Appendix B-8

LAKE TAHOE RESTORATION PROJECTS
ESTIMATED DIRECT COSTS & KEY MILESTONE DATES

Project Name: Invasive Warm Water Fish Species Management & Control Agency: US Forest Service

Prepared by: Barak Shemai Phone: 530 543-2622 EIP #: 339.595

SNPLMA Project #_____

Identify estimated costs of eligible reimbursement expenses:

1. **Planning, Environmental Assessment and Research Costs** (specialist surveys, reports, monitoring, data collection, analysis, NEPA, etc.)	$ 18,800	8	%
2. **Direct Labor (Payroll) to Perform the Project**	$ 65,800	28	%
3. **Project Equipment** (tools, software, specialized equipment, etc.)	$ 84,600	36	%
4. **Travel** (including per diem where official travel status required to carry out project, such as serve as COR, experts to review reports, etc.)	$ 2,350	1	%
5. **Official Vehicle Use** (pro rata cost for use of Official Vehicles when required to carry out project)	$ 2,350	1	%
6. **Cost of Contracts, Grants and/or Agreements to Perform the Project**	$ 28,200	12	%
7. **Other Direct Costs** (direct labor for agency personnel to do project procurements; COR; PI; personnel assigned as NEPA lead; personnel assigned to review contracted surveys, designs/drawings, reports, etc.; project manager and/or project supervisor; and contracted costs for project manager and/or project supervisor if contracted separately, public awareness and environmental education)	$ 11,750	5	%
8. **Indirect Costs**	$ 21,150	9	%
TOTAL:	$ 235,000	100	%

Estimated Key Milestone Dates:

Milestones/Deliverables:	Date:
Integrated GIS layer (temporal and spatial scales of species and habitat) identifying current distribution of warm-water invasives	Sept 2007
Complete Predictive Management Tools to identify location of future invasion potential & removal methods	Dec 2007
Phase I reduction and/or removal of identified site-specific areas and document treatment effectiveness	**Sept 2008**
Phase II reduction and/or removal of identified site-specific areas and document treatment effectiveness	September 2009
Effectiveness Monitoring of Treatments	2010
Final Completion Date:	Oct. 2011

Bold font identifies milestones completed with Round 8 funding.

APPENDIX I

LAKE TAHOE CAPITAL PROJECT PROPOSAL

Project Name: Invasive Warm Water Species Management & Control	**Capital Focus Area:** Watershed Restoration and Habitat Improvement (objectives 1, 6, 8, 9, 10, 16, 17)	**EIP #: 339, 595**
Lead Agency: USFS- Lake Tahoe Basin Management Unit **Threshold: F1; F2**	**Contact:**	Barak Shemai
	Phone Number:	530 543 2622
Threshold Standard: **Fisheries: Lake Habitat; Stream Habitat**	**Email Address:**	bshemai@fs.fed.us
Is this a multi-year Project? **(If "Yes", describe in the Detailed Project Description below number of years or phases and which year the requested funding will cover)** **yes**	**Total Project Cost:** **Funding Request in this Round:**	$ 1,100,000 $ 235,000

Project Summary (maximum 200 words):
In the last 125 years, a number of plant and animal species have been introduced into the Lake Tahoe Basin. In recent years however, there has been an increase in warm-water invasive species, which negatively affect the suitability of near-shore habitats for native species. Invasive species also affect water clarity and productivity. This project will develop and implement best management practices for the containment and reduction of at least 6 invasive warm water species (large/small-mouth bass, black crappie, bluegill, green sunfish, catfish) in the Lake Tahoe basin. (Phase 1 and 2 funded with non-SNPLMA funding).

Detailed Project Description:
Lake Tahoe is a high altitude, oligotrophic lake, possessing littoral and pelagic habitats favorable to fish species which thrive in clear, cool waters. Prior to the mid 1800s, the fish assemblage in the Tahoe Basin consisted of seven native species with Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*) as the primary game fish species. The cutthroat grew to a very large size (14 kg), utilizing primarily native zooplankton and pelagic chubs (*Siphatales bicolor pectinifer*) as their food source (Vander Zanden et al 2003; Chandra 2003; Chandra et al 2005).

Throughout the 19 th century, fish management agencies introduced numerous exotic species to the lake with the hope of improving recreational angling. The first series of introductions included nine species of salmonids, thought to be suited to Tahoe's environment (Cordone 1986). Only four (Mackinaw, Kokanee, brown trout, rainbow trout) of these species survived and persist in the lake today.

Starting around 1961, during a period of rapid development within the Tahoe basin, another wave of fish introductions occurred. For the most part, these introductions were illegal, being carried out by private citizens without the support of state or federal fish and wildlife agencies. These illicit fish plants did not receive the scrutiny of previous introductions. As a result, many species, inconsistent with Tahoe's clear, cold water environment and incompatible with persisting native fish populations were planted. This wave of introductions resulted in ten new species successfully populating the lake.

The ability of these species to establish reproducing populations was largely the result of anthropogenic features in the Tahoe shoreline. The establishment of the Tahoe Keys and other marinas created "ponded" water within the littoral zone of the lake. These artificial embayments allow elevated water temperatures to exist for prolonged periods of time. The warm water species thrive in this environment, reproducing within the window of opportunity, and thus increasing their abundance.

Increased Distribution of Invasive Species:
During the 1980s, the California Department of Fish and Game conducted annual fish collections in the Tahoe Keys. As late as 1990, warm water species were rare while native minnows remained abundant in the samples. By the end of the decade, large mouth bass (*Micropterus salmoides*) were common while Lahnotan redside shiner and Lahontan speckled dace populations declined or were virtually eliminated from the Tahoe Keys (DFG, unpublished data). The change in fish structure was substantiated by fishing guides operating out of the Tahoe Keys. Within a decade they could no longer collect minnows commonly used as bait during fishing charters on the lake.

Fish observations conducted by the University California- Davis, Tahoe Environmental Research Center (TERC) and the University of Nevada- Reno have shown the spread of warm water species around the lake and lagoonal habitats. As early as 1999, large mouth bass were observed in marinas along the Southern, Western, and Northern parts of the lake during the summer months. It is unclear whether these populations have persisted throughout the year, however they displayed a great degree of habitat overlap with native species assemblage.

Changes in Tahoe's Thermal Structure:
Scientists from TERC have measured an increase of 0.5 ^{0}C degrees in the deep water of Lake Tahoe (Coats et al. 2005). This incremental change at depth is consistent with other large lakes around the world and could be expected to represent greater temperature shifts in the shallow regions of the lake. Warm water fishes have been shown to proliferate with small changes in thermal regime thus these temperature changes could have a dramatic effect on how successfully warm water invasive species utilize the near shore habitat of Lake Tahoe. In Lake Opeongo (Canada) for example, scientists have tracked the slow expansion of invasive bass species during the latter half of the 20th century. They attributed the species success to changes in surface water temperatures and habitat structure presumably due to global warming and habitat disturbance (Shuter and Ridgeway, 2002). These processes are similar to those occurring in Lake Tahoe. Since it is early in the invasion process however, we believe there is a strong potential to control warm water fish species before they proliferate within the lake.

Describe the goals and objectives of the project: The primary goal of this project is to minimize and control the proliferation of invasive, warm water species within Lake Tahoe and pertinent tributaries. In order to facilitate these controls we will:

- Assess the contemporary and potential distribution and relative abundance of invasive species and their association with native species within the lake,
- Implement a program to control the introduction and proliferation of invasive warm-water species within the lake basin,
- Create a scientifically based, risk assessment tool to minimize costs to the agency associated with invasive species control by predicting locations of range expansion within the lake due to changes in thermal regime from global warming.

The proposed project covers three years. The first year is dedicated to the assessment of lake and lagoonal regions where warm water invasive species pose an immediate threat to native fish populations. The second year begins implementation of vector controls, specifically designed to limit range expansion of undesirable species and decrease existing populations. Tool development will take place concurrently to predict where future threats to native populations are likely to occur. The third year will continue the implementation of vector controls, incorporating model results and best management practices (BMP) found most effective in removing invasive species.

This project was initiated in Spring of 2006 using a cost-share agreement between the USFS-LTBMU, The University of Nevada- Reno and The California Department of Fish and Game. Matching funds were used to complete Phase 1 and portions of Phase 2. Completion of Phase 2 will go forth in a similar manner as Phase 1 using a cost-share agreement. The current request will be used to implement the strategies developed in previous phases with our collective partners.

Phase 1 (Completed through outside funding source $250,000):
Thermal Habitat Assessment:
Lake Tahoe's surface water temperatures have been monitored for the past 10 years through a cooperative project between TERC, the National Aeronautics and Space Administration (NASA), and the Jet Propulsion Laboratory (JPL). Surface temperatures have been measured every two minutes, with an accuracy of 0.05 ^{0}C, at four locations in the lake using thermal temperature recorders and infrared radiometers. These measurements have been used to calibrate thermal images collected by NASA's Terra satellite.

The satellite provides monthly thermal images of the entire lake. This data will be utilized to develop annual temperature regimes for the lake and will be incorporated into a GIS layer. The resulting information will be used to indicate when and where each species of invasive fish can thrive in Tahoe's littoral environment.

Additional temperature data will be collected at specific near shore locations using thermal recorders. These will be placed in areas where populations of invasive species are known to thrive. The data collected will be coupled with observational data to

determine critical temperatures causing behavioral shifts (spawning, immigration, and emigration).

Phase 1:
Structural Habitat Assessment:
Under contract with the Tahoe Regional Planning Agency (TRPA), the University California- Santa Barbara–Donald Bren School of the Environment conducted a survey of the structural habitat of Lake Tahoe. Satellite imagery was used to map TRPA fisheries habitat classifications in the littoral zone to depth of 10m. Scientists were able to determine five habitat types (sand, gravel, cobble, large boulder, and aquatic vegetation) from the images. This data was coupled with existing fish survey data collected by the TERC and Utah State University (Beauchamp 1994). The combined information was used to display fish distributions in the littoral zone of Tahoe in a GIS format.

During this study the same technique will be applied to each of the invasive fish species of concern. Using existing literature and additional survey observations from Tahoe, the structural habitat preferences and spawning locations of each species will be noted.

In addition, a portion of the adult population of one invasive species will be acoustic tagged. By placing acoustic receivers in strategic locations, the timing and location of fish movements can be recorded. This information will be added to the GIS database, further refining site specific overlap of invasive species with native fish assemblages.

Phase 1:
Risk Assessment:
By overlapping the thermal and structural habitat imagery, it will be possible to determine where in Tahoe's littoral zone, immediate threats to native fish populations exist.

Phase 2: (To be completed 08/07 through outside funding source $150,000):
Predictive Management Tool Development:
Based on data collected from the first year's assessment, a tool will be developed to predict future areas of overlap between warm water invasive species and Tahoe's native fish. The predictive tool inputs will take into account lake temperature increases based on global warming projections. It will serve as a predictive tool for evaluating the potential conflicts with future invasive species as well as evaluating potential conflicts with reintroduced native species (Lahontan cutthroat trout).

Phase 2:
Implementation effectiveness:
Based on the GIS maps and the observed behavioral shifts in each species from the first year of assessment, a program will be initiated to remove undesirable species from critical lake environments. The methods of removal will vary with the specific habitat type and will focus on the reproductive segment of the population. Methods are expected to include fyke nets, gill nets, electro shocking, and seining. The effectiveness of each management procedure will be evaluated based on its ability to remove invasive species while preserving natives and the time and cost associated with the procedure. The evaluation will guide project implementation toward best management practices.

Phase 3 (Round 8 funding $235,000; Round 9 funding $265,000):
Implementation:
The third year will focus on the refined implementation of BMPs for removal of undesirable warm water invasive species. This will involve a concentrated effort at specific locations where reproductive success has been determined to support the

spread of fish to other lake locations. Additional target areas are expected to include habitats where invasive species have been determined to immigrate and emigrate on a seasonal schedule. Periods of concentrated fish movement can provide optimal opportunities for population control and reduction.

Phase 4 (Round 10 funding $200,000):
Implementation of Monitoring:
Surveys to determine invasive species range distribution and quantification of localized populations will be initiated during the third year of the study. These surveys will be designed such that they are repeatable over time and capable of quantifying changes in the distribution and population of specific warm water species. It is anticipated that complete eradication of the current assemblage of warm water invasive species can not be obtained by mechanical means. Therefore, successful implementation will not be determined by eradication. Success will be determined by containment and suppression of the current populations and reducing the reproductive segment of the population.

Describe the anticipated project accomplishments: This project as a whole will accomplish the following: 1. Set a precedent for LTBMU interagency coordination in the field of invasive species control and eradication 2. Develop a predictive management tool to guide future invasive warm-water fish eradication in Lake Tahoe 3. Conduct a comprehensive eradication from the lake region identified as most the productive (breeding/feeding). This project will combine the best available science and investigation with proper aquatic management, to effectively prevent the proliferation of invasive warm-water fish species throughout the pristine waters of Lake Tahoe.

Describe the "readiness" of this project to move forward (Environmental documentation, etc.): A great deal of data and general information has been collected and project planning is underway. Due to the urgent nature and extensive interagency collaboration associated with this project, initiation will begin immediately proceeding funding allocation.

Describe partnerships for this project. (Include documentation): Tahoe Environmental Research Center at the University of California-Davis, Aquatic Ecology Laboratory at the University of Nevada-Reno, Ontario Ministry of Natural Resources, University of Toronto, Tahoe Regional Planning Agency, California Department of Fish and Game, Nevada Division of Wildlife.

Describe the project monitoring that will be implemented as part of this project including: (No monitoring will be accomplished as part of this round of funding, however funding in Round 10 will be used as described below.)

(1) The questions the monitoring program is designed to answer

1. How effective are invasive species removal efforts in extirpation of invasive species?

2. How efficient and effective is the developed predictive management tool in identifying hot spots for warm water fish invasion?

(2) The monitoring approach

Determine the effectiveness of invasive species removal (ex blue gill, bass, crappie).Monitoring results will be applied to future native fish management strategies and recovery efforts.

(3) Whether this project monitoring fits in to a larger monitoring or research program?

Part of LTBMU Forest Plan monitoring program, as described in LTBMU 5 Year Plan, 2006

Describe how the project results will be communicated and made-available to the public.

Results/accomplishments summarized in Annual Forest Monitoring Program Report, as well as project-specific monitoring reports. Project-specific monitoring reports will be produced one to five years after project implementation, depending on the variables being monitored and the questions to be answered.

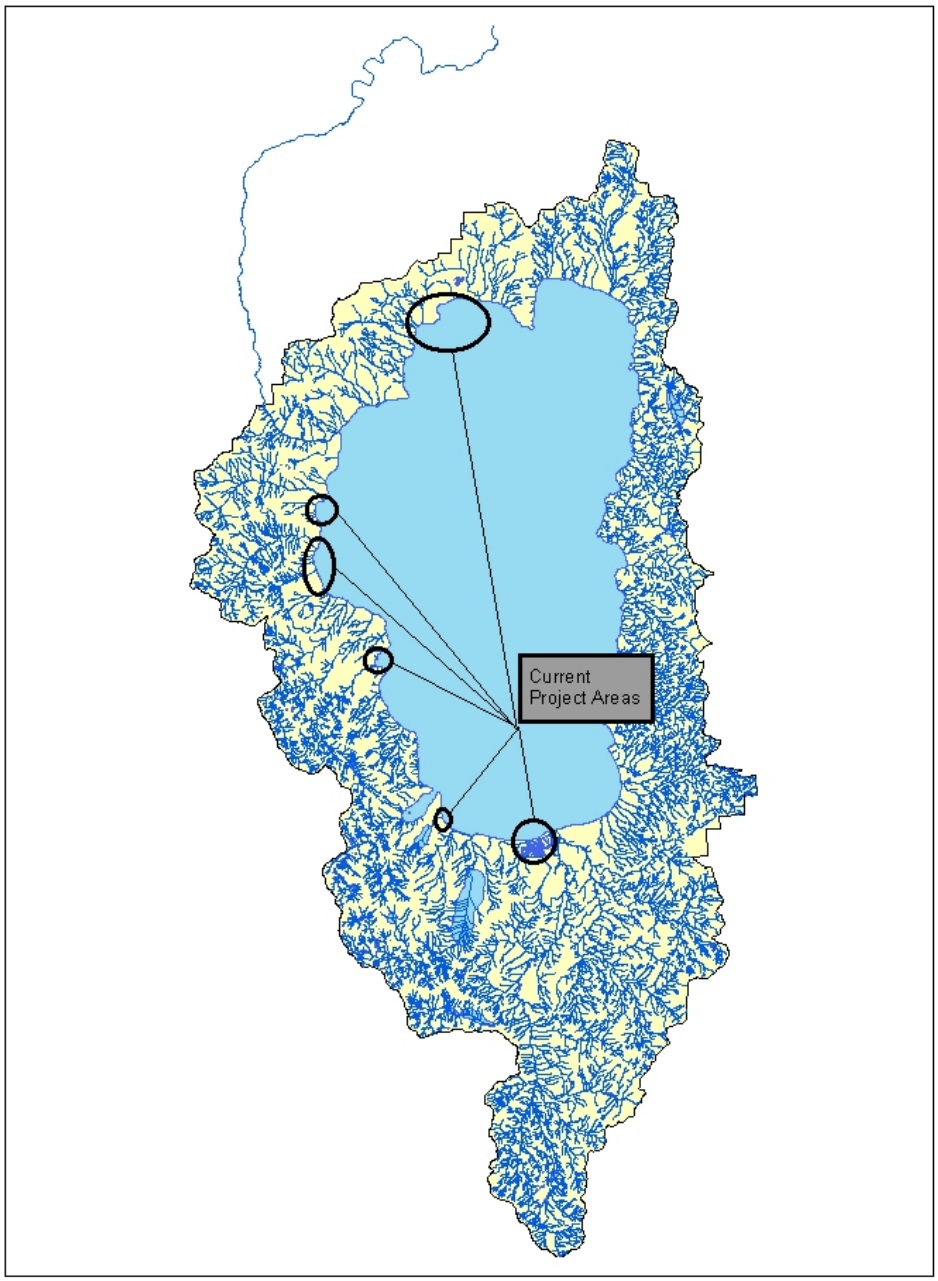
The information created from this project will be disseminated to three audiences: 1) the general public, 2) other resource agencies, and 3) the broader scientific community. The audiences will be informed respectively through the USFS website, public/interagency meetings, and peer-reviewed publication.

Information regarding the potential negative consequences of warm water invaders will be distributed by holding a series of public seminars sponsored by local nonprofit and community groups within the basin. These groups include the Tahoe-Baikal Institute, the Squaw Valley Institute, and Trout Unlimited. Specific details about the model and its GIS layers (habitat, thermal dynamics, and potential bass invasions sites) will be available to the general public and resource managers encountering similar issues within their ecosystems via the internet. This information will be available as free downloadable material which will be maintained at the Aquatic Ecology Laboratory website at the University of Nevada- Reno. In order to ensure strong scientific scrutiny and acceptance of these approaches we will present this information at two international conferences (American Society of Limnology and Oceanography and American Fisheries Society) and publish the results in leading journals dealing with controlling invasive species (Canadian Journal of Fisheries and Aquatic Sciences and Limnology and Conservation Biology).

Include an 8 ½ X 11 map depicting the project.

The following research will take place along the entire shoreline of Lake Tahoe. Specifically, we will determine specific, near shore habitats where invasive, warm water fishes prefer to live including shallow embayments, marinas, and outflow areas of streams.

Warm-water Invasive Fish Monitoring Sites



References

Beauchamp, D.A., E.R. Byron, and W.A. Wurtsbaugh, 1994. Summer habitat use by littoral-zone fishes in Lake Tahoe and the effects of Shoreline Structures. North American Journal of Fisheries Management 14:385-394.

Coats, R., J. Perez-Losada, G.S. Schladow, R.C. Richards, and C.R. Goldman, 2005. The warming of Lake Tahoe. Climatic Change (in press).

Cordone, A.J. 1989. Historic Background of Lake Tahoe Fisheries. An open letter to the Tahoe Regional Planning Agency, Stateline, Nevada 89449

Shuter, B and MS Ridgeway. 2002. Bass in Time and Space: Operational definitions in risk. *In* Black Bass: Ecology and Conservation. American Fisheries Society Symposium. 31: 235-249.

Vander Zanden, S Chandra, BC Allen, JE Reuter, & CR Goldman. 2003. Historical food web structure and restoration of native fish communities in Lake Tahoe (CA-NV) basin. Ecosystems 3: 274-288.

Chandra, S. 2003. The impact of nonnative species introductions and cultural eutrophication on the Lake Tahoe food web over time. PhD thesis. University of California- Davis.

Chandra, S, Vander Zanden, MJ, BC Allen, JE Reuter, & CR Goldman. In review. The impacts of nonnative species on food web dynamics, community composition, and ecosystem nutrient cycling in Lake Tahoe (Invited). Journal of Associated Society of Testing Materials International.

UNIVERSITY OF NEVADA
•Reno

NATURAL RESOURCES AND ENVIRONMENTAL SCIENCE

Mail Stop 186
1000 Valley Road
Reno, Nevada 89512-0013
(775) 784-6763
FAX: (775) 784-4583

November 30, 2006

RE: Joint Univ. of Nevada/ USFS LTBMU Warmwater invasion collaboration

To whom it may concern,

I want to acknowledge my appreciation to Mr. Barak Shemai and the USFS Lake Tahoe Basin Management Unit for supporting the study of the new warmwater, fish invaders of Lake Tahoe. Through close collaboration between USFS LTBMU and the Universities of Nevada, California- Davis, and the California Fish and Game we have been able to identify the locations of warmwater invaders in the nearshore areas of Lake Tahoe during 2006. Furthermore, we are working closely to develop a predictive model which will assist agencies in determining the location and timing of removal/ managing these new invaders. As you probably know, it is imperative to remove recently established or establishing nonnative species before they become permanent residents in ecosystems. Through our collaborations and your support, I believe we will be able to control the proliferation of these nonnative fishes and minimize their affects in Lake Tahoe.

Respectfully,

Dr. Sudeep Chandra