An Investigation of the Flooding and Salt Tolerance of Lepidium latifolium L. (Perennial Pepperweed) in the Bay Delta Region and its Relation to Habitat Restoration: A Manipulative Field Experiment

Project Information

1. **Proposal Title:**

   An Investigation of the Flooding and Salt Tolerance of Lepidium latifolium L. (Perennial Pepperweed) in the Bay Delta Region and its Relation to Habitat Restoration: A Manipulative Field Experiment

2. **Proposal applicants:**

   Eric Webb, H. T. Harvey & Associates, U.C. Davis
   Patrick Boursier, H. T. Harvey & Associates
   Max Busnardo, H. T. Harvey & Associates
   John Bourgeois, H. T. Harvey & Associates

3. **Corresponding Contact Person:**

   Eric Webb
   H. T. Harvey & Associates
   3150 Almaden Expressway Suite 145 San Jose, California 95118
   408 448-9450
   ewebb@harveyecology.com

4. **Project Keywords:**

   Habitat Restoration, Wetland
   Wetlands Ecology
   Wetlands, Tidal

5. **Type of project:**

   Research

6. **Does the project involve land acquisition, either in fee or through a conservation easement?**

   No

7. **Topic Area**:

   Non-Native Invasive Species

8. **Type of applicant:**

Private for profit

9. **Location - GIS coordinates:**

Latitude:	37.447
Longitude:	-122.000
Datum:	

Describe project location using information such as water bodies, river miles, road intersections, landmarks, and size in acres.

Project is proposed for implementation within the marshes of South San Francisco Bay. The sites include marshes adjacent to Mowry Slough, Alviso Slough and Coyote Creek. The results of the project have region wide implications.

10. **Location - Ecozone:**

Code 16: Inside ERP Geographic Scope, but outside ERP Ecozones

11. **Location - County:**

Santa Clara

12. **Location - City:**

Does your project fall within a city jurisdiction?

No

13. **Location - Tribal Lands:**

Does your project fall on or adjacent to tribal lands?

No

14. **Location - Congressional District:**

16

15. **Location:**

California State Senate District Number: 13

California Assembly District Number: 23

16. **How many years of funding are you requesting?**

1

17. **Requested Funds:**
    a) Are your overhead rates different depending on whether funds are state or federal?

No

If no, list single overhead rate and total requested funds:

Single Overhead Rate: 10

Total Requested Funds: $79,066.00

b) Do you have cost share partners already identified?

No

c) Do you have potential cost share partners?

No

d) Are you specifically seeking non-federal cost share funds through this solicitation?

No

If the total non-federal cost share funds requested above does not match the total state funds requested in 17a, please explain the difference:

18. **Is this proposal for next-phase funding of an ongoing project funded by CALFED?**

No

Have you previously received funding from CALFED for other projects not listed above?

No

19. **Is this proposal for next-phase funding of an ongoing project funded by CVPIA?**

No

Have you previously received funding from CVPIA for other projects not listed above?

No

20. **Is this proposal for next-phase funding of an ongoing project funded by an entity other than CALFED or CVPIA?**

No

Please list suggested reviewers for your proposal. (optional)

John Callaway	**University of San Francisco**	**(415) 422-5702**	**callaway@usfca.edu**
Joy Zedler	**University of Wisconsin, Madison**	**(608) 262-8629**	**jbzedler@facstaff.wisc.edu**

Irving A. Mendelssohn	**Louisiana State University**	**(225) 388-6425**	**imendel@lsu.edu**

21. **Comments:**

Environmental Compliance Checklist

An Investigation of the Flooding and Salt Tolerance of Lepidium latifolium L. (Perennial Pepperweed) in the Bay Delta Region and its Relation to Habitat Restoration: A Manipulative Field Experiment

1. **CEQA or NEPA Compliance**
   a) Will this project require compliance with CEQA?

      Yes

   b) Will this project require compliance with NEPA?

      Yes

   c) If neither CEQA or NEPA compliance is required, please explain why compliance is not required for the actions in this proposal.

2. **If the project will require CEQA and/or NEPA compliance, identify the lead agency(ies).** *If not applicable, put "None".*

   CEQA Lead Agency: None
   NEPA Lead Agency (or co-lead:) None
   NEPA Co-Lead Agency (if applicable):

3. **Please check which type of CEQA/NEPA documentation is anticipated.**

   CEQA
   XCategorical Exemption
   -Negative Declaration or Mitigated Negative Declaration
   -EIR
   -none

   NEPA
   XCategorical Exclusion
   -Environmental Assessment/FONSI
   -EIS
   -none

   If you anticipate relying on either the Categorical Exemption or Categorical Exclusion for this project, please specifically identify the exemption and/or exclusion that you believe covers this project.

   Minor project

4. **CEQA/NEPA Process**
   a) Is the CEQA/NEPA process complete?

      Not Applicable

   b) If the CEQA/NEPA document has been completed, please list document name(s):

5. **Environmental Permitting and Approvals** (*If a permit is not required, leave both Required? and Obtained? check boxes blank.*)

LOCAL PERMITS AND APPROVALS

Conditional use permit

Variance

Subdivision Map Act

Grading Permit

General Plan Amendment

Specific Plan Approval

Rezone

Williamson Act Contract Cancellation

Other

STATE PERMITS AND APPROVALS

Scientific Collecting Permit

CESA Compliance: 2081

CESA Compliance: NCCP

1601/03

CWA 401 certification

Coastal Development Permit

Reclamation Board Approval

Notification of DPC or BCDC

Other

FEDERAL PERMITS AND APPROVALS

ESA Compliance Section 7 Consultation Required

ESA Compliance Section 10 Permit

Rivers and Harbors Act

CWA 404

Other

PERMISSION TO ACCESS PROPERTY

Permission to access city, county or other local agency land. Agency Name:	
Permission to access state land. Agency Name: U. S. Fish & Wildlife Service	Required
Permission to access federal land. Agency Name:	
Permission to access private land. Landowner Name: Cargill	Required

6. **Comments.**

Land Use Checklist

An Investigation of the Flooding and Salt Tolerance of Lepidium latifolium L. (Perennial Pepperweed) in the Bay Delta Region and its Relation to Habitat Restoration: A Manipulative Field Experiment

1. **Does the project involve land acquisition, either in fee or through a conservation easement?**

   No

2. **Will the applicant require access across public or private property that the applicant does not own to accomplish the activities in the proposal?**

   Yes

3. **Do the actions in the proposal involve physical changes in the land use?**

   No

   If you answered no to #3, explain what type of actions are involved in the proposal (i.e., research only, planning only).

   Research only

4. **Comments.**

Conflict of Interest Checklist

An Investigation of the Flooding and Salt Tolerance of Lepidium latifolium L. (Perennial Pepperweed) in the Bay Delta Region and its Relation to Habitat Restoration: A Manipulative Field Experiment

Please list below the full names and organizations of all individuals in the following categories:

- Applicants listed in the proposal who wrote the proposal, will be performing the tasks listed in the proposal or who will benefit financially if the proposal is funded.
- Subcontractors listed in the proposal who will perform some tasks listed in the proposal and will benefit financially if the proposal is funded.
- Individuals not listed in the proposal who helped with proposal development, for example by reviewing drafts, or by providing critical suggestions or ideas contained within the proposal.

The information provided on this form will be used to select appropriate and unbiased reviewers for your proposal.

Applicant(s):

Eric Webb, H. T. Harvey & Associates, U.C. Davis
Patrick Boursier, H. T. Harvey & Associates
Max Busnardo, H. T. Harvey & Associates
John Bourgeois, H. T. Harvey & Associates

Subcontractor(s):

Are specific subcontractors identified in this proposal? Yes

If yes, please list the name(s) and organization(s):

Mike Galloway   Soil Control Lab

Helped with proposal development:

Are there persons who helped with proposal development?

No

Comments:

Budget Summary

An Investigation of the Flooding and Salt Tolerance of Lepidium latifolium L. (Perennial Pepperweed) in the Bay Delta Region and its Relation to Habitat Restoration: A Manipulative Field Experiment

Please provide a detailed budget for each year of requested funds, indicating on the form whether the indirect costs are based on the Federal overhead rate, State overhead rate, or are independent of fund source.

Independent of Fund Source

Year 1												
Task No.	**Task Description**	**Direct Labor Hours**	**Salary *(per year)***	**Benefits *(per year)***	**Travel**	**Supplies & Expendables**	**Services or Consultants**	**Equipment**	**Other Direct Costs**	**Total Direct Costs**	**Indirect Costs**	**Total Cost**
1	Marsh Determination	21	1,815.00							1815.0		1815.00
2	Install	147	12,985.00		101.20			4400.00		17486.2		17486.20
3	Progress Monitoring	108	9,200.00		101.20			1650.00		10951.2		10951.20
4	Harvest	208	17,160.00		101.20			1100.00	4972.00	23333.2		23333.20
5	Analyze Data	90	7,650.00			275.00				7925.0		7925.00
6	Report	140	12,000.00			275.00				12275.0		12275.00
7	Progress Reporting	56	5,280.00							5280.0		5280.00
		770	66090.00	0.00	303.60	550.00	0.00	7150.00	4972.00	79065.60	0.00	79065.60

Year 2												
Task No.	**Task Description**	**Direct Labor Hours**	**Salary *(per year)***	**Benefits *(per year)***	**Travel**	**Supplies & Expendables**	**Services or Consultants**	**Equipment**	**Other Direct Costs**	**Total Direct Costs**	**Indirect Costs**	**Total Cost**
		0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Year 3												
Task No.	**Task Description**	**Direct Labor Hours**	**Salary *(per year)***	**Benefits *(per year)***	**Travel**	**Supplies & Expendables**	**Services or Consultants**	**Equipment**	**Other Direct Costs**	**Total Direct Costs**	**Indirect Costs**	**Total Cost**
		0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Grand Total=79065.60

Comments.

Budget Justification

An Investigation of the Flooding and Salt Tolerance of Lepidium latifolium L. (Perennial Pepperweed) in the Bay Delta Region and its Relation to Habitat Restoration: A Manipulative Field Experiment

Direct Labor Hours. Provide estimated hours proposed for each individual.

Sr. Plant Ecologist - 24 Project Manager - 96 Sr. Ecologist 1 - 70 Ecologist 3 - 234 Field Biologist 3 - 244 Graphics/GIS - 44 Administrative Support - 58

Salary. Provide estimated rate of compensation proposed for each individual.

Sr. Plant Ecologist - $3480.00 Project Manager - $11,040.00 Sr. Ecologist 1 - $6,650.00 Ecologist 3- $21,060.00 Field Biologist 3 - $17,080.00 Graphics/GIS - $3,300.00 Administrative Support - $3,480.00

Benefits. Provide the overall benefit rate applicable to each category of employee proposed in the project.

We will be using fully burdened rates.

Travel. Provide purpose and estimate costs for all non-local travel.

Not applicable

Supplies & Expendables. Indicate separately the amounts proposed for office, laboratory, computing, and field supplies.

Office Supplies - $550.00 Field Supplies - $7,150.00

Services or Consultants. Identify the specific tasks for which these services would be used. Estimate amount of time required and the hourly or daily rate.

Not applicable

Equipment. Identify non-expendable personal property having a useful life of more than one (1) year and an acquisition cost of more than $5,000 per unit. If fabrication of equipment is proposed, list parts and materials required for each, and show costs separately from the other items.

None

Project Management. Describe the specific costs associated with insuring accomplishment of a specific project, such as inspection of work in progress, validation of costs, report preparation, giving presentatons, reponse to project specific questions and necessary costs directly associated with specific project oversight.

Progress Reporting - $5,280.00 Draft/Final Report Preparation - $12,000.00 Project Management - $3220.00 Quality Assurance/Control - $3190.00

Other Direct Costs. Provide any other direct costs not already covered.

Soil and Plant Analysis (Soil Control Lab) - $4972.00

Indirect Costs. Explain what is encompassed in the overhead rate (indirect costs). Overhead should include costs associated with general office requirements such as rent, phones, furniture, general office staff, etc., generally distributed by a predetermined percentage (or surcharge) of specific costs.

All rates are fully burdened (overhead included).

Executive Summary

An Investigation of the Flooding and Salt Tolerance of Lepidium latifolium L. (Perennial Pepperweed) in the Bay Delta Region and its Relation to Habitat Restoration: A Manipulative Field Experiment

Invasive, non-native plant species are displacing native plant species within salt and brackish marsh habitats throughout the Bay-Delta Region. Lepidium latifolium (perennial pepperweed) is a highly invasive plant species that is commonly found in tidal salt marsh and brackish marsh habitats. These tidal salt marshes provide critical habitat for several endangered plant and animal species. Invasion of tidal salt marshes by non-native plant species such as L. latifolium has the potential to greatly reduce the available habitat for this endangered species within the Bay-Delta Region. Numerous tidal wetland restoration projects are being planned or proposed for the Bay-Delta region. Tidal wetland restoration projects may be rapidly colonized by adjacent stands of L. latifolium. During the design of restoration projects, measures could be implemented to minimize or exclude L. latifolium colonization. Before implementing measures for control of L. latifolium, more information about its potential distribution and stress tolerances within coastal marshes should be collected. Specifically, depth and duration of inundation and interstitial soil salinity are two important factors that control the distribution of wetland plant species in estuarine environments. To better understand how these factors control the distribution of L. latifolium in the Bay-Delta Region, we propose to conduct a manipulative field experiment with L. latifolium. We propose to place sods of L. latifolium at three elevations (ambient pickleweed-dominated marsh elevation (n=10), 26 cm above the ambient marsh elevation (n=10), and 26 cm below the ambient marsh elevation (n=10)) and in two marsh types (high salinity tidal marsh and low salinity tidal marsh). Sods will also be replaced in the donor marsh at the ambient marsh elevation as an experimental control (n=10). Treatments will be blocked on the distance from slough channels. It is anticipated that the experiment will be initiated in September 2002 and harvested in September 2003. Plant height and soil redox potential will be measured quarterly and at the time of harvest. Aboveground and belowground plant biomass will be harvested and interstitial salinity and pH will be measured at the end of the experiment to determine the affects of varying salinity, depth and duration of flooding, and the combination of these factors on L. latifolium.

Proposal

H. T. Harvey & Associates, U.C. Davis

An Investigation of the Flooding and Salt Tolerance of Lepidium latifolium L. (Perennial Pepperweed) in the Bay Delta Region and its Relation to Habitat Restoration: A Manipulative Field Experiment

Eric Webb, H. T. Harvey & Associates, U.C. Davis
Patrick Boursier, H. T. Harvey & Associates
Max Busnardo, H. T. Harvey & Associates
John Bourgeois, H. T. Harvey & Associates

An Investigation of the Flooding and Salt Tolerance of *Lepidium latifolium* L. (Perennial Pepperweed) in the Bay – Delta Region and its Relation to Habitat Restoration: A Manipulative Field Experiment

Applicant: Eric C. Webb, Ph.D., Wetland Plant Ecologist, H. T. Harvey & Associates

Co-investigators: Patrick Boursier, Ph.D., Max Busnardo, M.S. and John Bourgeois, M.S., H. T. Harvey & Associates

Executive Summary

Invasive, non-native plant species are displacing native plant species within salt and brackish marsh habitats throughout the Bay-Delta Region. *Lepidium latifolium* (perennial pepperweed) is a highly invasive plant species that is commonly found in tidal salt marsh and brackish marsh habitats. These tidal salt marshes provide critical habitat for several endangered plant and animal species. Invasion of tidal salt marshes by non-native plant species such as *L. latifolium* has the potential to greatly reduce the available habitat for this endangered species within the Bay-Delta Region.

Numerous tidal wetland restoration projects are being planned or proposed for the Bay-Delta region. Tidal wetland restoration projects may be rapidly colonized by adjacent stands of *L. latifolium*. During the design of restoration projects, measures could be implemented to minimize or exclude *L. latifolium* colonization. Before implementing measures for control of *L. latifolium*, more information about its potential distribution and stress tolerances within coastal marshes should be collected. Specifically, depth and duration of inundation and interstitial soil salinity are two important factors that control the distribution of wetland plant species in estuarine environments. To better understand how these factors control the distribution of *L. latifolium* in the Bay-Delta Region, we propose to conduct a manipulative field experiment with *L. latifolium*. We propose to place sods of *L. latifolium* at three elevations (ambient pickleweed-dominated marsh elevation (n=10), 26 cm above the ambient marsh elevation (n=10), and 26 cm below the ambient marsh elevation (n=10)) and in two marsh types (high salinity tidal marsh and low salinity tidal marsh). Sods will also be replaced in the donor marsh at the ambient marsh elevation as an experimental control (*n*=10). Treatments will be blocked on the distance from slough channels.

It is anticipated that the experiment will be initiated in September 2002 and harvested in September 2003. Plant height and soil redox potential will be measured quarterly and at the time of harvest. Aboveground and belowground plant biomass will be harvested and interstitial salinity and pH will be measured at the end of the experiment to determine the affects of varying salinity, depth and duration of flooding, and the combination of these factors on *L. latifolium*.

PROJECT DESCRIPTION: PROJECT GOALS and SCOPE OF WORK

Background

Several non-native, invasive plant species are commonly found in the tidal marshes of the Bay-Delta region. These plants include *Spartina alterniflora*, *Salsola soda*, *Spartina densiflora*, and *Lepidium latifolium*. Many of these plant species continue to colonize existing marshes, displacing the dominant, native salt and brackish marsh plant species. Furthermore, tidal wetland restoration efforts throughout the Bay-Delta region must consider the implications for further spreading these invasive plant species. Because tidal marsh restoration projects provide a suitable substrate for the rapid establishment of many of these invasive species, the design of tidal wetland restoration projects usually include management and maintenance requirements for their eradication.

Many tidal wetland restoration projects in the Bay-Delta region have been colonized by non-native invasive plant species (e.g. Larkspur Ferry Terminal Salt Marsh Restoration project). Many others have implemented long-term, large-scale eradication programs at the onset of restoration activities (e.g. Cooley Landing Tidal Wetland Restoration project).

Non-native, invasive plant species continue to displace native plant species throughout the Bay-Delta region. As this occurs, there are further reductions in suitable habitat for many threatened and endangered plant and animal species including the California clapper rail (*Rallus longirostris obsoletus*) and salt marsh harvest mouse (*Reithrodontomys raviventris raviventris*).

Large-scale, invasive plant species eradication programs have been implemented both in tidal wetland restoration projects and within existing tidal marshes (e.g. Don Edwards San Francisco Bay Wildlife Refuge). Eradication programs are both costly and highly disturbing to plant and animal species within tidal wetlands. Furthermore, eradication programs are only limited in scope and attempt to control or minimize further expansion of invasive plants.

It is imperative to understand the mechanisms for invasive plant species colonization of existing tidal marshes and newly restored tidal wetlands. This will require studies that detail factors that control the abundance and distribution of these invasive plants. A number of variables have been shown to be important in controlling the distribution of plant species in coastal marshes. Interstitial soil salinity is one of the important variables correlated with vegetation change (Callaway and Sabraw 1994, Allison 1992, Callaway et al. 1989, Zedler 1983, 1986).

However, numerous other factors have also been found to control marsh species composition including: depth and duration of flooding over the marsh surface (Webb and Mendelssohn 1996, Webb et al. 1995, Pennings and Callaway 1992, Mendelssohn and McKee 1988), accumulation of phytotoxins such as hydrogen sulfide in marsh soils (Webb and Mendelssohn 1996, Webb et al. 1995, Koch and Mendelssohn 1989, DeLaune et al. 1983, King et al. 1982), interstitial nutrient concentrations (Koch et al. 1990, Bradley and Morris 1980, Koch and Mendelssohn 1989, Morris 1980) and soil mineral and organic matter content (Nyman et al. 1990, DeLaune et al. 1979). Except for *S. alterniflora*, little is known about the stress tolerances and mechanisms controlling the distribution of these invasive plant species in coastal marshes.

One of the most common invasive plant species within tidal salt and brackish marshes of the Bay-Delta region is *L. latifolium* L. (perennial pepperweed). *L. latifolium* is an invasive plant species, native to Europe, North Africa and much of southern Asia. *L. latifolium* has invaded nearly every state in the United States and has been recorded in California from as early as 1936. It is a perennial herbaceous plant species reaching approximately 1.5 m in height and has large below ground roots. *L. latifolium* flowers in late spring and early summer (Renz et al. 1997).

The roots of *L. latifolium* typically comprise 40% of the total plant biomass (Renz et al. 1997). The majority of the root biomass (~85%) typically occurs within the top 60 cm of the soil. Rooting depths have been found to be considerably greater, and rooting depths of 3 m and more have been observed (Blank & Young 1997, Patrick Boursier, personal observation).

Very few *L. latifolium* seedlings have been observed in the field and the reasons for low seedling densities in the wild are unknown. Seed viability for *L. latifolium* in the field is believed to be low (Miller et al. 1986). However, seed germination rate in laboratory conditions is high, therefore there may be a short period of viability in the soils (Miller et al. 1986). The low germination rate in natural conditions suggests that the potential for reinfestations from the seedbank by *L. latifolium* following eradication is likely to be low (Miller et al. 1986).

L. latifolium is found in a broad range of habitats in the United States. It is known to occur in large, nearly monospecific stands within wetlands, marshes, floodplains and riparian areas and has been reported from mountainous areas, agricultural fields and roadsides (Morisawa 1999). In California, it has been found in all counties except for those mainly comprised of coastal rainforest and desert habitats (Young et al. 1997). *L. latifolium* is also found in saline and alkaline soils. It has colonized the high marsh and marsh/upland ecotone in tidal marshes throughout much of the San Francisco Bay – Delta region (Eric. Webb, personal observation). In these tidal marshes *L. latifolium* displaces native species such as *Salicornia virginica*, *Grindelia stricta*, *Frankenia salina*, and *Distichlis spicata*. Conversion of *S. virginica* dominated high marsh and marsh/upland ecotone habitats to *L. latifolium* dominated habitat decreases the distribution of high quality, salt marsh habitat. In South San Francisco Bay, *L. latifolium* is found in tidal marshes with average interstitial salinities of 25 ppt (H. T. Harvey & Associates 2000).

We propose to conduct a study of *L. latifolium* in order to better understand its physiological tolerances to stressors common within tidal marshes. This information has several useful applications. Planning efforts for tidal wetland restoration projects can include measures that promote the colonization of native plant species and exclude the colonization of *L. latifolium*. Eradication efforts can focus on infested areas adjacent to marshes that fit the profile for likely colonization by *L. latifolium*. Finally, predictions can be made of marsh area within the Bay-Delta region susceptible to future colonization by *L. latifolium*. Funding for large-scale *L. latifolium* eradication programs could then be justified based upon the area of potential infestation.

Research Problem

As part of the Restoration Priorities for the Bay Region, CALFED has identified the need to implement actions to prevent, control and reduce impacts to non-native invasive species. This includes conducting research on the relationships between inundation, salinity and non-native, invasive species growth responses in tidal wetlands to identify the hydrologic regimes less favorable to the non-natives (Strategic Goal 5, non-native invasive species). Non-native, invasive plant species have rapidly colonized tidal marshes of San Francisco, San Pablo and Suisun Bays. One of the most common invasive plant species found within salt and brackish marshes is *L. latifolium*.

There is a lack of information regarding the ecology of *L. latifolium* in the habitats it has invaded in the United States. Specifically, in coastal zones, the flooding and salt tolerances of this species are not well understood. Research needs for *L. latifolium* have been identified by Marc Renz, University of California, Davis, Weed Science Program. These needs include understanding how *L. latifolium* copes with varying interstitial salinities and what environmental, physical and/or geographical factors limit the expansion of *L. latifolium* (Renz 2001). Based on field observations of its distribution, *L. latifolium* is obviously tolerant of some measure of flooding and salinity, but the maximum extent of its potential colonization in areas such as the San Francisco Bay – Delta region is not known. Furthermore, many studies of the stress tolerances of wetland plant species indicate that the combination of stressors (e.g. flooding stress and salt stress) may greatly reduce plant productivity and viability. The combination of these stressors is quite common in the San Francisco Bay – Delta marshes, therefore an understanding of the effects of flooding and salinity interactions on *L. latifolium* is needed as well.

In order to both predict the potential for future colonization of tidal marshes and to potentially control *L. latifolium* within future tidal wetland restoration projects, the ecophysiology of the plant needs to be understood. Knowledge of the effects of inundation depth/duration and salinity on *L. latifolium* establishment and productivity could be used to incorporate restoration design elements that minimize the potential for successful *L. latifolium* invasion. In addition, the ability to predict areas most susceptible to potential future colonization by *L. latifolium* would enable marsh managers to focus vegetation monitoring and early eradication efforts.

A field manipulative experimental approach is the preferred method for evaluating stress tolerances of wetland plant species. This approach manipulates the individual plants, subjecting them to varying levels and combinations of stressors in the environment where they occur. Edaphic and biotic characteristics are measured simultaneously to determine the stress tolerances (and limits) of individual plant species. A properly designed field manipulative experiment can provide reliable information regarding the effects of specific environmental factors (independent variables) on plant growth (Hurlbert 1984).

Hypotheses to be Tested

Several hypotheses will be tested by the proposed experiment. These hypotheses are directly related to CALFED problems outlined in the Proposal Soliciation Package. The hypotheses that will be tested by this experiment include the following:

1. The distribution of *L. latifolium* in marshes of San Francisco Bay is controlled by the combination of salinity and depth and duration of flooding.

2. *L. latifolium*'s stress tolerance allows it to readily colonize S. virginica-dominated marshes at approximately mean higher high water (MHHW).

3. L. latifolium's stress tolerance limits its distribution in marshes at mean high water (MHW).

4. Interstitial soil salinities in excess of 35 ppt will negatively stress *L. latifolium* at any marsh elevation.

Experimental Design

To better understand the stress ecophysiology of *L. latifolium*, we propose to conduct a field manipulative bioassay study of the plant species in the marshes of South San Francisco Bay. Although *L. latifolium* is quite common throughout much of the San Francisco Bay – Delta region, the South Bay has both highly stratified physical characteristics and is convenient to our offices (thereby reducing travel costs). The objective of the proposed bioassay study is to determine the relative importance of salinity and submergence on the productivity of *L. latifolium*. Therefore the bioassay experiment described below was designed to manipulate the elevation and salinity of *L. latifoliu*m marsh sods.. This will be accomplished by transplanting *L. latifolium* into low salinity (~ 20 ppt) and high salinity (~55 ppt) tidal marshes at three elevations: (1) ambient marsh elevation (mean higher high water); (2) 26 cm above the ambient marsh elevation; (3) 26 cm below the ambient marsh evlevation. The elevational treatments were chosen to represent the average elevational range for *S. virginica*-dominated salt marsh habitats in San Francisco Bay. *S. virginica* dominated marshes typically fall within a range of 26 cm above and below mean higher high water (MHHW). Furthermore, control treatments will be established at the ambient elevation of the site where *L. latifolium* was removed (donor marsh).

The treatments will be created by removing vegetated marsh sods containing an equivalent number and size of *L. latifolium* ramets and placing them in plastic pots with numerous (20+) holes in each pot to allow for drainage. The marsh sods of the elevated treatments will be placed on the marsh surface so that 26 cm of the sod extends above the soil surface. The marsh sods of the lowered treatments will be placed within the marsh so that the surface of the sod is 26 cm below the marsh surface. The ambient elevation treatment will be established by placing replicate marsh sods flush with the adjacent marsh surface.

These treatments will be replicated within a low salinity and high salinity tidal marsh. Ten replicates of each treatment within two marshes will be prepared as a randomized block design. Seven treatments (three elevations at two salinities and a control) will be analyzed where elevations will be blocked on distance from the edge of slough channels. The ambient elevations of the low salinity and high salinity tidal marsh will be determined prior to the initiation of the experiment. The experiment will be initiated in September 2002 and harvested in September 2003.

Soil redox potential from each sod at two depths, 2 and 15 cm, and plant height will be measured quarterly during the duration of the experiment. Upon completion of the experiment, soil redox potential will be determined in each sod. Following the collection of redox potential data, aboveground vegetation will be harvested at the soil surface from each sod. Plants will be brought to the laboratory and dried at 100^{o} C for 48 hours. Plant samples will be weighed for biomass determination. After the vegetation is harvested, soil cores will be extracted from the root zone of each sod. Soil cores will be analyzed for interstitial pH and salinity. Analysis of variance will be used to analyze the data.

Following data collection and analysis, a draft report will be provided to CALFED for review. The report will include summary graphs and tables, introduction including a thorough literature review of *L. latifolium*, detailed methods, results and discussion. It is anticipated that the project will result in a substantial amount of new information about this invasive species that will improve our understanding of its ecophysiology and aid in our ability to control and potentially eradicate it from tidal marshes of the San Francisco Bay – Delta region.

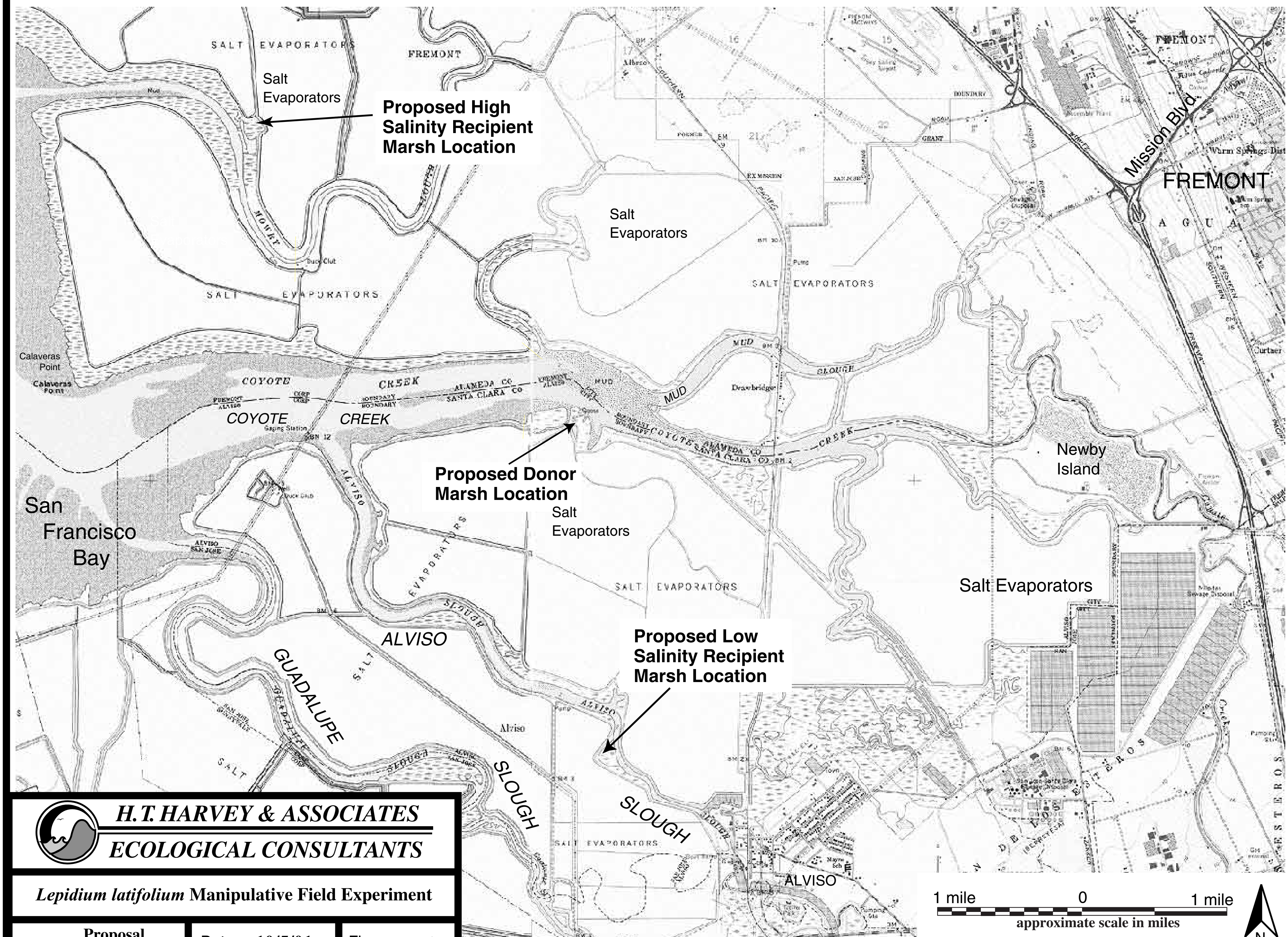
Scope of Work

Task 1. Locate Appropriate Marshes for Bioassay Experiment

At this time we anticipate locating the bioassay experiment within marshes of differing soil salinities in South San Francisco Bay. Specifically, marshes of high soil salinity along Mowry Slough (~50 ppt) have been chosen for the high salinity treatment. Marshes of low soil salinity along Alviso Slough (~15 ppt) have been chosen for the low salinity treatment (Figure 1). Soil salinities at these two locations are well described (H. T. Harvey & Associates 2000). This task also includes the preparation of permit applications for access to the marshes of South San Francisco Bay. It is anticipated that an access permit from Cargill, Inc. and a Special Use Permit from the U. S. Fish & Wildlife Service's San Francisco Bay Wildlife Refuge will be required.

Task 2. Install Bioassay Experiment

During the late summer/early fall 2002 the bioassay experiment will be installed. Sods of *L. latifolium* will removed from the donor marsh. Sods will be selected so that an equal number of ramets of the same size class are within each sod. Furthermore, belowground biomass will be equalized as much as possible during the removal of each sod. All sods will be placed in pots containing numerous drainage holes (20+) before being transported to the recipient marshlocations or immediately placed at the ambient elevation at the donor marsh (control treatment). Following removal and potting, sods will be transported to the recipient marsh locations (high salinity and low salinity) and placed at three elevations (ambient marsh elevation, -26 cm and +26 cm) at each recipient marsh. Ten replications of each treatment will be established. Therefore a total of 70 sods will be removed from the donor marsh and used in the experiment at the three marsh locations: (1) high salinity recipient marsh, (2) low salinity recipient marsh and (3) donor marsh - control. All treatments will be fully randomized and blocked on distances from slough channels and levees (randomized block design). The experiment will be implemented in the September 2002.



H.T. HARVEY & ASSOCIATES
ECOLOGICAL CONSULTANTS

Lepidium latifolium **Manipulative Field Experiment**

File No. Proposal 3069	Date 10/5/01	Figure 1

Task 3. Monitor Bioassay Experiment

Plant height and soil redox potential will be measured four times during the life of the bioassay experiment. Data will first be collected during the initiation of the project in September 2002. Subsequent measurements of plant height and soil redox potential will be conducted in December 2002, March 2003 and June 2003. Soil redox potential will be collected from all treatments when surface water levels are below the marsh elevation (falling or low tide).

At each site visit during the course of the experiment, adjacent marsh vegetation will be trimmed, by hand, as necessary. This will be done to minimize plant competition by adjacent marsh plant species.

Task 4. Harvest Experiment

The bioassay experiment will be harvested in September 2003. Prior to the removal of aboveground and belowground biomass, soil redox potential and plant height will be measured. Aboveground biomass will be harvested from each sod. Prior to the separation of the belowground biomass, a single soil core will be taken from the upper 15 cm of the sod. The soil core will be taken to the laboratory (Soil Control Laboratory, Watsonville, CA) and analyzed for interstitial pH and salinity. All plant material will be bagged, labeled and brought back to the laboratory. Sods will also be brought back to the laboratory where soils will be washed away from belowground biomass. All plant material will be separated by species (including belowground biomass, where possible) and dried at 100^{o} C for 48 h and weighed at a constant temperature.

Task 5. Analyze Data

Analysis of variance will be used to analyze the data. Seven treatments (three elevations at two marshes and a control) will be analyzed as a randomized block design (n=10) where elevation will be blocked on distance from the slough channel edge. All variables will be tested for normality and heterogeneity of variance to meet the assumptions of analysis of variance. All variables will be transformed as necessary to meet these assumptions.

Task 6. Prepare Report

A draft report will be prepared that details the results of the bioassay experiment. The report will include a literature review and a description of project methods including data analysis. Results will be described in detail and a discussion will be prepared that places the results in perspective given the current knowledge of wetland plant stress physiology.

A final report will be prepared following the review by the CALFED review committee. It is assumed that H. T. Harvey & Associates will be presented with one consolidated set of comments for incorporation into the report.

Task 7. Quarterly Progress Reports

Progress reports will be prepared quarterly. Progress reports will be brief and describe the status of the experiment and provide a summary of all data collected to date.

Feasibility

The proposed manipulative field experiment is highly feasible. This particular bioassay approach has been used by the authors in the past for answering similar questions about stress tolerance and its relationship to specific plant species distribution (Webb and Mendelssohn 1996, Webb et al. 1995). The project is proposed to be conducted in the marshes of South San Francisco Bay, an area where we have collected vegetation data annually for twelve years. We are very familiar with the system and have been operating in these marshes for many years. The proposed bioassay experiment is not dependent upon the timing or outcome of other experiments or dependent upon any specific environmental or operational condition.

Although the study is proposed in the marshes of South San Francisco Bay, the results of the experiment will be applicable to marshes of the Bay-Delta Region. The choice of South San Francisco Bay marshes for the experiment implementation was made to insure the success of the project. We specifically need to select recipient marshes with known elevations and soil salinities. Additionally, easily accessible recipient marshes of widely varying salinities are available in the South Bay. Therefore, the decision of location was based upon the vast amounts of data that has been collected in the marshes of the South Bay. For example a long-term database of vegetation change including the mapping of *L. latifolium* in these marshes since the 1980's at a scale that allows tracking of year-to-year changes is available. Also surface water elevation and salinity and interstitial pH and salinity data exists for these marshes.

H. T. Harvey & Associates has permits from the Refuge and Cargill to conduct long term analysis of the marshes of South San Francisco Bay. Although permits will be necessary for access to Cargill levees and to the marsh from the Refuge, we have obtained these permits annually for ten years. Therefore the acquisition of access permits should not be problematic.

Performance Measures

A quarterly evaluation of the field experiment will be conducted to determine the project progress. Plant height and soil redox potential is expected to be significantly different between treatments at the quarterly evaluation points; this information will also be used a measure of the performance of the experiment.

Data Handling and Storage

All field data will be entered into project specific field notebooks. Upon return to the office, the field notes will immediately be duplicated and filed. Additional copies will be electronically scanned and kept on a network folder for safety.

Data sheets will be prepared for all laboratory data. Data sheets will be immediately duplicated, filed and scanned electronically for additional safety. All data will be entered into spreadsheets for analysis as soon as possible.

Following data analysis, all of the raw data and results of the analysis will be given to CALFED. Furthermore, all analyzed data is kept in duplicate and also kept electronically on network computers. All data on the network is backed-up daily.

Work Schedule

Task 1. Locate Appropriate Marshes
Start: August 15, 2002
Finish: August 31, 2002

Task 2. Install Bioassay Experiment
Start: September 1, 2002
Finish: September 15, 2002

Task 3. Monitor Bioassay Experiment
Quarterly – December 2002, March 2003, June 2003

Task 4. Harvest Experiment
Start: September 15, 2003
Finish: Septemnber 30, 2003

Task 5. Analyze Data
Start: October 1, 2003
Finish: October 31, 2003

Task 6. Prepare Report
Start: November 1, 2003
Finish: December 15, 2003

Task 7. Quarterly Progress Reports
Due: October, 15, 2001, January 15, 2002, April 15, 2002 and July 15, 2002

APPLICABILITY TO CALFED ERP AND SCIENCE PROGRAM GOALS AND IMPLEMENTATION PLAN AND CRPIA PRIORITIES

The proposed *L. latifolium* manipulative field experiment addresses two of the Stage 1 PSP priorities. The Restoration Priorities and Action for the Bay Region priority BR-3, Implement actions to prevent, control and reduce impacts of non-native invasive species, will be addressed by this project. Specifically this is a pilot project in tidal marsh habitats that will be a successful approach to understanding the ecological impacts and control strategies of *L. latifolium* (Strategic Goal 5, non-native invasive species). Furthermore, this project will research the relationships between inundation, salinity and non-native invasive species needs in tidal wetlands. This research will identify hydrologic regimes and salinities that are less favorable to non-natives (Strategic Goal 5, non-native invasive species). The proposed work will also improve the knowledge base for controlling *L. latifolium* in tidal wetland restoration projects and in areas not yet colonized by *L. latifolium*.

The proposed manipulative field experiment is a first phase of studies to understand the mechanisms to be used to control the expansion of *L. latifolium*. Additional studies that can be implemented in the future include the survey of *L. latifolium* distribution in the Bay-Delta Region, plant competition studies with *L. latifolium* and native tidal marsh plant species and *L. latifolium* eradication methods. This study will provide useful information in the design of these and other future studies involving *L. latifolium*.

The proposed manipulative field experiment provides ecosystem benefits by identifying the physiological tolerances of a common non-native invasive plant species. Although the experiment is proposed in the marshes of South San Francisco Bay, the information generated by this study can be used within the entire Bay-Delta Region for tidal wetland restoration projects and eradication efforts.

Qualifications

ERIC C. WEBB, Ph.D., Wetlands Ecologist

Dr. Webb is an experienced wetlands ecologist with a strong technical background in the restoration and management of highly impacted coastal marshes. Eric has worked extensively with diked historic marsh restoration and management, specifically focusing on restoring critical hydrologic characteristics and marsh elevations to encourage re-colonization by target plant species and wildlife. The majority of his project sites have been hundreds and thousands of acres in size. Eric has managed over 150 projects including large-scale coastal restoration projects, mitigation and monitoring plan preparation, long-term wetland vegetation monitoring and plant stress ecophysiological studies. Eric has managed the restoration and management planning for the 1,400-acre Bair Island tidal wetland restoration site in Redwood City, California and the development of a restoration plan and permit package for the 145-acre Cooley Landing Wetland Restoration project in Menlo Park, CA. Eric has conducted research on the wetland plant stress tolerance, wetland plant distribution and the effects of oiling on wetland plant species in California, Louisiana, Kentucky, Texas, Minnesota and Ohio.

Webb, E. C., Mendelssohn, I.A., and B. J. Wilsey. 1995. Causes for vegetation dieback in a Louisiana salt marsh: A bioassay approach. Aquatic Botany 51:281-289.

Webb, E. C. and I. A. Mendelssohn. 1996. Factors affecting vegetation dieback of an oligohaline marsh in coastal Louisiana: Field manipulation of salinity and submergence. American Journal of Botany 83: 1429-1434.

PATRICK J. BOURSIER, Ph.D., Wetlands Ecologist, Plant Physiologist

Dr. Boursier conducts and directs a variety of projects related to special-status plant surveys, wetland delineations, restoration of endangered species habitats, impacts analysis and mitigation design, and acquisition of resource agency permits. Patrick has conducted and managed over 300 projects including environmental impact reports, constraints analyses, impact assessments, and mitigation and monitoring studies. He has mapped biotic habitats, conducted special-status plant surveys and performed wetland delineations in a wide variety of plant communities throughout Santa Clara, San Benito, Santa Cruz, Marin, Sonoma, Alameda, San Joaquin and Contra Costa Counties. Dr. Boursier has been extensively involved in a research and monitoring project in the Suisun Marsh at the Concord Naval Weapons Station. Additionally, he assisted the Santa Clara Valley Water District in obtaining resource agency permits to conduct their in-stream water recharge program at 52 creek locations throughout the county. This work included managing a multi-disciplinary team directed to conduct wetland delineations, biotic habitat impacts analysis, special-status species surveys, and preparation of mitigation and monitoring reports, alternatives analysis and an environmental impact report.

Boursier, P. and A. Lauchli. 1989. Mechanisms of chloride partitioning in leaves of salt-stressed Sorghum bicolor. Physiol. Plant. 77:537-544.

Boursier, P., C. A. Raguse and K. L. Taggard. 1989. Growth and nitrogen-fixing responses of subterranean clover to application and subsequent removal of ammonium nitrate. Crop Sci. 29:758-763.

Boursier, P. and A. Lauchli. 1990. Growth response and mineral nutrient relations of salt-stressed sorghum. Crop Sci. 30:1226-1233.

MAX J. BUSNARDO, M.S., Restoration Ecologist/Wetland Ecologist

Mr. Busnardo has extensive experience in field manipulative wetland ecosystem experimentation and in all phases of the wetland restoration process. Max applies his expertise in plant ecology, wetland science, and chemistry to the various aspects of wetland restoration design including: site selection, soil suitability, revegetation planning, hydrology design (teaming with a hydrologist), monitoring plan preparation, and long-term vegetation monitoring. Max has managed and assisted with management of over 60 multi-disciplinary, ecological restoration projects at H.T. Harvey & Associates. Two exemplary wetland restoration projects that Max has managed include the Salt Marsh Restoration/Mitigation Plan for the 101 Auxiliary Lanes Project and the Cooley Landing Tidal Marsh Restoration Project. Both of these projects involve restoration design for impacted former tidal salt marsh in the San Francisco Bay. Max's master's thesis research focused on the use of constructed wetlands as a tool for wastewater remediation and protection of downstream estuarine ecosystems. The project included the design and construction of an outdoor manipulative experiment with 20 wetland mesocosms simulating constructed freshwater wetlands receiving secondary wastewater loaded with nutrients (NH_4^+, NO_3^-, PO_4^{3-}) and heavy metals (Cd, Cu, Hg, Pb, Zn). His research assessed the removal efficiency and removal mechanisms for ammonium (NH_4^+), phosphate (PO_4^{3-}), and heavy metals (Cd, Cu, Hg, Pb, Zn) by constructed freshwater wetland mesocosms. The research program also tested the effect of hydroperiod manipulations on contaminant removal efficiencies (Busnardo et al., 1992; Sinicrope et al., 1992; Zedler et al., 1994).

Busnardo, M., R. Gersberg, R. Langis, T. Sinicrope, J. Zedler. 1992. Nitrogen and phosphorus removal by wetland mesocosms subjected to different hydroperiods. Ecological Engineering, 1:287-307.

Sinicrope, T., R. Langis, R. Gersberg, M. Busnardo, J. Zedler. 1992 Metal removal by wetland mesocosms subjected to different hydroperiods. Ecological Engineering, 1: 309-322.

Zedler, J., M. Busnardo, T. Sinicrope, R. Langis, R. Gersgerg and S. Baczkowski. 1994. Pulsed-discharge wastewater wetlands: the potential for solving multiple problems by varying hydroperiod. In: W. Mitsch (Ed), Global Wetlands: Old World and New. Elsevier, pp. 363-368.

JOHN A. BOURGEOIS, M.S., Wetlands Ecologist

John Bourgeois is a wetlands ecologist currently involved in the development of wetland and riparian ecosystem restoration projects in the San Francisco Bay area. He has worked in a variety of coastal and wetland ecosystems from the continental shelf in the Gulf of Mexico to mangrove swamps in the western Pacific. His graduate research examined patterns of benthic nutrient regeneration in continental shelf sediments via a field manipulative study using continuous-flow flux chambers. In the mangrove swamps of Micronesia, John was in charge of establishing permanent ecological study plots and performing research on ecological zonation patterns in mangrove forests. In the coastal wetlands of the Gulf Coast, John has also been involved in understanding the impacts and mitigation associated with OCS pipeline and navigation canals, the long-term monitoring of large scale wetland restoration projects, and the relative effects of accretion and subsidence in coastal marshes. John has done extensive monitoring of marsh management, shoreline protection, and hydrologic restoration projects in coastal Louisiana, which includes measurements of hydrology, vegetation health and cover, marsh accretion and subsidence, and shoreline movement, as well as making management decisions based on the results of this monitoring. His involvement in these endeavors includes interagency coordination, extensive fieldwork, permit analysis, monitoring and research design, data analysis, report writing, and presentations.

> Effects of Weirs on the Depth and Duration of Flooding in a Louisiana Marsh. J.A. Bourgeois and E.C. Webb. In: Recent Research in Coastal Louisiana: Natural System Function and Response to Human Influences. Louisiana Sea Grant College Program, Baton Rouge, LA. 1999.
>
> Environmental Effects of Canopy Gap Formation in High-Rainfall Mangrove Forests. Biotropica 30(4). Ewel, K.C., S. Zheng, Z. Pinzon, and J.A. Bourgeois 1998.
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> Variation in Environmental Characteristics and Vegetation in High-Rainfall Mangrove Forests, Kosrae, Micronesia. Global Ecology and Biogeography Letters 7(1):49-56. K.C Ewel, J.A. Bourgeois, T.G. Cole, and S. Zheng 1998.
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> Spatial Patterns of Benthic Nutrient Regeneration and Sediment Characteristics on the Louisiana Continental Shelf. Chapter 5, Pages 75-126 *in* R.R. Twilley and B.A. McKee, Editors. Ecosystem Analysis of the Louisiana Bight and Adjacent Shelf Environments. Vol. I. The Fate of Organic Matter and Nutrients in the Sediments of the Louisiana Bight. OCS Study, MMS 96-0057. Bourgeois, J.A. 1996.

DAVID THOMSON, M.S., Restoration Ecologist – Field Biologist 3

Mr. Thomson is a wetland ecologist who has worked on the restoration of both freshwater and estuarine ecosystems in Louisiana. Additionally, he has experience with fisheries research and control of invasive, estuarine plants in Washington. Mr. Thomson's background includes coursework in wetland hydrology and hydrodynamics, plant stress ecophysiology, and wetland ecology. David also has an extensive knowledge of experimental statistics, research design, and ArcView GIS.

- Thomson, D.M., 2000. The influence of altered hydrology upon wetland hydrodynamics and plant growth on the Manchac Landbridge. Master's Thesis, Southeastern Louisiana University. 90 p.

Cost

Please see attached budget spreadsheet.

Literature Cited

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Blank, R. and Young, J. A. 1997. *Lepidium latifolium*: Influences on soil properties, rates of spread and competitive stature. Pgs 69-80. *In*: J. H. Brock, M. Wade, P. Pysek and D. Green, eds., Plant Invasions: Studies from North America and Europe.

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DeLaune, R. D., Buresh, R. J., and W. H. Patrick, Jr. 1979. Relationship of soil properties to standing crop biomass of *Spartina alterniflora* in a Louisiana marsh. Estuarine and Coastal Marine Science 8:477-487.

DeLaune, R. D., Smith, C. J. And W. H. Patrick, Jr., 1983. Relation of marsh elevation, redox potential and sulfide to Spartina alterniflora productivity. Soil Science Society of America Journal 47:930-935.

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Koch, M. S. and I. A. Mendelssohn. 1989. Sulfide as a soil phytotoxin: Differential responses in two salt marsh species. Journal of Ecology 77:565-578.

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Mendelssohn, I. A., and K. L. McKee. 1988. *Spartina alterniflora* die-back in Louisiana: Time-course investigation of soil waterlogging effects. Journal of Ecology 76:509-521.

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Pennings, S. C. And R. M. Callaway. 1992. Salt marsh plant zonation: The relative importance of competition and physical factors. Ecology 72:681-690.

Renz, M. J., DiTomaso, J. M., and Schmierer, J. 1997. Above and below ground distribution of perennial pepperweed biomass and the utilization of mowing to maximize herbicide effectivness. Proceedings from the 1997 California Weed Science Society Meetings.

Renz, M. J. 2001. Element Stewardship Abstract for *Lepidium latifolium* L. The Nature Conservancy's Wildland Invasive Species Program. 22 pgs.

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Webb, E. C. and I. A. Mendelssohn. 1996. Factors affecting vegetation dieback of an oligohaline marsh in coastal Louisiana: Field manipulation of salinity and submergence. American Journal of Botany 83: 1429-1434.

Young, J. A., Turner, C. E., and James, L. F. 1995. Perennial peppergrass. Rangelands 17:121-123.

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H.T. HARVEY & ASSOCIATES
ECOLOGICAL CONSULTANTS

Project Name: Lepidium latifolium Manipulative Field Experiment

Project Number:

Proposal Number: 3069

Date: 10/5/01

	Personnel Hours by Task							Subtask Cost
Task	***Patrick Boursier***	***Eric Webb***	***Max Busnardo***	***John Bourgeois***	***David Thompson***	Graphic/GIS	Support	
1. Marsh Determination	1	4	2	2	12			$ 1,815.00
2. Install	1	24	24	48	48		2	$ 12,985.00
3. Progress Monitoring	4	8	8	40	40	4	4	$ 9,200.00
4. Harvest	8	16	16	64	64		40	$ 17,160.00
5. Analyze Data	2	8	4	40	24	4	8	$ 7,650.00
6. Report	4	24	8	24	40	36	4	$ 12,000.00
7. Progress Reporting	4	12	8	16	16			$ 5,280.00
Totals	**24**	**96**	**70**	**234**	**244**	**44**	**58**	$ 66,090
Technical Assignment	Sr. Plant Ecologist	Project Manager	Sr. Ecologist 1	Ecologist 3	Field Biologist 3			

H.T. HARVEY & ASSOCIATES
ECOLOGICAL CONSULTANTS

Project Name: Lepidium latifolium Manipulative Field Experiment
Project Number:
Proposal Number: 3069
Date: 10/5/01

PROJECT BUDGET

I. Personnel Costs			
Professional Staff	**Hours**	**Rate**	**Total**
Patrick Boursier	24	$ 145	$ 3,480
Eric Webb	96	$ 115	$ 11,040
Max Busnardo	70	$ 95	$ 6,650
John Bourgeois	234	$ 90	$ 21,060
David Thompson	244	$ 70	$ 17,080
Graphic/GIS	44	$ 75	$ 3,300
Support	58	$ 60	$ 3,480
		Subtotal	**$ 66,090**
Subcontractual Services			
Soil Control Lab			$ 4,520
			$ -
General Administrative Expense Percentage:		10%	$ 452
		Subtotal	**$ 4,972**

II. Direct Costs	**Miles/Days**	**Rate**	
Travel ($0.345/mile)	800	$ 0.345	$ 276
Per Diem (days x rate)		$ 125	$ -
GIS (per hour surcharge)		$ 10	$ -
Equipment			$ 6,500
Expendable Supplies			$ 500
Biological Data Base Searches			$ -
Service Fees (10%)			$ 727.60
Subtotal:			**$ 8,004**

III. Total Budget	**$ 79,066**