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DEPARTMENT OF INTEGRATIVE BIOLOGY

BERKELEY, CALIFORNIA 94720-3140

30 June 1998

CalFed Bay-Delta Program - Proposal Review Panel
1416 Ninth St., Room 1155
Sacramento, CA 95814

Dear Ecosystem Restoration Panel;

Enclosed is a preliminary proposal concerning riparian restoration following exotic species eradication projects, which I hope that you will be able to review as part of the regular program. I received the PSP in the mail this morning, and was unable to carry out all the instructions contained within or to go through the internal review process of our university. I plan to submit a proposal regarding impacts and control of exotic species as part of the exotic species panel tentatively to be held later this season; however, upon reviewing the Ecosystem Restoration PSP I see that the work we have proposed is directly relevant to the ecological restoration of riparian ecosystems for the purpose of protecting sensitive species habitat within the Bay/Delta Area. As part of an inter-agency working group which concerns invasive *Arundo donax* in northern California (Team Arundo del Norte), we have already received an EPA Wetlands grant (through CDF&G) which will support demonstration eradication work to take place this Fall 1998. While not presently funded, we hope to conduct trial re-vegetation and restoration projects as a follow-up to the control work. Hence, we have very little time to develop funding to carry this out, and with uncertainty whether we will receive the NFWF grant we have applied for, we hope that the CALFED program can provide some support to conduct this associated project properly.

If it is impossible to consider this proposal at this time because of limitations in the paperwork provided, I will understand, but if there is some possibility for consideration of our proposed work, I will be glad to prepare the additional items quickly. I have included a copy of the NFWF proposal, as it provides substantial background for the work we are planning to carry out.

Sincerely,

Tom Dudley
Research Associate
510-643-3021; tdudley@socrates.berkeley.edu

I-010345

Attachment H

COVER SHEET (PAGE 1 of 2)

May 1998 CALFED ECOSYSTEM RESTORATION PROPOSAL SOLICITATION

Proposal Title: Riparian Habitat Restoration Following Removal of Arundo donax

Applicant Name: Tom Dudley
Mailing Address: Dept. of Integrative Biology, Univ of Calif, Berkeley 94720-3140
Telephone: (510) 643-3021
Fax: (510) 643-6264

Amount of funding requested: $ 100,000 for 3 years

Indicate the Topic for which you are applying (check only one box). Note that this is an important decision: see page __ of the Proposal Solicitation Package for more information.

- ☐ Fish Passage Assessment
- ☐ Fish Passage Improvements
- ☑ Floodplain and Habitat Restoration
- ☐ Gravel Restoration
- ☐ Fish Harvest
- ☐ Species Life History Studies
- ☐ Watershed Planning/Implementation
- ☐ Education
- ☐ Fish Screen Evaluations - Alternatives and Biological Priorities

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

- ☐ Sacramento River Mainstem
- ☐ Sacramento Tributary: _____
- ☐ Delta
- ☐ East Side Delta Tributary: _____
- ☐ Suisun Marsh and Bay
- ☐ San Joaquin Tributary: _____
- ☐ San Joaquin River Mainstem
- ☐ Other: _____
- ☑ Landscape (entire Bay-Delta watershed)
- ☐ North Bay: _____

Indicate the primary species which the proposal addresses (check no more than two boxes):

- ☐ San Joaquin and East-side Delta tributaries fall-run chinook salmon
- ☐ Winter-run chinook salmon
- ☐ Spring-run chinook salmon
- ☐ Late-fall run chinook salmon
- ☐ Fall-run chinook salmon
- ☐ Delta smelt
- ☐ Longfin smelt
- ☐ Splittail
- ☑ Steelhead trout
- ☐ Green sturgeon
- ☐ Striped bass
- ☑ Migratory birds

May 1998 CALFED ECOSYSTEM RESTORATION PROPOSAL SOLICITATION

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

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

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

- ☐ Planning
- ☐ Implementation
- ☐ Monitoring
- ☐ Education
- ☑ Research

By signing below, the applicant declares the following:

(1) the truthfulness of all representations in their proposal;

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

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

Thomas L Dudley / July 1998

(Signature of Applicant)

Executive Summary

Riparian Habitat Restoration Following the Removal of *Arundo donax*

Tom Dudley, Department of Integrative Biology, University of California, Berkeley

Objectives and Approach The purpose of our proposed project is to restore the structural and functional components of native riparian habitat following the removal of the invasive, exotic plant *Arundo donax*. Removal work in four locations (Sonoma Creek, Napa River, Russian River, Sacramento River – Grey Lodge Wildlife Area) identified by CDF&G and our interagency task force (Team Arundo del Norte) has already been approved for funding, but no plans currently address the restoration at these demonstration sites. Our primary objective is to improve habitat characteristics for migratory birds, as well as the invertebrate assemblage they depend upon, and which, in turn, are indicative of riparian ecosystem quality and productivity. Secondarily, replacement of invasive species by native assemblages will have numerous positive consequences for other target and non-target species, including in-stream salmonids and other organisms. We will conduct re-vegetation trials using a variety of techniques, and monitor the responses of native (and non-native) plants, ecosystem processes (soil moisture, organic content and nutrient storage), and species composition and abundance of terrestrial insects and birds associated with the demonstration restoration plots (and on unmanipulated control plots). These trials are intended to demonstrate most effective approaches return these ecosystems to a more natural condition.

Baseline vegetation analyses will include vegetation transect surveys and GPS mapping prior to, and following Fall 1998 control work, and seasonal monitoring will continue for the three-year duration of the project (and beyond). The basic re-vegetation treatments will be initiated during spring 1999, and include (1) outplanting of site-appropriate native woody seedlings and stem cuttings (grown during winter in the greenhouse), (2) broadcasting of seeds of site-appropriate shrubs and herbaceous native species, (3) outplating of woody plants in combination with broadcasting seeds, and (4) natural establishment with no active re-vegetation; and with sub-plots to test the effects of leaving Arundo slash in place vs. removing it, and removal vs. presence of Arundo re-sprouts. Control plots will include sites where Arundo stands were not eradicated, and where native species dominate the riparian assemblage.

Within these treatment plots point census studies will be conducted to characterize foraging and nesting use of vegetation by migratory and resident birds, including comparison of diversity and abundance of all avian species in association with each riparian species. The resource base available to birds will also be tested by sampling ground-dwelling and flying insect populations using pit-fall and suspended sticky traps within the plots. These community studies will be done during and bracketing the general avian reproductive season of 1999 and 2000.

Project Justification and CALFED This proposed project addresses the regional decline in the quality of riparian habitat and the functions it serves in regional ecosystems. Declines have resulted from many factors, including habitat destruction, stream channel and discharge modifications, and it is becoming increasingly clear that

widespread invasions of non-native plant species which are purported to compete with native plants and provide inferior habitat for native species, especially including migratory songbirds, are having a substantial role in reducing the biodiversity of Bay/Delta watershed ecosystems. We have an excellent opportunity to incorporate demonstration studies of riparian restoration techniques into a series of funded exotic plant eradication projects, both to provide significant enhancement of local riparian ecosystems and associated fauna, and to serve as a model for restoration approaches throughout the region addressed by CALFED. The techniques we will be using are applicable to a wide variety of restoration project region-wide, both in promoting recovery of sites following eradication efforts directed towards a variety of non-native species, and in riparian site rehabilitation where native habitat has been degraded by many other factors.

Budget Costs The amount budgeted for this project is fairly minimal, providing support for two graduate students who will be conducting the restoration work and follow-up monitoring of vegetation, soil conditions, and invertebrate and avian communities in the study areas. These funds will be used to augment, or in lieu of, funds requested from the National Fish and Wildlife Foundation, and which are only designated for re-vegetation work but not towards assessment of wildlife use of restored habitat. Funds will also be used for expenses to cultivate plants for transplantation during the first year, including fees for U.C. greenhouse space and maintenance, and substantial costs will be incurred during travel among the several sites intended for restoration work. All of the laboratory work in analyzing soil samples will be conducted in-house in the laboratory of Dr. Carla D'Antonio, but per-sample charges will be assigned for maintenance of equipment and purchasing reagents and supplies, and minimal expenses will be incurred for materials used in sampling insects and birds. No Third Party Impacts are known to exist.

Applicant Qualifications The applicant has been conducting studies of the impacts of non-native species in western streams and riparian areas since 1990, and of riparian restoration since 1982, particularly the use of vegetation to restore montane meadows damaged by livestock grazing. His research has concerned the dynamics of stream communities and ecosystems since 1977, and he is currently a Research Associate at U.C. Berkeley. In addition, he is the Science & Technical Issues leader for Team Arundo del Norte, and the northern California contact for the statewide Teams Arundo network.

The graduate assistant conducting vegetation studies, Jim Robins, is a doctoral student associated with Drs. James Bartolome and Barbara Allen-Diaz (Div. of Range Science – Environmental Science, Policy & Mgt., U.C. Berkeley), both of whom have many years experience with the dynamics and restoration of California ecosystems. The graduate assistant conducting avian censuses and insect sampling (along with myself), tentatively Jennifer Pretare, has been a Research Assoc. conducting avian censuses on the parallel study of avian use of riparian habitat in Sonoma and Napa Counties in association with Dr. Donald Dahlsten (Div. of Entomological Science – ESPM, U.C. Berkeley).

Project Description and Approach

The eradication of invasive non-indigenous species from wetlands, attendant with the restoration of native species and natural ecosystem functions, is now recognized as a critical goal in the protection and management of California biodiversity (Dudley & Collins 1995). Unfortunately, in many situations simple removal of exotic species may not be sufficient to restore these ecosystems, and active re-vegetation may be required to 'jumpstart' the recovery process, particularly to reduce erosion of channel banks and prevent the re-invasion of the same or other invasive species. At the same time, many of the primary riparian species (*Salix* spp., *Populus* spp., *Alnus* spp., etc.) are adapted to rapid recovery from physical disturbance, whether it be from flooding events or control work. Extravagant efforts to manually re-plant these species may sometimes be unnecessary or even counter-productive if interference with natural re-colonization processes occurs (and limited funds are diverted to expensive planting programs). Furthermore, there is a need for more effective evaluation of whether both invasive species eradication and ecosystem restoration are truly providing the protection of riparian-dependent species (particularly neotropical migratory birds an the terrestrial insects they feed upon), and enhanced ecosystem characteristics, such as retaining soil nutrients, moisture and organic material, that resource managers intended.

Arundo donax (Giant reed) invasion of riparian areas has been recognized as a serious problem for some time in the floodplains of numerous southern California rivers, but is only recently becoming recognized as a current, and growing, problem in northern California, and the Bay/Delta region in particular (mission statement of Team *Arundo* del Norte 1997). Some of the concerns regarding its presence in floodplains include presumed competition with native riparian species, degraded habitat for riparian-dependent species, excessive transpiration of groundwater, increased risk of flooding and flood debris management, increased bank instability and re-routing of sediment, and risks of wildfire (Jackson et al. 1994, Bell 1997, Herrera 1997, Dudley, in press). Having been recently identified as one of the top five Invasive Species of Concern by the California Exotic Pest Plant Council, it is timely to undertake serious control and restoration efforts in the Bay/Delta region, and to consider how best to carry out such work in order to increase the effectiveness of action against a widespread problem.

To address these questions, we propose to conduct a variety of trial re-vegetation treatments within the context of a series of currently-funded eradication projects in which *Arundo donax* will be removed from riparian zones of five (tentatively) Bay Area and Sacramento River sites. These trials will include test plots in which various combinations of native riparian species will be planted, along with appropriate control plots without intervention in the recovery process. In addition, we will monitor the colonization and recovery of other naturally-establishing plant species, soil characteristics, and use of these habitats by wildlife (insects and birds) within these plots. We are partners in an inter-agency/multiple stakeholder project to conduct demonstration control work during Fall 1998, managed through the California Department of Fish & Game and funded by an EPA Wetlands Grant. Currently the project focuses only on the eradication efforts (along with related components concerning education/outreach, herbicide toxicity studies, and mapping work), but no plans have been made to otherwise manage or monitor the recovery of these ecosystems. We recently submitted a proposal to the National Fish and

Wildlife Foundation (NFWF) to carry out trial riparian plant restoration experiments (see Appendix 1), however, funding remains uncertain, and due to NFWF restrictions we were limited in the level of funding that we could request. Thus, it is necessary to seek additional funds to take advantage of the opportunity provided by the planned control work to document the process and effectiveness of various approaches to ecosystem restoration and recovery.

Proposed Scope of Work

Baseline Vegetation Analysis Pre-treatment, permanently monumented vegetation transects will first be set up during early Fall 1998 in each of the *Arundo* removal sites. Plant species composition and vertical structure will be documented using point-intercept techniques, and 1-meter square quadrats placed at each point for assessing groundcover species. Data will include percent cover of primary and secondary plant species and plant densities, as well as the precise location of dominant species in each plot. This information will be used as a baseline dataset for assessing vegetation dynamics during restoration/recovery, as well as to evaluate the effectiveness of *Arundo* control work and determine rates of its re-invasion. Larger-scale characterization of plant assemblage composition will also be done using GPS units, and translated onto California Water Resources floodplain basemaps using standard GIS programs (ArcView) at scales appropriate to each site.

Herbicide application and plant removal will occur subsequent to this in the Fall, as the greatest efficacy with glyphosate application is post-growing season when plants are translocating stored compounds into the rhizomes. A post-eradication transect survey will provide a dataset for comparing recovery in all of the study treatment plots, and additional plots will be set up as control plots in adjacent areas in which *Arundo* has not been removed, as well as in unmanipulated plots in which native species dominate the assemblage. The number of transects in each site, and density of points sampled, will be determined through site visits once eradication plans have been finalized.

Follow-up surveys will be done quarterly to assess changes within each of the demonstration plots. These surveys will be conducted during the entire 3-year period proposed here to document the seasonal patterns of vegetation change, after which surveys will be repeated annually (with new funds).

Restoration Treatments Four general re-vegetation treatments will be carried out in *Arundo* removal plots at each site, as follows: (1) outplanting of woody plants (seedlings or rooted stem cuttings); (2) outplanting of woody plants plus broadcasting of seeds of herbaceous plants and shrubs; (3) broadcasting of seeds of herbaceous plants and shrubs; (4) control plot with passive/natural re-vegetation.

Woody plants will be prepared by cultivating seeds or cut stems in the fall and winter in our greenhouse at U.C. Berkeley, for outplanting in the late spring once winter rains and high flows have subsided. Species used will depend upon those native species common at the demonstration sites, as well as the location of the *Arundo* eradication plots within the geomorphic system. We anticipate that for plots within the active stream channel, these species will include willow (*Salix* spp.), cottonwood (*Populus fremontii* or *P. trichocarpa*), box elder (*Acer negundo*) and possibly alder (*Alnus rhombifolia*); these

are all readily grown from cuttings, while box elder may also be grown from seeds. In terrace plots, anticipated species include bay laurel (*Umbellularia californica*), California buckeye (*Aesculus californica*), big-leaf maple (*Acer macrophyllum*), valley oak (*Quercus lobata*) and walnut (*Juglans hindsii*). An ample sub-set of the woody plants will be marked and their height, 'volume', and percent cover recorded during transect surveys to assess condition in each treatment.

A wide variety of common, native understory or floodplain plants will be proposed for the broadcast seeding, for example mulefat (*Baccharis salicifolia*), bee plant (*Scrophularia californica*), blackberry (*Rubus ursinus*), currants (*Ribes* spp.), etc. Seeds will be gathered in the field sites during the Fall 1998, while locally-indigenous seeds of some species are available commercially as well. These seeded plants, along with naturally recruiting native and non-native shrubs and forbs, will primarily be quantified as species densities in the quadrat samples conducted along the transects.

In each of the four treatments, two additional nested treatments will be conducted in 2 meter square plots within several (approx. 8 across all sites) of the main, larger plots. These will test two aspects of control procedures, one being the removal vs. presence of *Arundo* 'slash' following spraying and cutting and the other addressing the removal vs. leaving of new *Arundo* culms which have re-sprouted during the restoration process. Remaining slash may have negative consequences for restoration, such as inhibiting the germination and growth of some native species, or it potentially contributes organic material and moisture-holding capacity of the soil and thereby facilitates restoration. With re-sprouts, the main question is whether low densities of small *Arundo* plants are potentially out-competed by native species, and can give field validation of experimental studies of competition between *Arundo* and *Salix* that we are conducting at the U.C. agricultural research station in Berkeley. Detailed censuses of these nested plots to determine species composition, density and cover will be conducted during regular censuses.

Soil Characteristics Within each of the treatment plots, including the unmanipulated control plots as well as the sub-plots assigned to the presence of *Arundo* slash and re-sprouts, three 10 cm deep soil cores will be retrieved quarterly during plots censuses for characterization of soil organic material, nitrogen content and moisture. Pre-manipulation soil samples will also be retained. Soil cores will be kept on ice and returned to the laboratory, where they will be processed for carbon and nitrogen ratios and total content using a Carlo-Erba CHN analyzer (in laboratory of collaborator Dr. Carla D'Antonio). At each location where soil samples are collected, we will also take soil moisture measurements at depths of 2, 10 and 40 cm using a segmented TDR moisture probe to compare the capacity of each vegetation treatment to retain moisture. Increased soil moisture, especially during summer and fall dry periods, as well as greater accumulated soil nitrogen and carbon, would be expected to promote enhanced environmental conditions for associated plants and other ground-dwelling organisms.

Terrestrial Invertebrates Under natural conditions, riparian vegetation is expected to support a greater abundance and diversity of insects and other invertebrates, which form the trophic basis for many vertebrate wildlife as well as being indicators of 'healthy' ecosystems themselves. We have conducted preliminary analyses of

invertebrates associated with *Arundo* vs. Salix in Sonoma Creek riparian areas, and found that non-native vegetation resulted in approx. 50% reduction of flying insect abundances and a substantial reduction in taxon diversity, and mixed vegetation showed intermediate levels of both measures (Herrera 1997). We intend to continue these studies, and will set up 'sticky traps' (20 cm x 10 cm diam. cylinders coated with 'Tanglefoot') and pitfall traps (cups containing glycol and fit with inverted funnels buried at ground level to capture crawling invertebrates) within each restoration treatment to document invertebrate responses to changes in habitat during ecosystem recovery. The results will be used to understand mechanisms associated with use of these habitats by migratory birds.

Avian Use of Riparian Habitat On-going studies of avian use of riparian habitat in Napa and Sonoma counties conducted by Dr. Donald Dahlsten and Dr. Joe McBride (Dept. of Environmental Science, Policy and Management, U.C. Berkeley) will be used to characterize the composition and abundance of foraging and nesting songbirds at the spatial scale of the whole riparian zone. Their work is intended to associate bird communities with riparian zones of varying degrees of naturalness or degradation, and they will be collaborating closely in our studies in the same regions.

Instead of using belt transect surveys to detect presence of birds, we will be using point count studies to analyze finer grain associations with vegetation patch types. Specifically, census locations will be set up adjacent to each restoration treatment plot and during timed observation periods we will determine frequency of visitation and nesting densities within each plot and which plant species are being utilized. This will provide information on both micro-habitat or plant species preferences of bird species, and a more general assessment of how vegetation structure in each plot supports qualitatively different avian assemblages.

These avian censuses will be conducted monthly at a representative sampling of locations for the reproductive seasons during the three-year study period (approximately March through June) in order to accurately determine nesting habits and success. Periodic censuses will be conducted at other times of the year to assess post-breeding and overwintering use of riparian habitat by migratory and resident bird species. Our assumption is that greater diversity and abundance of native bird species is indicative of higher quality riparian habitat, while we will also focus on habitat use by regionally-declining migratory species (e.g. yellow-breasted chat, willow flycatcher, song sparrow; endangered least Bell's vireo and declining yellow-billed cuckoo were formerly associated with the willow-cottonwood vegetation type in the Central Valley and elsewhere, but appear to be extirpated from the study region).

Location of the Project

The planned *Arundo* control and proposed vegetation restoration sites include:

Sonoma Creek (Sonoma Co.)	Contact: Richard Dale, Sonoma Ecology Center
Napa River (Napa Co.)	Contact: Lois Battuelo, Landowner – St. Helena
Russian River (Sonoma Co.)	Contact: Karen Gaffney, Circuit Riders Productions
Grey Lodge Wildlife Area, Sacramento R. (Butte Co.)	Contact: Joel Trumbo, Calif. Dept. Fish & Game

I-010353

Also listed above is the Team *Arundo* del Norte contact person or site co-ordinator for each project area. The exact locations where restoration work will be conducted are not finalized, but current *Arundo* populations and potential restoration sites have been mapped by Team members. Additional sites being considered for action are Coyote and Uvas Creek in Santa Clara County, but we have not yet made specific plans with the local co-ordinators.

Expected Benefits

We hypothesize that the restoration of riparian vegetation and ecosystems damaged by the invasion of *Arundo donax* to something more similar to their natural composition will provide a variety of benefits to native biodiversity, particularly by enhancing the abundance and diversity of both terrestrial invertebrates and migratory birds which depend upon high quality riparian habitat.

The whole relationship among stream modification and land use impacts, non-indigenous species invasion, and protection of native biota is much more complex than this hypothesis suggests. Natural vegetation also contributes an important component to the in-stream ecosystem through the seasonal input of litter. This wood and leaf material provides the organic detritus that much of the forested stream trophic web depends on, and particularly leaf-feeding aquatic insects that are, in turn, fed upon by juvenile and resident steelhead trout and other salmonids. The replacement of these native plants by *Arundo* means that the form and timing of availability of detritus will be greatly modified. *Arundo* does not drop litter, rather the stems remain in place and semi-dormant during the winter, and typically only moves in the system via scouring during storm flows, so this nutrient source is largely unavailable to in-stream organisms. In another part of our current research, we have placed litter bags in several Bay Area streams to test the hypotheses that *Arundo* litter is relatively low in nutrient availability, is more resistant to decomposing organisms so inhibit nutrient cycling, and supports a depauperate invertebrate assemblage; results from those studies will be completed by Fall 1998.

While not applicable to bird impacts, the replacement of native overstory plant species by cane-like *Arundo* growth is expected to increase water temperatures, as it provides relatively little shading to the water surface. Such a change can be detrimental to salmonids, particularly in a Mediterranean climate region where summer temperatures can be high, so the restoration of native species in areas dominated by *Arundo* should enhance habitat quality for most aquatic species of management interest.

Migratory birds and other wildlife are also negatively affected by the identified stressors of flow alteration and channel form modification. Because *Arundo* grows as a dense thicket it tends to result in accumulation of sediment while forcing water flows into a constricted channel with possible resulting downcutting. It also is shallow-rooted, so provides little armoring of channel banks against high water slows. Replacement of the Giant reed by native riparian vegetation is intended to subsequently restore sediment dynamics and a more natural stream geomorphology, promoting enhanced conditions for further recovery of riparian areas and associated species. Unlike saltcedar (*Tamarix* spp.) which tends to increase in response to reduction in natural flood flows, we are as yet unable to understand the relationship between discharge regimes and *Arundo*

establishment, other than the fact that high flows are necessary for dispersal of the rhizomes to new habitats, as it is sterile and unable to reproduce via seed.

While the PSP identified Wildfire as a Low Priority Stressor on migratory birds and other affected wildlife or resource users, we would, in fact, clarify that *Arundo* has been shown to be highly flammable and because it can even grow under mature riparian canopies, recently was implicated in the destruction of a large cottonwood stand on the Russian River (Karen Gaffney, pers. comm.). It has also supported smaller wildfires in two locations in Contra Costa County, and has done major damage in the Santa Ana River in southern California (Jackson et al. 1994). Restoration of native riparian stands will promote the recovery of benefit of riparian areas as barriers to wildfire movement, rather than becoming a 'wick' for wildfire.

As with wildfire, restoration of riparian area will also reduce the risk of flood damage, with benefits to flood protection agencies and those who live or conduct business in regional floodplains. It will also provide a benefit to recreational users of riverways, as *Arundo* readily cuts the skin of users who pass too closely, and yields both an unpenetrable and unaesthetic barrier to use of the area for recreation or other purposes.

Finally, we suggest that restored native vegetation will provide a more effective agent to improve Water Quality than does *Arundo*, as the deeper rooting zone of willows, cottonwoods and other native species may filter greater amounts of anthropogenic chemicals, particularly nitrates from agricultural and domestic run-off, from groundwaters entering the stream channel. That is the subject of a proposal to be submitted to NSF this winter.

Background and Justification

(These issues were partly addressed in the previous section)

Monitoring and Data Evaluation

A major component of this project is to provide a monitoring program to assess the effectiveness of ecosystem restoration techniques applied to the *Arundo* removal areas. The strength of the proposed demonstration projects is in the quantitative comparison of the methods in a replicated, rigorous experimental fashion and still provide meaningful restoration of threatened natural resources. This work will be done in close collaboration of numerous representatives of state and federal resource agencies, conservation organizations, private landowners and consultants, and academic researchers, so there will be frequent discussion of approaches and presentation of results, intended to improve the methods and interpretations that are forthcoming. This will be particularly important in light of the fact that Team *Arundo* del Norte is also responsible for production of guidelines for eradication of problem invasive species, particularly *Arundo donax*, and promoting watershed-based approaches to riparian and resource protection.

Implementation

All appropriate regulatory issues will be addressed directly in the control portion

of the demonstration projects, co-ordinated by Team members Joel Trumbo (Pesticides Division, CDF&G) and Paul Jones (EPA Wetlands Division).

Costs and Schedules – 3 Years

Project Phase and Task	Direct Labor	Direct Salary & Benefits	Overhead, Indirect Costs	Service Contracts	Supplies Expenses/ Travel	Total Cost
Vegetation Sampling	0	45,000 (15K/yr)	16,500	0	4,500	66,000
Restoration Plantings	2,500 (Yr 1)	(included above)	1,500	0	2,000	6,000
Soil Sampling	0	(included above)	100	1,500	400	2,000
Insect Surveys	0	9,000 (3K/yr)	3,000	0	(included below)	12,000
Avian Surveys	0	36,000 (12K/yr)	13,000	0	3,000	16,000

Year 1 Total	37,333
Year 2	31,333
Year 3	31,333
Grand Total (3 Yrs)	$100,000

Schedules for component tasks of the project are included in the project description above. Vegetation sampling will be initiated first and continued throughout the project period, while Restoration plantings will be prepared and carried out in Year 1. Likewise, Soil sampling and analyses will be conducted pre- and post-Arundo treatment, and continued quarterly during all 3 years. Insect and Avian sampling and surveying will be conducted during and surrounding the primary nesting periods each year, approximately March through June.

Progress reports will be provided according to the PSP guidelines, with a detailed annual report of results to-date, along with appropriate vegetation maps, and the end of each year. Final results will be published in appropriate scientific journals, and Best Practices Guidelines for regional riparian restoration will be printed as part of the Education and Outreach component of the EPD Wetlands grant co-ordinated by Team Arundo del Norte.

Third Party Impacts are not anticipated in this project, as all lands where treatments are to take place are managed, at least in part, by the California Department of Fish & Game, according to restrictions of the parallel EPA grant with which our proposed work is co-ordinated.

Applicant Qualifications

(see Curriculum Vita of T. Dudley)

CURRICULUM VITA: Thomas L. Dudley

Personal:

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Phone:	510-204-9138, 510-643-3021
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E-mail:	tdudley@violet.berkeley.edu

Education:

B.A.	U.C. Santa Barbara	1975 Environmental Biology
M.S.	Oregon State University	1982 Aquatic Entomology
Ph.D.	U.C. Santa Barbara	1989 Aquatic and Population Biology

Relevant Research Experience:

Research Associate, Dept. of Integrative Biology, U.C. Berkeley; Invasion and control of giant reed in California riparian areas (Calif. Water Res. Cent). 7/96-present.

Research Associate, Marine Science Inst., U.C. Santa Barbara; Livestock impacts and restoration of Sierra Nevada sub-alpine riparian areas (U.S. Forest Service). 7/93-6/96.

Research Associate, Pacific Institute; Western water policy, ecosystem management and conservation of aquatic biodiversity (W. Alton Jones Found.). 10/92-3/95.

Consulting Researcher, Calif. Dept. of Parks & Recreation/U.C. Berkeley; Tamarisk invasion in Anza-Borrego State Park; Survey and management plan for aquatic habitats. 5/92-2/96.

Faculty Research Associate, Co-P.I.; Zoology Dept., Arizona State Univ.; Ecosystem consequences of trophic structure in a desert stream; (Nat'l. Science Found.). 8/89-6/92.

Research Assoc. & Assist.; Marine Science Institute and Biological Sciences Dept., UCSB; Community ecology of southern California streams (N.S.F. & Water Resources Center). 8/85-6/89.

Research Assistant, MSI and Biological Sciences, UCSB; Cattle grazing effects and the rehabilitation of Sierra Nevada streams (Calif. Water Res. Cent.). 6/83-6/86.

Research Assistant, Dept. of Fisheries and Wildlife, Oregon State Univ.; Recolonization following real and simulated disturbance in streams near the Mt. St. Helens volcano, WA (Oregon Water Res. Research Inst.). 9/81-6/82.

Biologist, U.S. Geological Survey, Mammoth Lakes, CA; Influence of copper on algae, invertebrates and fish in a montane stream community. 5/80-11/80.

Research Assistant, Dept. of Entomology, Oregon State Univ.; Invertebrates association and role in decomposition of wood in streams (NSF). 1/78-1/80.

Professional Experience:

Lecturer, Environmental Sciences Program, Univ. of Calif., Berkeley; Co-ordinate Senior Research Seminar 8/96-present.
Senior Research Associate and Head, Program on western water policy and aquatic biodiversity; Pacific Institute, Oakland, CA. 10/92-3/95.
Faculty Associate, Zoology Department, Arizona State Univ. 7/89-12/91.
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Biological Consultant, Aquatic Biology – stream and estuary impacts, biodiversity assessment, : Dames & Moore, Inc., A.D. Little, U.S.E.P.A., Calif. Regional Water Qual. Control Bd. – Victorville, etc.

Professional Organizations

Ecological Society of America	Entomological Society of America
North American Benthological Society	Society for Ecological Restoration
Societes Internacionales de Limnologie	California Exotic Pest Plant Council

Relevant Publications (32 total):

Dudley, T.L. 1982. Population and production ecology of *Lipsothrix* spp. (Diptera: Tipulidae). M.S. Thesis, Oregon St. Univ. 172 p.

Wilzbach, P., T.L. Dudley and J.D. Hall. 1983. Recovery patterns in stream communities impacted by the Mt. St. Helens eruption. Tech. Rept. A-059-ORE, Water Res. Res. Inst., Corvallis, OR.

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Dudley, T. and M. Embury. 1995. Non-indigenous species in Wilderness Areas: the status and impacts of livestock and game species in designated wilderness in California. Pacific Inst.

D'Antonio, C.M. and T.L. Dudley. 1995. Biological invasions as agents of change on islands vs. mainlands. In: Vitousek, P., L. Loope & H. Mooney (eds.) Islands: biodiversity and ecosystem function. Springer-Verlaug.

Sarr, D.A., R.K. Knapp, T.L. Dudley, D.C. Odion, K.R. Matthews & J. Owens. Livestock grazing impacts and the potential for riparian meadow recovery in the Golden Trout Wilderness Area, California. Final Report, U.S. Forest Service, Leopold Institute, Missoula, MT.

D'Antonio, C.M., M.M. Mack and T.L. Dudley. Biological invasions and disturbance. In: L. Walker (ed.). Ecosystems of disturbed ground. Elsevier Press. (in press)

Dudley, T.L. *Arundo donax*. In: Bossard, C., J. Randall and M. Hoshovsky (eds), Wildland weeds of California. (in press).

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Appendix I.

RIPARIAN HABITAT RESTORATION FOLLOWING THE REMOVAL OF *ARUNDO DONAX*: THE EFFECTS OF DIFFERENT REVEGETATION ON RESTORING STRUCTURE AND FUNCTION

Dates of Proposed Project Period: August 1, 1998 – July 31, 1999

Submitted to:

NATIONAL FISH AND WILDLIFE FOUNDATION
San Francisco, California

Submitted from:

THE UNIVERSITY OF CALIFORNIA
Berkeley, California

Principal Investigator:

Carla M. D'Antonio 5 June 98

Carla M. D'Antonio, Ph.D. Date
Dept. of Integrative Biology
3060 Valley Life Sciences Building
University of California
Berkeley, CA 94720-3140

Institutional Endorsement:

6-8-98

Lynn Deetz Date
Senior Research Administrator
Sponsored Projects Office
336 Sproul Hall
University of California
Berkeley, CA 94720-5940
510-642-8114 – Phone
510-642-8236 - Fax

National Fish and Wildlife Foundation Grant Application

Incomplete applications will be returned to applicant.

APPLICANT INFORMATION

Organization (to be named as Grantee): Regents of the University of California
c/o Sponsor Projects Office
Street: 336 Sproul Hall
City, State, Zip: Berkeley, CA. 94720-5940
Home Page: www.berkeley.edu

Project Contacts:

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Tele: 510-643-6113
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Financial Officer: Winnie Ng
Tele: 510-642-1370
Fax: 510-643-8897
E-mail: wng@uclink.berkeley.edu

Tax Status: 501 (c) (3) Tax ID#: 946002123 Fiscal Year: 07 / 98 to 06/99
(i.e. non-profit, university, 501(c)(3) etc.)

PROJECT INFORMATION

Project Name: Riparian Habitat Restoration Following the Removal of *Arundo donax*: the effects of different revegetation strategies on restoring structure and function.

Location(s) of Project:
City: (Counties) Napa, Sonoma, and Butte
State: California
Country: United States of America
Congressional District(s): 1st, 2nd, and 6th

Dates:
Project Start Date: 8/1/98 Project End Date: 7/31/99
Application Submission Date: 6/8/98

Project Type (Base your selection on discussions with NFWF staff) Check one or more if applicable:

[ ] *Conservation Education*
[ ] *Fisheries Conservation and Management*
[ ] *Neotropical Migratory Bird Conservation*
[ ] *Private Lands and Wetlands Conservation*
[X] *Wildlife and Habitat Management*

GRANT REQUEST

Use U.S. dollars (*rounded to the nearest hundred*) for all amounts listed below:

NFWF Funds:	$24,000	(NFWF Federal Funds)
Challenge Funds:	$63,600	(Non-Federal Funds to be Raised by Applicant)
Total Grant Amount:	$87,600	(NFWF Funds – Challenge Funds)

Sources of Challenge Funding:

Please list the names of organizations and the amounts they are donating to this project:

Received	*Amount*	*Application Submitted*	*Amount*
_____	$_____	Circuit Rider Productions	$7,000
_____	$_____	Cal. Dept of Fish and Game	$2,500
_____	$_____	Sonoma Ecology Center	$7,000
_____	$_____	Napa RCD	$1,000
_____	$_____	U.C. Berkeley	$10,100
		California Conservation Corp	$ 2,000
_____	$_____	Tom Dudley (consultant)	$10,000
_____	$_____	Total Challenge funding from eradication work	$24,000

Challenge funds raised by the grantee must be sent directly to NFWF from the donor. Donations must be received in the same fiscal year as the grant award. NFWF will not accept challenge funds from the grantee. If this is not possible, contact a NFWF representative.

PROJECT BUDGET

Budget Form

Use U.S. dollars (*rounded to the nearest hundred*) for all amounts listed below.

NOTE: *List only financial line items under the column "Budget Category." Contributed Services should be included under Challenge Funds.*

Budget Category	Expense per Category	Challenge Funds	NFWF Funds
Arundo Eradication and Debris Removal: salaries and equipment (will vary per site)	total = $24,000 approx. $6000/site (4 sites)	$25,000 (various non-federal)	$0
Field Equipment: measuring tape, field ribbon, sampling flags, tensimeter (for soil water potential), shovels, and stakes for reveg. work	$1,000 (tensimeter=$600)	$1,000 (Fish and Game)	$0

Lab Work: CHN analysis	$600 (200 samples @ $3/sample)	$400 (U C B)	$200
Revegetation Supplies: seeds, seed collection, seedlings, and nursery work	$4,000	$4,000 (Circuit Rider Productions and California Conservation Corp)	$0
Salary: Project Coordinator **Benefits:**	$14,900 (at 50% time) $4,700	$0 $0	$14,900 $4,700
University of California Matching Funds: 50.4% of MTDC for Project Coordinator	$9,700	$9,700	$0
Salary: Project Assistant **Benefits:**	$3,100 (at 15% time) $100	$0 $0	$3,100 $100
Other Salaries (Donated Services): Circuit Rider Productions Ca. Dept. Fish and Game Sonoma Ecology Center Napa RCD Tom Dudley (consultant)	 $5,000 (15% time) $1,500 (5% time) $1,000 (5% time) $1,000 (5% time) $10,000 (based on $100/hr.)	 $5,000 $1,500 $1,000 $1,000 $10,000	 $0 $0 $0 $0 $0
Travel Expenses: Driving to and from sites and attending professional meetings	$1000	$0	$1000
Publishing and Printing Costs: Citizens Handbook	$6000	$6000 (Sonoma Ecology Center)	$0
***TOTALS**	$87,600	$63,600	$24,000

If this space is not adequate, please use the same format on a separate sheet of paper.

***If the overall budget for this project exceeds the total NFWF grant amount (including both Challenge and NFWF Funds), please attach a copy of the overall project budget.**

AGENCY/PEER REVIEWERS

AGENCY/PEER REVIEWERS

The applicant must submit the proposal for review to one reviewer from each of the following categories:

A. U.S. Fish and Wildlife Service (or NOAA if the project is marine);
B. Federal (USFS, BLM, etc.) or State wildlife or land management agency in your area;
C. Conservation/Environmental organization;
D. Academic institution; and
E. Resource industry or corporation (e.g. timber, mining, and grazing interests).

The applicant must ensure that these reviewers (minimum of 5) submit their comments directly to NFWF **no later than two weeks after the application due date** (i.e. August 15 and December 30). NFWF reserves the right to require the applicant to send this proposal to additional reviewers selected by NFWF. **All reviews submitted to NFWF are kept confidential.**

You must send copies of your application directly to the reviewers listed below with copies of the NFWF Reviewer Guidelines (attached).

A) Name: Daniel Strait — Title: Assistant State Private Lands Coordinator
Organization: U.S. Fish and Wildlife Service — Phone/Fax: 916-979-2085
Address: Private Lands Office, 2233 Watt Avenue, Suite 375, Sacramento, CA 95825

B) Name: Joel Trumbo — Title: Environmental Scientist III
Organization: California Dept. of Fish and Game — Phone/Fax: 916-358-2952
Address: 1701 Nimbus Road, Suite F, Rancho Cordova, CA 95670

C) Name: Dr. Tom Dudley — Title: Lecturer and Researcher
Organization: University of California, Berkeley — Phone/Fax: 510-643-3021/ 510-643-6264
Address: Environmental Science Program, 29 Mulford Hall, U.C. Berkeley, Berkeley, CA 94702

D) Name: Richard Dale — Title: Director
Organization: Sonoma Ecology Center — Phone/Fax: 707-996-9744
Address: 205 First Street West, Sonoma, CA 95476

E) Name: Lois Battouelo — Title: Private Landowner/ Grape Grower
Organization: Battouelo Family Trust — Phone/Fax: 707-963-8960
Address: 1634 Main St., St. Helena, CA 94574

SIGNATURE OF APPLICANT *(An original signature page must be received with this application)*
I certify that the above information is true and accurate.

1. Lynn E. Deetz, Senior Research Administrator — Name of Executive Director or Project Officer
2. [signature] — Signature
3. 6-8-02 — **Date**

I-010364

Proposal Narrative

I. Project Summary

The primary objective of this project is to restore, both structurally and functionally, native riparian habitat following the removal of the invasive exotic plant *Arundo donax*. The secondary goal is to set-up a long-term monitoring project to evaluate the "success" of the various restoration techniques employed.

II. Project Abstract

Project Description This project was conceived by members of Team *Arundo* del Norte (to be discussed later) as part of a comprehensive effort to understand and control the invasion of *Arundo donax* in the waterways of central and northern California. Funding through grants from the California Department of Fish and Game and U C. Water Resource Center have been secured for *Arundo* mapping at various scales, several ecological research projects, and eradication efforts. Specifically, this project focuses on restoring riparian habitat after initial removal of *Arundo* has been carried out. This project will tie into planned eradication efforts at Gray Lodge Wildlife Refuge, Sonoma Creek, the Russian River and the Napa River.

Because the science of restoration is still in its infancy and there are no quantifiable guidelines for a project of this nature, we will employ a variety of different restoration techniques including different revegetation schemes and passive techniques. Additionally, by establishing a long-term monitoring program and criteria for defining success, we will be able to use these restoration sites to quantify the effectiveness of the different techniques. In order to accomplish replication we will control for native vegetation types, but select study sites that represent a diversity of geomorphologic profiles.

Why NFWF Should Fund This Project: In a recent report, Dudley and Collins (1995) identified the giant reed (*Arundo donax*) as one of the major problem species facing riparian areas in the state, and the California Exotic Plant Pest Council (CalEPPC) included it as one of the top 5 species of concern.

Arundo reproduces vegetatively and propagules, specifically rhizomes, are carried downstream during flooding events (Bell 1997). In riparian areas and wetlands, *Arundo* forms dense stands several meters tall which are purported to displace native riparian species and create unsuitable habitat for a variety of sensitive aquatic and riparian wildlife species. Because these dense stands are highly flammable, they often convert riparian areas from firebreaks into fire hazards (Scott 1994). Additionally, studies have suggested that *Arundo* both reduces groundwater because of its massive transpiration rates (Iverson 1994) and changes in-stream morphology by retaining sediments and constricting flow (Vicki Lake, pers. comm.).

It is clear that the immediate removal and the eventual eradication of *Arundo donax* will benefit a wide variety of stakeholders. At this time the funds have been secured to begin five pilot eradication efforts in the fall of 1998. A major dilemma remains about what to do once *Arundo* has been removed. Should the remaining slash be removed or left to decay? Should we initiate revegetation directly after the first removal or should we wait until all the re-sprouts have been removed? If we don't revegetate with native species will other invasive exotics colonize the site? What is the most efficient means by which we can accomplish revegetation and begin to restore vital functions such as stream shading and sediment mitigation? This project is a direct response to this dilemma and the questions that are being asked. With the help of NFWF we will be able to both initiate a variety of different restoration plans and address many of the ecological questions associated with riparian restoration.

Partner Justification: This work will be conducted as an integral component of the efforts of Team Arundo del Norte. Team Arundo del Norte is a partnership that is dedicated to the reduction and eventual elimination of *Arundo donax* (Giant Reed) where it threatens rivers, creeks and wetlands in central and northern California. The membership of this organization includes private landowners, members of academia, local non-profits, and both state and federal resource and land management organizations. The Grantee, the Regents of the University of California, has a long-standing reputation for its commitment to excellence in exploring issues and sharing knowledge. Additionally, the grantee has the administrative staff to execute the financial terms of the grant.

Final Products: There will be many products resulting from this project. We hope to publish articles in professional journals (i.e. Restoration Ecology) regarding management strategies for exotic plant removal and habitat restoration. We are also planning to put together a comprehensive guidebook focused on educating people about the ecological impacts of *Arundo donax* and recommending specific eradication and restoration protocols.

Additionally, the initial one year project will transition into a long-term monitoring project. Because sustainable restoration and the eradication of invasive species can take many years, this long-term approach will allow us to monitor the plots through time and constantly strengthen and refine our recommendations. Furthermore, we believe this research will not only be applicable to post-*Arundo* restoration but to also many restoration scenarios dealing habitat degraded by invasive species.

I-010366

III. Proposal

Project Need

Wetlands and low-elevation riparian areas are among the most endangered ecosystems in California. These systems provide habitat for over half of the species officially listed as threatened or endangered and are responsible for critical ecosystem functions such as facilitating water infiltration, reducing erosion and sediment input, and regulating nutrient cycling (Mitsch and Gosselink 1993). Additionally, riparian corridors and wetlands help to ameliorate the impact of floods and act as natural fire breaks. Agriculture, livestock grazing, dam construction, water diversions and gravel mining have historically wreaked havoc upon these systems. The degradation of riparian systems is clearly illustrated by increases in stream water temperature, sediment loads, and anthropogenic nutrient enrichment in degraded areas. In turn, these abiotic problems are linked to the decline in sensitive anadromous fish populations throughout the state.

In areas designated for riparian resource protection, biological invasions by nonindigenous species of plants and animals present a serious threat to persistence of these ecosystems. In a recent report, Dudley and Collins (1995) identified the giant reed (*Arundo donax*) as one of the major problem species facing riparian areas in the state, and the California Exotic Plant Pest Council (CEPPC) included it as one of the top five species of concern.

Arundo donax is an old-world grass planted for many years in California for both landscaping and bank stabilization. It has now spread to numerous river courses in the state. In riparian areas and wetlands, *Arundo* forms dense stands several meters tall which are purported to displace native riparian species and create unsuitable habitat for a variety of sensitive aquatic and riparian wildlife species. Because these dense stands are highly flammable they often convert riparian areas from firebreaks to fire hazards (Scott 1994). Additionally, studies have suggested that *Arundo* can reduce groundwater due to massive transpiration rates (Iverson 1994) and change in-stream morphology by retaining sediments and constricting flow (Vicki Lake, pers. comm.).

The potential range and effects of *Arundo* are not known, but incipient populations are known to occur in all bioregions of California. Based on experiences of land managers with *Arundo* invasions in southern California river valleys, it is suggested that this plant could present one of the most serious conservation and resource protection problems in the state (Jackson et al 1993).

It is clear that the immediate removal and the eventual eradication of *Arundo donax* should be a top conservation priority. Furthermore, post-removal restoration must be an integral component of all eradication plans. Major eradication efforts are underway in southern California and are now being formulated in central and northern California. Members of Team Arundo del Norte have conceived four pilot eradication projects which are slated to commence in the early fall of 1998.

Because the science of restoration is still in its infancy and there are no rigorously tested guidelines for a restoration project of this nature, a major dilemma remains about what to do once *Arundo* removal has begun. Should the remaining slash be removed or left to decay? If we do not revegetate with native species will other invasive exotics colonize the site? What is the most efficient means by which we can accomplish revegetation and begin to restore vital functions such as habitat requirements and sediment mitigation? Do naturally establishing plants perform better than plantings? What is the appropriate protocol for dealing with *Arundo* re-sprouts? This project is intended to serve as both an opportunity to speed the process of post-*Arundo* recovery through various revegetation schemes and to use the combination of restoration and long-term monitoring to quantify the effectiveness of the techniques for future habitat restoration projects.

Project Objectives:

(1) The primary objective of this project is to begin the habitat restoration process in the wake of *Arundo donax* removal. The first goal will be structural restoration, the establishment of native plant communities and the exclusion of invasive exotic plants. This goal will be accomplished through various revegetation techniques (described in methods section). The second goal is functional restoration which encompasses a return to native wildlife habitat, site appropriate water and nutrient cycling and natural disturbance regime.

(2) The second objective is to setup a long-term monitoring program to assess the success of the various techniques employed in the restoration project.

(3) The third goal is to synthesize the data from the long-term monitoring and create scientifically tested and quantifiable restoration protocols.

I-010367

(4) The last objective is to publish these findings. They will be an integral part of the "Citizens Handbook for Battling *Arundo donax*" which will be published by the Sonoma Ecology Center and used by local residents, land management organizations, and non-profits. Additionally, the findings will be published in related professional journals.

Methodology

The project will take place at four different sites: Gray Lodge Wildlife Refuge in Butte County, Sonoma Creek in Sonoma County, the Russian River in Sonoma County, and the Napa River in Napa County. Additionally, the sites will all be between 2-4 acres. There will be four distinct segments of this project.

A. The first part entails gathering all the baseline data at removal sites and reference sites and will take place between August and October of 1998.
B. The second part is the removal of the *Arundo donax*, which is scheduled to take place from the end of September through November of 1998.
C. The third part is the revegetation work which will take place from November 1998 through February of 1999.
D. The final portion of this project will be the establishment of a long-term monitoring program at all sites. The first set of data will be collected within a few weeks of the initial removal. Data will also be gathered in the spring of 1999 and the end of the summer of 1999.

A. Baseline data will be collected at each eradication site before the *Arundo* is removed. Site variables to be recorded will include total area covered by *Arundo*, percent *A. donax* coverage, *A. donax* density and stand structure, total vegetation composition, soil-water-potential, soil carbon and nitrogen, avian habitat use, slope, aspect, and elevation. Stand area will be calculated from the approximate circumference and radius of each stand (Knight, 1978). Total percent coverage will be calculated from the total area of the site and the total area of *Arundo* patches. *A. donax* density will be calculated in tillers/m^2 for each patch within the site. Height class will be used as an indicator of stand structure. Height classes will be separated as follows: (1) up to 1 meter, (2) 1 meter to 3 meters, (3) 3 meters to 5 meters and (4) above 5 meters (Bartolome, pers. comm.). Total vegetation composition will be determined from a combination of point-intercept line transects and 2m X 1m quadrats placed randomly along the transect. Transects will run perpendicular to the bank and be placed at random intervals. Distance and number of transects will vary by site. Soil-water-potential data will be gathered with a tensimeter and soil carbon and nitrogen concentrations and ratios will be calculated by CHN analysis. Habitat use data will be available from an already established avian project supported by U.C. Berkeley. Slope and aspect will be taken from a clinometer and compass respectively. Approximate elevation will be taken from a topographic map.

A reference sites will be selected for each eradication site. Reference sites will be chosen as representatives of "healthy" riparian communities based on native plant assemblages. These sites will be selected on the basis of geomorphologic similarity and appropriate elevation, slope and aspect. Four permanent transects will be set-up and the same sampling protocol as described above will be employed. The vegetation composition gathered through the sampling will be used to create specific revegetation plans for the respective eradication sites. Additionally, soil-water-potential, CHN analysis and bird use data will be collected.

B. *Arundo* eradication will follow the procedure recommended by Bell (1997). This procedure involves foliar spraying of the herbicide Rodeo®. This is the only herbicide on the market that is currently labeled safe for wetland use by the FDA. Plants will be sprayed in the early fall when they are translocating so that the herbicide will enter the root mass. Within two weeks the plants will be cut down

and removed. All permits and appropriate impact statements will be obtained by the agency responsible for the eradication project.

C. Revegetation plans will vary according to the data gathered at the reference sites. All seeds and planting materials will be collected from genetically appropriate stocks. At each site the following four revegetation treatments will be used: (1) Out-planting of woody seedlings, (2) Out-planting of woody seedlings and broadcasting of herbaceous plant seeds and shrub seeds, (3) Broadcasting of herbaceous plant seeds and shrub seeds, and (4) a control plot that represents passive/natural revegetation. Although specific revegetation plans have yet to be completed, herbaceous plants and shrubs that may be seeded include California blackberry (*R. ursinus*), bee plant (*S. californica*), stinging phacelia (*P. mavifolia*), various *Ribes* ssp., and mulefat (*B. salicifolia*). The woody species to be out-planted are split into two groups depending on where they are normally found, in and near the active channel or on terraces. Willow (*Salix ssp.*), cottonwood (*P. fremonti*) and box elder (*A. negundo californica*) will be planted in and near the active channel. On the terrace, a combination of elderberry (*S. mexicana*), valley oak (*Q. lobata*), California bay (*U. californica*), big-leaf maple (*A. macrophyllum*) and California buckeye (*A. californica*) could be planted. All treatment plots will run perpendicular to the bank such that active channel and terrace areas are included in each treatment.

Within each of the four treatments there will be two nested treatments. The first nested treatment will be the removal of *Arundo* slash from two $2m^2$ plots within each treatment. The second nested treatment will address follow-up control procedures. The exact protocol for follow-up treatment for re-sprouts will be dictated by the agency responsible for the original removal effort. The options are either cut-stem herbicide treatment or no treatment. The project will address both of these options in each treatment area.

D. Permanent monitoring protocols will be set up to assess both the short-term and long-term "success" of the various treatments. Permanent transects will run perpendicular to the bank and be placed at random intervals. Each treatment area will have at least two transects. Vegetation composition, plant establishment, density, and diversity will be determined from a combination of point-intercept sampling and 2m X 1m quadrats placed randomly along the transect. Soil-water-potential data will be gathered with a tensimeter and soil carbon and nitrogen concentrations and ratios will be calculated by CHN analysis. Also, bird use will be observed and catalogued. During the first year, vegetation data will be collected immediately following removal, at the time of revegetation, in the spring and in the late summer. Soil sample and tensimeter readings will be taken in the spring and in the late summer. During the following three to five years all data will be collected in the early fall and late spring. Similar data will also be collected from the permanent transects at the reference sites.

Research/Management Implications:

Millions of dollars are spent each year in the United States on riparian restoration projects. Additionally, the invasion of exotic plant species into wildlands has become a major conservation concern. This project is focused at the nexus of these two major management issues. We intend to use long-term monitoring techniques to examine the effectiveness of various revegetation techniques on the restoration of riparian corridors after the removal of the exotic invader *Arundo donax*. Effectiveness will be evaluated for both the short-term and the long-term. For the short-term, we will look to see which, if any,

revegetation techniques suppress further invasions by exotics and/or foster the maximum diversity, cover, and density of native species. In the long-term, we will be looking at how different revegetation schemes affect habitat use, water relations, and productivity. The data generated from both the long-term and short-term monitoring will be the foundation of a comprehensive revegetation protocol. Our protocol will be an invaluable tool for land managers working to eradicate invasive exotic plant species and implement restoration of riparian ecosystems. Additionally, this research will add to the body of scientific knowledge and may shed light on the debate between active and passive revegetation and control of exotic plant populations.

Evaluation:

This project has both short-term and long-term goals. At both time scales project "success" will determined by comparing data from reference sites to treatment sites as well as comparing data between treatment sites. The short-term goals are the restoration of structure (native vegetation) and the control/eradication of *Arundo donax*. This goal will be completed when the vegetation assemblages in the treatment sites are of similar composition and diversity as those in reference sites. Obviously, woody plants will not meet their growth potential in one season, hence survival through the summer will be the indicator of establishment. Additionally, eradication of *Arundo* and lack of invasion from other invasive exotic plants will be an important indicator of initial success.

Long-term success will be gauged using the above criteria as well as a variety of indicators of functional restoration. Three measures of ecosystem function, (1) habitat use, (2) soil-water potential, and (3) CHN concentrations, will be used to evaluate long-term project success. These factors have been chosen because prior research has indicated that *Arundo donax* is rarely used as an avian habitat (Hendricks and Reiger 1989; Zembal 1986, 1990) and uses prodigious amount of water (Iverson 1994). Additionally, it has been hypothesized that *Arundo* alters chemical cycling due to slow decomposition rates related to high structural carbohydrates content (Unpublished research). Again, reference sites will be used to gauge success. When the data for both structural and functional aspects of the eradication sites are no longer statistically significant from the data at the reference sites, restoration will be complete.

Overall Context:

This project is part of a larger program that is being initiated by Team *Arundo* del Norte. The overall context in which this project is couched is the collection and dissemination of information regarding the ecology, biology, distribution and eradication of *Arundo donax*. Funds have been secured from academia, environmental non-profits, and governmental agencies to realize this project. The restoration project discussed in this proposal ties into existing eradication work, habitat use studies, and research into ecosystem level impacts of *Arundo donax* invasions. It is imperative that *Arundo* be removed and riparian restoration is begun. The restoration guidelines that this project will produce will be an invaluable asset, both economically and ecologically, to the environmental community at large.

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