CALFED BAY-DELTA PROGRAM

CALFED SCIENCE FELLOWS PROGRAM

Sea Grant California

In cooperation with the

California Sea Grant College Program

FELLOWSHIP APPLICATION COVER PAGE

APPLICANT TYPE [X] Postdoctoral Researcher [ ] Ph.D. Graduate Student

PROJECT NUMBER ____________

PROJECT TITLE MEASURING AND PREDICTING THE SUCCESS OF RIPARIAN RESTORATION FOR WILDLIFE POPULATIONS: ACCOMMODATING UNCERTAINTY AND COMPLEXITY

FINANCIAL SUMMARY

First Year CALFED Funds Requested: $76,250
Total CALFED Funds Requested: $228,750
Duration: 3 years
Proposed Start/Completion Dates: 11/01/2006-10/31/2009

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Will animal subjects be used? [ ] Yes [X] No
APPROVAL DATE: ____________ PROTOCOL #: ____________ PENDING: ____________

Does this application involve any recombinant DNA technology or research? [ ] Yes [X] No

MEASURING AND PREDICTING THE SUCCESS OF RIPARIAN RESTORATION FOR WILDLIFE POPULATIONS: ACCOMMODATING UNCERTAINTY AND COMPLEXITY

INTRODUCTION

California Wildlife and Riparian Restoration

Riparian areas are some of the most productive systems in North America and provide a number of important ecosystem functions (Patten 1998). These functions include providing habitat for both aquatic and terrestrial wildlife (Knopf et al. 1988). For example, in California, riparian areas have been identified as the single most important habitat for the protection and conservation of songbirds (Davidson 1995; Gaines 1974; RHJV 2003). Further more, the diverse components of these systems may be linked in surprising ways. For example, riparian areas with fish may function better as bird habitat than areas without fish (Gende and Willson 2001). In the Central Valley, however, it is estimated that at least 98% of riparian habitat has been lost over the past century and a half (Katibah 1984; Smith 1977). The loss and degradation of riparian habitats has had deleterious effects on riparian birds and other wildlife.

As a result, public and private organizations are investing millions of dollars in river restoration and riparian habitat restoration (Bernhardt et al. 2005), with thousands of acres slated for restoration along the Sacramento and San Joaquin Rivers, their tributaries, and the Delta. However, there are still many scientific uncertainties about the most effective ways to restore and manage riparian habitat as well as uncertainty about how to evaluate restoration actions (Ruiz-Jaen and Aide 2005). In the face of such uncertainty, it may be difficult for management agencies and advisory panels to make recommendations for riparian restoration and conservation (Wiens et al. 1993). Future restoration and management decisions can be optimized by evaluating the success of past management actions within an adaptive management framework. The objective of this project is to develop a hierarchical modelling approach that can evaluate the ability of riparian restoration to sustain wildlife populations. This decision support tool will serve both a mensural function, as yardstick of current restoration projects, and a predictive function, as the models will feed into the adaptive management process.

How Much Restoration is Enough?

Field research in riparian habitats has generated a tremendous amount of data that links wildlife population information with local and landscape scale habitat characteristics, restoration actions, and management (Morrison et al. 1994). These data have been used to test and revise existing restoration and management recommendations and monitoring strategies for the region. Many of these results were used to refine the suggested riparian planting recommendation in the Riparian Bird Conservation Plan (RHJV 2004). Following the implementation of the revised planting strategy at the San Joaquin River National Wildlife Refuge, a pair of endangered Least Bell's Vireo was found breeding in the restored riparian. This species had not bred in the Central Valley in over 50 years. This does not appear to be a unique occurrence. In a study of restored riparian habitat along the Sacramental River, Gardali and co-workers (in press) demonstrated that trends for a wide variety of species were increasing after the areas had been restored. These studies demonstrate that restoration activities are successfully providing habitat for a diverse community of landbirds and that results from bird monitoring provide a meaningful way to evaluate restoration success.

Although we now know more about the response of wildlife populations to riparian restoration, especially in the Central Valley, we still lack an answer to one of the most important questions: How much riparian restoration will be needed to assure the persistence of the species that rely on these habitats? This is not a trivial question.

First, there are many ways in which the response of a wildlife population to restoration might be measured. Such performance measures include, but are not limited to, density, reproductive success, physiological condition, and population growth rate. Historically, many efforts at evaluating restoration success have focused simply on the density of organisms as a performance measure of habitat quality. Increasingly, conservation biologists are aware of the problems with extrapolating from a single measure of habitat quality to more general conclusions about the contribution of that particular habitat to population growth (Bock and Jones 2005). For example, there is increasing evidence that adult density may be a misleading indicator of habitat quality, because it does not provide information on reproductive success, juvenile survival, and other important demographic metrics that are "downstream" of the measurement of density (Vanhorne 1983). The effect of density on population growth may be further complicated if reproductive success is strongly density dependent, such that increasing density has a limited contribution to the number of young produced (Hellriegel 2000).

Second, the demographic parameters that contribute to the population dynamics of a species are often highly variable and influenced by many events other than just local restoration efforts. The challenge of evaluating the effectiveness of restoration is to tease apart the amount of variation related to restoration from the noise that is generated by other events in the environment. Many of these other events are stochastic processes, such as the weather, that are better thought of as a distribution of events, rather than a constant event with a fixed mean. Because these stochastic events generate variation in the variables that they influence, the propagation of error through the system can be considered "hierarchical". For example, variation generated at large spatial scales, often passes through the system to create variation at smaller spatial scales. Within the past 10 years, ecologists have realized that hierarchical Bayesian model offers a very powerful tool for understanding these types of systems. Hierarchical Bayesian modeling offers a novel way to address ecological complexity in a unified framework that until now has been difficult or impossible to achieve (Calder et al. 2003).

APPROACH

My project will integrate population modeling of passerine bird population with information on habitat quality and conservation strategies to develop a better understanding of how much restoration is required to allow songbirds to persist, which demographic parameters are critical factors influencing population growth, and the magnitude of demographic parameters that can be used targets for designing effective . Specifically, I will address the following objectives:

- Use existing demographic information on bird populations to build population models for riparian habitats in the Central Valley of California (data and some analyses available through PRBO).
- Use these models to investigate the ability of riparian restoration to change demographic parameters (e.g., density, reproductive success, survival) sufficiently to provide self-sustaining populations
- Use these models to describe the magnitude of changes in parameter values that lead to biologically significant changes in population growth rates as targets for riparian restoration and conservation
- Illustrate the application of hierarchical models to complex ecological systems in which quantifying uncertainty is important

Birds as a Model System

Birds are potential indicators of ecosystem health in general, and of riparian habitat quality in particular (Canterbury et al. 2000; Gardali et al. in press; Vos et al. 2000). This is because bird populations are sensitive to a number of important components of riparian ecosystem health, including the levels of primary and secondary productivity in the system, the structural and species diversity of vegetation, and the size and connectivity of habitat patches. Bird populations in riparian habitats are believed to respond to stressors such as human land conversion and altered hydrology via several mechanisms. Agricultural activities and urban development within floodplains may reduce the amount of riparian habitat available for birds, directly reducing population sizes. More indirectly, floodplain development also fragments and isolates remaining habitat patches and may affect the number and type of predators or parasites in the system (Robinson et al. 1995). This in turn interferes with the functioning of demographic processes, such as reproductive success and dispersal that are crucial to maintaining bird population sizes and preventing local extinctions.

Today, overall numbers and breeding range of the Least Bell's Vireo and Yellow-billed Cuckoo have been drastically reduced in the CALFED region and Yellow Warblers, Song Sparrows, and Warbling Vireos have disappeared from some areas of the Central Valley. Furthermore, many species that still breed in the region, such as Lazuli Buntings and Spotted Towhees, currently experience extremely low nesting success (PRBO unpublished data). However, the density of some, but not all, bird species have been demonstrated to respond quickly and positively to some, but not all, habitat restoration efforts (Gardali et al. in press). Thus, birds appear to be a suitable taxon for the application of hierarchical models to evaluate the success of riparian restoration efforts.

Why Use Hierarchical Models?

Increasingly, hierarchical Bayesian models are being used to understand the complexity and uncertainty of wildlife population dynamics. These methods are particularly well-suited to these problems for several major reasons. First, they allow one to link estimates of multiple layers of demographic processes and their uncertainty, such as reproductive success and survival, into a single model (Calder et al. 2003; Maunder 2004). Second, they can effectively incorporate the variation associated with unobserved processes, called "latent variables" (Clark and Bjornstad 2004). These two characteristics allow hierarchical models to provide realistic answers to complex questions (Clark 2005). Finally, the Bayesian framework allows one to make statements about the probability of a model (e.g. the effectiveness of restoration) given the data. In contrast, the classical frequentist approach draws conclusions about the probability of data, given a specific model. Thus, the results of a Bayesian analysis lend themselves to the decision making process of conservation much more readily than those of a classical frequentist analysis.

Though novel and new, the application of hierarchical Bayesian models to population dynamics is not unprecedented. Already this technique has been used to synthesize information and predict patterns of population change of Sacramento salmon (Newman et al. 2006), Northern Spotted Owls (Clark 2003), and passerine birds (Saether et al. 2000).

Synthesizing Data Across the CALFED Region

This project will capitalize on the rich data sets that are already available for riparian habitats in the Central Valley. PRBO Conservation Science, in partnership with federal, state, and non-profit agencies, has been conducting intensive monitoring of riparian bird systems in the CALFED region since 1991 including the Sacramento Valley(Gardali et al. in press); the Delta (Howell et al. 2006; Nur et al. 2006); and the San Joaquin River (see Table 1 for details of monitoring efforts). Collectively these dedicated biologists have accumulated massive amounts of data and provided a wealth of information on the response of bird populations to riparian restoration. These include data on the responses of birds to habitat variation within individual study sites, how birds respond to differences among study sites (including landscape features), and the demographic characteristics (e.g. reproductive success, annual survival, etc) at these sites. As a result, there are probably more data on the demography of birds in riparian habitats of the Central Valley than there are on any other animal. These data will provide the backbone of this project, and I will be collaborating on a daily basis with biologists at PRBO Conservation Science.

The key to the success of this project will be integrating the information of bird demography together with larger scale patterns of riparian restoration, hyrdrology, and climate. For example, preliminary analyses have indicated the hydrological events, especially flooding, are an important driver of annual variation in avian reproductive success (Howell et al. 2006). The frequency and magnitude of flooding events are likely linked to global weather patterns, which may be altered through climate change (Kim 2005). Thus, the ability to understand how global climate patterns lead to local flooding events, and subsequently change reproductive success of birds in riparian areas will be a crucial component of the model. Specifically, I will work with PRBO biologists to incorporate their information on fecundity and survival in the population models I am building. The data on fecundity and survival are briefly described below.

Fecundity- Information on avian reproductive success has been collected by searching for nests in unrestored (remnant) and restored riparian systems in a number of CALFED watersheds (Table 1). These data can be used to quantify the number of young birds that adults can be expected to fledge in a year and how much this number increases when riparian habitat is restored (Fig. 1).

Survival- In addition to searching for nests, PRBO has been banding adult birds at many of their sites. By examining the number of birds that are recaptured after the initial year they were captured, these data allow the probability of survival from one year to the next to be estimated. A wide variety of statistical models are available for quantifying spatial and temporal variation in fecundity and survival (Freeman and Morgan 1992, White and Burnham 1999, Dinsmore et al. 2002, Nur et al. 2004).

Evaluating Restoration Success: Are Populations of Riparian Birds Self-sustaining?

The major objective of this project will be to use demographic information about riparian birds to estimate the population trajectories of these species and the degree to which restoration is influencing these trajectories. Generally, changes in population size over time can be modeled with stage specific information on reproductive success (fecundity) and mortality risk (survivorship; Fig. 1). Additionally, taking recruitment into account may be important, especially when populations are fragmented into small sub-populations (which make a “meta-population”). With information on these parameters, matrix models provide a powerful tool for understanding the dynamics of population growth (McDonald and Caswell 1993). Information from PRBO long-term research projects on riparian bird in the Central Valley (see Table 1 for a summary of available data), will be used to generate this information.

The estimation of these parameters and the prediction of wildlife populations, have a long history of use in the field of conservation biology. More recently, these techniques have been incorporated into hierarchical Bayesian models (Marin et al. 2003). These analytical techniques provide an extremely powerful tool for understanding how populations are responding to management activities and for making predictions about what strategies are best for the conservation of a species (Borsuk et al. 2006; Zhang and Perry 2005). My work will apply these new techniques to the estimation of population growth rates of passerine bird populations. The goal of this work will be to understand whether or not riparian restoration is changing the demographic parameters of bird populations substantially enough to provide for stable populations.

PLAN OF WORK

Anticipated Products and or Benefits

This fellowship will have multiple benefits for the parties involved. First, it will allow the fellow, the research mentor, and the community mentor (PRBO scientists) to develop a new set of tools for solving complex problems associated with the conservation of wildlife populations. Hierarchical models are heralded as a tool that can contribute to many ecological problems (Clark 2005), but they are still used by relatively few conservation scientists.

Working with Dr. Jim Quinn and PRBO biologists will provide me with an excellent opportunity to learn about modeling fecundity and survival using nest-monitoring and banding data. Dr. Quinn has an active lab group at UC Davis (he is Director of Information Center for the Environment) and I am look forward to interacting with his lab group and benefiting from their collective expertise in modeling, statistics, and GIS. PRBO has an extensive history of data collection and modeling in the CALFED region (e.g. Howell et al. 2006; Nur et al. 2006) and I look forward to interacting with PRBO biologists

Moreover, I will advance my personal goals of working in biology at interface of quantitative ecology and conservation biology. I'm excited about the opportunity to work with scientists from a wide variety of institutions, including academia, NGOs, and state agencies.

Additionally, my work will provide PRBO the opportunity to build upon analyses they have done in the past, including their current CALFED grant which will be expiring in July 2007. The results of these analyses will be useful to PRBO and to applied conservation practitioners in the CALFED region and beyond.

Finally, and most importantly, this project will have both direct and indirect applications for CALFED priorities and mission. First, the information about bird populations will have direct application to management decisions about the restoration and conservation of riparian habitats. This information will provide a synthetic measure about the effectiveness of riparian restoration, an evaluation of the uncertainty associated with restoration success, and guidelines for how restoration efforts might be improved. Secondly, this approach will provide a model for how hierarchical models can be applied to other conservation and management questions in the CALFED region. The products that will be produced by this fellowship will directly address both of these aspects.

Year 1

<u>Tasks</u>

In the first year, my efforts will begin with compiling data/previous analyses and meeting with CALFED partners and other stake-holders to identify important model parameters. I foresee a series of meetings to solicit input on what variables are biologically important in addition to those that are logistically important for management plans. In the second part of the year I will begin to fit models and interpret results.

Products
1. Local presentations: Meetings with CALFED managers and biologists to discuss model development. This step will be a critical component of making sure that the models are useful to CALFED stakeholders. This will include presentations to groups in the San Joaquin area and to the Sacramento River Conservation Area Forum.
2. Scientific Presentation: Ecological Society of America annual meeting, Sacramento, California (August)

Year 2

Tasks

In the second year, I will finish the process of fitting the models and meet with local biologists and managers to discuss the results. I foresee these meetings as an opportunity to verify that model results are biologically realistic and that they capture the important variables. Furthermore, these meeting will allow me to begin planning for workshops that will be conducted in year three.

Products:
1. Manuscript: Applying hierarchical models to effectiveness monitoring for land management and restoration programs. This will be a general manuscript that reviews the application of hierarchical models to effectiveness monitoring and presents the objectives of this particular project as a case study.
2. Local presentations: Preliminary Results on the Effectiveness of Riparian Restoration for Bird Populations in the Sacramento Valley

Year 3

Tasks

In the third year I will finish model building and submit the results for publication. I will organize several major workshops with CALFED partners. One set of these workshops will be focused on interpreting the specific results of my models with the action plan of CALFED. These workshops will be designed to integrate the model results into the CALFED planning process and, if necessary, adjust goals or objectives of restoration accordingly. A second set of workshops will be designed to discuss the results of this modeling process more general. With a group of diverse biologists and managers, we will discuss how this process might be applied to other species and/or systems. From these discussions, I would like to select several candidate species or systems and conducting a feasibility analysis for future modeling projects.

Products
1. Manuscript: How much restoration is enough? Hierarchical modeling of restoration effectiveness for passerine birds in the Sacramento Valley.
2. Workshop: Evaluating Riparian Restoration Programs in the Sacramento Valley: What Does it Mean for Riparian Birds?
3. Workshop: Hierarchical Modeling and Environmental Monitoring: Applications and Design

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TABLES AND FIGURES

Table 1. List of past, ongoing, and proposed bird monitoring projects/locations conducted by PRBO Conservation Science in the CALFED region. Projects that include CALFED-supported research and/orrestoration actions are marked with *.

Project1	Years of Study	Fecundity	Survival
Upper Sacramento	1991-1997	4 sites	12 sites
Clear Creek *	1998-2006	2 sites	2 sites
Stony Creek	1997-1999	1 site	1 site
Lower Sacramento*	1993-2004	4 sites	2 - 4 sites
Mokelumne River *	2003-2006	3 sites	2 sites
Cosumnes River*	1995-2005	3-4 sites	2 sites
San Joaquin River*	2000-2005	3 sites	2 sites
San Joaquin River	1995-1997	6 sites	2 sites
San Joaquin BOR	2003-2005	2 sites	2 sites

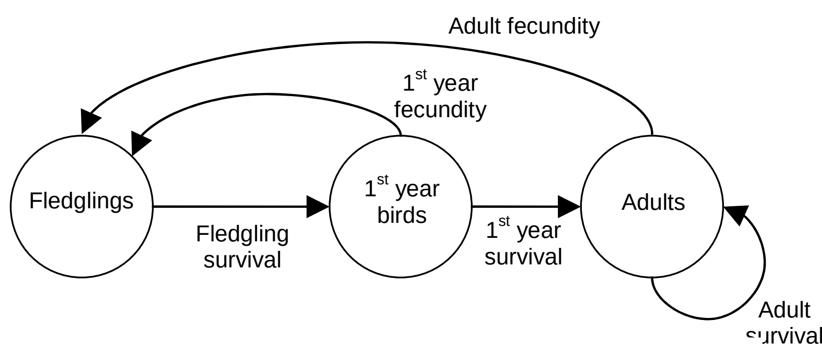

Figure 1. A diagram of a simple population model for a typical bird. Young birds enter the system and become adults by surviving the fledgling period, and the subsequent year. Circles represent stages, arrows represent transition probabilities between stages.