Ecological Impacts of Physical Habitat Restoration on Resources Available to Salmonids

Project Information

1. **Proposal Title:**

   Ecological Impacts of Physical Habitat Restoration on Resources Available to Salmonids

2. **Proposal applicants:**

   Paul Ehrlich, Stanford University, Center for Conservation Biology
   Sallie-Anne Bailey, CCB Stanford University

3. **Corresponding Contact Person:**

   Blanca Revuelta
   Stanford University
   651 Serra St Rm 260. Stanford. CA 94305
   650 7250515
   revuelta@stanford.edu

4. **Project Keywords:**

   Anadromous salmonids
   Habitat Restoration, Instream
   Restoration Ecology

5. **Type of project:**

   Research

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

   No

7. **Topic Area**:

   At-Risk Species Assessments

8. **Type of applicant:**

   University

9. **Location - GIS coordinates:**

Latitude:	37.883
Longitude:	-122.550
Datum:	NAD27

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

Study encompassing two creek channels in Marin County. Redwood Creek and Arroyo Corte Madera Del Presidio

10. **Location - Ecozone:**

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

11. **Location - County:**

    Marin

12. **Location - City:**

    Does your project fall within a city jurisdiction?

    Yes

    If yes, please list the city: Mill Valley

13. **Location - Tribal Lands:**

    Does your project fall on or adjacent to tribal lands?

    No

14. **Location - Congressional District:**

    California 6th

15. **Location:**

    California State Senate District Number: 3

    California Assembly District Number: 6

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

    3 years

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:	57
Total Requested Funds:	$391,447.64

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)

Peter B. Moyle	**University of California, Davis**	**530-752-6355**	**pbmoyle@ucdavis.edu**
Mary E. Power	**University of California, Berkeley**	**510-643-7776**	**mepower@socrates.berkeley.edu**
Robert Leidy	**US EPA**	**415-744-1305**	**leidy.robert@epamail.epa.gov**
Matthew Kondolf	**University of California, Berkeley**	**510 644 8381**	**kondolf@uclink.berkeley.edu**

21. **Comments:**

Environmental Compliance Checklist

<u>Ecological Impacts of Physical Habitat Restoration on Resources Available to Salmonids</u>

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

      No
   b) Will this project require compliance with NEPA?

      No
   c) If neither CEQA or NEPA compliance is required, please explain why compliance is not required for the actions in this proposal.

      The project does not involve the physical alteration of the creek channels, only the collection of macroinvertebrates and physical data. We believe this does not require CEQA and NEPA compliance.

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

   <u>CEQA Lead Agency:</u>
   <u>NEPA Lead Agency (or co-lead:)</u>
   <u>NEPA Co-Lead Agency (if applicable):</u>

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

   CEQA
   -Categorical Exemption
   -Negative Declaration or Mitigated Negative Declaration
   -EIR
   Xnone

   NEPA
   -Categorical Exclusion
   -Environmental Assessment/FONSI
   -EIS
   Xnone

   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.

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

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: Marin County	Required, Obtained
Permission to access state land. Agency Name:	
Permission to access federal land. Agency Name: National Park Service - GGNRA	Required
Permission to access private land. Landowner Name:	

6. **Comments.**

A National Park Service research and collection permit is required for work in Redwood Creek. The National Park Service is supportive of the proposed research and we do not foresee any difficulties in obtaining the permit.

Land Use Checklist

Ecological Impacts of Physical Habitat Restoration on Resources Available to Salmonids

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

Ecological Impacts of Physical Habitat Restoration on Resources Available to Salmonids

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):

Paul Ehrlich, Stanford University, Center for Conservation Biology
Sallie-Anne Bailey, CCB Stanford University

Subcontractor(s):

Are specific subcontractors identified in this proposal? Yes

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

Roy Richardson	Philip Williams & Associates Ltd
None	None
None	None
None	None
None	None

Helped with proposal development:

Are there persons who helped with proposal development?

Yes

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

Roy Richardson	**Philip Williams & Associates Ltd**

Comments:

Budget Summary

Ecological Impacts of Physical Habitat Restoration on Resources Available to Salmonids

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	Project Meetings	16	361.60	86.78	72.00		1693.00			2213.38	1261.63	3475.01
2	Restoration Design Review	16	361.60	86.78			880.00			1328.38	757.18	2085.56
3	Field Data Collection	928	14220.80	1611.84	738.00	2000.00	25222.00			43792.64	23368.65	67161.29
4	Data Analysis	1334	24511.60	4509.02		500.00	7760.00			37280.62	16826.76	54107.38
5	Conceptual Model Development	40	904.00	216.96			2800.00			3920.96	638.95	4559.91
6	Dissemination of Results	80	1876.80	450.43		500.00	3184.00			6011.23	1611.52	7622.75
		2414	42236.40	6961.81	810.00	3000.00	41539.00	0.00	0.00	94547.21	44464.69	139011.90

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**
1	Project Meetings	8	191.65	46.00	72.00		1309.00			1618.65	176.50	1795.15
2	Restoration Design Review	0	0	0						0.0		0.00
3	Field Data Collection	848	13852.93	1609.64	984.00	500.00	13259.00			30205.57	9659.54	39865.11
4	Data analysis	1484	29758.02	5685.74		500.00	5968.00			41911.76	20487.94	62399.70
5	Conceptual Model Development	72	1724.83	413.96			2952.00			5090.79	1219.11	6309.90
5	Dissemination of Results	106	2612.26	626.94		500.00	3342.00			7081.2	2131.35	9212.55
		2518	48139.69	8382.28	1056.00	1500.00	26830.00	0.00	0.00	85907.97	33674.44	119582.41

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**
1	Project Meetings	8	203.15	48.76	72.00		1361.00			1684.91	184.62	1869.53
2	Restoration Design Reviewfield data collection - biological									0.0		0.00
3a	Field Data Collection	848	14684.10	1706.22	984.00	500.00	13787.00			31661.32	10188.36	41849.68
3b	Data Analysis	1484	31543.5	6026.88		500.00	6256.00			44326.38	21700.12	66026.50
4	Conceptual Model Development	80	2031.47	487.55			6512.00			9031.02	1435.84	10466.86
5	Dissemination of Results	136	3530.80	847.39		500.00	4982.00			9860.19	2780.57	12640.76
		2556	51993.02	9116.80	1056.00	1500.00	32898.00	0.00	0.00	96563.82	36289.51	132853.33

Grand Total=391447.64

Comments.

Budget Justification

Ecological Impacts of Physical Habitat Restoration on Resources Available to Salmonids

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

Dr. Sallie-Anne Bailey - Year1, 654 hours; Year 2, 798 hours; Year 3, 836 hours. GIS Analyst - Year1, 120 hours; Year2, 160 hours; Year3, 160 hours. Life sciences research assiatant - Year1, 200 hours; Year2, 200 hours; Year3, 200 hours. Tempory employee - Year1, 1120 hours; Year2, 1040 hours; Year3, 1040 hours. Undergraduate - Year1, 320 hours; Year2, 320 hours; Year3, 320 hours.

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

Dr. Sallie-Anne Bailey - $22.6 per hour. GIS Analyst - $26.9 per hour. Lab Analyst - $21.33 per hour. Field Assistant - $14.4 per hour. Graduate Assistant - $12.0 per hour. Salaries are increased by 6% per year.

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

Dr. Sallie-Anne Bailey - 24% GIS Analyst - 24% Lab Analyst - 24% Field Assistant - 8.1% Graduate Assistant - 8.1%

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

Mileage ($0.30 per mile) to one meeting per year in Sacramento (240 mile round trip from Stanford). Mileage ($0.30 per mile) associated with fieldwork (30 trips/year, 82 miles round trip from Stanford).

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

Field supplies - Year 1,$2000; Year 2, $500; Year 3, $500. Lab supplies - Year 1, $500, Year 2, $500; Year 3, $500. Office Supplies - Year 1, $500; Year 2, $500; Year 3, $500.

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.

Task 1 - Project Meetings - Year1, 12 hours; Year2, 8 hours; Year3, 8 hours. Task 2 - Restoration Design Review - Year1, 8 hours. Task 3 - Field Data Collection - Year1, 241 hours; Year2, 121 hours; Year3, 121 hours. Task 4 - Data Analysis - Year1, 86 hours; Year2, 62 hours; Year3, 62 hours. Task 5 - Conceptual Model Development - Year1, 25 hours; Year2, 25 hours; Year3, 52 hours. Task 6 - Dissemenation of Results - Year1, 31 hours; Year2, 31 hours; Year3, 42 hours. Avarege Hourly Rate for Constultant - $94 per hour. Increased by 5% per year.

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.

We do not require equipment for this proposal

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.

Cost associated with report preparation, presentation of results and response to project specific questions are incorporated in Tasks 1 and 6 of our scope-of-work. Other Project Management tasks associated with validation of costs, project oversight etc. and incorporated in the hours of Dr. Sallie-Anne Bailey, who will act as a project manager for the proposed study.

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

none

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.

Indirect costs are broad categories of costs (facilities and administration). "Facilities" is defined as depreciation and use allowances, interest on debt associated with certain buildings, equipment and capital improvements, operation and maintenance expenses, and library expenses. "Administration" is defined as general administration and general expenses, departmental administration, sponsored projects administration, student administration and services, and all other types of expenditures not listed specifically under one of the subcategories of Facilities (including cross allocations from other pools). In addition, an overhead rate of 57% on fees up to $25,000 is applied to the subconsultant costs.

Executive Summary

Ecological Impacts of Physical Habitat Restoration on Resources Available to Salmonids

Restoration of creeks and rivers for salmonids is generally based on modifying the physical structure or morphology of a given reach to a form that is considered suitable for salmonid habitat. Changes caused by physical habitat restoration can have implications on aquatic diversity, community structure and abundance of species. Such changes, especially in macroinvertebrates that contribute to drift, may reduce the amount and quality of food resources available to salmonids. The aim of the proposed project is to advance the understanding of linkages between physical and ecological processes that provide salmonid food resources, by integrating interdisciplinary information that describes such processes in a range of existing creek reaches and a reach to be restored. We will develop the understanding of the impacts of restoration projects on these linkages, and therefore salmonid food resources, their recovery and potential enhancement. The information provided will be used to refine a conceptual model to better ensure the functional recovery of newly restored salmonid habitat and thus the sustainability of fragile salmonid populations. The model is directly applicable to future salmonid habitat restoration projects across the Bay-Delta system. We will test the hypothesis that the establishment of appropriate physical conditions for one taxa result in the establishment of the complement of native species. Should the results of this project indicate that this hypothesis does not hold and species present following restoration do not match the resource requirements of salmonids, the ability of the restoration to sustain salmonids maybe compromised. We will achieve our overall aim through a series of research questions; which represent our objectives. They will involve physical and ecological analysis of a reach of Redwood Creek, Marin County that is to be restored and paired reaches in Redwood Creek and the Arroyo Corte Madera Del Presidio. The products of this project directly contribute to ERP Strategic Goals 1 and 2, Multi-region priority and Action 6 and Calfed Science Program Goals; advance process understanding and compare relative effectiveness of different restoration strategies.

Proposal

Stanford University, Center for Conservation Biology

Ecological Impacts of Physical Habitat Restoration on Resources Available to Salmonids

Paul Ehrlich, Stanford University, Center for Conservation Biology
Sallie-Anne Bailey, CCB Stanford University

Ecological Impacts of Physical Habitat Restoration on Resources Available to Salmonids

Prepared for

CALFED

Prepared by

Center for Conservation Biology, Stanford

with

Philip Williams & Associates, Ltd.

October 4, 2001

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1. PROJECT DESCRIPTION

1.1 PROBLEM STATEMENT

Since glacial recession, some 15,000 years ago, Pacific salmonids have adapted to the emerging Bay-Delta ecosystem and the ecological communities that it supports (Taylor, 1991). Degradation of the physical habitat in the Bay-Delta system since European settlement has disrupted the relationship between physical and ecological processes and resulted in a decline in salmonid populations. Recently, an opportunity has arisen to reverse this decline through habitat restoration projects. These projects attempt to restructure creek reaches to emulate once natural systems that provide the physical habitat required by salmonids. Many examples of these projects are being constructed throughout the Bay-Delta system. However, given the present lack of a thorough understanding of the linkages between physical and ecological processes, little is known of what impacts these projects will have on the already disturbed ecosystems within a project reach, or on their likelihood of recovery.

Restoration of river and creek reaches for salmonids seldom consider salmonid ecology beyond physical habitat requirements, i.e., provision of suitable substrate in upper reaches for redd creation and spawning grounds and minimally inhibited passage to these areas (Flosi et al, 1998; Laasonen et al, 1998). Habitats restored for salmonids need to fulfill wider ecological functions to support the full range of salmonid requirements. Restored habitat must support not only the salmonids but also support and sustain the invertebrate food resources they require (Spence et al, 1996), so that lack of such resources does not become a controlling factor on salmonid population growth.

It seems possible that the true impacts of restoration schemes on aquatic biodiversity are being overlooked (Laasonen et al, 1998). Freshwater river and creek habitats in natural conditions will support remarkably diverse aquatic communities. Such diverse communities are more able to resist short-term environmental stresses (Polis and Strong, 1996) and thus ensure that salmonids are less likely to be impacted by resource limitation following disturbances. Yet, little is known of the impacts of physical habitat restoration on the biodiversity of already disturbed creeks. For example, what is the recovery time of the community following disturbances? Will recovery to level of diversity prior to restoration occur? If the disturbance has been sufficient to prevent recovery of original community, what impact will this have on the success of the restoration and provision of resources to salmonids? Are species salmon depend upon sufficiently ubiquitous that they will not become a limiting factor? As noted above, if restorations are geared solely to the physical requirements of salmonids, are the resulting habitats sufficiently diverse and suitable for the support of the larger aquatic community?

The proposed study will examine the impact of a salmonid restoration project in Redwood Creek, Marin County. The study will use a paired creek study, the Arroyo Corte Madera Creek Del Presidio, also in Marin County (Figure 1).

1.1.1 Project Goal & Objectives

The goal of the project outlined in this proposal is to advance the understanding of linkages between physical and ecological processes, by integrating interdisciplinary information that describes such processes in a range of existing creek reaches and a reach to be restored. By addressing this goal, we hope to develop the understanding of the impacts of restoration projects on salmonid food resources, their recovery and potential enhancement. The information provided will be used to develop a conceptual model to better ensure the functional recovery of newly restored salmonid habitat and thus the sustainability of fragile salmonid populations. The conceptual model will be directly applicable to future salmonid habitat restoration projects of creek reaches across the Bay-Delta system.

Our proposed project will incorporate two of the six CALFED multi-regional goals through advancing understanding of linkages between physical habitat restoration and the resultant ecological communities in the restored site. A recent review of research needs in conservation biology also highlights the need to uncover the role of feedback loops between structure and function in the maintenance of restored sites (Ehrenfeld and Toth, 1997) and the relationship between species composition and ecosystem structure.

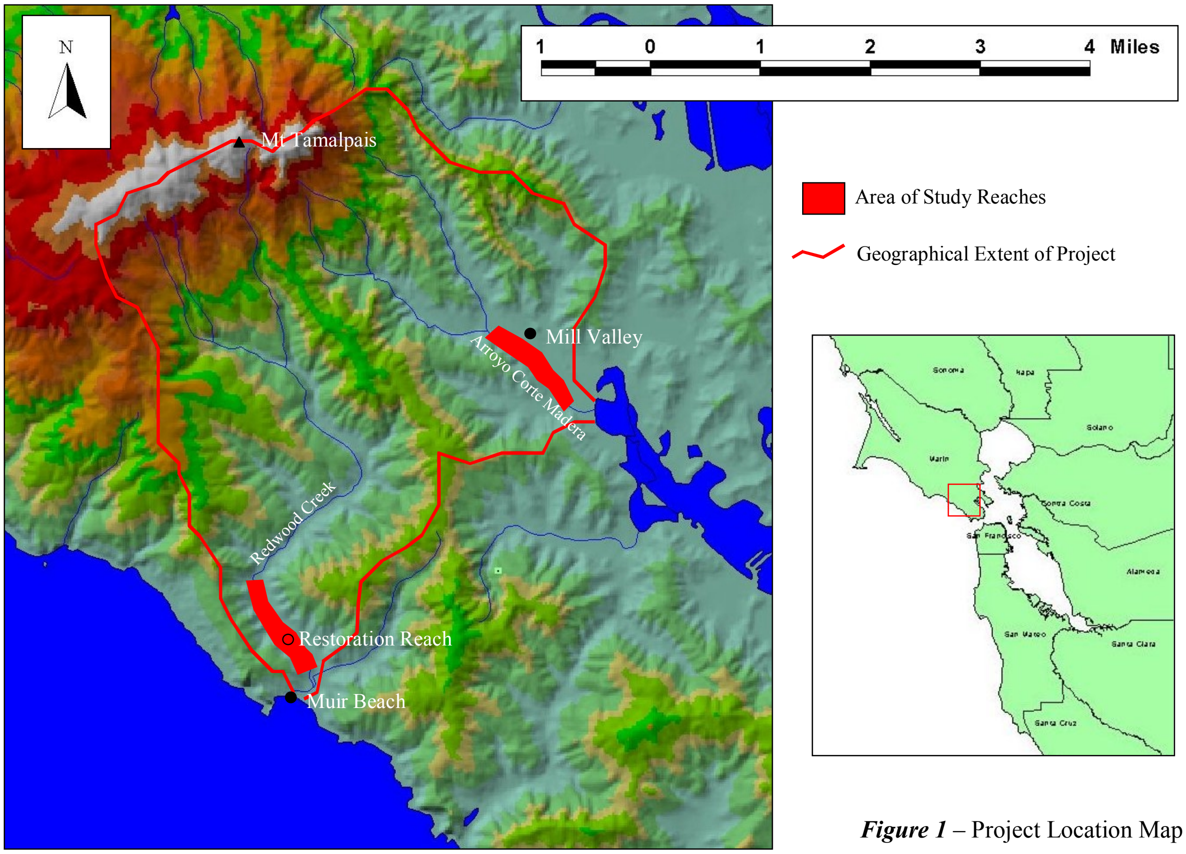


Figure 1 – Project Location Map

The hypothesis that we plan to test is adapted from a question recently posed by MacMahon and Hall (2001):

> '*Does the establishment of appropriate physical conditions for one taxa result in the establishment of the complement of native species*?'

The project is structured to provide answers to five specific research questions (stated below). By developing our understanding of linkages between physical and ecological processes, we aim to answer these research questions. Answering the research questions represent the objectives of the proposed study.

Research Question 1: *Is macroinvertebrate diversity, community structure or abundance influenced by any of the following factors: watershed land use intensity, riparian habitat structure, reach scale disturbance and creek habitat structure?*
To address this question, we will establish a baseline survey of the restoration reach, two undisturbed upstream reference reaches, a downstream reach and two reaches of a neighboring drainage with similar underlying geology and hydrology. Physical characteristics of each reach, flow conditions and riparian structure will be surveyed together with macroinvertebrates. Surrounding land uses will be assessed using existing GIS databases. This baseline information will enable us to evaluate present diversity, abundance

and community structure at the project site in the context of the gradient of disturbance, and establish the influence of past disturbance on present diversity. We will also be able to ascertain the impact of increasing land use intensity together with the role of small scale physical structure on macroinvertebrate diversity and community structure in Bay-Delta creeks. This will provide valuable information for the conceptual model, defining creek characteristics that maximize macroinvertebrate diversity in the CALFED region. We will be able to detect species sensitive to land use intensification and physical structure. By assessing watershed features and riparian habitats at each study site we will be able to control terrestrial factors known to influence creek biodiversity.

Research Question 2: *Is macroinvertebrate diversity, community structure or abundance changed following the disturbance associated with the restoration work?*
We will re-sample each site, in each reach, following the restoration project (no more than 1 month after restoration) and then at regular intervals following the restoration. By addressing this question we hope to better understand the impacts of salmonid habitat restoration on macroinvertebrate community ecology (Friberg et al, 1998; Gortz, 1998; Laasonen et al, 1998). If there are changes in community structure, we aim to determine the nature of those changes and what the implications are for ecological functioning and stability. Surveying the paired reaches will enable us to verify that any changes observed in the restoration reach are local, therefore correlated with the restoration effort.

Research Question 3: *Will changes in macroinvertebrate diversity, community structure or abundance have implications for resources available to salmonids following physical habitat restoration?*
By analyzing macroinvertebrate samples collected in reaches and identifying macroinvertebrates that are palatable to salmonids, we hope to better understand impacts of salmonid habitat restoration on salmonid resource requirements. We will be able to ascertain, that if there are changes in community structure and relative abundance of palatable species, the implications for sustaining desired population levels of salmonids.

Research Question 4: *Are physical structures created and changes in morphology that result from the restoration at a suitable scale to provide the diversity of habitats found in less disturbed reaches? If not, is there a difference in the diversity of the aquatic macroinvertebrate community supported between the less disturbed reaches and restoration reach?*
Modification of river structure for salmonids may not provide appropriate physical structures required by the full range of aquatic macroinvertebrates. If there is insufficient diversity of habitats available, the recovering aquatic community may lack the desired, or even baseline (pre-restoration), levels of diversity (Laasonen et al, 1998). However, there is also the assumption that some macroinvertebrates can invade rapidly into new areas (Harris et al, 1995), suggesting that physical changes will not modify macroinvertebrate community structure for long (Friberg et al, 1998 – but see Fuchs and Statzner, 1990). To address this question, in conjunction with the planned macroinvertebrate surveys, we will survey the physical morphology and flow patterns of the sampling reaches at a scale appropriate to macroinvertebrate use. The surveys will be conducted at the restoration site, the upstream reference reach and in the reach immediately downstream of the restoration before and after construction.

Research Question 5: *How long following restoration will the macroinvertebrate community require to stabilize?*
The continued monitoring of the restoration site, in conjunction with the reference reaches, will enable us to address another area of priority in restoration ecology (MacMahon and Holl, 2001) – that is, to what degree do early indications of restoration success suggest long term establishment of native species. If community structure has changed, we will examine the survey data for indications of development of a stable and sustainable community.

1.2 JUSTIFICATION

1.2.1 The effect of disturbance on aquatic biodiversity and macroinvertebrate community structure

Membership of biological communities is controlled by resource availability, structure of physical habitat and related ecosystem processes (Thorp and Covich, 2001). Modification of physical structure of habitat results in an alteration of both the combination of species present and their relative abundance within the community (Harris et al, 1995; Power et al, 1995; Rader, 1997; Hershey and Lamberti, 2001). However, little is understood about the relationship between the change in physical structure of habitats and the ecological functioning of communities and feedback loops therein.

Disturbance in physical habitat from river and creek engineering has been shown to lead to a change in ecological structure and functioning of aquatic communities (Carlson et al, 1990; Spence, 1996) and can lead to a degradation of aquatic resources (Karr, 1991). Habitat restoration inevitably creates disturbance by altering physical elements of existing habitat. Such projects therefore have the potential to change the composition of the communities present (Fuchs and Statzner, 1990; Gortz, 1998; Laasonen et al, 1998).

1.2.2 Macroinvertebrates: ecology and role in salmonid ecology

Salmonids feed predominantly on drift in creeks (Spence et al, 1996) and drift is composed of macroinvertebrates of both terrestrial and aquatic origin. Drifting aquatic invertebrates are derived from the benthic community (Allan, 1995). The composition of aquatic drift is controlled by species present in the benthos and their propensity to drift (Brewin and Ormerod, 1994; Schreiber, 1995; Rader, 1997). Aquatic macroinvertebrates can form diverse and specialized communities given the variety of habitats available across the physical gradient of river morphology. Species richness and abundance have been found to reflect the diversity of habitats within the creek, particularly with increasing substrate heterogeneity (Minshall, 1984; McLaughlin et al, 1994). Riparian vegetation, structure and land use influences the proportion and composition of terrestrial invertebrates that contribute to drift (Brewin and Ormerod, 1994; Bridcut, 2000 – but see Meehan, 1996).

As noted above, disturbance can result in species replacement and adjustments of the functional characteristics in the community (Minshall et al, 1983; Power et al, 1995; Rader, 1997; Cederholm et al, 2000; Hershey and Lamberti, 2001). For example, mayfly and stonefly density and richness can be reduced by physical alteration to the creek corridor, which may have significant implications to the salmonid food base (Cederholm et al, 2000). Loss of a number of functioning groups will lead to a simplification of community structure, dominated by generalists. Less diverse communities are often less able to recover from periods of environmental stress and can be more susceptible to invasion (Levine, 2000). Studies have shown that invertebrate species relied upon by salmonids may be replaced by an unpalatable non-native species (Spencer et al, 1991), or cause further changes in the community deleterious to the top-level consumers.

Therefore, both aquatic and terrestrial macroinvertebrates play an essential role in the ecology of salmonid taxa as their major food source in creeks and rivers (Spence et al, 1996). Modification to macroinvertebrate community structure can, therefore, have significant implications to salmonid populations (Rader, 1997). Salmonids are not selective about which macroinvertebrates they consume, choice appears to be based on abundance in drift and size (Rader, 1997). Salmonids may not be impacted by subtle changes in the macroinvertebrate community structure. However, shifts in the community to a predominance of unpalatable species (Tait et al, 1994) and/or a decline in abundance or size will have significant implications to salmonid productivity (Keeley and Grant, 2001).

1.2.3 Role of terrestrial processes in macroinvertebrate diversity

Much attention has been given to the influence of terrestrial factors on aquatic biodiversity (Hershey and Lamberti, 2001). Modifications to riparian habitat and watershed land use have been demonstrated to have both direct and more subtle impacts on habitat quality and macroinvertebrate diversity in rivers and creeks (Carlson et al, 1990). Removal of riparian vegetation will reduce shade, thus increasing water temperature directly limiting salmonid presence (Li et al, 1994) and increasing photosynthetically active radiation. Increased photosynthesis will increase periphyton production, which can increase macroinvertebrate density (Carlson et al, 1990) with potential to modify community structure. The input of organic material of a terrestrial origin, important to detritivores, will be reduced as will the proportion of terrestrial macroinvertebrates contributing to drift, hence, available to salmonids.

Modification of land uses within watersheds can have more chronic impacts on water courses. Removal of woodland and inappropriate agricultural practices will increase sediment load, which can increase turbidity and fine sediment on creek bottoms (Nerbonne and Vondracek, 2001). Both of these impacts can dramatically modify aquatic community membership (Lenat et al, 1979; Waters, 1995). Agricultural runoff can elevate nutrient levels in creek, again causing increases in primary productivity and can lead to anoxia (Hershey and Lamberti, 2001).

1.2.4 Conceptual Model

Figure 2 presents an outline of a conceptual model of the interactions between physical and ecological processes, and how these interactions affect food resources available to salmonids. Linkages within the conceptual model will be evaluated and our understanding of them enhanced through the proposed research.

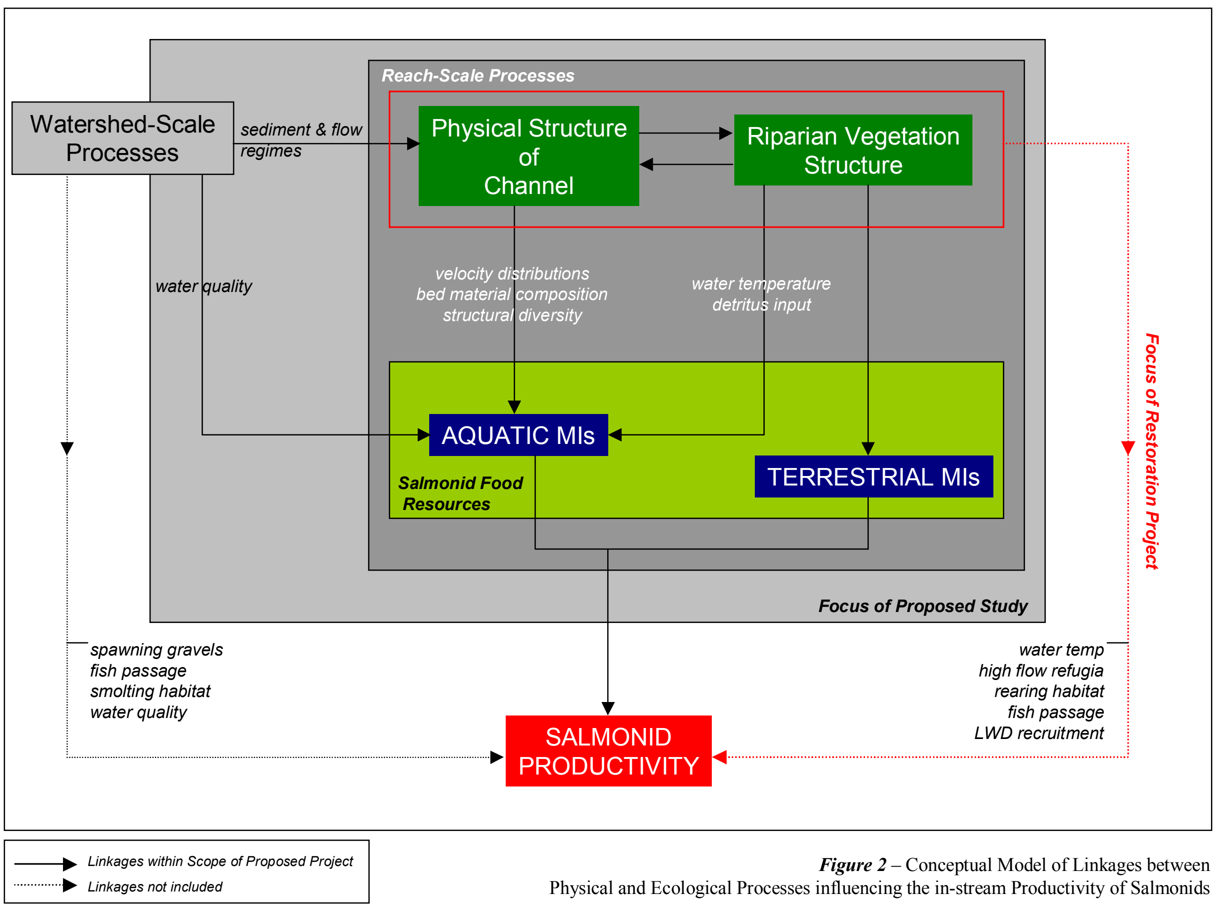


Figure 2 – Conceptual Model of Linkages between Physical and Ecological Processes influencing the in-stream Productivity of Salmonids

In an undisturbed setting, salmonids have adapted to take advantage of the food resources made available. The conceptual model illustrates how disturbance in these processes at the reach and watershed scales can impact the food resources available to salmonids. As noted above, change in upstream land-use within a watershed, either for agriculture or residential development, will impact the sediment, flow regimes and water quality at a reach scale. Changes in flow and sediment regimes will trigger adjustments in the physical structure, or morphology, of a given reach, which in turn changes the physical habitat that supports salmonids. In addition to altering salmonid physical habitat, disturbance to reach-scale processes will also impact salmonid food resources through changing micro-habitat conditions (near-bed velocity distributions, bed material composition, structural diversity, water temperature and the input of organic material). The same watershed-scale processes can also affect water quality, further influencing the abundance diversity and community structure of aquatic macroinvertebrates.

The primary focus of the proposed project is to examine how a restoration project will affect the linkages within the model between reach-scale processes and salmonid food resources. The restoration work itself represents the first level of disturbance to these linkages, while the long-term evolution of the channel following restoration represents a second level of disturbance. We anticipate that the short-term impacts to these linkages will be deleterious to salmonid food resources, while long-term impacts, by restoring reach-scale processes to those similar in a pristine physical environment, will be positive. By examining a neighboring creek system with similar underlying geology and hydrology, we will be able to examine the linkages between watershed-scale processes and salmonid food resources, directly through water quality and indirectly through changed reach-scale morphology and riparian vegetation structure.

1.3 PROJECT APPROACH

To help answer the research questions posed in Section 1.1, and to develop our understanding of the linkages within the conceptual model, we will examine the macroinvertebrate diversity, community membership and abundance before, during and following a creek channel restoration, together with changes in the physical structure of the creek at a scale considered representative of macroinvertebrate habitat use. We will also evaluate the changes in terms of ecological functioning of the aquatic community. This will enable us to address study objectives and provide boarder lessons applicable in subsequent restoration projects.

1.3.1 The Restoration Reach

The first phase of the restoration project is due to be constructed in late Summer 2003. The aim of the restoration project is to restore a 300m reach of the creek to conditions that will support the native endangered coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Oncorhynchus mykiss*) at levels present prior to habitat degradation. Although a stated goal of the restoration project is to restore ecosystem function and process, evaluation criteria for the project are physically based and reflect the single taxa focus of many restoration projects currently undertaken.

Specific objectives of the restoration project include restoring juvenile rearing and high-flow refugia habitat for coho and steelhead. The success of the project in meeting these objectives will be evaluated using physical structure criteria over three time frames: short-term (1-2 years), medium term (5-10 years) and long-term (>20 years). Analysis of how conceptual project alternatives will evolve over these time-frames, in respect to the physical structure criteria, has been used to select the most appropriate restoration approach. Little is understood about how the selected restoration approach will impact the invertebrate food resources critical to juvenile rearing.

We anticipate almost complete removal of the benthic macroinvertebrate community during the restoration. This will provide us with a rare insight into the impact of physical habitat change on these species, which in turn, will enable us to explore the complement of native species that becomes established following introduction of ‘appropriate’ physical conditions (*sensu* MacMahon and Holl, 2001). However, as we will know the composition of the community beforehand, we will also be able to compare communities before and after the restoration. Implications for ecological functioning, community sustainability and resources available to salmonids can then be evaluated.

The following scope of work is designed to meet the project objectives, address the research questions outlined above, and develop the understanding of our conceptual model.

1.3.2 Task 1 – Project Meetings

The project team will schedule up to four meetings with representatives of CALFED and local stakeholders to discuss project progress, attainment of performance criteria and issues that arise during the course of our fieldwork, subsequent data analysis and conceptual model development. This task includes a project kick-off meeting with all project stakeholders to discuss the proposed work-plan, areas of cooperation, project goals, performance measures and logistical issues regarding timing and access for fieldwork. We will also hold annual meetings at the end of the first and second years of fieldwork to discuss project progress. This task includes a final project meeting, at which the project team will present the results from the tasks described below. It is assumed that the project team shall organize and host the above meetings, which will be located at the Stanford University Campus. The Center for Conservation Biology (CCB) and Philip Williams & Associates, Ltd. (PWA) will participate equally in this task.

1.3.3 Task 2 – Restoration Design Review

The CCB, in collaboration with PWA, shall review all documents related to the proposed restoration project at Redwood Creek. These shall include the feasibility study conducted by PWA, the preliminary design documents and existing conditions analysis. The objective of this step in our project approach is to allow full dissemination of design detail, objectives and proposed performance criteria between PWA and the CCB. CCB and PWA will contribute equally to this task.

1.3.4 Task 3 – Field Data Collection

The field data collection program is comprised of two components: biological and physical data collection. Up to six reaches will be sampled at varying times during the course of the project. In addition to sampling in the restoration reach, we will replicate the surveys in the reach immediately downstream of the restoration to examine downstream impacts of restoration that may occur. We will also survey neighboring paired reaches. The first two paired reaches are upstream of the restoration reach. They are less disturbed and will be used to explore the effects of reach scale disturbance on physical and ecological linkages and processes while controlling for watershed-scale processes. The next two paired reaches are in a neighboring creek that is more disturbed at the creek and watershed scale. The neighboring drainage is disturbed by light industry and residential development. These will be used as a comparison to further explore the effects of reach scale disturbance (without watershed-scale control) and the effects of watershed-scale processes (land use intensity) on macroinvertebrates. The creek systems to be used within the study drain the southern slopes of Mount Tamalpais, and share the same underlying topography, geology and hydrology. Surveys of the paired reaches will be conducted within a few days of the restoration reach surveys to control for temporal changes in factors influencing macroinvertebrates.

The paired reach surveys will also enable us to put into context the present state of the macroinvertebrate community in the reach of Redwood Creek to be restored. Figure 1 shows the geographical extent of the proposed project, and proposed study reaches. The information provided will be used to develop the conceptual model of the interactions between physical and ecological processes, and how these interactions affect food resources available to salmonids.

1.3.4.1 Biological data collection

Sample sites within the six reaches will be selected according to physical attributes delineating different physical habitats; i.e., riffles, pools and woody debris assemblages where present. A minimum of two sites representing examples of each physical habitat will be sampled in each reach. Surveys will start downstream and then move upstream to avoid contamination of samples. In addition for each reach, samples of riparian terrestrial invertebrates will be collected at four locations; two representing simplified and two developed riparian vegetation structure. All biological surveys will be conducted during four different seasons/hydrological periods, the exact timings of these surveys coinciding with the middle of each season, based on historic flow records. These periods will account for seasonal variation in macroinvertebrate abundance, community composition and diversity. Annual surveys of riparian vegetation structure at terrestrial sampling sites will be conducted. Each site location will be located by stakes, directly opposite on the nearest bank, marked on the physical survey map and recorded by GPS.

Benthic macroinvertebrate survey
A modified Hess sampler (0.3m diameter with 250 μm netting), will be used to sample benthic macroinvertebrates (Meehan, 1996; Bridcut, 2000). The sampler is placed on the creek bed, perpendicular to the direction of flow. The enclosed substrate agitated for two minutes to release macroinvertebrates into the sample bag. Two samples will be collected and then combined from each site. Samples will be preserved in 5% ethanol/formalin solution in the field then sorted and counted in the lab. Invertebrates will be identified to the lowest taxonomic level possible.

Drift macroinvertebrate survey
Drift will be sampled using a (0.28*0.47*1m with 250 μm netting) drift net, prior to the benthic sampling. Nets will be placed at the downstream end of duplicate examples of morphological units. The bottom of the net will be in contact with the creek bed and the top above the creek surface, perpendicular to water flow. They will remain in place for 24 hours to ensure inclusion of diel drifters. Samples will be preserved in 5% ethanol/formalin solution in the field then sorted and counted in the lab. Invertebrates will be identified to the lowest taxonomic level possible.

Terrestrial macroinvertebrate survey
The terrestrial contribution to salmonid diet will be sampled using the water trap method (*sensu* Meehan, 1996; Bridcut, 2000). Plastic pans (0.35m diameter) will be half filled with water and then preservative and surfactant added. One pan will be securely anchored in the creek in four sites, two with high riparian cover and two with low riparian cover. The pans will be left in place for 24 hours. A small hole fitted with a stopper will be bored in the bottom of each bucket to enable easy removal of contents. When the pan is emptied a 250 μm sieve will be used to remove sample. Samples will be preserved in 5% ethanol/formalin solution in the field then sorted and counted in the lab.

Riparian habitat survey
Riparian habitat will be surveyed by inventorying all trees and shrubs in a 20m strip from edge of river. A complete survey of vegetation structure (height, DBH and canopy cover) will be made of each study reach at start of the project and on an annual basis thereafter.

1.3.4.2 Physical data collection
The physical data collection program is designed to complement the biological data collection program described above. Data will be collected concurrently with the biological data at the six sampling reaches, and will include detailed surveys of reach topography, morphology, bed material composition, velocity distributions, water quality and discharge.

Reach Topography
Detailed surveys of the restoration reach topography (at approximately 0.5m resolution) will be collected at the start of the study period and on an annual basis (four surveys in total). The surveys will be conducted using a total station survey instrument. Plots of topographic variation will be produced for each survey period. This data will not be collected at the other five sampling reaches.

Morphology mapping
Detailed maps of reach morphology (distribution of pools, riffles, eroding bank-lines, gravel deposits, exposed root masses) will be produced at the start of the study and on an annual basis for each sampling

reach (four surveys in total). Morphology mapping will conducted following the guidelines presented by Thorne (1998).

Velocity Distributions & Water Quality
During each biological sampling session, measurements of channel velocity distributions will be produced using a hand-held velocity gauge. In addition, measurements of water temperature (in shaded and unshaded sites), dissolved oxygen content, N and P will be conducted to monitor water quality.

Bed sediment samples
Up to three bed material samples will be collected on an annual basis from each of the six sampling reaches. A grain size analysis will be conducted on the bed material samples to characterize bed material composition. Bed material sampling locations will be located to represent differing morphological units within each reach.

Discharge Gauging
Existing discharge gauges maintained by the National Park Service (NPS) and Marin County will be used to monitor daily discharge patterns on Redwood Creek and the Arroyo Corte Madera Del Presidio respectively.

1.3.5 Task 4 – Data Analysis
The following task describes the analysis that will be conducted based on the data collected under Task 3. The data analysis task will provide the necessary quantitative information to develop our understanding of the linkages within the conceptual model and address the research questions outlined above.

Between reach comparison of macroinvertebrate diversity, community composition and abundance
The diversity, community structure and abundance of macroinvertebrates, both within distinct physical habitats and pooled to represent the complete reach, will be compared between the undisturbed, restored and disturbed reach. Comparison will be made in the context of the physical data and surrounding land use. GIS databases will be used as a source for land use information, for example: the Bay area EcoAtlas (SFEI, 1998) and NOAA Land Cover Change data set for the San Francisco Bay (NOAA, 1998). The objective of this analysis will be to answer Research Question 1. For this and other analyses in which diversity, abundance and community structure are quantified, diversity will be measured using the reciprocal of Simpson's index (Whittaker and Levin, 1975), abundance by proportional abundance and community structure will be compared using the percentage similarity index (van Tongeren, 1995; Krebs, 1999). CCB will lead this section of analysis.

Temporal differences of macroinvertebrate diversity, abundance and community structure within and between reaches
The diversity, abundance and community structure of macroinvertebrates both within distinct physical habitats and pooled within each reach will be compared between reaches annually. Any significant differences detected within the restored reach and not in the reference or disturbed creek can be attributed to restoration. Any changes in the macroinvertebrate community will be interpreted in terms of ecological functioning of the community. The objective of this analysis will be to answer Research Question 2. CCB will lead this section of analysis, PWA will provide results on physical variables.

Dietary requirements of coho and steelhead
A literature review will be used to provide information of the dietary requirements of coho and steelhead and suitability of macroinvertebrate taxa in meeting those requirements (e.g. Spence et al, 1996; Rader, 1997). The composition of macroinvertebrate community in the restored reach and the abundance of palatable macroinvertebrates will be assessed in light of estimated salmonid population requirements. The objective of this analysis will be to answer Research Question 3. CCB will lead this section of analysis.

Diversity of habitats and macroinvertebrates
The diversity of physical habitats within each reach, determined by the morphology mapping task, will be correlated with the diversity of macroinvertebrates within each reach. The diversity of physical habitats available between each reach will also be compared before and after the restoration project. The objective of this analysis will be to answer Research Question 4. In addition, the detailed data on the restoration reach physical structure, provided by the topographic mapping will be used to examine the effect of the restoration on the physical processes and channel dynamics that shape the channel morphology. The changes in physical habitat at the restoration site will be correlated with changes in macroinvertebrate diversity and community structure. PWA will lead this section of analysis and the CCB will provide results on biological variables.

Stability of macroinvertebrate communities at the restoration site
Variation in diversity of macroinvertebrates both within distinct physical habitats and pooled within each reach will be compared between reaches seasonally. Communities in the restored reach will be considered stable when variation in community composition is no greater than that in the other reaches. Stability will be measured by lack of significant variation beyond that which occurred in the reference and disturbed reach. Stability in the restored site will indicate recovery of the macroinvertebrate community following restoration. To assess the stability of creek communities through time previous data collected for the Arroyo Corte Madera Del Presidio, by Marin County Stormwater Pollution and Prevention Program, will be examined. The objective of this analysis will be to answer Research Question 5. CCB will lead this section of analysis. Stability in the restored site may not be detected within the duration of this project. Further funding may be sought to continue this analyses.

1.3.6 Task 5 – Conceptual Model Development

Based on the results from the analysis described above, the linkages illustrated in the conceptual model will be further evaluated and defined. The role of each linkage and its effect on the food resources available to salmonids will be described. At the end of year one, we will examine the linkages between reach- and watershed-scale processes and salmonid food resources. Data collected during years two and three will enable us to build on this understanding and to examine the effects of the restoration project on these linkages. The CCB will lead this task effort.

1.3.7 Task 6 – Dissemination of Results

The project team will submit quarterly written reports to CALFED and the NPS, summarizing the progress of the project, overall schedule and issues arising during field data collection and subsequent analysis. In addition, the team will submit two annual progress reports, detailing the field data collection program and results of analysis to date. A draft final report outlining the results from the work tasks described above will be submitted six weeks after the completion of the final fieldwork season. The project team will then present the results of the above effort to CALFED and the NPS, and based on comments received finalize the draft report. Results will also be submitted for publication in relevant scientific journals. The project team will also present results at suitable conservation and restoration meetings, for example: the Society of Ecological Restoration or Annual San Francisco Bay Area Conservation Biology Symposia (attended by practitioners and academics alike). CCB and PWA will contribute equally to this task.

1.4 PROJECT FEASIBILITY

1.4.1 Field Data Collection Program & Subsequent Analysis

The project team will be collecting field data a maximum of 4 times per year. We envisage that each data collection session will take approximately 7 days. The field sites are easily accessible from the CCB and PWA. The mid-winter field data collection program may be interrupted by flood events. However, peak flows typically last less than 48 hours in the creek systems to be studied. Taking these factors into consideration, we do not anticipate delays to the field data collection program. Sorting and classification of macroinvertebrates, analysis of macroinvertebrate and physical data will take place at CCB and PWA. Both the CCB and PWA have the staff and resources to complete the above scope-of-work within the overall schedule.

1.4.2 Restoration Schedule

As stated above, the restoration project on Redwood Creek has not yet been constructed. This allows the project team to collect the necessary baseline data to enable a proper evaluation and analysis to be conducted. The restoration project is due to be constructed in late summer 2003. In the event of the restoration project being constructed earlier (summer/fall 2002), funding for one season of baseline field data collection (spring 2002) will be sought. The fieldwork will then be continued as planned through the summer of 2005.

1.5 PERFORMANCE MEASURES

1.5.1 Field Data Collection Program

The above scope-of-work includes the collection of numerous samples of macroinvertebrates, riparian vegetation structure and physical parameters. The performance of our field-data collection program will be evaluated annually based on the attainment of the specified numbers of samples of each parameter. A summary of this performance evaluation will be included within the annual progress reports.

1.5.2 Data Analysis & Conceptual Model Development

The data analysis and conceptual model development components of the proposed study will be evaluated based on their ability to successfully address, with an acceptable level of certainty, the research questions outlined in Section 1.1. A discussion of this assessment will be included in our final technical report.

1.6 DATA HANDLING & STORAGE

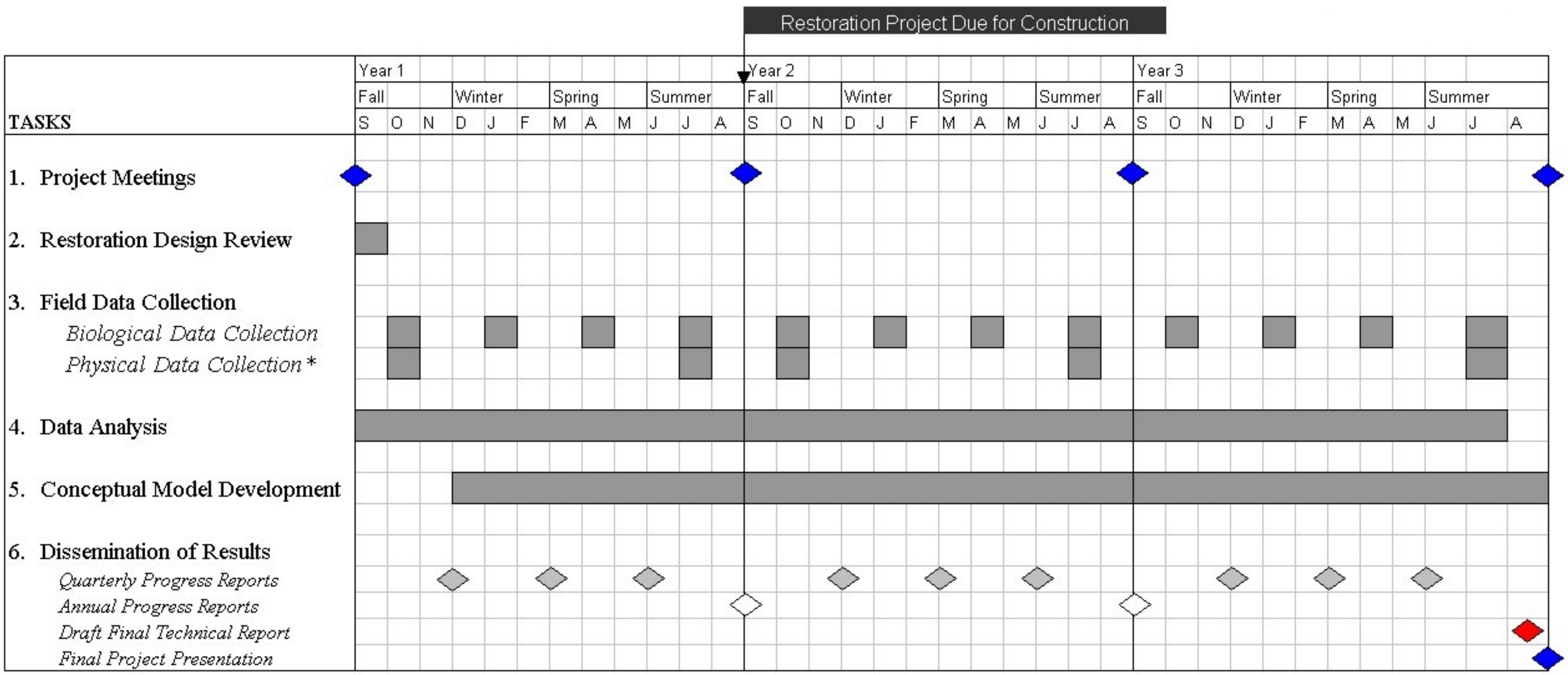
Copies of all biological and physical data will be stored within a data file to be managed and maintained by the CCB at Stanford. Copies of data will be made available to CALFED upon request.

1.7 EXPECTED PRODUCTS/OUTCOMES

Task 6 of the above scope-of-work outlines the expected work products from the proposed study. These include a final technical report, detailing all field data collection, subsequent analysis and conceptual model development, presentations at appropriate conservation and restoration meetings, and scientific technical publications.

1.8 WORK SCHEDULE

Figure 3 presents the anticipated work schedule for the proposed study. The schedule assumes work will begin no later than September 1, 2002.



*Physical Data Collection Schedule does not include velocity and water quality measurements
- these will be conducted concurrently with biological data collection program. Discharge gauging will be conducted continuously.

figure 3 - Project Schedule

2. PROJECT RELEVANCE TO ECOSYSTEM RESTORATION PROGRAM

The project outlined in this proposal incorporates the following Ecosystem Restoration Project strategic goals, Multi-region Priority Actions and CALFED Science Program Goals:

ERP Strategic Goal 1 - *Achieve recovery of at-risk native species dependent on the Delta and Suisun Bay as the first step toward establishing large, self-sustaining populations of these species; support similar recovery of at risk native species in San Francisco Bay and the watershed above the estuary; and minimize the need for future endangered species listings by reversing downward population trends of native species that are not listed.*

We will provide new information on the potential for newly restored salmonid habitat to support at risk species, namely, steelhead trout and coho salmon. Currently few empirical studies are available on the recovery of macroinvertebrates following physical habitat restoration projects. The studies available present conflicting results (Fuchs and Statzner, 1990; Friberg et al, 1998; Gortz, 1998; Laasonen et al, 1998). Information from this project will be valuable in ensuring the most effective construction of creek habitats for recovery and support of salmonid populations in the future.

ERP Strategic Goal 2 - *Rehabilitate natural processes in the Bay-Delta system to support, with minimal ongoing human intervention, natural aquatic and associated terrestrial biotic communities and habitats, in ways that favor native members of those communities.*

The project will provide new information on the recovery of functioning ecological communities following habitat restoration. The ability of the restored physical habitat, especially the new channel dynamics, to support natural aquatic and associated terrestrial biotic communities will be assessed. Physical and ecological processes that control the stability and sustainability of the macroinvertebrate community following restoration will be explored, with particular reference to provision of resources for salmonids. The impact of watershed land use intensity on community structure will be evaluated.

Multi-region Priority and Action 6 - *Ensure the recovery of at-risk species by developing a conceptual understanding and models of processes that cross multiple regions.*

& **CALFED Science Program Goal -** *Advance process understanding.*

The project will advance the understanding of linkages between physical and ecological processes, by integrating interdisciplinary information that describes such processes in existing and restored creek systems. This will lead to a more thorough understanding of the impacts of restoration projects on macroinvertebrate (including benthic) communities, their recovery and potential enhancement. Key to the project is the integration of information on flow, channel morphology, distribution and quality of in-channel and riparian habitat, biological interactions and human disturbance. The information provided will be used to construct a conceptual model to better ensure the functional recovery of newly restored salmonid habitat, resources vital to salmonids and thus the sustainability of fragile salmonid populations. The conceptual model will be directly applicable to future salmonid habitat restoration projects of creek reaches across the Bay-delta system. Performance measures will be developed based on the membership of communities in undisturbed, disturbed and restored creeks and their stability.

CALFED Science Program Goal - *Compare relative effectiveness of different restoration strategies.*

The conceptual model to be developed will explain part of the linkages between physical and ecological processes and the effects of restoration within creek systems on these linkages within part of the CALFED region. It will provide a basis for the future comparison of creek system restoration effectiveness. In particular, the conceptual model could aid in the selection of the most appropriate restoration approach, especially where the level of intervention within the creek system is to be determined.

3. PROJECT TEAM QUALIFICATIONS

PAUL EHRLICH (Principal Investigator)

Center for Conservation Biology, Stanford

Professional preparation

University of Pennsylvania	A.B., 1953
University of Kansas	M.A., 1955
University of Kansas	Ph.D., 1957

Appointments

1977—	Bing Professor of Population Studies, Stanford University
1974—1976	Director of Graduate Studies, Dept. of Biological Sciences, Stanford University
1966—1969	Director of Graduate Studies, Dept. of Biological Sciences, Stanford University
1966—	Professor of Biological Sciences, Stanford University
1962—1966	Associate Professor of Biological Sciences, Stanford University
1959—1962	Assistant Professor of Biological Sciences, Stanford University
1957—1959	Research Associate, Chicago Academy of Sciences and University of Kansas
1956—1957	Associate Investigator, Department of Entomology, University of Kansas
1952—1954	Research Assistant, Department of Entomology, University of Kansas
1951—1952	Field Officer, Northern Insect Survey (Canadian Arctic and Sub-arctic)

Five publications most closely related to the proposed project

Ehrlich, P. R., with Daily, G.C. (1993) Population extinction and saving biodiversity. *Ambio* 22:2-3, pp. 64-68.

Ehrlich, P. R., with Saunders, D.A. and Hobbs, R.J. (1993) Repairing a damaged world: An outline for ecological restoration. Beatty & Sons Pty. Ltd., Australia.

Ehrlich, P.R. (1995) Biodiversity and ecosystem functioning: Basic principles. Context: Biodiversity and ecosystem services. In: *Global Biodiversity Assessment*, V.H.Heywood, Ed., UNEP, Cambridge University Press, 1995. pp. 282-285.

Ehrlich, P.R. with E. Fleishman, G.H. Wolff, C.L. Boggs, A.E. Launer, J.O. Niles, and T.H. Ricketts. (1999) Conservation in practice: Overcoming obstacles to implementation. *Conservation Biology*, 13:450-452.

Ehrlich, P.R. with C, J. B. Hughes and G. C. Daily. Conservation of insect diversity: a habitat approach. *Conservation Biology*, 14:6, pp. 1788-1797.

Synergistic activities

1. Cofounder of the field of coevolution.
2. Director of long-term research on the structure, dynamics, and genetics of natural butterfly populations with applications to such problems as the control of insect pests and optimum designs for nature reserves.
3. Pioneering efforts in alerting the public to the problems of overpopulation, and in raising issues of population, resources, and the environment as matters of public policy.
4. Heads a research group with a central focus on investigating ways that human-disturbed landscapes can be made more hospitable to native biological diversity.
5. Long-term service to the scientific community via fellowship in the American Association for the Advancement of Science, American Academy of Arts and Sciences, American Philosophical Society, and National Academy of Sciences.

SALLIE-ANNE BAILEY (Post-doctoral fellow)
Center for Conservation Biology, Stanford

Education

1998 Ph.D. Conservation Biology, University of Nottingham
1992 MSc. Geographic Information Systems, University of Leicester
1991 BSc (hons) Environmental Science, University of Northumbria

Present and Previous Positions

1999 -	Post-doctoral fellow, Stanford University
1997 – 1999	Habitat Restoration Project Officer, English Nature, UK.
1993 – 1997	Postgraduate researcher, University of Nottingham
1991 – 1992	Teaching assistant, University College, Chester.

Research Interests

Dr. Bailey's research interests cover the implications of disturbance, habitat restoration or other modifications (e.g., fragmentation) to community structure at the habitat scale and biodiversity at landscape scales. She is now focusing on the prediction of restoration success of projects using ecological modeling techniques. In addition, Dr. Bailey is developing the application of spatially explicit modeling techniques to explore underlying mechanisms of change.

Selected Professional Service

1997 – 1999	Grant in aid supervising officer for the Cheshire Econet project
1994 – 1997	Editor of Newsletter for International Association of Landscape Ecology (UK)
1994 – 1997	Committee member of International Association of Landscape Ecology (UK)

Publications Relevant to Proposal

Bailey, S-A., Haines-Young, R.H. and Watkins, C. (in review) Species presence in fragmented landscapes: modelling of species requirements at the national level. *Biological Conservation*.

Balvanera, P., Daily, G.C., Ehrlich, P.R., Ricketts, T., Bailey, S-A., Kark, S., Kremen, C. and Pereira, H. (2001) Conserving biodiversity and ecosystem services. *Science*, 291 (5511): 2047.

Bailey, S-A., and Issacs, J. (1999) *Translation of Phase 1 data from field maps to GIS: learning gained from the Habitat Restoration Project*. English Nature Research Report 312. Peterborough.

Bailey, S-A., Haines-Young, R.H. and Watkins, C. (1996) Opportunities to protect the biodiversity of ancient woodland. In Dennis, P. (Ed) *The Spatial Dynamics of Biodiversity*. IALE(UK), UK. pp 139 – 146.

Bailey, S-A., Haines-Young, R.H. and Watkins, C. (1999) Habitat fragmentation in England's ancient woods: implications for managing biodiversity. In Maudsley, M. and Marshall, J (Eds) *Heterogeneity in Landscape Ecology: Pattern and Scale.* IALE (UK), UK

ROY RICHARDSON
(Associate, Philip Williams & Associates Ltd.)

Dr. Richardson's professional expertise integrates applied fluvial geomorphology with hydraulic engineering. In these technical areas, he has experience in one and two-dimensional numerical modeling of flow and sediment transport processes, stream reconnaissance, instrumentation and field measurements in large river systems. His research work has focused on the interaction of flow structure and geomorphic processes in rivers. In 1996, Dr. Richardson upgraded the sediment transport code in the one-dimensional river model, ISIS. In addition, he has consulted on a wide range of protected river and flow management issues for government agencies in Europe and the U.S. He acted as the U.K. Environment Agency's expert witness in the 1998 landmark River Teign public inquiry. Since joining PWA, Dr. Richardson has focused on the role of restoring geomorphic processes for the sustainable improvement of threatened and endangered fish habitat.

Education	Ph.D., 1997	Fluvial Geomorphology, Department of Geography University of Nottingham, UK
	B.Eng., 1993	Civil Engineering, Department of Civil Engineering University of Nottingham, UK
Professional Experience	1999-Present	Associate: Fluvial Geomorphologist Philip Williams & Associates, Ltd. Corte Madera, CA
	1997-1999	Research Associate: 2-D numerical modeling University of London, UK
	1996	Research Associate: 1-D sediment transport modeling Halcrow & HR Wallingford, UK
	1993-1996	Research Associate: Fluvial Geomorphologist Danish Hydraulics Institute & Delft Hydraulics
	1995	Research Associate: River gauging and instrumentation US Army Corps of Engineers

Selected Publications

Richardson, W.R. (in review). A Simplified Model for Assessing Meander Bend Migration Rates. *Journal of Hydraulic Engineering, ASCE.*

Shannon, J., W.R. Richardson, and J.B. Thornes, (in press, 2001) Short term dynamics of ephemeral streams. In Bull, L. J. and Kirkby, M. J. (Eds) *Ephemeral Channels in the Mediterranean.* To be published by John Wiley 2001.

Richardson, W.R., and C.R. Thorne, 2001. Multiple Stream Flow and Channel Bifurcation in a Braided River. *Geomorphology*, 38, p. 185-196.

Richardson, W.R. and C.R. Thorne, 1998. Secondary Currents around Braid Bar in Brahmaputra River, Bangladesh, *Journal of Hydraulic Engineering, ASCE,* Volume 124(3), p. 325-328.

Richardson, W.R., C.R. Thorne and S. Mahmood, 1996. Secondary Flow and Channel Changes around a Bar in the Brahmaputra River, Bangladesh. In: *Coherent flow structures in Open Channels,* John Wiley & Sons, p. 519-544.

4. STAKEHOLDER/LOCAL INVOLVMENT

The Redwood Creek Restoration Project is being managed by the NPS, Golden Gate National Recreation Area. CCB, in collaboration with PWA, will work closely with the NPS to coordinate our field data collection program, share data and discuss results of the project analysis and interpretation. The NPS will be involved in all project stakeholder discussions and meetings. They are aware of our proposed project and are supportive of the efforts (see Attachment A). The NPS also organize a Redwood Creek watershed group. As part of our stakeholder/local involvement efforts, we plan to invite members of the watershed group to stakeholder meetings and presentations.

The Marin County Stormwater Pollution and Prevention Program have been conducting physical and biological data collection on the Arroyo Corte Madera Del Presidio for several years. We plan to involve this group in our project stakeholder meetings to seek input on our field data collection program and share results of those surveys and subsequent analysis. The Marin County Stormwater Pollution and Prevention Program are supportive of the proposed research. We will also invite members of the Mill Valley Creek Keepers (formerly Friends of the Arroyo Corte Madera) to project stakeholder meetings and presentations.

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Attachment A – National Park Service Letter of Support

United States Department of the Interior

NATIONAL PARK SERVICE

GOLDEN GATE NATIONAL RECREATION AREA

FORT MASON, SAN FRANCISCO, CALIFORNIA 94123

IN REPLY REFER TO:

October 3, 2001

Roy Richardson
Phil Williams and Associates
770 Tamalpais Drive, Suite 401
Corte Madera, CA 94925

Dear Roy:

The Natural Resource Division of the Golden Gate National Recreation Area, National Park Service, supports the goals and project approach proposed in "Ecological Impacts of Physical Habitat Restoration on Resources Available to Salmonids," September 2001, prepared jointly by the Center for Conservation Biology at Stanford and PWA.

As the project manager for the proposed restoration project on NPS property at Redwood Creek, it is evident that the additional data collection and analysis to be conducted under the proposed research project could not only enhance the evaluation of the NPS restoration project, but could enhance the relevance of our restoration project to other salmonid restoration activities.

I look forward to the opportunity to work with you on this project.

Sincerely,

Carolyn Shoulders
Natural Resource Specialist