds</b>	\$ -	\$ -	\$ -	\$ -

1/ *Cost share funds* are specifically dedicated to your project and can include private and other State and Federal grants. Any funds listed in this line must be further described in the text of your proposal (see Chapter 3, Section D, of the PSP document)

2/ *Other matching funds* include other funds invested consistent with your project in your project area for which the ERP grant applicant is not eligible. Any funds listed in this line must be further described in the text of your proposal (see Chapter 3, Section D, of the PSP document)



BUDGET FOR TASK TWO	Year 1			Year 2			Year 3			
	TOTAL AMOUNT TASK 2 All Years	Amount per hour	Number of Hours	Total Amount for Year 1	Amount per hour	Number of Hours	Total Amount for Year 2	Amount per hour	Number of Hours	Total Amount for Year 3
<b>Personnel</b>										
Adjunct Professor V (B. May)	\$ 57,050.00	\$ 53.00	350	\$ 18,550.00	\$ 53.00	350	\$ 18,550.00	\$ 57.00	350	\$ 19,950.00
SRA II -TBD	\$ 23,100.00	\$ 17.00	440	\$ 7,480.00	\$ 17.50	440	\$ 7,700.00	\$ 18.00	440	\$ 7,920.00
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<b>Personnel Subtotal</b>	<b>\$ 80,150.00</b>			<b>\$ 26,030.00</b>			<b>\$ 26,250.00</b>			<b>\$ 27,870.00</b>
<sup>1/</sup> Benefits as percent of salary	30%			\$7,809.00			\$7,875.00			\$8,361.00
<b>Personnel Total (salary + benefits)</b>	<b>\$104,195.00</b>			<b>\$33,839.00</b>			<b>\$34,125.00</b>			<b>\$36,231.00</b>
<b>Other Costs</b>	<b>Total All Years</b>			<b>Total Year 1</b>			<b>Total Year 2</b>			<b>Total Year 3</b>
Operating Expenses: (ex: seed, plant materials, irrigation supplies, software, office supplies, etc)	\$ 77,000.00			\$ 39,000.00			\$ 19,000.00			\$ 19,000.00
2/ Travel and Per Diem	\$ 5,250.00			\$ 1,750.00			\$ 1,750.00			\$ 1,750.00
3/ Equipment	\$ -			\$ -			\$ -			\$ -
4/ Sub-Contractor	\$ -			\$ -			\$ -			\$ -
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<b>Other Costs Subtotal</b>	<b>\$ 82,250.00</b>			<b>\$ 40,750.00</b>			<b>\$ 20,750.00</b>			<b>\$ 20,750.00</b>
<sup>5/</sup> Overhead Percentage (Applied to Personnel & Other Costs)	25%			\$ 18,647.25			\$ 13,718.75			\$ 14,245.25
<b>Total Costs for Task Two</b>	<b>\$ 233,056.25</b>			<b>\$ 93,236.25</b>			<b>\$ 68,593.75</b>			<b>\$ 71,226.25</b>

1/ Indicate your rate, and change formula in column immediately to the right of this cell

2/ Travel expenses and per diem must be at rates specified by the Department of Personnel Administration. The contractor is required to maintain travel receipts and records for auditing purposes. No travel out of the state of California shall be reimbursed unless prior written authorization is obtained from the State.

3/ Please provide a list and cost of major equipment (\$5,000 or more) to be purchased, and complete "Equipment Detail" Worksheet

4/ Please list each subcontractor and amounts (if subcontractor not selected yet, use function like "ditch construction subcontractor")

5/ Indicate rate in column immediately to the right of this cell; and provide a description of what expenses are covered by overhead. If overhead is > 15% must provide justification

BUDGET FOR TASK THREE	Year 1			Year 2			Year 3			
	TOTAL AMOUNT TASK 3 All Years	Amount per hour	Number of Hours	Total Amount for Year 1	Amount per hour	Number of Hours	Total Amount for Year 2	Amount per hour	Number of Hours	Total Amount for Year 3
<b>Personnel</b>										
Graduate Research Assistant (A. Wintzer)	\$ 44,720.00	\$ -		\$ -	\$ 21.00	1040	\$ 21,840.00	\$ 22.00	1040	\$ 22,880.00
Undergraduate Assistant - TBD	\$ 15,000.00	\$ 10.00	500	\$ 5,000.00	\$ 10.00	500	\$ 5,000.00	\$ 10.00	500	\$ 5,000.00
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<b>Personnel Subtotal</b>	<b>\$ 59,720.00</b>			<b>\$ 5,000.00</b>			<b>\$ 26,840.00</b>			<b>\$ 27,880.00</b>
<sup>1/</sup> Benefits as percent of salary		5%		\$250.00			\$1,342.00			\$1,394.00
<b>Personnel Total (salary + benefits)</b>	<b>\$62,706.00</b>			<b>\$5,250.00</b>			<b>\$28,182.00</b>			<b>\$29,274.00</b>
<b>Other Costs</b>	<b>Total All Years</b>			<b>Total Year 1</b>			<b>Total Year 2</b>			<b>Total Year 3</b>
Operating Expenses: (ex: seed, plant materials, irrigation supplies, software, office supplies, etc)	\$ 9,400.00			\$ 4,700.00			\$ 4,700.00			
2/ Travel and Per Diem	\$ 5,250.00			\$ 1,750.00			\$ 1,750.00			\$ 1,750.00
3/ Equipment	\$ -			\$ -			\$ -			\$ -
Tuition and Fees	\$ 21,000.00						\$ 10,000.00			\$ 11,000.00
4/ Sub-Contractor	\$ -			\$ -			\$ -			\$ -
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<b>Other Costs Subtotal</b>	<b>\$ 35,650.00</b>			<b>\$ 6,450.00</b>			<b>\$ 16,450.00</b>			<b>\$ 12,750.00</b>
<sup>5/</sup> Overhead Percentage (Applied to Personnel & Other Costs)		25%		\$ 2,925.00			\$ 8,658.00			\$ 7,756.00
<b>Total Costs for Task Three</b>	<b>\$ 117,695.00</b>			<b>\$ 14,625.00</b>			<b>\$ 53,290.00</b>			<b>\$ 49,780.00</b>

1/ Indicate your rate, and change formula in column immediately to the right of this cell

2/ Travel expenses and per diem must be at rates specified by the Department of Personnel Administration. The contractor is required to maintain travel receipts and records for auditing purposes. No travel out of the state of California shall be reimbursed unless prior written authorization is obtained from the State.

3/ Please provide a list and cost of major equipment (\$5,000 or more) to be purchased, and complete "Equipment Detail" Worksheet

4/ Please list each subcontractor and amounts (if subcontractor not selected yet, use function like "ditch construction subcontractor")

5/ Indicate rate in column immediately to the right of this cell; and provide a description of what expenses are covered by overhead. If overhead is > 15% must provide justification

BUDGET FOR TASK FOUR	Year 1			Year 2			Year 3			
	TOTAL AMOUNT TASK 4 All Years	Amount per hour	Number of Hours	Total Amount for Year 1	Amount per hour	Number of Hours	Total Amount for Year 2	Amount per hour	Number of Hours	Total Amount for Year 3
<b>Personnel</b>										
Adjunct Professor V (B. May)	\$ 8,150.00	\$ 53.00	50	\$ 2,650.00	\$ 53.00	50	\$ 2,650.00	\$ 57.00	50	\$ 2,850.00
SRA II - TBD	\$ 11,550.00	\$ 17.00	220	\$ 3,740.00	\$ 17.50	220	\$ 3,850.00	\$ 18.00	220	\$ 3,960.00
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<b>Personnel Subtotal</b>	<b>\$ 19,700.00</b>			<b>\$ 6,390.00</b>			<b>\$ 6,500.00</b>			<b>\$ 6,810.00</b>
<sup>1/</sup> Benefits as percent of salary	30%			\$1,917.00			\$1,950.00			\$2,043.00
<b>Personnel Total (salary + benefits)</b>	<b>\$25,610.00</b>			<b>\$8,307.00</b>			<b>\$8,450.00</b>			<b>\$8,853.00</b>
<b>Other Costs</b>	<b>Total All Years</b>			<b>Total Year 1</b>			<b>Total Year 2</b>			<b>Total Year 3</b>
Operating Expenses: (ex: seed, plant materials, irrigation supplies, software, office supplies, etc)	\$ 9,213.00			\$ 2,500.00			\$ 2,500.00			\$ 4,213.00
2/ Travel and Per Diem	\$ -			\$ -			\$ -			\$ -
3/ Equipment	\$ -			\$ -			\$ -			\$ -
4/ Sub-Contractor	\$ -			\$ -			\$ -			\$ -
4/ Sub-Contractor	\$ -			\$ -			\$ -			\$ -
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4/ Sub-Contractor	\$ -			\$ -			\$ -			\$ -
<b>Other Costs Subtotal</b>	<b>\$ 9,213.00</b>			<b>\$ 2,500.00</b>			<b>\$ 2,500.00</b>			<b>\$ 4,213.00</b>
<sup>5/</sup> Overhead Percentage (Applied to Personnel & Other Costs)	25%			\$ 2,701.75			\$ 2,737.50			\$ 3,266.50
<b>Total Costs for Task Four</b>	<b>\$ 43,528.75</b>			<b>\$ 13,508.75</b>			<b>\$ 13,687.50</b>			<b>\$ 16,332.50</b>

1/ Indicate your rate, and change formula in column immediately to the right of this cell

2/ Travel expenses and per diem must be at rates specified by the Department of Personnel Administration. The contractor is required to maintain travel receipts and records for auditing purposes. No travel out of the state of California shall be reimbursed unless prior written authorization is obtained from the State.

3/ Please provide a list and cost of major equipment (\$5,000 or more) to be purchased, and complete "Equipment Detail" Worksheet

4/ Please list each subcontractor and amounts (if subcontractor not selected yet, use function like "ditch construction subcontractor")

5/ Indicate rate in column immediately to the right of this cell; and provide a description of what expenses are covered by overhead. If overhead is > 15% must provide justification

## **Budget Justification**

### **Task 1 – Administration**

#### **Personnel**

Dr. May will devote 120 hours per year to the administration of this project. Dr. May is a 100% soft money scientist. Fringe benefits are estimated at 20% for this task.

#### **Operating Expenses**

We request \$600 per year for office related costs (phone, postage, copying, etc.) and \$500, \$1,000, and \$1,000 for publication charges for manuscripts in years 1, 2, and 3, respectively.

#### **Travel**

We request \$500 per year for in state travel in the administration of this contract.

#### **Indirect Cost Rate**

Please note that the University of California, Davis federally negotiated indirect cost rate agreement is currently 51.5% of Modified Total Direct Costs (MTDC). However, the University has an approved rate with State Agencies for 25% MTDC. The MTDC base excludes equipment capital expenditures in excess of \$5,000, patient care costs, tuition remission, rental costs, scholarships and fellowships, as well as the portion of each subcontract in excess of \$25,000. When applicable, these items have been excluded when calculating the indirect costs.

### **Task 2 - Genetic Studies**

#### **Personnel**

Dr. May will devote 350 hours per year to this phase of the project. An SRAII (to be determined) will devote 440 hours per year to assist in the genetic studies outlined in the proposal. Fringe benefits are estimated at 30%. PhD student Mariah Meek will perform much of the work and this section will constitute a major portion of her PhD dissertation. Ms. Meek has just started a four year Dr. Nancy Foster marine biology fellowship for her stipend and tuition and fees.

#### **Operating Expenses**

Funds of \$39,000 in year 1 and \$19,000 in years 2 and 3 to cover the molecular studies in this project and equipment maintenance (estimated at \$6,000 per year). The extra cost of \$20,000 in year 1 is to cover the purchase of four enriched microsatellite libraries, sequencing of 300+ clones, and primer development. The May lab has extensive experience in this aspect of the project.

#### **Travel**

Travel expenses of \$1750 are requested for Ms. Meek to attend one national/international meeting and two regional meetings per year to present the results of this work.

### **Task 3 - Ecological Field Studies**

#### **Personnel**

PhD student Alpa Wintzer will conduct the studies on this task under the direction of Dr. Moyle. Ms. Wintzer is in the third year of an IGERT fellowship and will need two years of support from this contract. Her tuition and fees for these two years are estimated based on recent historical trends for these costs. Undergraduate help is needed to assist Ms. Wintzer and budgeted at \$10 hr.

#### **Operating Expenses**

Field sampling expenses of \$4700 per year in each of years 1 and 2 are requested (truck rental for 20 days at \$130/day, 300 gal of gas at \$3.50 per gallon, boat maintenance at \$600, and field supplies of \$450).

#### **Travel**

Travel expenses of \$1750 per year are requested for Ms. Wintzer to attend one national/international meeting and two regional meetings per year to present the results of this work.

### **Task 4 - Ecological Laboratory Studies**

#### **Personnel**

Dr. May will devote 120 hours per year and the SRA 220 hours per year to this task. Fringe benefits are estimated at 30%. Ms. Meek will do much of the work on this task.

#### **Operating Expenses**

Funds of \$2500 are requested each year to cover the costs of aquaria, fish food, and space rental and field sampling in year 3 of \$1713 (truck rental for 5 days at \$130/day, 75 gal of gas at \$3.50 per gallon, boat maintenance at \$600, and field supplies of \$200).

## Cost Share

### Personnel

Year 1 – A. Wintzer, IGERT fellowship for stipend and tuition/fees	\$40,000
M. Meek, Dr. Nancy Foster Fellowship for stipend and tuition/fees	\$32,000
P. Moyle, 5% time, Professor VII, salary and fringe	\$8,000
Total	<b>\$80,000</b>
Year 2 – M. Meek, Dr. Nancy Foster Fellowship for stipend and tuition/fees	\$32,000
P. Moyle, 5% time, Professor VII, salary and fringe	\$8,000
Total	<b>\$40,000</b>
Year 3 – M. Meek, Dr. Nancy Foster Fellowship for stipend and tuition/fees	\$32,000
P. Moyle, 5% time, Professor VII, salary and fringe	\$8,000
Total	<b>\$40,000</b>

California Home

## Signature

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

*Failure to sign and submit this form will result in the application not being considered for funding.* The individual submitting this proposal will receive e-mail confirmation as soon as this signature page has been processed.

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 confidentiality 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:** Predicting the effects of invasive hydrozoa (jellyfish) on pelagic organisms under changing saline and temperature regimes

**Proposal Number:** 2006.01-0026

**Applicant Organization:** University of California at Davis

**Applicant Contact:** Kimberly Lamar

**Applicant Signature**

**Date**

Kimberly Lamar

8/30/06

Help is available: [help@solicitation.calwater.ca.gov](mailto:help@solicitation.calwater.ca.gov), +1 877 408-9310

We care about the data we collect. Please read our [privacy policy](#).

URL:

<https://solicitation.calwater.ca.gov/solicitations/2006.01/proposals/0026/forms/60>

time: 2006-08-25 11:18:25 PST

user ID: mariahmeeek

client IP: 169.237.145.187

## UNIVERSITY OF CALIFORNIA, DAVIS

BERKELEY • DAVIS • IRVINE • LOS ANGELES • MERCED • RIVERSIDE • SAN DIEGO • SAN FRANCISCO



SANTA BARBARA • SANTA CRUZ

Kimberly Lamar, Contracts and Grants Analyst  
Office of Research, Sponsored Programs  
1850 Research Park Drive, Suite 300  
Davis, California 95618

Sponsored Programs, 118 Everson Hall  
Telephone: (530) 747-3924  
Fax: (530) 747-3929  
e-mail: [kdlamar@ucdavis.edu](mailto:kdlamar@ucdavis.edu)

August 30, 2006

California Bay-Delta Authority  
650 Capitol Mall, 5<sup>th</sup> Floor  
Sacramento CA 95814

To Whom It May Concern:

Letter in Support of Project Entitled  
"Predicting the Effects of Invasive Hydrozoa (jellyfish) on Pelagic Organisms Under Changing  
Saline and Temperature Regimes"  
Principal Investigator- Dr. Bernie May, UCD

It is our pleasure to forward institutional support and approval of the collaboration by UCD's Dr. May on the referenced research project to the California Bay-Delta Authority Science Program.

Please note as outlined in Attachments 1 and 2 of the CALFED Science Program Solicitation UCD takes exception to the following proposed standard clauses:

- Exhibit C – General Terms and Conditions for Science Program Grants (specifically Indemnification and Termination clauses)
- Exhibit D – Special Terms and Conditions for Science Program Grants

Should CALFED make an award to the University, we would anticipate negotiating terms that comply with University guidelines as they pertain to the higher learning institutions and retention of intellectual property rights.

Please contact the principal investigator for scientific information. Administrative questions may be directed to me by telephone, facsimile or electronic mail at the numbers cited above.

Sincerely,

A handwritten signature in cursive script that reads 'Kimberly Lamar'.

Kimberly Lamar, CRA  
Contracts & Grants Analyst

cc: Dr. Bernie May

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UNIVERSITY OF CALIFORNIA, DAVIS

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Department of Animal Science  
Telephone: (530) 752 – 1250  
Facsimile: (530) 752 – 0175

One Shields Avenue  
Davis, California 95616  
August 24, 2006

Bernie May, Adjunct Professor  
Department of Animal Science  
Director, Genomic Variation Laboratory  
University of California, Davis  
One Shields Avenue  
Davis, CA 95616

Dear Bernie:

I enjoyed our recent discussions regarding your plans to conduct temperature/salinity tolerance tests and feeding rates studies of the different invasive jellyfish in the Delta. I know you have published in the past on temperature/salinity tolerance differences between zebra and quagga mussels, so that part should be reasonably straightforward. My experience at rearing and nutritional studies of marine invertebrates should provide the other expertise that you and Mariah will need. The rearing studies can be done at the facilities in our department and/or at CABA. I hope you are successful in your efforts to secure the funding and I look forward to helping in any way I can.

Best wishes,

A handwritten signature in dark ink, appearing to read "Douglas E. Conklin".

Douglas E. Conklin, Professor

Phone: 530/ 752 – 4177  
E-mail: [deconklin@ucdavis.edu](mailto:deconklin@ucdavis.edu)

24<sup>th</sup> August 2006

To the CALFED Science Program funding review committee,

I am writing to support the project entitled "Predicting the effects of invasive Hydrozoa (jellyfish) on pelagic organisms under changing salinity and temperature regimes". The two issues of invasive species and of jellyfish blooms that the proposed research integrates are broadly considered to be increasingly serious problems for coastal ecosystems in California and globally. However, we know exceedingly little about the invasive species, their ecologies, and their impacts on the invaded systems.

Discussions with Dr. May and Ms. Meek demonstrate they are familiar with and/or experienced in the necessary genetic and ecological techniques required to complete the proposed work; Dr. Moyle has a long-standing field program successful in monitoring invasive medusae. Our discussions have also highlighted the relevance of my research interests in jellyfish phylogeography, biogeography, ecology, and species introductions to the goals of the proposal. As such, I will provide consultation on genetic and field- and lab-based ecological studies of medusae and will help investigate more broadly the ecological genetics of invasive species and the impacts of jellyfish blooms on ecosystems, areas identified in the scientific literature as needing considerable research.

Sincerely,



Michael N Dawson

Assistant Professor  
School of Natural Sciences  
University of California  
PO Box 2039, Merced  
CA 95344, USA



DEPARTMENT OF FISH AND GAME

<http://www.dfg.ca.gov>  
Central Valley Bay-Delta Branch  
4001 N. Wilson Way  
Stockton, CA 95205



August 30, 2006

CALFED Science Program  
650 Capital Mall, 5<sup>th</sup> Floor  
Sacramento, CA 95814

Subject: Support Letter for Invasive Hydrozoa Project

To Whom It May Concern:

The proposed project, "Predicting the effects of invasive hydrozoa (jellyfish) on pelagic organisms under changing saline and temperature regimes", would result in important new information about the ecology of San Francisco Estuary. As stated in the proposal, the hydrozoa introduced to the upper Estuary are believed to prey upon zooplankton, fish eggs, and fish larvae and compete with pelagic fish species for food items. Studies of this type will inform hypotheses posed as part of the current Pelagic Organism Decline investigations.

Several monitoring studies conducted by the California Department of Fish and Game are prepared to coordinate with the project's principle investigators. We record count by species data for hydromedusae from our trawls surveys, which is available for distributional and abundance analyses. We also will save hydromedusae from our samples for genetic analyses and other project tasks, as needed.

Sincerely,

Kathryn Hieb  
Associate Marine Biologist