Sacramento River Riparian Monitoring & Evaluation Plan

2011

Prepared by:

Fraser Shilling[a], Heidi Schott[a], Michelle Early[a], Christine A. Howell[b], Marcel Holyoak[a]

[a] University of California, Davis

[b] PRBO Conservation Science

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Contents

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Executive Summary

California's Central Valley once hosted great riparian forests along its many large rivers, in dynamic interaction with their river channels and floodplains. Over a century of wood-cutting, agriculture, water diversion, and urbanization have led to the destruction of >95% of these gallery forests. Over the last decade and a half, the state and private conservation organizations have acquired lands with the purpose of re-planting native vegetation along the Sacramento River in an attempt to restore a portion of the river's historic ecological function. As part of this overall restoration program, restoration and ecological scientists have partnered to determine how best to encourage ecosystem recovery through natural and horticultural means. This science-based monitoring and evaluation plan is one tool that can be used to track riparian vegetation, channel, and floodplain forest riparian condition and recovery in response to natural variation and to various management actions.

The Large Sacramento River

Large rivers and floodplains have extensive influence over large areas of the planet's surface through their movement of water and sediment. Historically, these landscapes have been the focus of intensive economic activity and settlement and thus are often radically altered. Large river restoration requires new paradigms in thought and practice with the recognition that facilitating basic system processes is fundamental to successful river protection and restoration. Historically, the Sacramento River moved 18,000,000 acre-feet of water (Turner, 1996) and 1-10 million metric tons of sediment (Wright and Schoellhamer, 2004) annually from its tributary rivers to the San Francisco Bay. Its meandering channel dynamically interacted with surrounding landscapes through an ebb and flow of flooding events. Over the centuries the deposition of water and sediment, movement of materials, and land re-working have made Sacramento River riparian areas very productive both ecologically, and following extensive modifications, agriculturally.

Large river system processes including flow dynamics and geomorphic activities have been impaired throughout the Sacramento River main-stem and riparian areas due to water management, levee construction, and changes in adjacent land-uses and vegetation. The Sacramento River's constrained channel meanders much less now than it did historically and has little opportunity to interact with its true flood-plain. As a consequence the current riparian ecosystem supports only a fraction of the species, communities, and natural processes that it once did.

A major question for this large river system is whether or not it can function at a fraction of its historical level and still produce the many ecosystem services and natural values that it once provided to residents of the Great Valley. Comprehensive monitoring and evaluation of its diverse attributes and functions in the presence of agricultural practices and horticultural activities is crucial to understanding what has been lost in this large river, what the impact of recent and current restoration practices has been and the trajectory of what is possible in the future.

Goals and Objectives

The intent of this Plan is to describe how land managers, state agencies, and others can monitor and evaluate the changing conditions of the Sacramento River Riparian as natural and management-induced changes occur. The Plan is not prescriptive, it describes options for monitoring and choices of indicator. The Plan may also have different purposes for different audiences: for managers, the Plan is useful for strategizing approaches, for practitioners, it is useful for selecting indicators to monitor and approaches to monitor them. The Plan is based upon the best available science and describes methods that are robust and repeatable. It provides the most up-to-date monitoring approaches, describes appropriate analytical uses of information, and is presented in a language that should be easily understood by land managers and restoration practitioners.

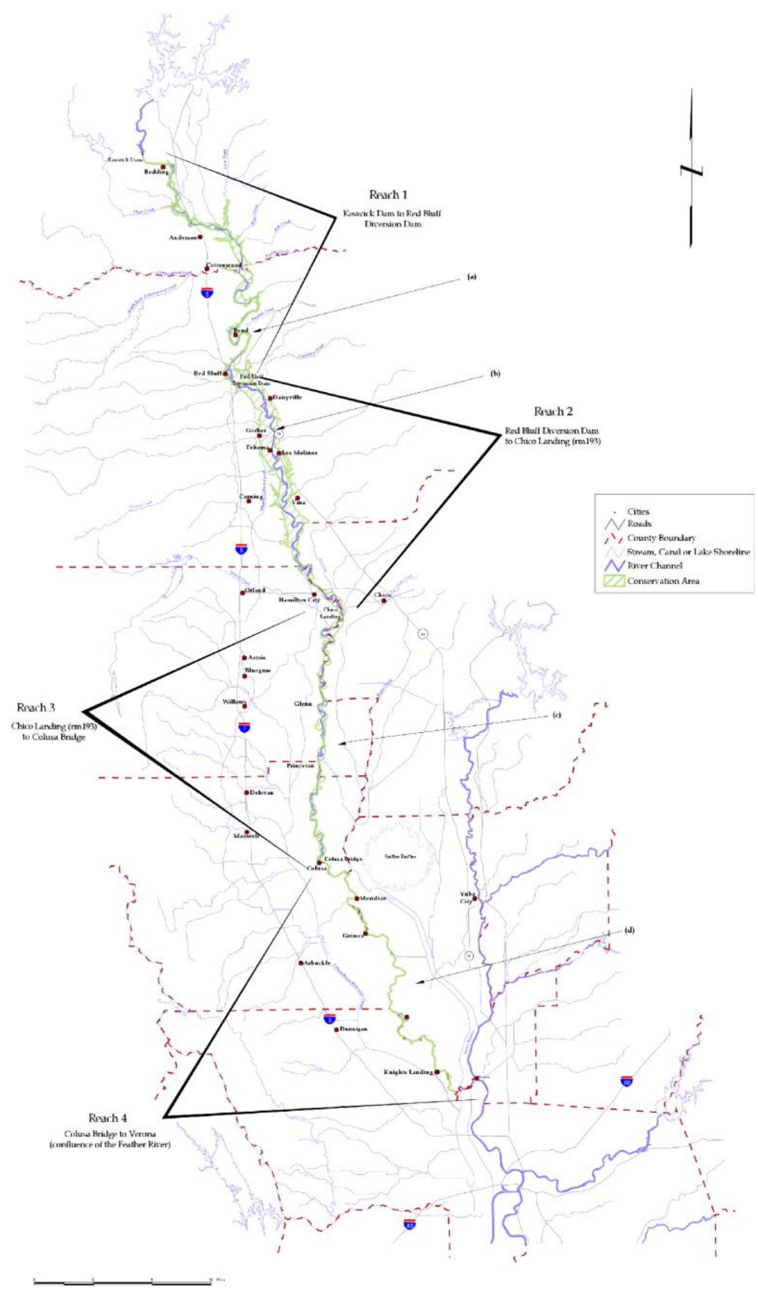


Figure 2-1. The four reaches of the Sacramento River Conservation Area. Letters refer to cross sections shown in Figure 2-4.

The Sacramento River and Sacramento Riparian Conservation Area (from SRCAF Handbook, 2003)

Questions the Plan Covers

Monitoring based on management or scientific questions tends to be more directed and the results better understood than monitoring without such direction. We have designed the monitoring and evaluation approach described here to address the following major questions:

1) What is the current status of natural riverine processes compared to hypothesized potential natural conditions and desired future conditions?

2) How are the ecological and hydrological changes that have occurred related to vegetative restoration activities?

3) What is the overall status of riparian vegetation, riparian bird communities, and Valley Elderberry Longhorn Beetle populations along the Middle Sacramento River?

4) How do restored and remnant riparian sites compare in terms of the parameters listed above?

5) What other elements should be considered for monitoring to complement those parameters described in detail in this report?

6) What monitoring programs are in place to complement the program presented herein?

Conceptual Model

Ecologists often use diagrammatic or narrative descriptions to conceptually model the operation of complex systems. The conceptual model in Figure 1 shows major relationships among compartments of a riparian forest system. In this model, an active channel interacts with the floodplain and its associated vegetation. This interaction includes erosion of banks and

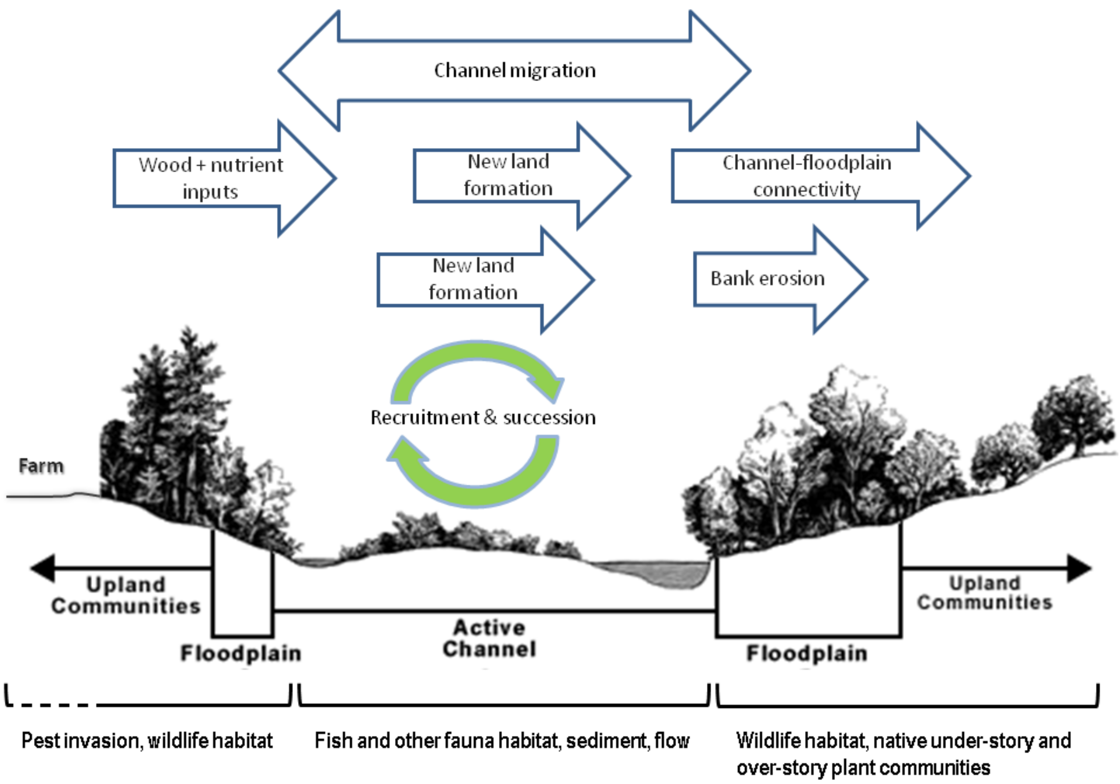


Figure 1 Riparian cross-section conceptual model (adapted from NOAA diagram, http://csc-s-maps-q.csc.noaa.gov/salmonid/html/water/images/streamx.gif).

floodplain into the channel itself, as well as deposition of material onto the floodplain. Material, including sediment and plant material, enters the channel due to the erosion and contributes to aquatic habitat structure, food for herbivorous aquatic organisms, deposited sediments on floodplains, and new land formation on the edge of existing channels. Habitat structure and function is maintained in both the channel and the floodplain/riparian zone by these dynamic interactions. Historically, natural channel meander and seasonal/episodic flooding would maintain erosion and deposition of sediment and plant material from and to banks and floodplains. After the construction of Shasta Dam, withdrawal of water from the river, agricultural development of the riparian zone, modification of the hydrograph, and flood-management these dynamic processes have changed, impacting both the creation and turn-over of both aquatic and terrestrial riparian habitats. Effective restoration means advancing riparian areas to a state where dynamic interactions are once again possible and concomitant structure and function are restored.

Effective monitoring to understand the ecological health of the riparian zone includes measuring both the dynamic process of channel-floodplain interaction and the structural and functional outcomes of the interaction. This includes the patterns of channel and floodplain interaction, vegetation structure, composition and distribution along the riparian zone, and the use of riparian and channel habitats by fish, birds, mammals, insects, and other organisms. This is the basis of the Monitoring Plan.

Another way to depict the combined riparian vegetation and channel system is by using a simple box and arrow model (Figure 2). This diagram conceptually describes the interactions among processes and attributes of the riparian system through the lens of restoration effectiveness. In this case, restoration success is dependent upon habitat structure and function, habitat use, and geomorphic processes. Both conceptual models are consistent with the more detailed riparian conceptual model developed for the Delta Regional Ecosystem Restoration Implementation Plan (Fremier et al., 2008).

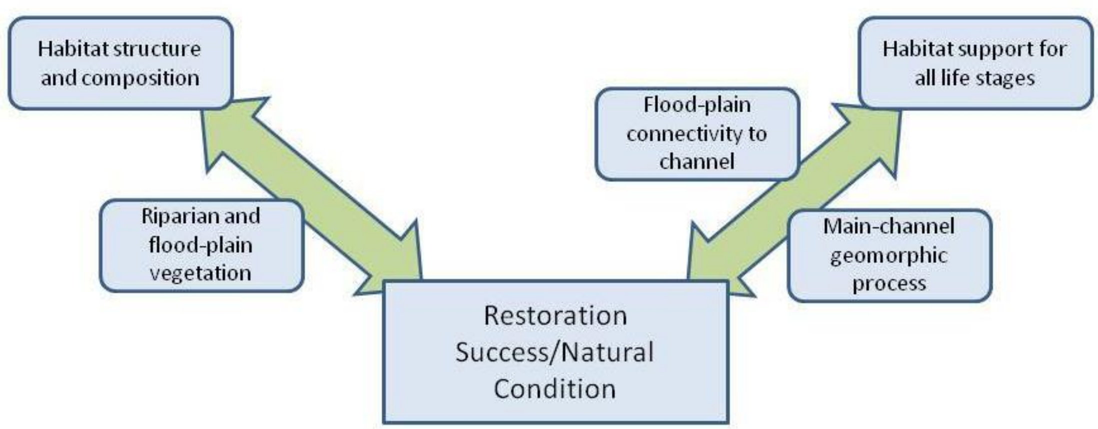


Figure 2 Simple conceptual model for evaluating restoration success.

By conceptually modeling the relationship between habitat conditions and management goals/desired outcomes, monitoring plans can help evaluate current conditions relative to natural and social goals.

Indicator Framework

This monitoring plan is based on the indicator framework used in the Sacramento River Riparian Scorecard which reflects major aspects of riparian and channel condition, but is not intended to cover all ecosystem processes and attributes. The scorecard approach was developed by The Nature Conservancy to measure attainment of conservation targets (Parrish et al., 2003). It is similar in structure to other indicator-based reporting systems used around the world and is based on categories of ecological condition (e.g., landscape condition) within each conservation target (e.g., terrestrial riparian habitat). The categories contain indicators that correspond to specific ecosystem processes and attributes and provide information that can be used to evaluate attainment of the goals set for the conservation targets.

Conservation targets are listed in Appendix 1 and certain environmental indicators are used to evaluate each target in the framework and scorecard. This evaluation consists of comparisons of the status of the ecological process or attributes relative to a target conditions. Within the monitoring method descriptions in Section II, relevant indicators are highlighted within each section.

I. Background, Overview and Purpose of the Monitoring Plan

I.A Introduction to the Sacramento River

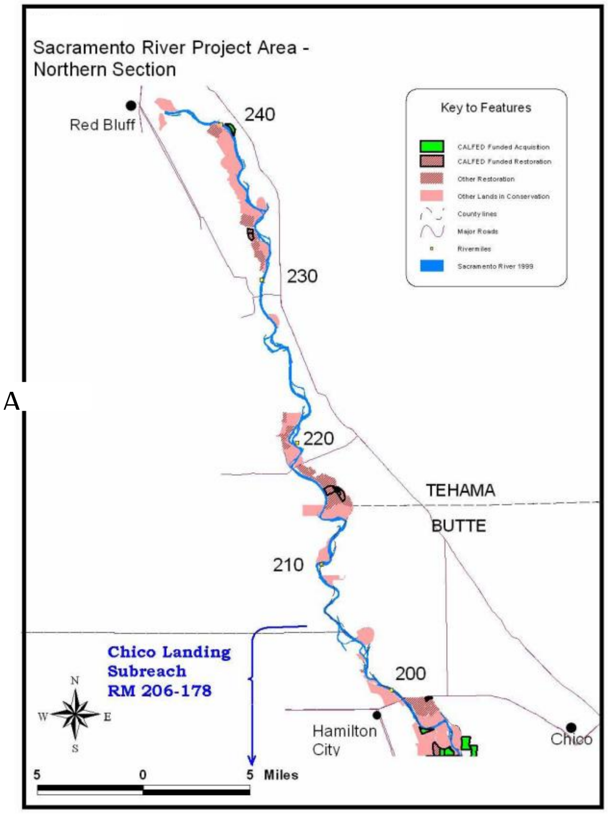
The Sacramento River is the largest river in California, extending from southern Oregon, past Shasta Dam, through Sacramento and the Delta, to the San Francisco Bay. It is a heavily-used river, with diversions and returns by agriculture, wastewater disposal, flood-control structures along its banks, and water removals for urban and agricultural uses to the south. It supplies 80% of the flows through the Bay-Delta (California State Lands Commission, 1993). The riparian zone of the Sacramento River is fragmented and lacks much of its original structure and function. Since settlement of the Sacramento Valley, 90% of the original 88,000 hectares (value from Golet et al., 2003) has been destroyed due to a variety of water and land development projects. This situation has led to state and federal investments in land acquisition and horticultural restoration along several reaches between Red Bluff and Verona.

The loss of riparian habitat along the Sacramento River has caused local extirpations and threatens the persistence of important native species. At-risk species include resident and Neotropical migratory songbirds and the Valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*), taxa which are the focus of this proposal. The valley elderberry longhorn beetle (VELB), is a federally threatened species that is absent from large areas within its historical range (CALFED 2000a). Special-status songbirds that have declined and/or have experienced range retractions include the western yellow-billed cuckoo (*Coccyzus americanus occidentalis*), yellow-breasted chat (*Icteria virens*), yellow warbler (*Dendroica petechia*), and Modesto song sparrow (*Melospiza melodia mailliardi*). Bird species that no longer reproduce along the river include least Bell's vireo [*Vireo bellii pusillus*] and willow flycatcher [*Empidonax trailii*]) (Gaines 1977, CDFG, and PRBO 2001).

Although severely degraded, the Sacramento River still hosts one of the most diverse and extensive river ecosystems in California, composed of a rich mosaic of aquatic habitats, oxbow lakes, sloughs, seasonal wetlands, riparian forests, valley oak woodlands, and grasslands.

A striking feature of the Sacramento River is the great potential for restoration that it presents. Recognizing this potential, and in an effort to restore habitat as well as viable populations of resident and migratory birds, VELB, anadromous fish, and other wildlife, government and non-government organizations have begun to implement a series of restoration programs along the river. The CA State Legislature, in 1986, passed Senate Bill 1086, which mandated the development of a management plan to protect, restore and enhance riparian habitat along the Sacramento River and its tributaries. The Sacramento River Conservation Area Forum (SRCAF) non-profit organization was formed, with the primary goal of both ensuring the preservation of remaining riparian habitat and the reestablishment of a continuous riparian corridor from Red Bluff to Colusa. CALFED specified collaboration with the SRCAF as a priority for the Sacramento River region.

A



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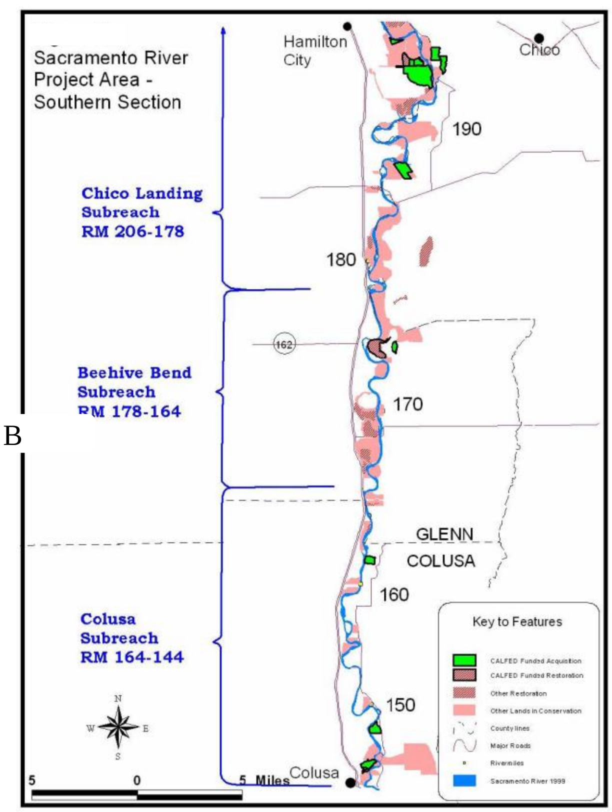

Figure 3. CALFED and CVPIA investments

Over the past 20 years, The Nature Conservancy (TNC), River Partners (RP), CSU Chico, and agency partners (including the U.S. Fish and Wildlife Service, the CA Department of Water Resources, the CA Department of Fish and Game, and the CA Department of Parks and Recreation) have worked to implement many of the conservation initiatives outlined in the SRCAF handbook (CA Resources Agency 2003). TNC and RP have planted a suite of native woody species (trees and shrubs, Alpert *et al*. 1999), and more recently, forbs and grasses (McClain *et al.* in press) on 3,600 acres of Sacramento River floodplain habitat **(Figs. 3a & 3b).** CALFED and CVPIA have provided direct support to this effort by funding projects focused on planning, acquisition, restoration, research, and monitoring. Through grants to TNC, RP and other organizations, CALFED has funded 5,683 acres of habitat protection between Red Bluff and Colusa in the SRCAF Inner River Zone (D. Burmester *pers. comm*.), with 15,000 total acres of protected habitat called for under ERP Milestone 60 (USFWS et al. 2004).

Although localized monitoring and research has confirmed the success of restoring habitats for wildlife (Alpert *et al*. 1999, Borders et al. 2006, Brown and Wood 2002, Griggs and Golet 2002, Golet *et al*. 2003 & 2008, Hunt 2004, Stillwater Sciences 2003, Wood 2003, Gardali *et al.* 2004 & 2006), there is a need for both more comprehensive and continuous assessment of riparian condition and restoration effectiveness. In particular, it is necessary to understand the effectiveness of proposed and existing hydrograph modifications and proposed and existing horticultural restoration projects in achieving CALFED's recovery goals for habitat (ERP goal 4, CALFED 2000), and native at-risk species including songbirds, the VELB, and salmonids (ERP goal 1, CALFED 2000) on a wider geographic basis. A thorough analysis of the relative functioning of major ecological processes throughout the river system as a whole including both restored and non-restored areas is essential to understanding the success and trajectory of human restoration actions (e.g., channel and floodplain processes). Answering these questions is important for determining the effectiveness of existing CALFED-funded projects, informing adaptive management of current riparian restoration efforts in the Project area, and developing and monitoring future restoration strategies and actions.

To comprehensively address existing information gaps a paired system of integrated remote sensing and field-based monitoring techniques would be extremely useful in characterizing existing habitat. Comparative information on species abundance, distributions, fecundity, growth and survival at both restoration sites and in remnant riparian areas can be collected this way at the landscape scale. Only by examining the system as a whole can we evaluate the relative contribution that horticultural restoration projects and other management actions are making to ecosystem recovery.

The study area for the Sacramento River Monitoring and Assessment Program includes both restored and un-restored riparian areas stretching from Red Bluff to Colusa as shown in Figures 3 a & b. The monitoring and evaluation approaches described herein are intended for that riparian zone.

I.B Previous Planning Efforts and Associated Goals and Objectives

A variety of programs and actions have been established to benefit the Sacramento River riparian area and are contextually useful in understanding current restoration programs and this Monitoring Plan.

SB1086-- The Upper Sacramento River Fisheries and Riparian Habitat Management Plan

SB1086 was passed in 1989 and called for a Sacramento River management plan to protect, restore, and enhance fish and riparian habitat, thereby creating a contiguous riparian ecosystem along the Sacramento River. The plan was guided by several "themes" or goals, useful in evaluating program success, which include:

1) Management of riparian ecosystems should be accomplished from an ecosystem perspective, providing for listed species recovery while recognizing human-imposed constraints.

2) Private landowners should play an active role in riparian habitat management.

3) Local impacts, such as tax base reduction and public access to riparian zones, should be minimized and managed.

4) When and where bank stabilization is deemed necessary, it should be accomplished using the least environmentally-damaging methods possible.

5) Natural re-vegetation should be permitted in the floodplain, but valley oak woodland should be actively restored on terraces.

6) An information and education clearinghouse is needed to help riparian landowners obtain grants and technical assistance.

Available online at:
http://www.sacramentoriver.org/srcaf/library_doc/Upper_Sacramento_River_Fisheries_Riparian_Habitat_Management_Plan_%28DWR_1989%29.pdf

Sacramento River Advisory Council-- Sacramento River Conservation Area Forum Handbook

The Handbook (Sacramento River Advisory Council, 2003) describes the implementation of SB1086, including organizational interactions, land acquisitions, and land management. It describes the biophysical setting of the riparian zone and includes several proposed research and monitoring actions including: development of a GIS model to prioritize habitats for protection, investigations of succession and geomorphic processes, mapping topography, and monitoring of vegetation structure and composition. It describes each sub-reach of the riparian zone and what strategies and actions can be employed for restoration.

The 2003 Handbook is available online at:
http://www.sacramentoriver.org/srcaf/library_doc/SacRivHand03_webready.pdf

CALFED-- Ecosystem Restoration Program Zone Vision and Priorities for the Sacramento River

The Ecosystem Restoration Program of CALFED identified the Sacramento River and its tributaries as critical restoration and monitoring targets for Delta watershed protection (CALFED, 2001). Several of the Program's goals and objectives apply directly or indirectly to the Sacramento River Riparian zone. Including Goal 1, the "Endangered and other at-risk species and native biotic communities" objective, which calls for the recovery of bank swallow and western yellow-billed cuckoo (among other birds) habitat, through restoration of a healthy channel and healthy riparian forest. Another goal concerning "Ecological processes," includes several objectives related to flows and geomorphic processes that support restoration of riparian habitats, channel forms, and floodplain interactions. The basis of future actions is considered to be enhanced scientific understanding of fluvial processes (e.g., flows and sediment movement) and their interaction with the riparian zone. Planning investments and actions in support of ERP's goals and understanding the effectiveness of these investments, depends upon scientific monitoring and assessment approaches.

USFWS--Sacramento River National Wildlife Refuge Comprehensive Conservation Plan

The USFWS Sacramento River National Wildlife Refuge CCP seeks to define management objectives, goals, and a 15-year plan for the entire 18,000 acre, 77 miles of river riparian zone protected as Sacramento River National Wildlife Refuge which extends from Red Bluff to Princeton. These 26 properties host important habitat for myriad listed species and the plan seeks to address the needs of wildlife and rare habitat while managing the public use requirements of the refuge system. Created in 2005 as called for by the National Wildlife Refuge System Improvement Act of 1997 the plan unifies the management of the refuge under a set of common goals and plans for restoration and protection. The plan has detailed directives and goals pertaining to hydrology, restoration within the Sac Refuge, and habitat for listed bird, fish, mammal, and herpetological species.

The complete plan can be found at:
http://www.fws.gov/pacific/planning/draft/docs/CA/docssacriver.htm

USFWS – Ecosystem Restoration: Sacramento River Processes

The FWS describes riparian zone restoration success through the combined processes of fluvial geomorphology and vegetation succession, hence these processes directly affect how restoration success is perceived and how it is implemented in the riparian zone. The report supports a suite of indicators for assessing condition and restoration success. Processes and quantitative indicators used in evaluation include: flow regimes, erosion/deposition, lateral channel migration, ecological succession, large woody debris, retirement of bank stabilization, neotropical bird populations, gravel recruitment, and shaded riverine aquatic habitat. Finally, the FWS recommends that condition monitoring follow standardized methods and that the results of monitoring and focused research be integrated into an evaluation framework useful for decision-support.

Wildlife Conservation Board--California Riparian Habitat Conservation Program

Developed by legislation in 1991 within the Wildlife Conservation Board, the California Riparian Habitat Conservation Program was created to coordinate riparian conservation efforts throughout California. It was created as a cooperative effort between state, federal, and local agencies and provides grant opportunities for non-profits and other groups interested in protecting and restoring the state's riparian ecosystems. The program adopted the following objectives taken directly from http://www.wcb.ca.gov/Riparian/:

1. Assess the current amount and status of riparian habitat throughout the state.
2. Identify those areas which are critical to the maintenance of California's riparian ecosystems.
3. Identify those areas which are in imminent danger of destruction or significant degradation.
4. Prioritize protection needs based on the significance of the site and potential loss or degradation of habitat.
5. Develop and fund project-specific strategies to protect, enhance, or restore significant riparian habitat.
6. Develop, administer, and fund a grants program for riparian habitat conservation.
7. Provide a focal point for statewide riparian habitat conservation efforts.

DFG--Wildlife Area Management Plan

This plan, completed in 2004, was created to dictate objectives and goals for management of the 3770 acre Sacramento River Wildlife Area managed by the Department of fish and Game. It contains a detailed description of the 13 discrete properties managed by DFG which extend along approximately 70 miles of meandering Sacramento River with management goals for the protection and restoration of these important riparian sites. Goals focused on renewing natural ecological and hydrological cycles which contribute to a continuously evolving and meandering channel, as well as objectives for protecting the numerous listed and threatened species which the Sacramento River Wildlife Area provides habitat for. Highlighted within this plan is the need for monitoring of the horticultural restoration projects which have taken place on these properties in order to elucidate further management and restoration practices.

The complete plan can be found at: http://www.dfg.ca.gov/lands/mgmtplans/srwa/.

TNC--Sacramento River Project Plan

This plan finished in April 2000 by the Nature Conservancy highlights the condition of and threats to the Sacramento River riparian channel and forests throughout its meandering span and summarizes the non-profit's goals and plans for land acquisition and restoration along its riparian corridor. The plan summarized key legislative advances which laid out the ground work for the non-profit's land acquisition and restoration efforts - SB1086 and Calfed - and also delineates the means by which The Nature Conservancy would seek to achieve conservation efforts along the riparian corridor. These include operating through:

- "Land Acquisition – Secure the Inner River Zone and Riverine Nodes to protect key habitats and set the stage for the return of natural flows and processes."
- "Riparian Habitat and Natural Process Restoration – Restore riparian habitat and natural riverine processes by planting vegetation, reconnecting the floodplain and channel, reestablishing channel meander, and restoring natural hydrologic variability."
- "Compatible Agriculture – Work with local stakeholders to develop and implement a plan for compatible agriculture in the Sacramento River Conservation Area that preserves agricultural crops and practices compatible with priority natural systems and ecological processes."
- "On the ground demonstration theater – At a subreach level, show to public and private stakeholders the feasibility and benefits of restoring natural processes while maintaining multiple uses in the floodplain."
- "Agency Policy and Practice Influence – Primarily through TNCC's California Water Program, ensure that 'one blueprint' for sound conservation and ecosystem restoration is adopted and implemented by public and private water resource institutions, including critical stakeholders such as CALFED, ACOE, the Reclamation Board, and the Bureau of Reclamation."

PRBO Conservation Science – Sacramento River Program

PRBO Conservation Science has been monitoring riparian habitat in the Sacramento Valley since 1993. By partnering with those who own and manage land PRBO has provided recommendations to enhance habitat for birds and other wildlife species. This work has resulted in numerous publications and restoration guidelines including the *Riparian Bird Conservation Plan* and *A Guide to Habitat Enhancement for Birds in the Sacramento Valley* http://www.prbo.org/calpif/pdfs/SacValleyHabitatEnhancement.pdf. PRBO's Sacramento River Program conducts research and outreach to meet the following objectives.

- Determine what riparian songbirds need to reproduce and survive in riparian habitats of the Sacramento River.
- Assess how successful re-vegetation and restoration efforts are at creating habitat for threatened and sensitive bird populations, as well as for more common indicator species.
- Inventory all habitat types (including agricultural and other highly managed areas) to determine the status of landbird populations in these areas.

- Determine how management practices and agricultural spraying affect the health bird populations.
- Assess the status of the sensitive bird species associated with riparian zones or with the river.

RHJV and California Partners in Flight – Riparian Bird Conservation Plan

In order to benefit riparian land-birds and their habitats, the Riparian Habitat Joint Venture (RHJV) collaboratively developed this plan to guide conservation policy and action. The plan includes background information about the distribution of birds in California riparian habitats, the threats facing the birds and their habitats, conservation targets and objectives, conservation recommendations, and monitoring guidance. The plan was originally intended as a living document through continued posting of information to a companion web site (http://www.prbo.org/calpif/htmldocs/riparian.html). The plan uses a focal species approach, where the assumption is that protection of a select group of species will result in benefits to other birds, animals in general, and plants. The plan and the parent group CalPIPF also are based upon the premise that engaging landowners and land managers in a flexible process of riparian conservation can result in benefits to birds.

Riparian Habitat Joint Venture (2004) http://www.prbo.org/calpif/htmldocs/riparian.html

I.C Implemented Management Actions to be Evaluated

Riparian restoration along the Sacramento River has involved several primary actions: land acquisition, horticultural restoration, and levee removal and setback. Each contributes different values to the overall program of riparian system restoration. Monitoring the effectiveness of these actions in restoring riparian system function is the primary objective of this monitoring plan. At the same time, monitoring the status and trends in key indicators is a critical activity for understanding the health of the system and how it is responding to pressures from management activities, such as flood control, agriculture, and flow regulation for consumptive uses.

A. Land Acquisition

Since the passage of SB 1086 in 1986 calling for a management plan which would restore, manage and protect fisheries and riparian habitat along the Sacramento river there have been many public acquisitions of land along its channel thanks to collaborations between DFG, FWS, The Nature Conservancy and many other interested parties (SRMAP report 2010). Whenever possible, acquisition of lands within the River zone – where the channel has passed over the last 100 years and where it is projected to pass over the next 50 – or along tributaries or other lateral points of ecological significance, is the best way to ensure a contiguous, fully functioning River channel and riparian ecosystem. Conservation agencies take into account target species or habitats, threats to these habitats/species, and current and future probable land-uses when prioritizing land acquisitions. Given these factors along with current hydrological factors and constraints, TNC decided to concentrate primarily on reaches 2 and 3 of the channel, between

Red Bluff and Colusa for its acquisitions. This nearly contiguous stretch of 18,000 acres of floodplain forests, wetlands, grasslands, and aquatic habitats now managed by the Fish and Wildlife Service between Red Bluff and Colusa is called the Sacramento River National Wildlife Refuge.

B. Horticultural Restoration

Once properties are under the ownership/management of public institutions or interested non-profits like The Nature Conservancy they become eligible for horticultural restoration which involves the topographical and soil analysis of a location followed by appropriate planting of key native species for restoration. Many large swaths of riparian forest have been established in this way in the Sacramento River Riparian Area and studies have shown that the biological diversity and use by native species within these zones compares, equals, and even sometimes surpasses that in remnant riparian forests. However there is an increasing need for monitoring of these sites to assess their ecological health and restoration success in order to inform adaptive management strategies as well as ensure the most optimum use of future funding for restoration.

C. Flood Control Structures

Levees and dams along the Sacramento River have historically, severely impacted the amount and quality of habitat for migratory birds, anadromous fish, as well as the natural hydrological processes of the river which are necessary for riparian ecosystem health. Tightly controlled channel flows and passage reduce the natural meander and dynamic flooding events of the river which are necessary for wide, healthy, riparian forests. Also, rip rap and levees reduce the amount of erodible bank habitat for bank swallows a critical species within the Sacramento riparian zone. These levees and rip rap are owned and controlled by various private entities as well as the US Army Corps of Engineers and the California Department of Water Resources. However, the removal of levees and the reestablishment of annually eroding high and mid level floodplain comprised of Columbia silty-loam and Columbia sandy-loam soils, within the Sacramento riparian area has had positive results showing major Bank Swallow colony activity in areas which did not previously provide habitat (Sacramento River National Wildlife Refuge Comprehensive Conservation Plan).

D. Other Management Activities

Managing river flows for flood management and consumptive uses impacts both geomorphic processes and availability of water for riparian and aquatic biological systems. Changing the hydrograph over the water year can have severe consequence for timing of connectivity with off-channel and flooplain habitats (e.g., fish-rearing habitats in back and side channels), for availability of water for cottonwood root establishment, and for maintaining appropriate temperature regimes. By tempering higher flows to reduce risk of flood damage, the river channel loses contact with its floodplain, less material is recruited to and is moved down the channel, and habitat is lost and degraded. Treating the river channel as a conveyance device for water used by agriculture and urban areas results in an artificial situation which may only incidentally reflects natural processes. When adjacent lands are intensively used for agriculture, protected from flooding, and irrigated, there may be many effects on riparian health. Indicators described here are appropriate for monitoring the effects of these water and land management actions. They may be used to both understand impacts to the riparian system and the effectiveness of actions taken to remediate the impacts and restore structure and function of the system.

I.D Desired Outputs and Outcomes of Riparian Restoration

A common restoration objective is that riparian zones are restored to resemble their natural counterparts, which is measured both in terms of restoration outputs (area horticulturally-restored) and outcomes (restoration of ecological processes). The desired outcome of horticultural restoration in riparian zones is to re-create many of the structural, functional, and compositional characteristics of forests. Because this process of restoration begins with plantations of native plants, an important determination is whether or not these plantations eventually successfully transition into thriving riparian forests. There is much debate over the definition between what is considered a forest vs. a plantation but two helpful working definitions include:

Forests are complex tree dominated ecosystems with particular structural biotic and abiotic components, assembled within temporal and spatial limits and with a self sustained successional dynamic determined by its biodiversity;

and

Plantations are planted and managed tree dominated system, generally not self-successional and less complex both in structure and in biodiversity than forests.

Monitoring the outputs of restoration can include measuring structural, compositional, and functional characteristics of a restored area. Monitoring outcomes can include measuring these output metrics, as well as measuring biotic and abiotic processes (e.g., succession) and habitat values (e.g., occupancy by desired species). The timeframe for measuring outputs may begin immediately after restoration activities have taken place, but decreases markedly in importance through time, while outcomes can be investigated immediately but are usually most noticeable months or years after restoration establishment (Harris, 2005).

I.E Asking the Right Questions:

Monitoring for restoration effectiveness is best conducted when questions of interest and objectives are well-defined. Questions may cover a range of topics from contractual satisfaction to ecological function.

The following is a list of potential questions which might be addressed through monitoring (from Harris 2005):

- Did planted vegetation survive at an acceptable rate?

- Did the restoration practice increase the cover of native riparian vegetation?
- Did the restoration practice increase the amount of shade canopy on the channel?
- Did the restoration practice reduce the abundance of exotic species in the riparian community?
- Did the restoration practice reduce encroachment of vegetation into the active channel?
- Did the restoration practice increase the abundance of coniferous trees in the riparian community?
- Did the restoration practice increase the connectivity and/or area of native riparian vegetation?
- Did the restored area provide habitat for target and native species?

Questions should establish a clear line of reasoning between stated goals of a restoration program, such as to restore habitat for a particular taxonomic group, and the indicators of restoration outputs (e.g., planting success) or ecological outcomes (e.g., reproductive success of target animals). This clear line of reasoning will reinforce monitoring as the link between implementing management actions and evaluating the effects of management actions as part of an overall adaptive management process.

I.F Evaluating and Reporting Success

Monitoring approaches described in the Monitoring Plan are intended to support reporting of ecological condition and restoration success for independent ecological attributes (e.g., channel dynamics, bird populations). This could be achieved using The Nature Conservancy's scorecard approach. This scorecard evaluates conditions at site scales relevant to ecological goals in order to report conditions relative to those goals. In order to inform the development and updating of the scorecard, periodic monitoring must be conducted. This frequency will vary with the process or attribute under investigation. Other approaches to reporting condition exist and the selection of a report card system should be based upon both the need for simple expression of complex ecosystem information and the need for the comprehensive coverage of riparian conditions.

The process of transforming monitoring data into meaningful information for any report card is described in Section III.A. In short, site conditions monitored at a certain time or place are compared with both desired target conditions and un-desirable conditions and the distance calculated on a 0 – 100 scale. This uniform re-scaling of each monitoring variable type allows comparison of a combination of these variables in a scorecard environment and is a common feature of the better report cards. Subsequent to developing a raw score on the 0 – 100 scale, users can then lump score ranges into "good", "fair", and "poor" classes dramatically simplifying presentation of information.

Whether the reporting mechanism for monitoring results and restoration effectiveness involves the scorecard method or some other approach, each monitoring program should be designed with a process in mind for attaching meaning to data collected and reporting this meaning to audiences from whom change or investment is desired.

II. Monitoring Plan of Action

This Monitoring Plan includes approaches for monitoring major components of the riparian system – riparian vegetation pattern, composition, and structure; channel structure and dynamics; and habitat occupancy by select biota. For each riparian component, the Plan includes the following vital information as part of the guidance for how monitoring should be conducted:

- Purpose of the monitoring, i.e. questions the monitoring is intended to answer
- TNC scorecard indicators covered by the monitoring approaches described
- Ecological condition evaluation the monitoring will inform
- Appropriate spatial and temporal scale
- Timing and frequency of monitoring for optimum change detection
- Specific field and/or computational methods
- Data analysis and interpretation approaches

Because not all parameters require each of the afore-mentioned vital information, these descriptions are included where appropriate. For an additional set of components that are not part of the Plan, a brief and general overview of monitoring approaches is provided, including references to appropriate literature and descriptions of relevant existing Sacramento River Riparian monitoring programs for which information was available at the time of writing.

The approaches described in the Monitoring Plan are primarily for quantitative monitoring. Qualitative monitoring also has its place in evaluating ecosystem condition and restoration effectiveness. For example, photo-point monitoring is both an effective way of documenting change at restoration and reference sites and results in very effective outreach and education material. Qualitative monitoring methods for riparian system restoration are available from the CDFG (http://www.dfg.ca.gov/fish/Resources/HabitatManual.asp).

II.A Summary Plan

The monitoring plan can be summarized as being composed of what is monitored, where, when, how, by who, and why. General guidance is provided here for carrying out the monitoring approaches described in later sections. This is summarized in two ways. One is as a table (Table 1) showing when particular types of indicators should be investigated and at what spatial scales. The other is a timeline (Figure 4) showing an approximate schedule for monitoring different attributes of the riparian system to determine changes in the overall system and changes at the site scale in response to restoration actions.

Table 1. Summary of indicators for monitoring, and spatial and temporal scale.

Monitoring Component	Monitoring indicator/method	Spatial Extents	Spatial Grains	Season	Temporal Frequency
Vegetation: Landscape	Fragmentation	parcel, riparian	30 m cell, parcel	--	5 years
	Connectivity	riparian	30 m cell, parcel	--	5 years
Vegetation: Composition	Photopoint	site	meter	Spring -- Summer	annual (before/ after
	Native over-story cover	parcel, riparian	site, parcel	Spring -- Summer	5 years
	Native under-story cover	parcel, riparian	$1m^2$ quadrat, parcel	Spring -- Summer	5 years (before/ after restoration)
	Non-native species cover	parcel, riparian	$1m^2$ quadrat, parcel	Spring -- Summer	5 years (before/ after restoration)
Vegetation: Habitat function	Birds (point counts, nest monitoring, mist netting)	(site, riparian, site)	site	Year-round	annual
	Valley-Elderberry Longhorn Beetle	site, riparian	site, parcel, patch	Summer	2 - 3 years
	Mammals, reptiles, amphibians	site, riparian	site	Spring -- Fall	annual
Soil	Structure	parcel, grid cell	$1m^2$ quadrat, soil pit patch	Spring -- Summer	before/ after restoration
	Composition	parcel, grid cell	$1m^2$ quadrat, soil pit patch	Spring -- Summer	before/ after restoration
	Processes (nutrients)	parcel, grid cell	$1m^2$ quadrat, soil pit patch	All year	before/ after restoration
Aquatic: Geomorpholgy	Channel meander rate	reach, river	reach	--	5 years
	Channel sinuousity	reach, river	reach	--	5 years
	Channel angle	reach	1/4 channel width segment	--	5 years
	Channel length	river	river	--	5 years
	Floodplain age	parcel, riparian	site, parcel	Summer	5 years
	Land re-worked	reach, river	1/4 channel width segment, reach	--	5 years
	Bank types	reach, river	1/4 channel width segment, reach	--	5 years (annual update revetment map)
	Side/back-channels	reach, river	reach	Spring -- summer	5 years
Aquatic: Hydrology	Flows	site, reach, river	site	Continuous	hourly-annual
Aquatic: Habitat function	Fish populations	reach, river	reach		annual
	Benthic macroinvertebrates	reach, river	reach	Spring, Fall	annual
	Algae and macrophytes	reach, river	reach	Summer	annual
Definitions					
Site	A monitoring location or station at a point in space				
Parcel	An area on the landscape with one owner and boundary, often defined by homogeneity (e.g., a "patch of grassland")				
Riparian	The whole riparian zone along the river				
Reach	A geomorphologically continuous stretch of river				
Grid cell	A virtual square on the landscape (e.g., 30 m grid cell)				
River	The whole river				

The summary of spatial and temporal scales indicates the resolution and frequency needed to provide sufficient information about conditions to inform restoration planning, restoration effectiveness, and to understand trends over time. The spatial extent (how large of an area is typically measured) varies because certain metrics may only be relevant or measurable at certain extent. The spatial grain, or resolution varies among indicators primarily because measurements are conducted at varying grains (e.g., quadrat). Typically, findings at a fine-scale are generalized to coarser scales, such as a parcel or patch of native vegetation.

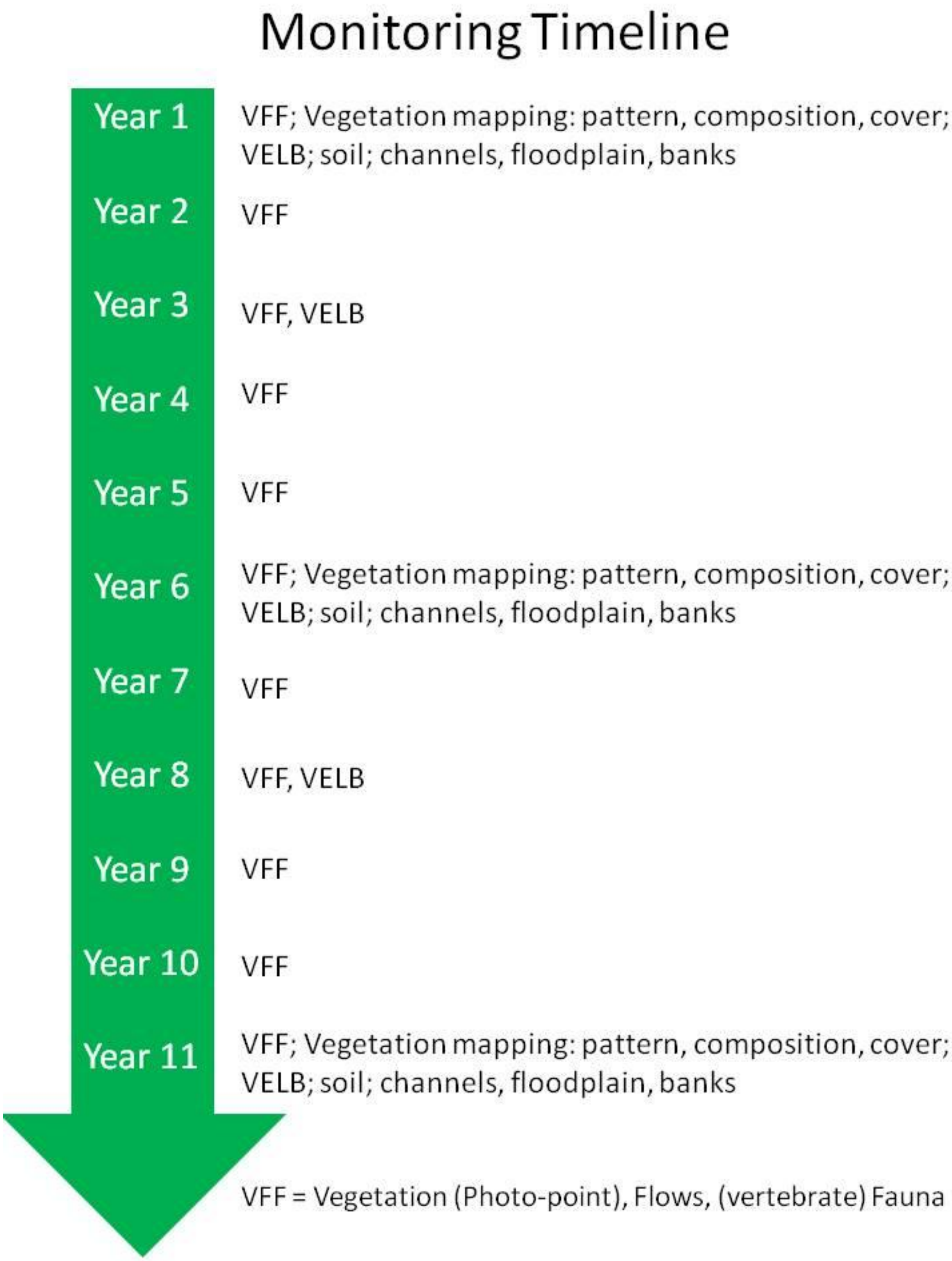

Figure 4. The timeline shows an approximate schedule that could be followed to monitor riparian conditions, based upon frequencies in published reports for the Sacramento Riparian and other similar systems.

The spatial and temporal scales for monitoring particular indicators and the scheduling for monitoring riparian conditions comprise a general scheme for periodically assessing vegetation and channel structure and dynamics, as well as habitat utilization by animals. The specific sites and seasons of monitoring depend on the individual indicators used to measure riparian zone condition and management performance.

II.B Indicator Relationship to Conceptual Model

Each of the proposed indicators for monitoring represents part of the systems that are described in the conceptual model (Figures 1 & 2). There are likely to be other indicators not listed here that could also be informative for understanding status and trends in riparian condition. The table below shows how each indicator informs understanding about riparian structure and function.

General Structure/Function	Specific Structure/Function	Indicator
Land Cover (terrestrial habitat)	Riparian vegetation	Area of native species
		Area of non-natives
		% Historical riparian in conservation
		% Historical riparian in natural habitat
		Length of river bank in conservation
	Fragmentation	Vegetation patch edge contrast
		Patch proximity
		Patch core size
		Patch morphology
	Species composition (over-story)	Importance value of native woody species
		Frequency of larger native woody species
	Species composition (under-story)	Species frequency
		Species richness
		Relative species cover
	Soil structure	Soil texture, moisture, composition
	Soil function	N-mineralization
Channel/Floodplain (Aquatic/floodplain habitat)	Floodplain pattern	Area < 10 years-old
		Area connected to channel
	Flood-flows	Frequency of bank-full flows, over-bank flows, side-channel connecting flows
	Flood protection	Length of bank with rip-rap
	Bank pattern	Length of riparian shoreline
		Number of bends, sinuosity >2
		% Shore with >500 m-deep natural bank

	Channel Pattern	Average bend entrance angle
		Average distance between bends
		Density of in-channel LWD deposits
		River length
		River sinuosity
	Geomorphic process	Floodplain re-worked
		Channel bend migration rate
Biotic Responses	Bird populations	Nest survival indicator species
		Adult survival indicator species
		Species richness
		Abundance of indicator species
		Number of egret & heron rookeries
		Number of bank swallow burrows
		Area Yellow-billed Cuckoo habitat
	Valley Elderberry Longhorn Beetle	Average number of exit holes per shrub
	Mammal populations	Bat species richness
		Bat activity
		Species diversity & richness
		Genetic diversity
	Terrestrial insects	Ground-dwelling insect diversity & richness
	Fish populations	Population size and demographics
		Population distribution
		Proportion native species
	Benthic macroinvertebrates	Species richness and diversity
		Proportion disturbance tolerant/sensitive
	Algae and macrophytes	Community composition (e.g., % disturbance sensitive)
		% cover or biomass

II.C Prioritizing Monitoring

Monitoring can be prioritized based on a fixed schedule (Figure 4), or on a more ad hoc basis, such as before and after restoration activities or particularly large events expected to significantly change the riparian and floodplain zones. The prioritization process should be laid out along 3 primary axes: management need, temporal scale, and spatial scale. Management need includes situations like understanding the effectiveness of restoration investments and activities. Temporal scale includes length of monitoring period and frequency of monitoring and spatial scale includes geographic extent of monitoring, and spatial grain of investigation or analysis (see Table 1).

Four commonly used monitoring spatial scales (Ralph and Poole, 2003) are:

- *Basin-scale* incorporating major river drainages, such as the Sacramento River Basin

- *Watershed-scale* focusing on the watersheds of major tributaries
- *Segment-scale* includes a specific stream reach or sub-watershed
- *Site-scale* encompasses a single management location, such as a parcel or monitoring station.

Decision-making about what to measure, when to measure it, and where to measure it depends ultimately on the questions being asked in the monitoring program. Prioritization of activities thus depends on these questions and a logistically feasible program to answer the questions. Thus far, vegetation monitoring has generally only been conducted for 3 years, until the active restoration efforts end. But, such a time period is much too short to evaluate whether the forest is actually recovering. The decision about monitoring intensity should be based upon the combination of obtaining enough information for the kinds of decisions that need to be made and conducting sufficient monitoring to understand the overall ecosystem functoining over time.

III. Monitoring Guidance

The following sections provide detailed guidance on how technical/scientific staff and supervisors can select indicators, methods, and analysis approaches that are suitable for understanding the structure and function of riparian habitats of the Sacramento River. The guidance is detailed enough to plan field effort, but additional detail may be needed for certain protocols when actually implemented. At the beginning of each section, a table describes the indicators for which monitoring guidance is provided. The result of monitoring using the approaches described should be data collection for developing an overall picture of riparian ecosystem condition and function, judging effectiveness of management actions, and quantifying the impacts of continued agricultural, flood management, and other activities in the riparian.

III.A Mapping & Validation of Terrestrial Riparian Vegetation from Aerial Photographs

There are several purposes for measuring and mapping distribution of riparian vegetation as a way of monitoring restoration effectiveness and ecosystem condition. One is because riparian vegetation is a straightforward measure of the output of restoration and protection useful for accounting purposes. A second is that riparian vegetation is habitat for plant and animal species and vegetation characteristics can determine habitat quality. A third is that riparian vegetation has two-way interactions with the river channel and floodplain, both responding to and influencing channel dynamics.

III.A.1Conservation Ownership

A positive change in public-ownership of riparian and floodplain zones for conservation and restoration purposes can be a legitimate measure of conservation outputs (Dykaar and Schrom,

Table 2 Relevant indicators.

Conservation Targets	Category	Key Attribute	Indicator
Terrestrial riparian habitat	Landscape condition	Species composition/dominance	Area of: Arundo, Black walnut, Himalayan blackberry
	Landscape size	Size/extent of characteristic communities	Area of: annual perennial grasses and forbs, Fremont cottonwood forest, Mixed riparian forest, Riparian scrub, Valley oak woodland
			Percent of historical riparian zone currently in conservation
			Percent of historical riparian zone currently in natural habitat
Aquatic riverine habitat	Landscape context	Connectivity among communities and ecosystems	Length of river frontage in conservation ownership on both sides of the river
	Landscape condition	Species composition / dominance	Area of *Ludwigia* (water primrose)

2003). This means that purely measuring change in total area conserved in public ownership and restored can be a monitoring tool. There are several important qualifiers to this statement. One is that total area is a meaningful area if the increase in area is meeting the conservation goals of the program. Another qualifier is that not all areas or parcels are equal in their conservation value, restoration potential, or affordability (Turner et al., 2006). A third caveat is that the role of science, property availability, and local decision-makers may change during the program, affecting the meaning of incremental increases in area over time. Understanding the changing role of scientific understanding about natural processes and fluxes in ecosystems themselves (Bosselmann and Tarlock, 1994; Greene, 2005) is important in understanding how to use this indicator for measuring conservation outcomes, rather than just conservation outputs.

Conservation ownership can be calculated using GIS for the historical riparian area of the River. This area has been mapped and can be used to clip a land-cover or land-ownership map. The Sacramento River Conservation Ownership GIS layer maintained by TNC can be used to determine what lands are in conservation ownership. The output measure would be "% of historical riparian zone currently in conservation ownership", which is calculated by dividing the area in the historical riparian zone in conservation ownership by total area. A related measure to total area of conservation ownership is "length of river frontage in conservation ownership". To measure river frontage the main-stem river channel GIS polygon layer is viewed on a computer screen at a 1:4000 scale. One scrolls through the entire mainstem Sacramento River from Colusa Bridge to Red Bluff, dividing the river polygon into areas either with or without conservation ownership on both sides of the river bank. Parts of the river polygon without conservation ownership on both sides of the river are removed from the data layer. The remaining polygons are then converted to polylines. Line segments not contiguous to the bank of the river are deleted. The sum of the lengths of the remaining polylines is the river frontage in conservation ownership.

III.A.2 Mappable Vegetation Cover

Mapping vegetation cover from aerial photos and validating that work with field surveys is a comprehensive way of mapping large areas riparian vegetation. A large project to do just that in the Sacramento River Conservation Area was enacted by the Geographical Information Center (CSUC) and validation of that mapping effort was completed by researchers at UCD. The methods that follow come directly from Carlson and Funes (2010) as well as the report on map validation by Viers (2009) and more information on method specifics can be accessed through those reports.

Researchers at CSUC delineated and digitized 14 vegetation types and 2 habitat types from true color aerial photographs of the Sacramento River Conservation Area at a scale of 1:15,840. Polygons were digitized by floristic alliance, which is characteristic of the dominant species present. Polygons where the tree canopy cover was 10% or greater were considered dominated by tree species while those with less canopy cover were considered shrub type, and an herbaceous alliance was assigned if both the tree and shrub crown cover were less than 10%.

As floristic alliances are named after the dominant plant species present, polygons which are identified as floristic alliances named after a native species will undoubtedly still contain some non-native species on the ground. Here however is a list of the floristic alliances named for and dominated by a native plant which CSUC mapped in the Sacramento River Conservation Area:

1. *Acer negundo*/Box Elder alliance – Trees on aerial imagery characterized by yellow-green, round to flattish tops.

2. *Populus fremontii/* Fremont Cottonwood alliance – Trees on aerial imagery characterized by medium gray-green, wispy open tops.

3. *Salix gooddingii/*Gooding's black willow alliance – Medium-dark green plants appear open when mature and pointed when young from aerial photographs.

4. *Quercus lobata/*Valley oak alliance – Trees appear dark green with rounded tops on aerial photos.

5. *Platanus racemosa/*California Sycamore alliance - Trees appear medium green with rounded tops similar to Valley oaks on aerial photos.

6. Mixed willow alliance – These trees appear gray to medium green in small semi-course mounds.

7. Riparian scrub alliance – These plants appear variable in both color and texture.

8. *Scirpus typha/*Bulrush-cattail series – Bulrush appears brown to gray and course and choppy in aerial photos of marsh, while cattail appears reddish when in bloom and smooth.

9. Podweeds and floating leaved plants alliance - These plants appear light green and smooth to grainy in aerial photos of water bodies.

Floristic alliances which are dominated by and named for a non-native species and which were mapped in the Sacramento River Monitoring and Assessment Project (SRMAP) include:

1. *Juglans x hindsii/* Northern California Black Walnut hybrid alliance – Trees on aerial imagery characterized by dark green round to flattish tops.

2. *Rubus discolor (armeniacus)/*Himalayan blackberry alliance

3. *Arundo donax/*Giant reed alliance – Plants are mint green in color and appear wispy to mounded in aerial photographs.

4. California annual grassland/herbaceous alliance – These areas appear golden to light brown and can be either smooth or rough in texture.

5. Introduced perennial grassland – These grasslands appear medium to dark and even cool green in color with smooth to rough low growth.

6. *Ludwigia* semi-natural stands/Water primrose semi-natural stands- Water primrose appears in smooth stands of light yellow green with small to large "holes."

III.A.3Vegetation Map Validation

After aerial classification of floristic alliances, map validation and accuracy assessments are necessary in order to achieve the best results. One approach is to conduct rapid assessment surveys on the ground of representative floristic alliances to assess the accuracy of heads up digitization. Another approach is to use a combination of vegetative field surveys and mapping and statistical analysis to create a validated map of the study area with estimated accuracy rates. This can be done by randomly sampling 10% of the vegetation polygons for each vegetation classification and re-sampling within 500m blocks to determine interpreter consistency (Viers, 2009).

CNPS rapid assessment and releve protocols were used in the on the ground vegetation surveys and are considered optimum for classifying vegetation. A more thorough explanation of the protocols can be found at http://www.cnps.org/cnps/vegetation/protocol.php#instructions and they are summarized here. The first step in a rapid assessment is to identify a "stand" or a relatively homogeneous unit of vegetation which has high internal compositional and structural integrity. This unit of vegetation area can be of any size and can be selected prior to site visit from aerial imagery of at the site. Once a stand is delineated information on the geology, topography, and general location of the site is collected and the site is assigned a field assessed vegetation alliance name following the CNPS classification system (Sawyer and Keeler-Wolf 1995). Sites are named after the dominant species present - which usually covers the most amount of area and is often of the highest stratum. The size of stands are estimated and adjacent floristic alliances are documented

Once a stand has been delineated it is assigned to a size/height class category using the following protocols:

1. Tree class -- If the tree canopy closure exceeds 10% then the stand is characterized as being a tree type and an average DBH (diameter at breast height) of all trees within the stand is estimated. Additionally one should identify the dominant species which make up the canopy.

2. Shrub class -- If the shrub canopy cover exceeds 10% then the stand is characterized as a shrub stand and a size class is estimated based on the amount of crown decadence.

3. Herbaceous class -- If the tree and shrub canopy covers do not exceed 10% but herbaceous cover exceeds 2%, then the stand is classified as an herbaceous class.

After conducting the prior analysis an over-all estimate for the percent cover of vegetation is established using the following habitat classification per California Wildlife-Habitat Relationships (CWHR) cover intervals: <2%, 2-9%, 10-24%, 25-39%, 40-59%, 60-100%. Percent cover is estimated by the stand of each vegetation type as if from a bird's eye view looking down at canopy closure, ignoring overlap and taking living plant matter into account only. The vegetation classifications for this metric are as follows:

1. Overstory Conifer/Hardwood Tree cover – Compiling percent cover of conifers and hardwoods separately one estimates the total aerial coverage of all live trees.

2. Shrub cover – Total aerial canopy closure of all live plants.

3. Ground cover -- Total aerial cover by all herbaceous species.

4. Total Vegetation Cover – An estimate of the absolute vegetation cover of the stand by each individual functional life form classification.

III.A.4 Monitoring Frequency

Vegetation mapping is a considerable investment of time for an area the size of the Sacramento River Riparian Zone. To date, mapping has taken place approximately every decade. However, this frequency misses important changes that occur at shorter intervals (such as recruitment and loss of cottonwoods and willows on point bars). A 5-year frequency for whole river-riparian mapping is more suitable rate of information gathering, especially considering the amount of money already invested in the success of the riparian and the number of listed species dependent on the healthy functioning of the riparian. For particular parcels of restoration or other interest, more frequent (annual) mapping can be carried out and the riparian-scale map updated accordingly.

III.B Terrestrial and Riparian Vegetation Landscape Structure, Patterns, and Function

The purpose of monitoring the structural and pattern components of the riparian terrestrial vegetation is that it provides habitat for birds, mammals, herpetofauna, arthropods and other invertebrates, and plants. A combination of habitat structure, community composition, and habitat function will determine the value of the terrestrial component of the riparian ecosystem to various taxa.

Table 3 Relevant indicators.

Conservation Targets	Category	Key Attribute	Indicator
Terrestrial riparian habitat	Landscape context	Connectivity among communities and ecosystems	Forest edge contrast
			Forest patch proximity
	Landscape size	Community architecture	Forest patch core size
			Patch morphology

III.B.1 Structure: Fragmentation/patchiness

An important structural attribute of natural landscapes is the relative fragmentation of the landscape. Fragmentation refers to the breaking up of landscapes and component habitats into smaller pieces. To varying degrees, most landscapes naturally occur in fragments (e.g., mature riparian forest bordering a gravel bar bearing willow saplings). Most fragmentation in the Sacramento River riparian forest is a product of human development activities. Agriculture, road development, water infrastructure, flood control levees, and urbanization have contributed to the once-continuous riparian forest being broken into pieces and separated from its floodplain.

Fragmentation disrupts movement connections across landscapes among habitat patches needed by individual species. Functional connectivity is the corollary to habitat fragmentation that disrupts movement and can be important for determining occupancy and use of riparian forest areas by medium-sized, ground-dwelling mammals (FitzGibbon et al., 2007), large mammals

(Hilty and Merenlender, 2004), insectivorous bats (Pavey, 1998), and birds (Darveau et al., 1995).

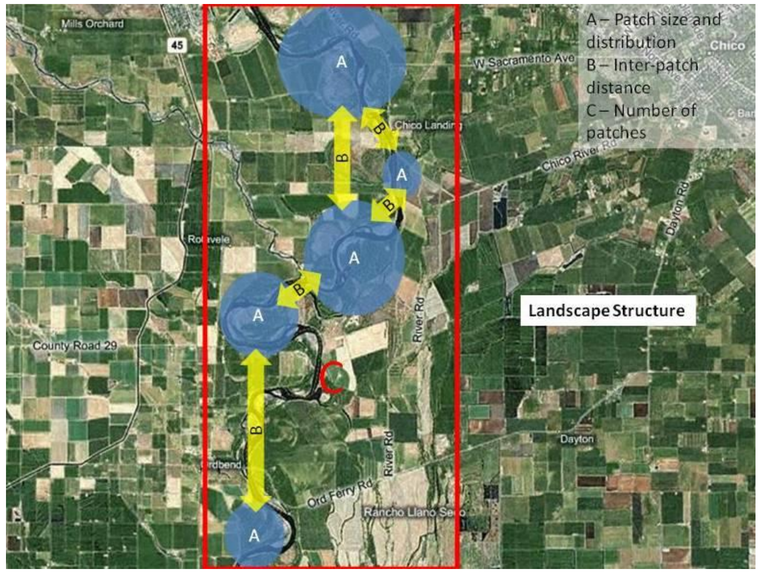

Figure 5 Patch distribution across riparian landscape

Measuring fragmentation of habitat and landscapes into patches usually consists of calculating metrics that are surrogates for shapes of patches, creation of patches, sizes of patches, edge-core ratios, and proximity to other patches (Figure 3). These are similar metrics for measuring connectivity. These metrics are often calculated using GIS tools such as FRAGSTATS (McGarigal, 2002), which provide metrics for the entire landscape/study area, for classes of patches (e.g., forest type), and for individual patches. Certain of these landscape pattern metrics have been found to be associated with bird occupancy in the Sacramento River riparian forest (Small et al., 2000)

Structural vs. functional connectivity

A common differentiation made in the connectivity literature is between “structural connectivity” and “functional connectivity”, where the former is measured as landscape structure that may facilitate or inhibit wildlife movement and the latter is measured directly from wildlife movement, or estimated based on rules of organismal behavior and responses to landscape attributes (Kindlmann and Burel, 2008 for summary). The field of applied conservation is changing rapidly so that connectivity is more often estimated for several species on a landscape, rather than just calculating “structural connectivity” based on fragmentation patterns. Many landscapes will vary in their “functional connectivity” for different motile species. By measuring connectivity of landscapes for a wide-range of movement needs, conservation scientists can reveal the range of needs across landscapes and estimate how these needs might change or be impacted with future land-cover changes. Taylor et al. (2006) argue that structural connectivity is not a good stand-in for landscape connectivity, which was historically and is usually defined as being an attribute having relevance to moving animals (or similar flows). Landscape or habitat intactness is essentially what most investigators and land managers mean by “structural connectivity” and is an important landscape attribute when considering wildlife movement. This suggests that it might be simpler to do away with the term structural connectivity altogether and emphasize that landscape intactness facilitates connectivity, which is defined by wildlife movement behavior and other ecological flows. This change would have ramifications for studies and plans that claim to discover, describe, or plan for connectivity in that it would require that these studies and plans be based upon wildlife needs and behaviors, not just landscape structure.

For the Monitoring Plan, landscape intactness and fragmentation is described, with the assumption that these analyses will be interpreted with some knowledge of the functional connectivity needs of individual taxa of concern. For example, if patch isolation is measured over time as a metric of fragmentation, its relevance to a species of concern, like western yellow-billed cuckoo, is based on the need for the species to have inter-patch distances less than a certain distance.

III.B.2 Fragmentation indicators

Before measuring fragmentation, one must first have a digital map of the Sacramento River riparian landscape (see Section 1). Ideally, this will include all landscape patches accurately delineated and classified by land cover type (including plant community type). Because the landscape is composed of native and non-native vegetation and structures, all of these should be included, within some geometric or functional distance from the river.

There are three primary measures of fragmentation: 1) landscape metrics (e.g., mean size of all patches), 2) habitat class metrics (e.g., size of cottonwood forest patches), and 3) patch metrics (e.g., shape of each patch). Measuring landscape fragmentation consists of treating all patches in the landscapes as essentially identical and measuring attributes such as their distributions, average size, and . Measuring habitat class fragmentation consists of selecting patches of the same class and separately measuring characteristics of each class.

Table 4 Sample fragmentation metrics for landscape, habitat class, and patches using FRAGSTATS (McGarigal, 2002)

Metric Type	Description	Units
Number of patches	Number of patches of each class of habitat in the landscape	Number
Largest patch index	The percentage of the landscape made up of the largest patch	%
Area-weighted mean shape index	A simple measure of shape complexity, related to perimeter-area ratio index	Number
Normalized landscape shape index	Measure of aggregation of similar patch types. Increases in values with fragmentation	Proportion 0 - 1
Patch Isolation	Isolation of a patch relative to other patches of the same type	Continuous value from 0 to study area size
Patch core area	Core area size of patch, where size = patch area minus edge effect zone (user-defined)	Area (e.g., acres, hectares)
Patch edge contrast	Measure of contrast between adjacent patches (e.g., low contrast = mature riparian and older restored riparian)	Proportion (0-1 or 0-100)

Fragmentation Metrics

The following metrics descriptions are taken directly from or adapted from the FRAGSTATS manual that accompanies the downloadable software.

Patch core area is the area of each patch away from possible edge effects, which is perhaps the single most important and useful piece of information contained in the landscape. Not only is this information the basis for many of the patch, class, and landscape indices, but core patch area has a great deal of ecological utility in its own right. Mean core patch area equals the sum, across all patches of the corresponding patch type, of the corresponding patch metric values, divided by the number of patches of the same type.

Number of patches is a simple measure of the extent of subdivision or fragmentation of the patch type (e.g., mixed chaparral). Although the number of patches in a class may be fundamentally important to a number of ecological processes, often it has limited interpretive value by itself because it conveys no information about area, distribution, or density of patches. Of course, if total landscape area and class area are held constant, then number of patches conveys the same information as patch density or mean patch size and may be a useful index to interpret.

Largest patch index equals the area (m2) of the largest patch of the corresponding patch type divided by total landscape area (m2), multiplied by 100 (to convert to a percentage); in other words, largest patch index (LPI) equals the percentage of the landscape comprised by the largest patch. Largest patch index at the class level quantifies the percentage of total landscape area comprised by the largest patch. As such, it is a simple measure of dominance.

Area-weighted mean shape index equals patch perimeter (given in number of cell surfaces) divided by the minimum perimeter (given in number of cell surfaces) possible for a maximally compact patch (in a square raster format) of the corresponding patch area. Shape index corrects for the size problem of the perimeter-area ratio index (see previous description) by adjusting for a square (or almost square) standard and, as a result, is the simplest and perhaps most straightforward measure of overall shape complexity.

Normalized landscape shape index (NLSI) is the normalized version of the landscape shape index (LSI) and, as such, provides a simple measure of class aggregation or clumpiness. NLSI = 0 when the landscape consists of a single square or maximally compact (i.e., almost square) patch of the corresponding type; LSI increases as the patch type becomes increasingly disaggregated and is 1 when the patch type is maximally disaggregated. Increases in NLSI will accompany increased disaggregation or fragmentation of habitat patches.

Patch edge contrast represents the degree of contrast between each pair of patches. Contrast is measured using a unitless scale and = 0 when adjacent patches are identical to each other (e.g., two patches of tall canopy, riparian forest) and contrast = 100 (or similar maximum value) when adjacent patches are at the full range of difference from each other (e.g., riparian forest and row crop agriculture).

Analytical Approach

There are not very many tools for measuring fragmentation on landscapes that suit monitoring programs. Most such tools that have been developed have been part of research into effects of fragmentation on processes and biota and thus may be more complicated than is needed. One tool that has been useful in investigations of fragmentation effects on animals and is usable in monitoring programs is Fragstats. This is a powerful, memory-intensive program that can be run by anyone with a moderate level of GIS experience. It provides useful estimates of fragmentation that can lead to restoration solutions to reduce fragmentation effects. The Fragstats's Web site (http://www.umass.edu/landeco/research/fragstats/documents/fragstats_documents.html) contains downloadable software, user manual, descriptions of metrics, and various background material. The manual does not capture all of the nuances of actually using the software.

There are several ways to "run" Fragstats. An example of one way, including the basic steps, is provided here:

1) The first decision is to select a study or analysis area appropriate for the needs of the monitoring program. For example, for understanding benefits to mammals from restoration projects, the study area would need to be several times larger than the current mammal species' distribution and include potentially-restorable areas.

2) Based on a vegetation or other land cover map, categories for major plant community types, land uses, or other defining structural attributes should be developed. For the Sacramento River Riparian, these categories could consist of the plant community types in the CSUC/UCD vegetation map (e.g., cottonwood forest), or of a more generalized class, such as "forest".

3) For the sake of computational speed, either merge very small patches (e.g., <0.1 Ha) with adjacent patches of the same class, or erase these patches altogether.

4) Create a raster map of either the generalized, or specific vegetation patch map, with an associated class properties description. The raster cell size will affect whether or not computation will be possible. You will want to find a balance between a cell size adequately representing the patches and not being so small as to prohibit analysis (Figure 7).

Figure 6 Combining patches within generalized classes

5) Run Fragstats for the input land cover map and selected landscape, class, and patch metrics. You will be able to view the outputs in tabular form as well as joining the metrics values to the patches themselves.

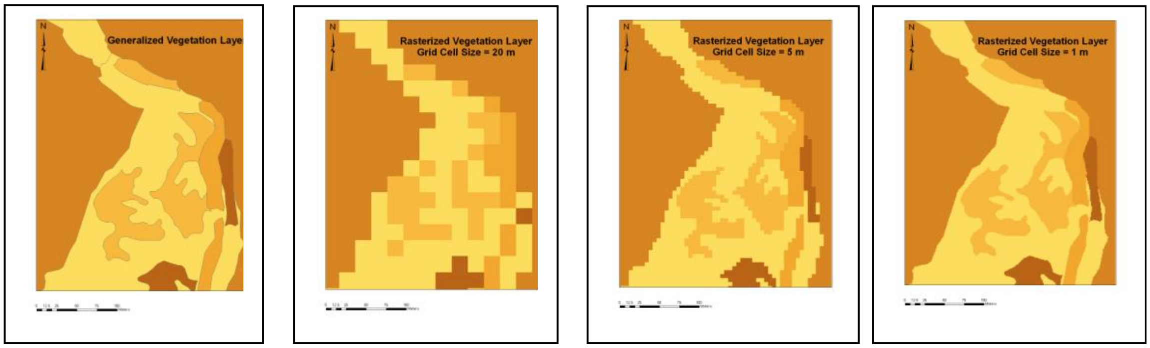

Figure 7 Picking the right raster grid cell size

III.B.3 Connectivity indicators

The corollary to fragmentation is connectivity, which can be measured as the opposite of fragmentation, or as its own value. Connectivity is often thought of as “connectivity for whom or what”. Functional connectivity is one way to measure this landscape attribute: “Does the landscape meet the connectivity needs of a particular animal taxon?” In a recent study, Girvetz and Greco (2007) used a GIS tool he developed (PatchMorph) to create a map of patches, potentially meeting the connectivity needs of the Yellow-billed Cuckoo. The patches were defined by the habitat and movement needs of the species and the landscape measured for its ability to meet the species’ needs.

Two primary ways to measure connectivity are: 1) to measure connectivity within patches on a landscape and 2) to measure connectivity among patches on a landscape. One measure of patch habitat quality is its attractiveness for wildlife of various taxa for movement. Another, more common measure is of connections among patches, including distance between similar patches and adjacency of similar patches.

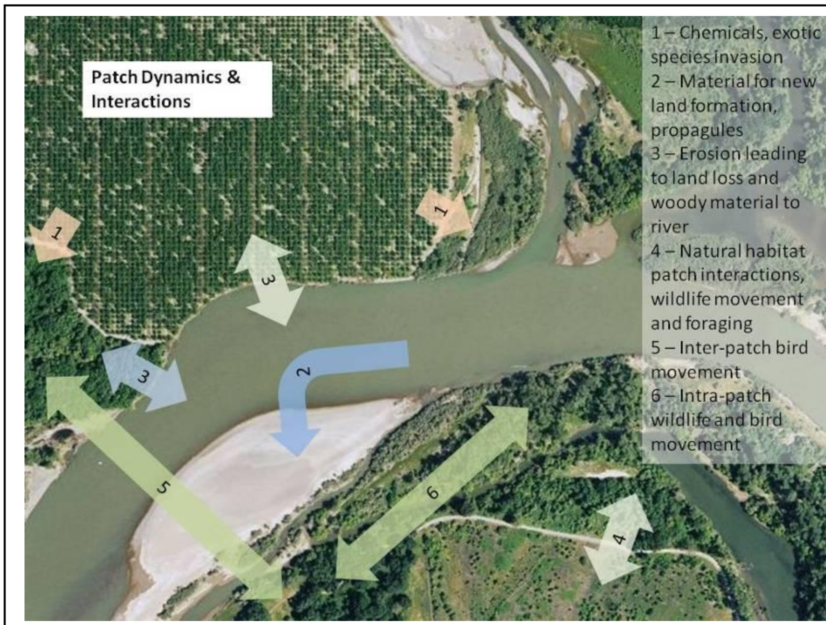

Figure 8. Riparian zone interactions.

However, researchers have begun to acknowledge that connectivity may be better represented through continuous rather than binary models of landscapes, using “resistance” to ecological flows as a relative measure of the permeability of pixels on a landscape rather than the binary representation of patches of habitat. Researchers have begun to use a combination of genetic and traditional field method tracking approaches (i.e. radio collaring) to construct population structure for many at-risk species in a landscape context and then relate this structure to the best landscape feature model (Cushman, 2006; Vitalis and Couvet 2001; Manel et al. 2003; Coulon et al. 2004, 2006; Scribner et al. 2005).

Cushman et al. (2006) used a least cost analysis and resistance layer created from a combination of genetic and field data of population structure in bears in Northern Idaho to map the most likely paths of wildlife movement and dispersal. They then compared the ability of 108 different models, which considered all manner of topographic features and typical landscape barriers to explain the patterns of population genetic structure garnered from actual field data. This method could be replicated and used with any species in any environment to capture actual connectivity throughout a landscape, as each species reacts differently to landscape features and topography and as analyses are much stronger when based on empirical data.

III.C Terrestrial Riparian Vegetation Community Composition from Ground Surveys

The purpose of monitoring the composition of riparian terrestrial vegetation is that it provides the structure and forage for many animal and plant species and defines much of the riparian habitat. There are several key field methods for investigating conditions in this zone.

III.C.1 Photo point monitoring

This qualitative monitoring approach uses repeat photography to document changes in soils and vegetation. Hall in his handbook (2001) thoroughly documents the application and methods of this practice and the methods herein are taken directly from that handbook. This technique requires the use of permanent markers to mark the locations of both the camera and photo point in order to ensure a constant distance between the camera and photo point through each documentation. Hall recommends the use of a stamped metal fencepost for marking permanent locations and urges that practitioners setting out the initial location of a photo point assume that they will not be the ones to find it again, so effective maps to the location are a necessity. One must take into account *what* one is trying to document in order to then make decisions on the best location as well as timing and frequency of documentation. A meter board at a constant location in the photo and distance from the camera is helpful in setting up a size reference for analysis of features as well as for providing a focus point for the camera. And of course, each photo should be marked with a clear description of the site name, photograph number, and date. Analysis of the photos can be accomplished with computer programs that allow for digitization on top of photos. Using the meter board as a reference for proper sizing of the photograph and features within it, habitat features like vegetation can be outlined and then compared through time for shifts in size.

III.C.2 Native over-story species cover

Indicators

Riparian forests are dominated by woody species, often tree species. These form the over-story cover in the riparian forest. There are three primary indicators for well-being of over-story plants – stem size distribution, basal area, and importance value. Stem size distribution is the frequency distribution of stem diameters of the major tree species in this system and is useful because it directly tracks tree growth. Basal area is the total cross-sectional area of all plants in an area such a plot. Importance value is the combined relative density and relative basal area for a single riparian species. Basal area is an absolute measure of forest structure, and is useful because it generally is proportional to foliage coverage (Barbour, *et al.* 1999). As restoration sites age, foliage cover is predicted to increase and basal area provides an effective measure of this. Basal area is often used as a target for reforestation/restoration projects. All of these indicators can be used to assess condition of both remnant and restored riparian forest.

Table 5 Relevant indicators.

Conservation Targets	Category	Key Attribute	Indicator
Terrestrial riparian habitat	Landscape condition	Species composition / dominance	Importance value of Arroyo willow, Blue elderberry, Box elder, Coyote brush, Fremont cottonwood, Goodding's black willow, Valley oak, Western sycamore,
		Successional dynamics	Frequency of: Box elder with DBH >10 cm, Fremont cottonwood with DBH >40 cm, Gooding's black willow with DBH >20 cm, and Valley oak with DBH >20 cm

1) **Plot sampling**

Plots are either randomly selected within a forest area, or selected because they have been previously sampled and a growth and succession trajectory within the plot is desired. Random selection can be carried out by randomly selecting among all areas, or within each area, which is called stratified random sampling design. When an area is stratified for sampling, that means that meaningful vegetation types have been delineated for a study area. So, stratified random sampling for a riparian zone could include sampling several sites within each of several types of vegetation, several geomorphic classes (e.g., floodplain of different ages), or across a restoration scheme – from un-restored remnant riparian to newly-restored agricultural land.

2) **Measurements**

a) Stem Size Distribution -- The diameter of all tree stems >2.5 cm dbh (diameter at breast height, or 1.5 m) is recorded in plots of size 20 × 30 m. Species usually included are Fremont cottonwood, valley oak, box elder, and Goodding's black willow. The size classes (in cm dbh) used for the frequency distribution for each species are <5, 5-10, 10-20, 20-30, 30-40, 40-50, 50-60, 60-70, and >70.

b) Basal Area – The diameter of individual trees are measured at 1.3 m ("breast height") above the ground (dbh) and then diameters are converted to an area (m^2) basis. Basal area is calculated at the plot level for any woody species with stems >2.5 cm dbh and then reported on a per-hectare basis (m^2/ha) to afford easy comparison with published values for other systems in the literature. Basal area includes all tree species as well as shrubs with woody stems such as willows, elderberry, and coyote brush. Shrubs are included because of their high planting density in this system, which contributes a great deal to foliage cover especially in early-stage restoration sites, and also because of their high wildlife value (e.g. willow and elderberry). In plots where trees occur (i.e. most plots) the relative contribution of shrub basal area to total basal area is small.

c) Importance Value -- Importance Value is calculated for an individual species as the sum of (relative density + relative basal area) with a theoretical maximum of 200. It is calculated for each woody species within a study plot. Plot values are averaged within and across sites. Relative density is the stem density for each species relative to all species in a plot. Basal area is calculated as above.

3) **Native and non-native vegetation cover**

Each sampled plot will be covered by some combination of native and non-native plant species. Stem size distribution, basal area, and importance values can be calculated for individual and combined non-native species as a group and compared to the same values for native species.

<u>Scale, frequency, distribution</u>

Stem size distribution, basal area, and importance values are most useful at the site and whole-river levels. Basal area can be used to compare forest development in sites of similar age with different planting approaches or locations and with reference forests. Importance value may be used to compare the performance of individual species in sites of similar age with different planting approaches or locations and with reference forests. Averaged across sites it may be used to characterize restoration success in general in this system. Stem size distribution can be used to compare forest development in sites of similar age with different planting approaches or locations and with reference forests. Averaged across sites the values are useful to characterize restoration success in general in this system

Interpretation

As restoration sites age, importance values should continue to increase, and eventually stabilize, for the eventual dominants. Species with high importance values early in succession, e.g. high-light requiring shrubs, should decrease in importance value as the canopy closes. A desirable endpoint of restoration in this system is to re-create forests with large-diameter trees (such as Fremont cottonwood and valley oak), simulating the conditions that existed prior to habitat alteration (e.g. Thompson, 1961).

Individual Tree Species

1) Cottonwood: *Populus fremontii* (cottonwood, Fremont cottonwood or Fremont's cottonwood) is a deciduous tree in the Willow family (Salicaceae). It is the target of restoration planting and other conservation activities because of its habitat value and bank stabilization capacity. Cottonwood tree cover is measured as the total area mapped as CW (Cottonwood) in the height classes 1 (Seedling tree, 0 to 2 m) and 2 (Sapling tree, <6 m) within the area that was photographed and mapped in 2007 as part of the Sacramento Monitoring and Assessment Project. Young cottonwood is fairly easy to spot on the color aerial photographs when it is in open to semi-open restoration sites. Its color differs from surrounding vegetation by appearing as a light, gray green. Cottonwood has a flattish top and the spreading branches give a wispy appearance. If it is in the open or the trees are the dominant or tallest in the polygon, then it is easy to interpret on the aerials. However, outside of restoration sites cottonwood may be harder to identify. Cottonwood forest is included in the CSU Chico Geographic Information Center's GIS mapping as CF.

III.C.3 Native and Non-Native understory species cover

Indicators

Understory vegetation species cover and composition is a good indicator of riparian ecosystem condition and restoration success. Research shows that while some native understory species will recruit naturally into sites planted with native overstory species alone, some later successional species need to be introduced as conditions become appropriate (McClain et al. in press). Therefore, understanding the status of native understory species in previously restored sites is a fundamental part of adaptive management. The primary indicators for understory health are absolute and relative native and non-native vegetation cover, native species frequency of occurrence, and native species richness. Holl and Crone (2004) and (McClain et al. in press) used the following methods to compare previously restored riparian with remnant mature riparian sites. These methods can be adapted to answer various questions about understory vegetation as it relates to native vs. non-native species composition, vegetation cover under various successional conditions, and comparison among restored and un-restored sites.

Table 6 Relevant indicators.

Conservation Targets	Category	Key Attribute	Indicator
Terrestrial riparian habitat	Landscape condition	Species composition / dominance	Native understory species frequency of occurrence
			Native understory species richness
			Relative native understory cover

1) Plots and sampling

Most restoration success monitoring will be carried out to compare restored areas to natural areas in various stages of succession. Plots are either randomly selected within a forest area, or selected because they have been previously sampled and a growth and succession trajectory within the plot is desired. Each plot is sampled using quadrats (often 1 × 1 m), several of which (>20) should be placed randomly within the plot. Holl and Crone (2004) used a systematic grid of points separated by a constant distance, (40-80 m) which was determined by the size of the site, to place 1 × 1 m quadrats. At each point they walked a random distance 1-5 m to the left or right, perpendicular to the grid in order to randomly select points relative to rows of planted trees.

2) Measurements

a) Understory Vegetation cover -- For each quadrat, estimate total percent cover of that quadrat by live vegetation <1.5 m tall (including shrubs and vines <1.5 m tall), litter/thatch, and bare ground. Additionally, one can estimate the cover of each species or functional group present. The individual percent cover of each native species can be totaled to come up with an absolute native species percent cover as can non-native species cover. Since absolute cover varies greatly depending on interannual rainfall and temporally throughout the growing season, relative native species cover - which is defined as the percent native cover divided by the percent total vegetative cover (native + exotic + unknown species cover) - is an important metric as it allows for comparisons across years and accounts for phenological differences. Holl et al and McClain et al used a modified Braun Banquet ranking scale: 0-1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-100% (Mueller-Dombois and Ellenberg 1974), in their vegetation surveys to quantify percent cover in which the midpoints of these ranges were used for data analysis. Such a ranking system minimizes the differences in cover estimations from different observers and speeds up measurements.

b) Native understory species frequency of occurrence -- This is measured as the proportion of quadrats (1 m^2) in which at least one native species <1.5 m is present. Frequency of occurrence provides information on abundance and spatial dispersion of native understory plants that complements information on relative native cover. Frequency of occurrence is useful for site-level comparisons but it can also be used to compare sites of similar age with different planting approaches and with reference forests. It can also be used to compare the relative success of restoration efforts across the landscape.

c) Native understory species richness -- This measure is defined as the quantity of unique native herb, shrub, and vine *species* less than 1.5 m tall observed in quadrats (1 m^2) as opposed to the number of unique plants or percent cover of those plants. It does not include seedlings of tree species such as *Acer negundo* and *Quercus lobata*, which may be found in the understory. Species richness is commonly used as a measure of species composition and ecosystem complexity and is useful for making comparisons with reference systems.

d) Vegetation type -- The California Native Plant Society's Rapid Assessment Protocol has been utilized by many different agencies (California State Parks, CA Dept of Fish and Game, the US Forest Service, etc.) to assess and document vegetation communities in vegetation surveys throughout the state. Vegetation is delineated into floristic alliances as developed by the Manual of California Vegetation (Sawyer and Keeler-Wolf, 1995). Quadrats can therefore be characterized by floristic alliance usually named after the dominant/characteristic canopy species.

e) Topographical Plot Parameters – Other plot parameters which one may want to collect at each quadrat to better assess the health of the vegetation community include soil type, soil moisture, and relative elevation. Soil type data at course scale is usually available from local resource conservation districts but for most restoration success analyses plot specific soil data collection is necessary as differences in soil consistency and type have tremendous effect on restoration success. Wood (2008) recorded surface substrate type each quadrat in his vegetation surveys as silt, sand, gravel, cobble, or their combination (not more than two combinations per quadrat). And he then quantified the microtopography of each plot along the transect using a rod and level and the river's height at the time of sampling as a zero point for relative elevation. If desired, soil moisture can also be assessed through field surveys though obviously this varies tremendously temporally. Soil of a constant volume is simply collected at quadrats and then weighed before and after drying.

<u>Scale, frequency, distribution</u>

Relative native understory cover is useful at the site level. It can be used to compare sites of similar age with different planting approaches and with reference forests in order to compare the relative success of restoration efforts across the landscape. Native understory plant species richness can be a site-specific indicator for comparing sites, or as an indicator of the overall health of the river. Species richness can be measured and useful at multiple scales and tends be positively correlated with spatial scale. It is a commonly used indicator in evaluating vegetation.

<u>Non-native, Invasives in the Sacramento River watershed</u>

Given the unique nature of the threat to riparian ecosystems by non-native invasive species, several non-native species have become indicator species of ecosystem health and restoration success. Following is a list of non-native species which are of great concern in the Sacramento River watershed:

1) Giant Reed (*Arundo donax*) is a native of tropical Asia and the Mediterranean region and is now widely naturalized in warm temperate to tropical areas, including the Sacramento River Riparian corridor. Giant reed cover is measured as the total area mapped as GR (Giant Reed) within the area that was photographed and mapped in 2007 as part of the Sacramento River Monitoring and Assessment Project, between Red Bluff and Colusa along the mainstem of the Sacramento River. The mapped area extends outward from the river to include most of the current riparian zone. Giant reed is fairly easy to spot on color aerial photographs when it is in open to semi-open areas. Its color differs from surrounding vegetation by being the only plant species that appears as a light, mint green. It has a rounded shape with a wispy appearance. The fronds are sometimes noticeable and at times can be seen spreading outward from a centralized point.

Giant reed maps are available from the CSU Chico Geographic Information Center (GIC) and coded as GR (Giant Reed). Individual plants are included as polygons in the GIS map, regardless of size. When it occurs in clumps or in close proximity to other giant reed plants, they are mapped together as one polygon. There are several ecological calculations that can then be made once the plants have been mapped: total area, number of patches, dispersion or isolation of patches, and number of new patches (after time interval).

2) Floating/Water Primrose (*Ludwigia peploides*) is a perennial flowering, aquatic plant in the Evening Primrose (Onagraceae) Family. Common names are floating primrose, water primrose, creeping water primrose and false loosestrife. Both native and non-native *Ludwigia* species occur in the Sacramento River. *L. peploides* is native to South America, Central America, West Indies, Cuba and portions of the United States and Mexico. Ludwigia infestations are currently documented in Belgium, Italy, France, the Netherlands, Australia, the UK and infestations are spreading into regions of the United States where it was previously undocumented. Cover is measured as the total area mapped as *L. peploides* within the area that was photographed and mapped in 2007 as part of the Sacramento River Monitoring and Assessment Project.

L. peploides stands out on color aerial photographs when it is in open to semi-open areas. Its signature differs from surrounding vegetation by being the only medium, bright yellow-green vegetation in open and drying water bodies. Often it will have the appearance of small, brownish holes along the outer edges of the floating mats. It is found growing in slow moving backwaters and other permanently and seasonally flooded habitats such as tributaries where water levels have dropped or current is slow, ditches, irrigation canals and ponds. *L. peploides* is found throughout the Red Bluff to Colusa riparian map and is included in the GIC vegetation map as LP. There are several ecological calculations that can then be made once the plants have been mapped: total area, number of patches, dispersion or isolation of patches, and number of new patches (after time interval).

3) Himalayan Blackberry (*Rubus discolor*) is a perennial, woody, shrub in the (Rosaceae) Rose Family. Common names are Himalayan blackberry, Himalaya berry, or Armenian blackberry. Himalayan blackberry is an aggressive, non-native that grows in riparian habitats and disturbed sites throughout the northwest. Himalayan blackberry cover is measured as the total area mapped as blackberry scrub (BS) within the area that was photographed and mapped in 2007 as part of

the Sacramento River Monitoring and Assessment Project. *R. discolor* is fairly easy to identify on the color aerial photographs when it is in open to semi-open areas. Its signature differs from surrounding vegetation by being a bright green, dense, mounded mat with rounded edges. Its height is low to medium. The native blackberry *Rubus ursinus* does not form large, dense mats and would be very difficult to identify and map using aerial photographs and most is under tree canopy. Himalayan blackberry is found growing in the open as well as under tree canopies. Himalayan blackberry grows in the riparian habitat of the Sacramento River and its tributaries, and around other wet areas such as ponds, ditches and irrigation canals. It is also found in pastures, home sites and disturbed areas. There are several ecological calculations that can then be made once the plants have been mapped: total area, number of patches, dispersion or isolation of patches, and number of new patches (after time interval).

2) Black walnut (*Juglans hindsii x*) is a deciduous walnut tree species that is found throughout the riparian vegetation on the mainstem of the Sacramento River and its tributaries. Hinds x is a hybrid of the native Hinds walnut (*Juglans hindsii*) and possibly up to five other species of Juglans that are non-native to northern California. The Hinds hybrid is believed to be displacing native riparian vegetation species in the riparian systems of Northern California. Black walnut cover is measured as the total area mapped as black walnut (BW) within the area that was photographed and mapped in 2007 as part of the Sacramento River Monitoring and Assessment Project. The signature for Hinds x is dark green with a rounded shape and rounded to flattish tops. In general, its mature height is lower than mature valley oak (*Quercus lobata*) and cottonwood (*Populus fremontii*). There are several ecological calculations that can then be made once the plants have been mapped: total area, number of patches, dispersion or isolation of patches, and number of new patches (after time interval).

III.D Habitat Function for Terrestrial & Riparian Biota

Most riparian restoration and conservation occurs in order to benefit terrestrial and aquatic fauna. These may be listed species, or organisms of some management or societal concern. One way of thinking of them is as success markers for riparian restoration. Previous sections describe how to monitor the habitat structure and composition. The purpose of monitoring actual habitat occupancy by native animal species is that it is the best and most immediate determinant of restoration and conservation success.

III.D.1 Birds

Birds are a diverse group of organisms with respect to ecology and life history evolution; they interact with ecosystems (whether aquatic, terrestrial, or wetland) in a diversity of ways. Birds found along the Sacramento River include members of the following orders: Anseriformes, Galliformes, Charadriiformes, Podicipediformes, Cathartiformes, Ciconiiformes, Cathartiformes, Falconiformes, Gruiformes, Columbiformes, Cuculiformes, Strigiformes, Caprimulgiformes, Apodiformes, Coraciiformes, Piciformes, and Passeriformes. Birds are predators of fish, small

Table 7 Relevant indicators.

Conservation Targets	Category	Key Attribute	Indicator
Birds (resident and migratory)	Condition	Demography (depredation and parasitism)	Nest survival for Black-headed Grosbeak, Lazuli Bunting, Spotted Towhee
		Population structure and recruitment	Adult survival for Black-headed Grosbeak, Lazuli Bunting, Spotted Towhee
		Species composition and dominance	Bird species richness
	Size	Population size and dynamics	Abundance for Black-headed Grosbeak, Common Yellowthroat, Spotted Towhee, Yellow Warbler, Yellow-breasted Chat
			Number of egret and heron rookeries
		Presence/ abundance of keystone species	Number of bank swallow burrows , colonies
		Size / extent of characteristic communities	Acres of Yellow-billed Cuckoo habitat

mammals, insects, and other invertebrates, and at the same time they are the prey of mammals, reptiles, and other birds.

Some bird species are year-round residents along the Sacramento River; others make use of this region for only part of the year (e.g., during winter only, during summer only, or during fall and spring migration only). Movements can be substantial on the seasonal scale (e.g., using one area during the breeding season but a different area in the post-breeding phase). Even with respect to the diurnal cycle, birds can move among habitat types. A successful comprehensive avian monitoring program must accommodate these challenges.

Landbirds provide an excellent means to evaluate riparian habitat health. Because landbirds respond to changes in the environment over multiple spatial scales (Temple and Wiens 1989, Chase et al. 2000, 2004), they are ideal study organisms for monitoring and evaluating ecosystem restoration and management (Carignan and Villard 2002). From a practical viewpoint, landbirds are well-suited for evaluating habitat enhancement (especially in comparison to other taxa such as fish or mammals) because: (1) different bird species announce themselves by species specific vocalizations making most species relatively easy to detect and identify, (2) large areas can be surveyed efficiently and cost effectively, (3) demographic parameters can be directly measured, (4) they show a relatively quick response to restoration (changes in abundance and diversity), and (5) landbird monitoring protocols are standardized and contain strict guidelines that aid in the repeatability and interpretation of results. This monitoring plan focuses on riparian landbirds (generally Passeriformes) that breed in riparian habitat along the Sacramento River; it does not include landbird species that require specialized monitoring protocols such as the Bank Swallow (*Riparia riparia riparia*) and the Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*).

Special status landbird species in the Sacramento Valley

A number of landbird species have been extirpated or suffered range and population reductions in the Sacramento Valley. The federally endangered Least Bell's Vireo (*Vireo bellii pusillus*), once a common species (Grinnell and Miller 1944), has been extirpated as a breeder from the Sacramento Valley for over 50 years, although in recent years there have been isolated individuals or breeding attempts in the San Joaquin Valley (Howell et al. 2010). The Willow Flycatcher (*Empidonax trailii)* has also been extirpated as a breeder in the Central Valley (Gaines 1977). Other bird species of special concern (Shuford and Gardali 2008) suffering population declines or range reductions in the Central Valley include the Yellow-breasted Chat (*Icteria virens)*, Yellow Warbler (*Dendroica petechia)*, Loggerhead Shrike (*Lanius ludovicianus*), Yellow-headed Blackbird (*Xanthocephalus xanthocephalus),* and Tricolored Blackbird (*Agelaius tricolor*).

The Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*) was once common in riparian areas throughout the west, but is now listed as state endangered with only a handful of breeding populations in California, including the Sacramento River. The Yellow-billed Cuckoo must be surveyed using playback surveys and are not reliably detected using other methods. The state threatened Bank Swallow (*Riparia riparia riparia*) once occurred in local populations throughout northern, central, and southern California. The largest extant population is along the Sacramento River which likely constitutes half of the entire breeding population of this species in California (RHJV 2004). Bank Swallows are best censused using counts of their nest burrows, although they may be detected using other survey methods.

Landbird relationship to riparian habitat

The presence, extent, and quality of riparian habitat is an important consideration for landbirds in the Central Valley, including the Sacramento Valley. Riparian habitats are among the rarest and most threatened in North America, constituting less than 5% of the continental land mass. Yet they are also among the most productive habitat types in North America, supporting a large diversity of aquatic and terrestrial wildlife (Knopf et al. 1988). More than 60% of the non-game migratory bird species identified as conservation priorities by Partners In Flight (PIF), including tens of millions of individuals, regularly use western riparian areas for breeding, migration, or wintering habitat (Krueper 1993). However, in the west approximately 95% of riparian habitat has been heavily affected by human factors including habitat conversion, flood control, and habitat loss over the past 100 years (Ohmart 1994, Krueper 1996); and in the Central Valley over 98% of riparian habitat has been lost in the past 150 years (Katibah 1984, Smith 1977).

Riparian fragmentation and conversion to agriculture have dramatically altered the structural and functional integrity of western riparian habitats including deleterious effects on riparian birds and other wildlife (Johnson et al. 1977, Krueper 1993, Ohmart 1994, Krueper 1996, RHJV 2004). In the Central Valley many former riparian lands now are used for agriculture. This conversion has often included the establishment of livestock feedlots which have attracted Brown-headed Cowbirds (*Moluthrus ater*) to the region. Cowbirds require grazed lands and/or feedlots for foraging habitat and have a negative impact on native riparian bird species. With the increase in agriculture and urbanization in the Central Valley, there have also been impacts on water flow. There are now greater water diversions, reduced water levels, and altered natural flooding regimes in the region. Reduced water levels have had a direct and deleterious effect on the quantity and quality of riparian habitat which in turn affects riparian obligate species.

Factors that may aid increased population sizes and/or distributional extent

Despite the loss and degradation of riparian habitat throughout the Central Valley, there is great potential for riparian restoration to benefit landbirds and other wildlife. Recognizing this potential, numerous public and private agencies continue to invest millions of dollars to restore and manage riparian habitats (Bernhardt et al. 2005). U.S. Fish and Wildlife Service, River Partners, California Department of Parks and Recreation, The Nature Conservancy, California Department of Fish and Game, California Department of Water Resources, local resource conservation districts, local watershed groups, other organizations, and private landowners are actively engaged in on-the-ground restoration activities. Riparian restoration activities have benefited landbirds in the Central Valley in terms of increased species richness, increased abundance for many species, and nest survival levels that are similar between restored and remnant riparian sites (Gardali et al. 2006, Small et al. 2007, Golet et al. 2008, Howell et al. 2010). Riparian restoration and management activities should be planned to maintain a range of successional stages because different breeding landbirds species vary in their riparian habitat requirements. Other factors that may benefit landbirds include avoiding further habitat loss and managing the landscape for deleterious Brown-headed Cowbird impacts.

Cowbirds are obligate brood parasites that lay their eggs in the nests of many landbird species. The Cowbird young are fed by the host parents typically to the detriment of the host young. The presence of Cowbird young in the host nest reduces the number of host young that survive to fledge. The negative effects of Cowbirds on their hosts can be reduced indirectly by managing factors in the landscape, or by directly managing the Cowbirds. Cowbirds prefer fragmented landscapes with livestock feedlots within close proximity (2-10 km; Thompson 2004, Howell et al. 2007). Cowbirds feed on insects associated with livestock in feedlots and commute between breeding and feeding areas. Reducing the amount of fragmentation in the landscape, the number of cattle within feedlots, and the overall size and number of feedlots are indirect methods to potentially reduce the number of cowbirds and the frequency of host parasitism.

Direct methods of cowbird control include the trapping or shooting of adult female cowbirds and/or addling cowbird eggs in host nests; both approaches require numerous permits and coordination with federal and local wildlife offices. Addling eggs will render the Cowbird egg non-viable in the nest and allow the host to potentially fledge natal young. However if Cowbird pressure is particularly great, the adult Cowbirds may depredate the host nest in order to induce another nesting cycle and parasitism opportunity (Hoover and Robinson 2007). Trapping cowbirds is generally only undertaken when long term nest monitoring has shown that a federally endangered host species is severely imperiled due to Cowbirds. Trapping should be done in concert with nest monitoring to determine how the target host population is affected. Trapping and shooting of adult female cowbirds at Fort Hood, Texas, reduced Black-capped Vireo parasitism from 90% to <9% (Eckrich et al. 1999) and trapping at Camp Pendleton, California, increased Least Bell's Vireo reproductive success by 129% (Griffith and Griffith 2000). Funding for control efforts must be continuous for these programs to be successful (Rothstein and Cook 2000).

Previous surveys

PRBO has been conducting breeding season investigations of riparian bird systems along the middle reach of the Lower Sacramento River (Red Bluff to Colusa) since 1993 in partnership with federal, state, and non-profit agencies (with most surveys conducted between 1995 and 2002). These studies have included investigations of species presence and abundance (Table 1) using point count methods and have been conducted on restored and remnant riparian lands from Red Bluff to Colusa with most surveys occurring between Red Bluff and Princeton (Figure 1).

More intensive surveys have been conducted at a subset of these sites and on a subset of species, especially Black-headed Grosbeaks (*Pheucticus melanocephalus*) and Spotted Towhees (*Pipilo maculatus*) in order to determine demographic parameters such as adult survival and reproductive success. Demographic studies require more intensive methods and multiple years of data collection may be required to estimate some demographic parameters. Results of previous studies have demonstrated that species diversity increases with time since restoration (Golet et al. 2008), species abundance for some species is equal on restored and remnant riparian sites (Gardali et al. 2006), some bird species do not utilize restored habitats until 5-10 years following restoration (Gardali et al. 2006), and reproductive success is similar for some species (Spotted Towhee and Black-headed Grosbeaks) on restored versus remnant plots (Small 2005, Small et al. 2007, Golet et al. 2008), and that for Lazuli Buntings reproductive success was generally quite low (Gardali et al. 1998). Many of these results have been included in a restoration and enhancement guide for Sacramento Valley birds (CalPIF 2008) which synthesizes many of the results from PRBO's restoration monitoring along the Sacramento River.

MONITORING

Monitoring landbirds in the Sacramento Valley has played a vital role in bird conservation planning in California (RHJV 2004) and results to date clearly reveal its value to understanding and conserving songbird populations as well as evaluating and guiding restoration activities. The following sections provide specific objectives (derived from Gardali et al. 2004), recommend monitoring programs to meet these objectives, and summarize sampling protocols and analytical approaches. The monitoring program outlined here is for the *breeding season only* but it is important to consider the degree to which habitats along the Sacramento River are meeting the needs of birds in the migratory and winter seasons as well. Many avian species other than those that breed in the area rely on the Sacramento River as an important migratory corridor and wintering area.

Suggested specific monitoring objectives

1. Determine the annual changes in species composition and abundance for landbirds along the riparian corridor of the Sacramento Valley between Red Bluff and Colusa. ***Justification.*** *An effective monitoring program must be able to provide reliable estimates of trends in abundance and species composition over time. Information on overall population dynamics provides context for interpreting results at the site or treatment level.*

2. Determine the annual changes in species composition and abundance for landbirds in remnant and revegetated riparian habitats. ***Justification.*** *Evaluating the success of revegetation to birds requires comparison to reference (in our case remnant) habitats. It also requires long-term data in order to fully understand the response to revegetation.*

3. Determine the annual changes in species composition and abundance for landbirds in relation to age of revegetation. ***Justification.*** *It is valuable to understand the patterns of response as the age of planting increases. These data will provide information on how and when to manage for a variety of riparian seral stages.*

4. Determine the annual changes in species composition and abundance for landbirds in relation to age of habitat that is naturally recruited. ***Justification.*** *Sampling must take place at areas where woody riparian species have recently recruited to evaluate bird use of these "natural" early seral stage habitats. Although these are not widespread, there are sufficient numbers of sites to support the needed monitoring efforts.*

5. Investigate bird – habitat relationships and how they potentially relate to remnant and revegetated riparian plant community changes either by natural or human-induced processes. ***Justification.*** *The abundance and species composition of bird populations respond to habitat features. Understanding and predicting how management activities that alter plant communities modify bird abundance and species composition is desirable to weigh the costs and benefits of management activities.*

6. Estimate reproductive success for landbirds in remnant and revegetated riparian habitats. ***Justification.*** *Reproductive success is a primary demographic parameter that provides critical information for understanding patterns of population change. Hence, these data can be used to understand trends, focus conservation and management action and money, and identify hypotheses for further evaluation.*

7. Estimate annual survival for landbirds. ***Justification.*** *Monitoring annual adult and juvenile survival is important in the same was as discussed for reproductive success; population trends can thus be better understood from monitoring the interaction of these demographic parameters and conservation and management actions focused accordingly.*

Sampling protocols

Monitoring strategies are most effective when goals are clearly defined, data collected are summarized and disseminated promptly, and goals are periodically evaluated and refined as needed. For monitoring objectives where extensive data are required, the point count method is recommended because it allows data to be collected over a large region and only 2-3 visits per site are required during the breeding season. An additional visit is needed to collect vegetation data if habitat modeling is proposed.

If there are monitoring objectives in which intensive data are needed then mist-netting and nest monitoring are suggested depending on the overall goals of the project. Nest monitoring plots are smaller in area than point count transects but may be extrapolated to larger areas depending on the experimental design and degree of replication. The first five objectives listed above require an extensive data collection method that allows for data to be collected over a relatively large geographic range. The latter two objectives involve the collection of demographic parameters and require the use of intensive data collection methods.

Point counts are an extensive sampling method that produce data on species richness and abundance. This method involves recording data on each individual bird species detected at a fixed point location for a specified period of time (generally a 5-minute sampling period). Birds may be detected visually or aurally because each bird species generally has a unique song or vocalization. In temperate regions most often sing to attract a mate or defend a territory during the breeding season, and they are most territorial during the beginning and middle of the breeding season. Thus point counting is most effective for monitoring birds from April through June in the Central Valley. Although breeding continues through July, males may be less vocal at the end of the breeding season. The species and distance from the observer to the bird is recorded (distances are measured using a rangefinder).

Nest monitoring is an intensive sampling method in which territories of all species, or focal species, are monitored and mapped within each 10 to 40 ha study area and the nest within each territory is located using bird behavioral cues (Martin and Geupel 1993). Study areas are chosen to meet the goals and study design of the project. Nest monitoring requires almost daily effort in the field at each study site in order to locate nests and because nests must be checked a minimum of every four days. Each nest is monitored until it has fledged or failed. Generally a minimum of ten nests of each species must be monitored in order to draw inferences about reproductive success at the study area.

Mist-netting is an intensive sampling method in which each study area consists of permanent mist-net sites located opportunistically, but rather uniformly, within the interior eight ha of a 20-ha area (DeSante et al. 2002). Study areas are chosen to meet the goals and study design of the project. Typically, there are ten 12-m, 36-mm-mesh mist net is operated at each study area. All birds captured are identified to species, age, and sex using criteria in Pyle (1997) and, if unmarked, are banded with a uniquely numbered aluminum ring provided by the U.S. Geological Survey/Biological Resources Division Bird Banding Laboratory.

All data protocols, data structures, field data forms, and programs for data management and analysis for these methods are available under “Research Tools” at http://www.prbo.org/cadc/.

Site selection

Future point count surveys should be conducted at sites previously visited by PRBO in which there have been multiple years of data collection (Table 2). Additional transects should be added as needed in order to meet the objectives of the project (e.g. to include a range of restoration ages or restoration planting composition). New transects should be situated in riparian areas such that each point within a transect is at least 250 m apart with approximately 12 points per transect. Because restoration age and planting composition may influence species richness and abundance (Gardali et al. 2006; Gardali and Holmes in review), it may be desirable to select a range of restoration ages or planting composition as part of the overall experimental design of the project.

Future mist-netting should be conducted at a minimum of two sites; Phelan Island and Sul Norte. If funding allows, then Ohm and Flynn should be added.

Future nest monitoring should be conducted at five sites; two remnant forests (Sul Norte and Kaiser) and three revegetated (Phelan Island, Kopta Slough, and Pine Creek).

Frequency of sampling

<u>Point counts</u>

For a point count survey, each point must be visited by one individual two times during the peak of the breeding season (generally between April and June). Each point is surveyed for 5 min during the first three hours of the daylight so multiple points (typically 12) may be surveyed in one day. An additional visit is needed during the breeding season to collect vegetation data if habitat modeling is proposed.

Three different point count monitoring scenarios are suggested depending on project objectives and funding. All of these survey suggestions require paired surveys of remnant riparian sites. Note that it would be informative to survey some sites prior to revegetation as well.

- **Conduct surveys every year.** This approach will determine trends—trends should be compared to reference condition to confirm that the restoration is following its intended trajectory. This approach will also reveal abundance patterns in relation to revegetation age.
- **Conduct surveys every other year.** This approach will also evaluate whether the revegetation is flowing its intended trajectory but will be less sensitive to abundance patterns in relation to revegetation age.
- **Conduct three consecutive years of surveys on a survey cycle of three years** (i.e., each survey round lasts three years with a total of three years between rounds). This design may not capture planting year specific changes but should do well to estimate trends. We are suggesting that each survey round be three consecutive years to account for the potential impact of annual variation; avoids single year sampling during anomalous years.

Nest-searching

For nest searching, one individual must visit a site every other day during the breeding season (April through July). Each site is surveyed for the first six hours of daylight and multiple sites cannot be surveyed in one day. There is a minimum of approximately ten nests monitored per species in one season in order to make inferences about nest survival. An additional visit is needed during the breeding season to collect vegetation data if habitat modeling is proposed.

Mist-netting

For mist-netting, a team of 3-4 individuals must visit a site every ten days during the breeding season. Each site is surveyed for the five morning hours per day and multiple study areas cannot be surveyed in one day. Each study area is surveyed for one day during each of six to ten consecutive 10-day periods during the breeding season. There is a minimum of three years of data collection needed in order to estimate adult survival using mark-recapture methods. An additional visit is needed during the breeding season to collect vegetation data if habitat modeling is proposed.

Data analysis

Point count data

The statistical analysis of count data is a rapidly evolving field and has been the subject of numerous symposia and studies (Ralph et al. 1995, Rosenstock et al. 2002, Farnsworth et al. 2005, Nichols et al. 2008). The analyst should consult the latest peer-reviewed literature in relation to the goals and objectives of the study when undertaking data analysis. In the past decade there has been a movement to adjust species occurrence estimates to adjust for detectability. There are a number of methods for adjusting count data to calculate more realistic estimates of occurrence, and these indices are generally based on corrections using distance to recorded individuals (Alldredge et al. 2007), multiple observers (Alldredge et al. 2006), repeated samples at the same locations (Royle et al. 2005), and hybrid methods. These methods allow the estimation of detectability.

Without adjusting for detectability and other biases, occurrence estimates are still useful as indices of abundance and density, but must be considered in context or they can be misleading (Johnson 2008). The use of counts as a measure of relative abundance assumes that differences in counts reflect differences in the true population, such that the proportion of animals detected is constant across all plots or times (Thompson 2002). In particular, ignoring inter-specific differences in detectability can lead to vastly underestimating abundance for inconspicuous species and makes comparisons across species difficult (Kery and Schmid 2004). However, these potential biases may be less important when measuring temporal patterns for one species in a habitat with relatively little changes from year to year (e.g. remnant forests). If unadjusted counts are used then detectability could still be calculated in order to demonstrate that detectability is relatively high and does not vary.

Thompson and LaSorte (2008) compared five common approaches (including unadjusted counts and program DISTANCE [Buckland et al. 2001]) for estimating annual abundance or indices and population trends from point count data. While they found strong evidence that detection probabilities varied among species and years, there was good overall agreement across trend estimates from the five methods for 9 of 12 comparisons. They note that: "Proponents of abundance estimation will likely interpret this study as support for the growing concern that counts of bird detections from point counts should not be used as indices of abundance. Proponents of indices, however, will likely interpret our results as support that even with moderate departures from assumptions, in most cases, indices will result in similar conclusions or management decisions. Given that detection probabilities often vary among species, years, and observers we believe investigators should address detection probability in their surveys; whether it be by estimation of the probability of detection and abundance, estimation of the effects of key covariates when modeling count as an index of abundance, or through design-based methods to standardize these effects."

Whatever the approach is used in analyzing point count data it should be carefully documented and justified in light of the overall goals of the research question and a discussion of the potential biases associated with detectability should be included.

Nest-monitoring data

Data analysis of nests should be weighted by the period of time that the nest was observed (i.e. the exposure period). The Mayfield analysis method of nest survival incorporates the number of days that each nest observed remained active (exposure period), from the find date, to calculate the daily survival probability (Mayfield 1975, Johnson 1979). The daily survival probability is raised to the power of the total number of days in the nesting period (laying, incubation, and nestling phases), which differs among species, to obtain the probability of fledging at least one host young. The Mayfield method provides a less biased estimate of reproductive success than proportional success. More recently, Shaffer (2004) and others developed the logistic exposure method to analyze nest data which also incorporates the exposure period in the analyses. Survival estimates are similar between Mayfield and logistic exposure methods (Lloyd and Tewksbury 2007), however the logistic exposure method allows for more sophisticated statistical modeling.

Mist-netting data

Mist-netting data may be analyzed using mark-recapture analysis methods to estimate adult survival (Ralph et al. 2004). There are a number of programs available to analyze mark-recapture data such as mist-net data. Program MARK (White and Burnham 1999, Cooch and White 2004) computes the estimates of model parameters for mark-recapture data via numerical maximum likelihood techniques and is one of the more frequently used programs for calculating demographic parameters such as adult survival from capture data. The user must construct an encounter history for each species and the program is relatively straightforward to use. A minimum of three years worth of data are needed to construct an encounter history, and estimates are generally more robust with a minimum of four years worth of data.

III.D.2 Valley Elderberry Longhorn Beetle

The Valley Elderberry Longhorn Beetle (VELB, *Desmocerus californicus dimorphus* Fisher) (Coleoptera: Cerambycidae) is endemic to riparian and scrub habitats in California's Central Valley and is an obligate specialist on its host plants, blue elderberry (*Sambucus mexicana*) and red elderberry (*Sambucus racemosa*). The known range of the VELB extends from southern Shasta County to Fresno County, and from the east side of the Coast Range to the foothills of the Sierra Nevada in the Central Valley (Barr 1991). The VELB usually occurs only in small local populations (Collinge et al. 2001, Talley et al. 2006). Specialism, small geographic range, and low abundance have all been cited as reasons for rarity (e.g., Collinge et al. 2001). The VELB's range is also centered on Sacramento, California, a city of over 450,000 and which is growing at over 3% per year (US Census Bureau 2005), leading to a broad overlap between the beetle's occurrence and urbanization.

Table 8 Relevant indicators.

Conservation Targets	Category	Key Attribute	Indicator
Terrestrial riparian habitat	Landscape size	Population size and dynamics	Average number of VELB exit holes per shrub

<u>Conservation Status and Legal History</u>

The VELB was listed by the US Fish and Wildlife Service (USFWS) as a federally threatened species under the Endangered Species Act in 1980 due to habitat loss and degradation (Federal Register 1980). A recovery plan for the VELB was published in 1984 (USFWS 1984), but was based only on the small amount of biological information that was then available. The recovery plan contained no explicit criteria by which the beetle could be regarded as recovered, and based recommendations on general biological criteria such as planting elderberry, and avoiding harmful factors like pesticides, dust, and habitat destruction. These recovery strategies have not clearly lead to increases in the abundance or distribution of the beetle, and new threats to survival have been discovered including loss of VELB from some sites that have been colonized by invasive predatory Argentine ants (Huxel 2000). On September 26, 2006, USFWS completed a 5-year review of the VELB and recommended that the beetle be proposed for delisting under section 4 of the federal Endangered Species Act of. Review of the delisting recommendation is currently underway by USFWS (in May-June 2010), and even if delisting occurs, USFWS is required to implement a system of monitoring for not less than 5 years. The delisting recommendation from USFWS cited protection of habitat areas (~50,000 acres) and restoration of riparian habitat areas (~5,200 acres) as reasons for recommending delisting. Sites along the Sacramento River accounted for approximately a half of the natural habitat area protected and the vast majority of restored habitat. Hence, it is important to understand the status of VELB populations in these sites.

Background Biology

Adult VELB are sexually dimorphic with females having dark metallic green to black elytra with a bright red border and males having red elytra with four dark elongated spots (Talley et al. 2006). Adult females lay eggs in crevices of elderberry stem surfaces or on leaves, then the first instar larvae bore into the stems where they develop for one to two years while feeding on pith (Halstead and Oldman, 1990). Adults chew through the outer bark and emerge through this exit hole during the flowering season of elderberry in mid-March through June (Barr 1991). After emergence, adults live for a few days to a few weeks while mating and feeding on elderberry leaves, flowers and nectar (Halstead and Oldman, 1990). The distinctive emergence holes left by the beetle are the main way its populations have been censused.

Similar to many other extreme habitat specialists, the population structure of the VELB is that of a metapopulation (Collinge et al. 2001); with a regional population consisting of discrete patches with low occupancy rates, small local population sizes, and occasional colonization and extinction events (Levins 1969, Hanski 1994). A more detailed analysis by Talley (2007) supported the notion that the beetle exists as a metapopulation. The VELB has a very low reproductive rate, which likely contributes to its low population densities (Collinge et al. 2001). When combined with the beetle's poor dispersal ability, these factors make the influences of environmental and demographic stochasticity likely (Talley 2007). VELB populations may have always been relatively small because of their specialized life history and restricted distribution (Linsley and Chemsak 1972).

Threats to the VELB:

At the time of listing, habitat loss and degradation were cited as being the primary threats to the VELB (USFWS 1980). Riparian areas have declined significantly throughout the beetle's range, and it is estimated that 90% of riparian woodlands in the Central Valley have been lost (Smith 1980) due to flood control methods, stream channelization, residential and commercial development, and agricultural activities (Collinge et al. 2001).

The invasive Argentine ant (*Linepithema humile*) appears to have a negative impact on VELB populations. This aggressive ant species may predate upon VELB eggs, although the exact mechanism of their interaction is unknown at this time (Huxel 2000). The Argentine ant has been shown to be spreading, on average, 16 meters per year along riparian woodland habitat and displacing native riparian invertebrates (Holway 1998). The Argentine ant may pose a threat that is compounded by the combined effects of habitat loss and the population structure of the VELB (Huxel 2000).

The majority of commonly used pesticides and insecticides in the VELB range are broad-spectrum and are therefore likely to be toxic to the beetle, and herbicides may be detrimental or lethal to elderberry shrubs (Talley 2006). Given the proximity of agriculture to riparian areas it is likely that pesticides are affecting the VELB and its restricted elderberry host plant, however, there have been no studies on the effects of pesticides on the VELB specifically (Talley 2006).

In the long-term, the effects of climate change also need to be considered. Hayhoe et al. (2004) provide some estimates based on the more widely used climate models for California. Both increases in temperature and changes in precipitation (rain and snow) could have large effects on both VELB and elderberry. By year 2100 snowpack declines of 30-70% were predicted, with similar magnitude declines expected in runoff and stream flow. Winter precipitation also declined in 3 of 4 model scenarios (Hayhoe et al. 2004). Annual statewide temperature increases of 2.3-5.8 ^{o}C coupled with 2.2 to 8.3 ^{o}C (Hayhoe et al. 2004) increases in summer temperatures are likely to greatly alter the timing of elderberry growth (and season length) and could impact the overall quality of elderberry as a host plant for the VELB. Northward and elevational shifts in range are also likely to occur. For the VELB this could also lead to hybridization with the California elderberry longhorn beetle, CELB (*Desmocerus californicus californicus*), which occurs at greater elevations and areas outside of the Central Valley (Linsley and Chemsak 1972).

Factors that may increase population sizes and/or distributional extent:

Both Elderberry and the VELB have been widespread targets of habitat restoration, and it is possible that the beetle will show a net gain in population size because of this. Recovery methods for the VELB include planting of elderberry and avoiding detrimental factors such as further habitat loss and/or degradation, pesticides, herbicides, and construction dust (Holyoak and Koch-Munz 2007). Approximately 50,000 acres of existing riparian habitat has been protected in the Sacramento and San Joaquin Valley since 1980. In addition, approximately 5,000 acres of habitat has been restored for the benefit of the beetle (including planting of elderberries) (Talley et al. 2006).

Previous surveys:

In a survey conducted by Barr (1991), 31 new exit holes were found in 117 elderberry groups (26.4% of groups), new or old exit holes were found in 29 of 79 sites (36.7%), and new holes only were found in 16 of the 79 sites (20.2%). In 1997, Collinge et al. (2001) found 27 new exit holes in 111 elderberry groups (24.3% of groups), new or old exit holes were found in 30 of 65 sites (46.2% of sites), and new holes only were found in 13 of the 65 sites (20.0% of sites). Only about 25% of elderberry groups sampled contained new exit holes, only about 20% of riparian sites that contained elderberry shrubs supported VELB populations, and the majority of sites sampled (52.3%) remained unoccupied by VELB in both 1991 and 1997 (Barr 1991; Collinge et al. 2001).

In a survey by Talley et al. (2007), shrub occupancy by the VELB was highest (11.2%) in the lower alluvial plain of the American River. Shrub occupancy by the beetle was 10.5% in the mid-elevation riparian corridor, 8.7% in the upper riparian terrace, and 2.9% in non-riparian scrub (Talley et al. 2007). Within individual shrubs, exit holes are more likely to be found in stems of 1 to 2 inches (2.5-5 cm diameter) than in larger stems (Barr 1991; Collinge et al. 2001; Talley et al. 2007).

Holyoak et al (personal communication) surveyed 34 sites in 10 watersheds throughout the Central Valley of California. They surveyed for signs of beetle presence on 4,247 stems within 441 shrubs. Beetles were present in nine of 10 watersheds and in 27 of 34 sites. This survey provided estimates of the number of shrubs needing to be sampled to obtain estimates of the frequency of VELB per shrub (or elderberry stem) that had reasonable coefficients of variation, such that there would be a reasonable chance of detecting a decline in population size.

Sampling at restoration sites consists primarily of the surveys conducted by River Partners (2004) and Gilbart (2009):

The River Partners (2004) survey presents data on VELB density for several Sacramento National Wildlife Refuge units surveyed between October 31, 2003 and December 18, 2003:

- Flynn Unit, Tehama County, River Mile 230.5-233
- Rio Vista Unit, Tehama and Butte Counties, River Mile 215.5-218
- Phelan Island Unit, Glenn County, River Mile 190.5-191.5
- Ord Bend Unit, Glenn County, River Mile 183.7-184, and
- Packer Unit, Glenn County, River Mile 167-168.

Sites visited by Gilbart (2009) include surveys of 432 shrubs conducted during March to July 2007 and 2008. Sites visited are summarized in Table 1.

METHODS

<u>Site selection</u>

As a first step study sites should be selected at sites along the Sacramento River and its tributaries between Colusa and Red Bluff. Since it is not clear that restored and natural sites are directly comparable, these site types are treated separately and coverage should be obtained for each type of site. Restoration sites should duplicate the 22 visited by Gilbart (2009) in 2007 and 2008, which are listed in Table 1. Based on estimates of population size in Gilbart (2009) this represents a somewhat minimum level of sampling for sites within Sacramento NWR. It would be sensible to include some other areas that are both north and south of Sacramento NWR, perhaps including 10 fields in more northerly areas and 10 at more southern sites. Some Phelan Island and Packer Unit sites were surveyed by River Partners (2004) and these sites would sensibly be included in the present monitoring. For natural sites, Barr (1991) lists 23 sites in Tehama County, 3 sites in Sutter, 15 in Butte, and 4 in Yuba County. There are also known sites in Glenn County that were not visited by Barr (1991). Hence it should be possible to identify on the order of 30 natural sites along the Sacramento River and its tributaries in the study area. The number of sites required will depend on the density of VELB, as described in the following paragraph.

<u>Selecting elderberry groups to sample</u>

In each restoration site or along each tributary, walk or drive through accessible portions of the riparian habitat (restored or natural) to identify areas with “groups” or “clusters” of elderberry shrubs (groups and clusters are used synonymously). Aim to establish 5–20 sampling locations per site, meaning per field of a restoration site or natural site. To avoid over-sampling at some locations and extensive searches in sites with very few beetles, a minimum of 10 elderberry shrubs and a maximum of 20 elderberry shrubs should be surveyed at each site/Field; if 20 exit holes are found and at least 10 shrubs have been surveyed then surveying of new shrubs should cease. Although some candidate areas can be identified in advance using high-resolution satellite data or aerial photographs, identification of sampling locations will need to be conducted in the field. To some extent sampling locations can be identified concurrent with selection of tributaries; but follow-up visits may be necessary after all tributaries have been selected. The focus of the sampling sites will be on reasonably abundant and dense shrubs; however, less dense areas may also be selected to determine status in these areas and to avoid biasing study results towards only dense habitat. The objective of this step is to survey a minimum number of both shrubs and recent beetle exit holes that is sufficient to achieve a high likelihood of detecting a defined trend in abundance of beetles within a metapopulation, as determined by an analysis of existing census data.

Establish sampling locations within all reaches of the Sacramento River between Red Bluff and Colusa. The objective of this step is that sampling is designed to be (1) for populations within a metapopulation, (2) sufficient in scope to ensure trends would be detectable, (3) stratified geographically and by habitat types, (4) stratified by elderberry shrub density, and (5) representative of VELB habitat configuration, including restored/created habitat. Sampling of 10-20 shrubs per site may serve as these sampling locations (see previous paragraph), and shrub locations should be recorded using a highly accurate GPS. Where access is adequate and density of elderberry is reasonably high, sampling locations might be established in upland shrub lands beyond the riparian corridor. A range of habitat conditions should be included in the study areas selected. Areas selected for study may also include restoration areas to determine if such areas are affective for conserving the beetle.

<u>Measurements within each elderberry group</u>

Within each sampling location, search all elderberry shrubs for evidence of beetle presence (recent holes or old holes); See http://web.mac.com/tsinicrope/Site/VELB_info/VELB_info.html for an illustrated guide. The abundance of shrubs, number of stems (emerging from ground) greater than 1 inch in diameter (2.5 centimeter), presence of exit holes, relative age of exit holes (judged by appearance and annual censuses for new holes), within each sampling location will be recorded. Table 2 presents an example of an appropriate data recording table. The objective is to measure shrub abundance/density by mapping sampled shrubs using GPS technology. Areas to be monitored will be selected to represent a range of shrub densities, rather than areas of high shrub abundance. All study locations identified and location of elderberry shrubs will be recorded using highly accurate GPS. All GPS/GIS data recorded will be to established Service standards. Data should be gathered in the North American Datum 1983 and Universal Transverse Mercator projection (NAD 1983 UTM) format.

To help determine the number of site that need to be sampled a power analysis should be conducted. To determine if sampling of the baseline is adequate, samples should be used to calculate likelihoods or probabilities of detecting a regional population decline for VELB of a given size (e.g., a 50% drop in abundance or site occupancy). For instance a statistical power of at least 0.8 is desirable. A similar analysis should be performed on per year survival rates of elderberry shrubs.

Frequency of sampling and detection of temporal trends

The sampling scheme is flexible in that it aims to obtain a somewhat reliable sample of abundance from each site type within each year sampled. There is a need for an initial sample to establish site and shrub locations. After this at least one sample is needed to determine survival of elderberry shrubs and new shrubs should be found where possible to replace shrubs that died (to avoid a decline in sample size). There is an advantage to collecting data every few years (perhaps 2-3 years) rather than every year since this will give a stronger chance to detect temporal trends in abundance or survival. With just two samples a simple t-test can be used to detect changes in abundance, but with more samples linear regression and regression corrected for temporal autocorrelation can be used.

III.D.3 Mammals, reptiles, and amphibians

Fragmentation of wildlife habitat is one of the primary global threats to species diversity and cause of endangerment. Fragmentation is a spatially and temporally continuous process that leaves a gradient legacy across the landscape. The Sacramento River Riparian zone is naturally and artificially fragmented, which will have implications for occupancy, movement, and persistence of land-dwelling vertebrate species. An important outcome of riparian zone restoration is demonstrated use of habitat by these vertebrate species. The purpose of monitoring mammals and herpetofauna is that terrestrial wildlife are often one target of habitat restoration efforts, so they make good indicators of both ecological condition and restoration effectiveness. A critical factor in this use of animals as indicators is the variable responses that different taxa

Table 9 Relevant indicators.

Conservation Targets	Category	Key Attribute	Indicator
Terrestrial riparian habitat	Landscape condition	Species composition / dominance	Bat species richness Mean Bat Activity Level
			Mammal species diversity and richness
			Mammal movement
			Genetic diversity and relatedness (birds and mammals)
			Ground-dwelling insect diversity and richness

show to environmental conditions, including restoration actions. For example, Golet et al (2011) demonstrated that comparing sites along the Sacramento River riparian zone varied in findings about restoration effects, depending on the time of year and taxanomic groups selected. A solid conclusion from this type of work is that several complementary taxanomic groups (e.g., terrestrial insects, mammals, birds) be used to evaluate ecosystem condition and restoration success, rather than any one or two.

A common method for predicting and evaluating vertebrate habitat is to calculate total area and disturbance of areas suitable for the species. This method is described in section II.D.1 and provides an estimate of usable habitat, which is not necessarily the same as occupied habitat. Demonstrating occupancy and movement can be accomplished with methods varying in their complexity and expense: 1) visual or auditory detection, 2) sign (track and scat) detection, 3) camera trapping, 4) radio/GPS-collaring, 5) genetic analysis, and 6) live and pit-trapping.

1) Visual/auditory detection

Seeing or hearing animals in field surveys, or ad hoc during visits, is one of the most direct ways to measure occupancy of habitat. The Breeding Bird Survey is a good example of this approach, where trained ornithologists traverse transects once per year searching for bird by sight and sound, in order to detect bird species. Surveys where direct observations are recorded often also collect evidence of sign and possibly genetic analysis (e.g., from scat or hair). Additionally one can visually detect roosts and flight by bats which are an important indicator of ecosystem health.

Though not detectable by the human ear, ultrasonic echolocation calls produced by bats can be recorded by specialized equipment and the resultant calls can be typed by species with sophisticated computer software. Golet et al 2008 used three Anabat II ultrasound detectors (Titley Electronics, Ballina, NSW, Australia) deployed at each of various restored and non-restored sites along the Sacramento River to assess presence/absence of important bat species in each habitat type. As frequency of calls varies from night to night detection is usually monitored over at least two weeks time and the resulting data can be an important indicator of restoration success. A generalized measure of bat activity can be derived by measuring the mean number of acoustic files per sampling period recorded by the ultrasound detector. Golet (2008) used mean ± SE to compare bat activity levels at young versus older restoration sites within the Sacramento River Project Area.

2) Sign detection

There are two primary types of sign collected during field surveying for land-dwelling vertebrates – tracks and scat. Track detection can occur as a result of investigating natural media (e.g., soil or mud), from artificial application of media (e.g., sand or gypsum), or from track plates (figures).). Ford et al (2009) used a tracking material consisting of a dry, loamy mixture of sand, silt, and clay, 1–4 cm deep at either end of culverts in order the capture the movement of large mammals. Alternatively track plates can be used which usually involve a surface with a marking substance such as printer toner followed by an often baited surface lined with contact paper in order to capture the track of the visiting animal.

Recently researchers have begun using dogs to locate scat for species of interest as they have the ability to detect this sign over large and complex landscapes and can easily be used ensure unbiased sampling of sites (Smith et al., 2006; Vynne et al., 2009). Dogs can be trained to locate a particular species' scat both new and old, and do so with greater efficiency than traditional techniques (Smith et al. 2006). Long et al. (2007) found that scat detection dogs yielded higher detection rates and probability of detection (given presence) for black bears, fishers, and bobcats than cameras or hair snares. Smith et al. (2006) walked transects strategically through habitats which were likely to host their target species (San Joaquin Kit Foxes) assuming that dogs were likely to detect sign on average 4m to 6m away from transect routes. Once scat is located, samples can reveal important information about species, wildlife movements, diet, disease and even provide tissue or fluids for genetic analysis (Smith et al. 2006, Vynne et al. 2009, Wasser et al. 2004). Smith et al (2006) calculated the rates of various species of scat found in transects as # of scats/km. These measures of frequency can then be used in comparisons between different habitat types or in order to evaluate relative restoration success.

3) Camera trapping

Wildlife cameras are now commonly-used to monitor the presence of wildlife and the movement of wildlife through enclosed or restricted spaces (e.g., culvert under road). Photographs from these cameras provide information at least about relative abundance of specific species and biodiversity in general. Motion-triggered cameras may be at baited or un-baited stations and typically point toward a trap area of a known size. Although informal uses of cameras is common (i.e., lacking a structured sampling protocol), recently wildlife biologists have developed formal methods for using camera traps to sample large areas relatively cost-effectively over long periods of time. Ford et al. (2009) used infrared cameras stationed at 15 crossing structures within their study area along the Trans-Canada Highway in Alberta, Canada to monitor wildlife crossing. The methods involved in camera trap studies within restricted spaces are likely to differ however, from those methods useful in scenarios which are likely to be present in restored riparian landscapes.

Larrucea et al., (2007) used unbaited cameras to census bobcats at locations in California. They placed cameras in a grid at various densities and found that, as could be expected, they had more accurate population estimates from data from the highest density camera grid level which was 8 cameras per square km within a 10 km^2 grid. Cameras were placed usually at the center of grid squares but if squares were intersected by paths or areas with heavy sign they were placed in order to optimize these features (Larrucea et al., 2007). Researchers in this study were able to identify individuals based on pelage pattern and then were able to re-construct elaborate capture histories based on these findings for each camera. They basically recorded presence/absence of each individual over a one week period on each camera and then used a mark recapture program, CAPTURE to estimate abundance. They then used this data to calculate densities by dividing abundance by estimated total area covered by each camera (Larrucea et al., 2007).

4) Radio/GPS collaring

Probably the best way to determine how wildlife are using a landscape on a daily basis is to track them as they move. Traditionally radio-collars and now GPS collars are used to track individuals. Radio-telemetry is used with traditional radio collars to detect the locations of wildlife on a daily basis but requires that a researcher is in the field to collect data and often that two researchers are available to triangulate the locations of hard to detect species. GPS collars however can operate without field technicians, recording information on acceleration and movement of individuals and then uploading that data to satellites from which researchers can have easy access. For obvious reasons, GPS collars can be costly so sometimes other options like genetic analysis (below) of populations is used to infer population structure.

5) Genetic analysis

Population structure of various species of interest can be inferred through genetic analysis of random individuals. This analysis can be completed with samples of hair, tissue, or blood and can be extracted from road kill, individuals who have been trapped/snared, or from simple hair analysis from hair corrals. In general, DNA analysis using these various samples concentrates on microsatellite locations which are not prone to evolution through natural selection but which gain repetitions in alleles through mutation over generational time. They can therefore be used to infer relatedness between individuals. Each species has particular loci that have been chosen by researchers for their utility in genetic population structure analysis. As mentioned earlier in the segment on connectivity, some researchers are using population structure data derived from genetic analysis to create probable wildlife movement paths and continuous resistance-based connectivity rasters throughout landscapes which then can be correlated with models based on topographic and landscape features to better understand the effect of these features on a particular species' movement and dispersal (Cushman, 2006).

6) Live/pit trapping

Sherman traps are often used to assess the densities and presence/absence of various small mammal species within restored riparian lands. As Golet et al. (2008) showed, different small mammal species seem to thrive in restored sites as time since restoration increases. As many rodent species are of interest ecologically as either human/agricultural pests (California voles, *Microtus californicus)* or even as threats to other native species, Black Rat (*Rattus rattus*) through nest predation etc., live trapping of small mammals can be an integral part of restoration monitoring. Typically traps are located in a grid throughout a landscape in such a way as to capture the heterogeneity of that landscape and are set in the evening with a small amount of food – sterile seed – and in cold climates, bedding in the form of a cotton square. Traps must be checked early in the morning the next day to prevent mortality due to heat and if desired small tags can be used in a catch and release study in order to estimate abundance. Koenig et al. (2007) and Golet et al. (2007) used 100 Sherman traps set out in a 10 by 10 trap grid with 10m between traps over a five day period for their small mammal studies on restored and unrestored properties on the Sacramento River (Golet et al., 2008).

Pitfall traps can be used to survey for important indicator insect species such as beetles at restored riparian sites. Hunt (2004) used comparisons in the biodiversity of ground-dwelling, surface active beetle assemblages (Order: Coleoptera) to assess differences in taxonomic diversity between restored and non-restored riparian sites (Golet et al., 2008). Researchers have found in surveys of riparian restored and non-restored sites along the Sacramento River that biodiversity of beetles was strongly associated with season and suggest that Spring is the best time of year to conduct a beetle morpho-species richness survey. Three replicates of each site type were chosen and on a monthly basis for one year, 12 traps were left open for 7 consecutive days, 15m apart in a 3 x 4 grid (Golet et al., 2009).

III.E Soil Conditions and Nutrient Cycling as Indicators of Ecosystem Health

Soil is the life blood of all productivity in riparian corridors, as it contains precious nutrients and moisture that plants need to grow and thrive. The purpose of monitoring soil in riparian zones includes assessing ecological condition at various scales, measuring the effectiveness of vegetation and channel process restoration, and advance planning for site restoration. Soils can be classified by their texture which constitutes the relative proportions of sand, silt, and clay (NRCS 2006). These relative proportions in turn determine a soil's structure which is basically the arrangement of a soil's particles. Soil structure is important as it determines a soil's ability to hold and drain water and air as well as to provide room for root growth. The three major classes and contained sub-classes of soil include: Structureless (which includes Single grain and Massive), With Structure (which includes Granular, Platy, Wedge, Blocky, Prismatic, and Columnar), and Structure Destroyed (which includes Puddled) (NRCS 2006). Additionally, soils contain a certain amount of organic matter which is comprised of microorganisms and decomposing residues of plants and animals. As this organic matter is broken down by microbes the soil becomes aerated and important nutrients such as nitrogen, phosphorus and sulfur are released into the soil and made available to vegetation. Researchers commonly use soil pits in randomly selected plots to reveal the soil horizons or distinct soil layers due to weathering and addition and subtraction patterns, for soil surveys. The top soil horizon contains the most organic matter and appears darker in color than the other layers as it is where depositions from flooding events and leaf litter are broken down by microbes providing nutrients and vital space for root growth. Characterization samples from each soil horizon can be collected for physical and chemical sampling with the use of augers or probes.

Table 9 Relevant indicators.

Conservation Targets	Category	Key Attribute	Indicator
Terrestrial riparian habitat	Landscape condition	Soil structure	Soil texture, moisture, particle composition, horizons, soil bulk density, soil organic matter
		Soil function	N-mineralization

In-depth soil survey methods, resources, and tools are available at: http://www.nrcs.usda.gov/, and an easy to use manual on soil field surveys is available from the NRCS at: ftp://ftp-fc.sc.egov.usda.gov/NSSC/Field_Book/FieldBookVer2.pdf. Soil conditions have been shown to be extremely site specific and may vary within a restoration site dramatically over just a few meters, while having extremely important implications on plant growth. Because of this, soil surveys should be plotted out at a density which reflects this diversity. Alpert et al (1999) in an assessment of restored sites along the Sacramento river for The Nature Conservancy found that top-soil depth before reaching sand or gravel, as well as the texture or coarseness/sandiness of soil significantly affected planted vegetation growth, with planted oaks favoring deeper and finer (clay) soils. They used an auger to collect 25g soil samples at every 30cm of soil depth within randomly selected plots throughout restored areas and found that the patchiness of both soil depth and texture could vary extremely and are important predictors for planting success. There is also a method classifying soil texture developed by the NASA's Goddard Space Flight Center that simply involves moistening and kneading an egg sized amount of soil in one's hand, and then following a set of procedures to in order to classify the soil's texture: http://www.sacramentoriverportal.org/eco_indicators/plant_communities/figure_2.pdf.

Brown and Wood (2002) conducted a similar analysis for The Nature Conservancy of restored sites along the Sacramento River to determine whether soil conditions and nutrient cycling could be used as indicators of ecosystem success and recovery throughout the restoration process. What follows is taken directly from their report and findings and the full report can be found at: http://www.sacramentoriverportal.org/reports/index.htm. As stands age and restoration sites mature from orchard sites into mature riparian forest it would be expected that there would be measurable changes in the condition of soils. Increased leaf drop adds nutrients like carbon and nitrogen to the soil and flooding events blur the boundary between the river and bank, increasing productivity within the water while depositing nutrients on the soil. As time passes and leaf litter increases to build up in restored riparian forests, the action of soil microbes will presumably continue to change soil conditions change further.

Brown and Wood were interested in understanding the relationship between age of a restoration stand and the evolution of soil nutrient (nitrogen and carbon) cycles as indicators of ecosystem health. They measured N-mineralization rates, along with the simpler and more conventional measures of soil condition: soil bulk density, soil carbon, and soil moisture. As nitrogen is an important limiting nutrient in terrestrial systems (Aber et al., 1991) which must be fixed by microbes into bioavailable forms like ammonium and nitrate before it can be used by plants, the N-mineralization rate is an important measure of fertility in soil (Robertson et al. 1999). Brown and Wood (2002) used two sophisticated approaches to measure the nitrogen mineralization rates within soils at their three sites, but in the end found no significant differences between sites and concluded that given the great expense in measuring N-mineralization rates that the simpler and more conventional indicators of soil condition: soil bulk density, soil carbon, and moisture were more effective ecosystem indicators of riparian forest restoration success.

Brown and Wood (2002) used traditional Natural Resource Conservation Service soil survey (http://soils.usda.gov/) methods to examine the soil physical conditions and classify soil types at each of their study sites. Soil horizons were examined in pits which averaged 2m in depth and soil cores were collected at the 25cm depth with brass rings carefully pounded into the ground with minimum disturbance. Water retention curves were established for the samples following the methods described by Klute (1986).

1) Soil bulk density is simply a measure of the compaction of the soil: dry soil mass divided by volume. It is important as many plant species' seedlings have trouble recruiting into highly compacted soils and orchards tend to exhibit soils which are more compacted than restored and mature riparian forest. An augur is used to collect soil cores from randomly-selected soil pits, samples dried, and soil bulk density calculated as soil mass divided by soil volume. Gravimetric water content is also measured, which is the percent moisture loss upon drying.

2) Soil organic matter (SOM) is a very important measure of ecosystem health as it is an integral part of the global carbon cycle (Brown and Wood 2002). Fallen and decaying leaves are the primary source of SOM in healthy riparian forests (Paul and Clark, 1989), and as orchards are often managed to be free of fallen leaf litter it might be expected that as former orchards planted with riparian forest species mature SOM and therefore soil carbon might increase (Bashkin and Binkley 1998). Soil cores are taken in the manner described above from each distinct soil horizon found in soil pits at random or selected study sites. Triplicate subsamples of approximately 50g are combed for large rocks and debris and then pulverized and homogenized before being analyzed using a Shimadzu 5050A Total Organic Carbon (TOC) analyzer (or similar).

Frequency

Soils can be sampled monthly for a year and then used a repeated measures ANOVA with time as the repeated measure to analyze data.

III.F Hydrology, Floodplain, Channel Structure and Dynamics

The purpose of monitoring the physical interactions between channels and their floodplains and banks is that these interactions determine much of the overall shape of a river and its ability to provide structure for habitat to form. The shaping process is continuous and any measurement of river flows and morphology will necessarily be a snapshot. Certain attributes, like flows, are critical to measure instantaneously and over long periods. Others can be measured less often, like whole river shape or sinuosity, but over years can tell a powerful story. Other attributes, like erosion and sediment deposition, occur at microscopic and very large scales and respond to forces at these scales.

III.F.1 Channel Migration

The migration of bends is indicative of the movement of a dynamic channel across the landscape. This movement is critical to sediment movement, new land formation, and aquatic and riparian habitat creation. Migration rate can be increased by the conversion of riparian vegetation to agriculture (Micheli et al., 2004), increasing bank erosion rates and highlighting the important two-way relationship between channel dynamics and riparian vegetation composition and structure. The first step to measuring and understanding channel migration is measuring bend geometry over time. *Bend geometry* refers to the shape of bends, including the angle at which a channel enters a bend and the angle at which it exits the bend. Bends move across a floodplain, eroding banks on the outside of the bend and forming new land on the inside of the bend. *Sinuosity* describes the net result of many channel bends and is a measure of overall shape of the channel. As channels migrate, conditions sometimes arise where the flows against and over a bank upstream of a bend have sufficient power to form a new channel, a short-cut or *chute cutoff*, that eventually results in abandonment of the old channel. The old channel will become

Table 10 Relevant indicators.

Conservation Targets	Category	Key Attribute	Indicator
Terrestrial riparian habitat	Landscape size	Community architecture	Area of geomorphic surfaces <10 years old
Aquatic riverine habitat	Landscape context	Connectivity among communities & ecosystems	Area of floodplain hydraulically connected of the river; Length of river frontage in conservation ownership on both sides
		Hydrologic regime - (timing, duration, frequency, extent)	Frequency of bankfull flows, overbank scour flows, side-channel connection flows
		Landscape pattern (mosaic) & structure	Length of riparian shoreline; Number of bends with sinuosity greater than 2.0; Percent of riparian shoreline bordered by >500 meters of natural banks;
		Soil / sediment stability & movement	Meters of bank with riprap
	Landscape condition	Successional dynamics	Area of floodplain reworked; Channel bend meander migration rate
	Landscape size	Community architecture	Average bend entrance angle; Average distance between inflection points; Number of in-channel large woody debris aggregations; Total river length; Whole river sinuosity

important habitat for many species, including juvenile salmonids when wet and connected to the new channel.

Bend Geometry

Four important indicators of bend geometry are: radius of curvature of a bend, normalized to channel width (“R/w” in figure x), angle of bend entry (“θ” in figure x), half-wavelength of the channel meander (“L” in figure x), and sinuosity of the channel bend (fig. 7).

Scale, frequency, distribution

Individual bend geometry can change rapidly (within one rainy season) due to chute cutoff, or rapid channel migration. Individual bends may have enough management concern associated with them that fine temporal and spatial scale analysis of their dynamics

Mapping

Mapping the channel for sinuosity is sufficient base information for calculating bend geometry. An additional step is the definition and location of bend inflection points, where a bend inflection is defined as a change in sign of channel centerline curvature. The node where sign change occurs is the bend inflection point for the sake of calculating geometry.

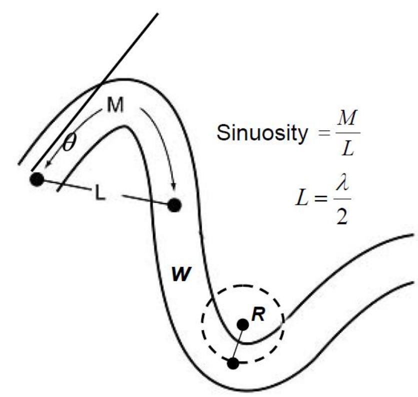

Figure 7 Measures of bend and channel geometry.

Modeling – calculating

The radius of curvature for a bend is calculated as the average of all radii calculated at every .25 channel widths along the center-line from the start of the bend to the end (Johannesson and Parker, 1988). Radius of curvature can be normalized by dividing by channel bankfull width to create a non-dimensional parameter comparable to other rivers (Larsen et al., 2002). The angle of bend entry and exit is calculated as the angle between the channel direction at the point of bend initiation and the straight line direction of the bend-end from the bend-beginning. Half wavelength ($\lambda/2$) is measured as the straight-line distance between the two inflection points of a bend (“L”, figure 7), and sinuosity is calculated as the ratio of the length of the curved arc of a channel bend to the half wavelength (“M/L”, figure 7).

Interpreting

High incidence angle of entry (> 90^o) indicates a sharp bend, which concentrates river power against the outside bank; low angle indicates the opposite. Large normalized radii of curvature values (>2.25) tend to indicate stable channel bends, whereas smaller values may indicate bends prone to cutoff. Short half-wavelengths (values between 2 and 4) tend to be associated with bends prone to chute cutoffs. Bends likely to migrate gradually tend to have lower sinuosity (<1.4) than bends prone to chute cutoff (>2.0).

None of these parameters is functioning alone in the natural system, therefore interpreting values for each bend geometric variable is best done in concert with the other variables and with flow conditions in mind.

Sinuosity

An alluvial river like the Sacramento River will naturally curve, eroding banks and creating and abandoning channels. No net change in overall sinuosity or curvature of the channel over time, including time before flows and flooding management, may indicate a healthy channel interacting with its floodplain. Loss of sinuosity, as has occurred on the Lower Truckee River (Micheli, 2000) and is occurring on the Sacramento River, indicates a loss of channel, bank, and floodplain extent and complexity.

Scale, frequency, distribution

Certain geometric and other changes in individual bends can and will occur during a single rainy season. For an entire river, sinuosity gradually changes and may only need to be calculated every decade. Previous research (Larsen et al., 2010) has shown that the Sacramento River channel may be decreasing in overall sinuosity since the construction of Shasta Dam, agricultural development, and emplacement of flooding-related revetment. By calculating sinuosity every decade or so and for the entire channel-length, the gradual evolution of the River can be assessed. Determining causal relationships for sinuosity change in response to land and water management would require more frequent monitoring.

Mapping

The primary data source for calculating sinuosity is the mapped channel centerline at a given time point. Two ways have been used to generate these maps from historic sources: 1) manual drawing of channel centerlines on acetate overlaying aerial photographs, then digitization, geo-referencing, and projection of the channel lines in a GIS; 2) digitization of channel centerlines over digital photographs in a GIS environment. It is likely that most applications today will use method 2. Once channel centerlines are mapped for specific times, then change in channel characteristics over time can be automatically calculated. Channel centerlines are typically mapped at low flows as this is when banks are evident and the channel flows are following the thalweg.

Modeling – calculating

Sinuosity for a given stretch of river can be calculated in two primary ways: 1) the sum of arc length of the channel divided by the straight line length of the river and 2) the sum of arc length along the channel (figure 7, sum of M) divided by the sum of the straight line distances between channel bend inflection points (figure 7, sum of L).

Interpreting

A reduction of sinuosity over time can indicate channel simplification, because channel complexity and dynamic interaction is linked to channel sinuosity. However, this interpretation is also related to rate of channel migration and flows, because a highly-sinuous, but non-migrating and low-flow channel would provide less habitat value than a sinuous and migrating channel.

Channel Migration Rate and Land Reworked

As a channel migrates, materials eroded from stream banks and floodplains are re-deposited on other floodplains, or as point bars growing into the channel. This new land may be re-worked and be too dynamic for woody plant colonization. Other new land may be stable and recruit new vegetation (e.g., willows, cottonwood seedlings), which will in turn tend to stabilize the new banks. The migration of channels contributes to and removes from the riparian floodplain landscape and rate of channel migration can help to measure this process.

The rate of movement of the channel centerline is a key measure of channel dynamicim in alluvial systems. The basic concept is that a bend in the channel moves across the floodplain through gradual erosion and sediment deposition and the rate is calculated as distance moved per unit time (Micheli et al., 2004; Lagasse et al., 2004; Larsen 2007). There are several axes of migration that can be moved and all may be important for understanding channel dynamics (Lagasse et al., 2004). For example, a bend may migrate downstream, outward (away from the bend curvature), inward (toward the bend curvature), or at a rotating angle (e.g., bend “swings” downstream). One common feature of these types of migration is that banks and bars will be eroded and deposited.

Calculating area of land re-worked

As the channel centerline moves, the eroded area from the outside bend and the depositional area on the inside bend can be estimated between time point 1 (t_1) and time point 2 (t_2) by calculating the area between the channel curves at t_1 and t_2, respectively (figure 8; Micheli et al., 2004). This area is the land re-worked for this channel segment.

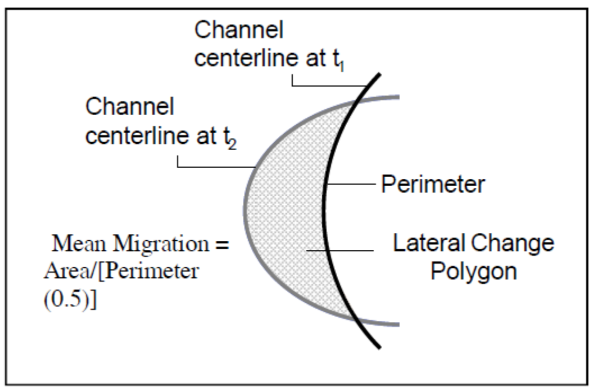

Figure 8 Meander resulting in land re-worked (“Lateral Change Polygon”).

Calculating channel migration rate

One method of calculating channel migration rate is as area re-worked normalized by the channel segment length times the length of time between channel centerline mapping. This is expressed as A_r/tL where A_r is area re-worked for a channel segment, t is the elapsed time between channel mapping events, and L is the average channel length for the two centerlines at t_1 and t_2. Because the area of the land (m^2) re-worked is divided by the channel length (m), the units for migration rate are m/yr.

III.F.2 Bank Structure and Dynamics

Revetment

Riprap and other revetment infrastructure restricts physical fluvial processes on the Sacramento River. Erosion, lateral migration, and flooding are essential physical processes to the creation and maintenance of critical habitats for endangered and threatened species. Site specifically, riprap can degrade and destroy habitats at the river bank interface adversely impacting multiple species. Reduction of riprap is identified as a desired action in recovery plans for bank swallow and salmonids.

1) Sampling – The whole study area should be assessed for revetment because the intent is usually not to monitor representative locations, but to get a measure of total bank stabilization.

2) Measurements -- Length of riprapped bank is measured between the Red Bluff Diversion Dam and Colusa Bridge (RM 244-144). Riprap includes cobble, rubble, rock, and any other hardened material placed on the bank of the river to prevent erosion. Riprap is mapped and documented in GIS as lines from multiple sources. Riprap locations are usually derived from previous mapping and field investigations.

3) Frequency -- DWR staff at Northern District currently maintains a data base that maps all the riprap on the river, federal, state, local, and private. This effort is not done on a formal schedule, but is part of data acquisition effort that spans multiple programs. Products include GIS files of riprap mapped in the field. These data are updated when funding is available through various programs, however, they are not updated through any current funding source.

III.G Floodplain and Channel Habitat Structure

Restoration practitioners now acknowledge the importance of a natural flow regime to native fish restoration, but habitat distribution and connectivity have also been shown to be important factors in restoration success (Poff et al. 1997; Meffe 1991; Marchetti and Moyle 2001; Brown and Ford 2002; Feyrer 2006). The purpose of monitoring floodplain and channel is because structure can indicate restoration effectiveness for physical processes, which are critical for habitat function of the channel and floodplain. Much of the Sacramento River has experienced modifications over the last hundred years for flood control, water storage and conveyance. These modifications including levees, riprap, and segment straightening have greatly reduced natural floodplain inundation and aquatic habitat complexity (Feyrer et al., 2006). Additionally many reaches and streams which salmonids would have used for spawning have become inaccessible to migrating populations through dams and other barriers (Mertz et al., 2004). Salmonids prefer cool, clear, well-oxygenated streams with specific gravel size, depth and water velocity for use as spawning beds (Bjornn and Reiser 1991).

Gravel mining activities, and disruption of sediment transport in accessible potential habitat have inspired the use of gravel augmentation as a restoration tool (Mertz et al., 2004). Mertz et al (2004) used field surveys to assess the impacts of gravel augmentation on salmonid habitat. They surveyed reference points for elevation, latitude, and longitude in order to create a digital terrain model, and conducted pebble counts along transects before and after gravel augmentation. Four 30m transects were randomly placed at each site and researchers collected gravel samples every 0.3m, using a device with slots of various sizes for individual pebble measurements (Mertz et al., 2004). Additionally Mertz et al measured velocities and depths with a Marsh-McBirney Flo-Mate model 2000 flowmeter and used a modified Terhune Mark VI standpipe to measure gravel permeability, DO and temperature at random locations. Water samples were collected using a vaccum hand pump at depths of 15, 30 and 45 cm to evaluate stratification of compaction and sedimentation. From September until January researchers conducted weekly surveys of stream reaches for evidence of newly constructed redds and documented locations using GPS equipment.

III.G.1Floodplain Age

Measuring the time since last inundation of floodplains is useful in understanding riparian dynamics over long periods. Floodplains that have been recently inundated (<10 years) are "young" and will have different plant communities and soil characteristics than floodplains that have not been inundated for a long time (>100 years). A mixture of floodplain ages is ideal for maintaining successional and vegetative/structural heterogeneity suitable for the wide range of plant and animal species in the riparian zones. Reduction in channel access to floodplains reduces fish habitat, the potential for natural erosion and sediment fluxes, and floodplain/riparian vegetation succession and condition. Annually inundated floodplain in the riparian may be critical for spawning and rearing of fish of management importance (e.g., splittail; Feyrer et al., 2006).

One method for estimating age of floodplains is to calculate the age of floodplain vegetation and use that as a surrogate for the last inundation (Beechie et al., 2006; Kloehn et al., 2008). Kloehn et al. used crown size to estimate vegetation age (time since establishment), based upon a previously determined relationship between age and crown size (Beechie et al., 2006). Grass and herbaceous vegetation was not used in this estimation, meaning that young ages were not estimated.

Another method is to overlay channel and floodplain boundaries from successive series of aerial photographs to determine whether or not areas of the landscape near a channel have been occupied by channel or floodplain during any particular year (Miller and Friedman, 2009). The change in occupancy provides an estimate of when and how often a part of the channel-associated landscape has been inundated. This method's accuracy is restricted by frequency of aerial photographs. Contemporary changes can be recorded using satellite imagery, but long time frames may be more restricted in temporal granularity.

III.H Fish Habitat and Populations

Fish populations are important beneficiaries and responders to riparian restoration. The purpose of monitoring fish populations directly are several-fold. The first is that fish population restoration is often the goal of riparian restoration, so measuring fish populations directly is an effective tool for gauging restoration success. A second reason is that the presence, size, and reproductive success of fish populations are good indicators of system ecological condition. A third is that people often relate more directly to fish populations than other measures of restoration investments, such as channel or terrestrial habitat. Thus measuring fish is a direct way of assuring people that their investments are paying off. This section provides a brief introduction to fish population monitoring as this approach is described in more detail in other plans and reports.

Table 9 Relevant indicators.

Conservation Targets	Category	Key Attribute	Indicator
Aquatic habitat	Fish populations		Population size and demographics
			Population distribution
			Proportion native species

III.H.1 Measuring fish population size

Rotary Screw Traps are often used to collect fish for taxa population surveys. These simple devices allow for fish to follow the flow of the river through the large end of a revolving cone and be deposited into a live car where they can be easily sampled. They are checked on a daily basis, and Feyrer et al (2006) operated 2.4 m diameter rotary screw traps (EG Solutions, Corvallis, Oregon) up to 7 days a week from January until June for two years in order to assess populations at sites along the Sacramento River for research on predictive habitat factors in fish populations.   In their research all species were counted, species identified, and measured for fork length (mm). Moyle (2002) provides a comprehensive guide for classifying species as either native or alien as well as freshwater, estuarine, or anadromous (Feyrer et al., 2006). They then used NMDS ordination to classify differences between site populations.

III.H.2 Fish population distributions

There are myriad effects of tidal, hydrological, and environmental forces throughout the complex network of channels and rivers that make up the Bay-Delta watershed on out-migrating salmon.

Recent research has involved collecting location data from acoustically-tagged fish as well as current speed, solar radiation, etc. These data have been used in numerical hydrodynamic particle-transport models to understand fish behavior and the impacts of their behavior and water management on distribution of the sensitive populations of out-migrants. For more information on their methods see their report, "Sacramento/San Joaquin river delta regional salmon outmigration study plan: Developing understanding for management and restoration," at: http://www.science.calwater.ca.gov/pdf/workshops/workshop_outmigration_reg_study_plan_011608.pdf.

III.I Other aquatic Indicators

Monitoring fish is a critical part of understanding riparian restoration success. There are other aquatic measures of disturbance and condition that may be as easily or more easily monitored. The purposes of monitoring other aquatic indicators include: 1) That sometimes fish are not present, or are hard to find, but other biota may be (e.g., benthic macroinvertebrates); 2) Fish depend upon forage condition, so measuring the condition of their food supply makes sense; and 3) To triangulate the causes of both environmental problems and restoration success, sometimes more than one responding indicator is needed.

Table 9 Relevant indicators.

Conservation Targets	Category	Key Attribute	Indicator
Aquatic habitat	Benthic macroinvertebrates		Species richness and diversity
			Proportion disturbance tolerant/sensitive
	Algae and macrophytes		Community composition (e.g., % disturbance sensitive)
			% cover or biomass

III.I.1 Benthic macroinvertebrates

Freshwater benthic macroinvertebrates (BMI) are small animals without backbones that live on and under submerged rocks, logs, sediment, debris and aquatic plants during some period in their life. BMI include the immature forms of aquatic insects such as mayfly and stonefly nymphs, as well as crustaceans such as crayfish, molluscs such as clams and snails, and aquatic worms.

They are commonly monitored by various agencies because many BMI are highly sensitive to changes in their aquatic environment and thus can act as continuous monitors of the condition of the water they live in. Human activities that interfere with or disrupt natural processes in a watershed, such as urban development and agriculture, can have significant impacts on the types and numbers of BMI that live there. We can assess the biological health of a waterway by looking at the types of BMI that either thrive or do not thrive in it. BMI represent an extremely diverse group of aquatic animals, with a wide range of responses to stressors such as organic pollutants, sediments, and toxicants. If only a few types of BMI live in a stream or waterbody, or if the BMI present are primarily species that are insensitive to disturbed systems, the water quality is likely impaired.

BMI represent ideal bio-monitors for assessing the overall health of watersheds for a number of reasons:

1. They are widespread
2. They are easy to collect and identify
3. They are relatively sedentary and long-lived, so reflect the longer-term effects of activities within their watershed
4. Some species of BMI are highly sensitive to pollution

BMI-related metrics (e.g., taxa richness and diversity, specific taxa pollution sensitivities/tolerances, etc.) have been used by varied US agencies for many years as “bioindicators” of water quality. Some BMI taxa require very good water quality, whereas others tolerate a wide range of environmental conditions.

Healthy streams can be expected to have BMI communities. A stream lacking any BMIs is in severe crisis. The composition of the BMI community is what is important. The more sensitive BMI species there are (sensitivity to disturbance and pollution), the more likely the stream is in good condition and serving as good habitat for other aquatic species. There is extensive information on interpreting results of sampling, as well as standardized sampling procedures (SWAMP stream bioassessment manual, Ode 2007). Regulatory agencies are increasingly requiring BMI monitoring.

III.I.2 Algae and macrophytes

Vascular and non-vascular aquatic plants can grow attached to the benthos (periphyton), or float freely in the water column. They provide part of the primary production foundation of the food web, feeding fish and benthic macroinvertebrates. They can also indicate excessive nutrient inputs, excessive light inputs, high water temperatures, and exotic species invasions. In the Sacramento River, benthic invertebrate community composition has been found to be correlated with benthic algal biomass (Nelson and Lieberman, 2002). Measuring a combination of the biomass of periphyton and the composition of aquatic plant communities, is an important part of determining the relative health of a waterway.

There are two recent guidance documents in California for periphyton investigations. The first is a chapter in the California Watershed Assessment Manual, Volume II (http://cwam.ucdavis.edu), which describes how to measure periphyton in the context of waterway and watershed assessments (Shilling et al., 2007). The second is a statewide document sponsored by the State Water Resources Control Board, Surface Water Ambient Monitoring Program, which describes the use of algal periphyton as a bioindicator of water quality (Fetscher and McLaughlin, 2008). These two documents together should enable anyone to use aspects of periphyton community structure and total biomass as indicator types for assessing benthic habitat quality in the Sacramento River.

IV. Converting Parameter Monitoring Data to Report Indicators

Summary

Individual parameters from monitoring programs and scientific investigations are reported in distinctly different units from each other. In raw form, they have no relationship to each other than how they might influence each other. In order to compare or aggregate them into an index, they must first be converted to a common scale. One approach is for individual parameters to be converted to a common scale of 0 to 100, where 0 corresponds to a very poor condition and 100 corresponds to a very good condition. Poor and good are defined by goals or targets set for the individual conditions that are reflected by the measured parameters. The method used here to re-scale raw parameter values to a common scale is called the distance to target method. As it sounds, this method consists of measuring the distance between an existing condition and a desired/undesired reference or target condition. The distances for each parameter are on the same conceptual and numeric scale (0 to 100) and are thus comparable. This approach is useful for any report card development using monitoring data. Scores can be retained on the continuous 0 – 100 scale, converted to letter grades, or even color schemes (e.g., red to green).

Background

Comparing parameter or indicator values against a fixed/reference value is a critical requirement for using these parameters to inform condition assessments. This fixed value could be an historical condition, a desired future condition, a legal threshold, or some other reference value. It provides the context for interpreting parameter results — a number against which current or future status and trends can be compared. For instance, a high water temperature or an increasing trend in water temperature only tells us something meaningful about the risk of this condition to fish if we know at what temperature fish will be adversely affected, and whether the current trend is moving closer to or further away from that temperature threshold. A reference value is a quantity/value of a parameter that reflects some threshold, desired goal or target, or historic and/or pristine condition, according to what is most meaningful for the assessment and reporting purpose, and supported by science. The selection of reference values is as important as the selection of the scorecard indicators themselves because, without this baseline, it is difficult to assess the magnitude of change objectively, whether the magnitude of change is important, or if any efforts at improving conditions are succeeding (National Research Council, 2000).

The term reference condition may have multiple meanings. Stoddard et al. (2006) suggest that the term ‘‘reference condition’’ is reserved for referring to the ‘‘naturalness’’ of the biota (structure and function) and that naturalness implies the absence of significant human disturbance or alteration. They further propose specific terms to characterize the expected condition to which current conditions are compared: ‘‘minimally disturbed condition,’’ ‘‘historical condition,’’ ‘‘least disturbed condition,’’ and ‘‘best attainable condition.’’ A similar concept of reference conditions is considered in the USEPA Science Advisory Board’s environmental reporting framework (Young and Sanzone, 2002): “*Reference conditions that attempt to define a ‘healthy’ ecological system are often derived from either the conditions that existed prior to anthropogenic disturbance or conditions in a relatively undisturbed but comparable system in the ecoregion. Alternatively, reference conditions can be inferred from a combination of historical data, a composite of best remaining regional conditions, and professional judgment*.”

Ideally, reference conditions will include sites with little or no indication of stressors associated with human disturbance. However, this is not always the case and most landscapes have already been altered. Where undisturbed sites are absent, Stoddard et al. (2006) propose a combination of methods to determine reference conditions: (1) sampling biota from least disturbed sites (reference sites), (2) interpreting historical records to deduce which characteristics occurred at times with substantially less human disturbance, (3) developing models that incorporate the best ecological knowledge, and (4) using best professional judgment.

For each indicator in the evaluation approach, target or reference conditions should be selected for comparison based on the best available science. These could range from an estimate of historical condition, to legal guidance for endangered species, to comparisons against the best or worst condition in the study area. Targets should be set for both the good reference condition (score = 100) and for the poor reference condition (score = 0). Indicators should be evaluated on this range from poor to good reference conditions. All targets should be transparently derived and can be changed in the future as needed.

Distance to Target

An important step in turning parameters into indicators is describing the meaning of particular values or ranges of values from an educational or decision-making perspective. For example, surface water temperature is a parameter that can be reported daily or annually, but if reported on its own, may not be overly meaningful. When water temperatures are compared with temperatures important for the salmonid life cycle, then water temperature can be reported as an indicator of condition relative to the needs of fish, this provides a more meaningful context in which to interpret indicator status and trends. A creek with a temperature of 20^{o}C may be fine for recreational use and may support certain fish and wildlife species; however, salmon eggs and fry will be stressed at this temperature, thus the indicator score relative to salmonids may be low for this temperature.

A very important benefit of measuring the distance to target of each indicator is that scores can be combined across very different indicators (e.g., water temperature and floodplain connectivity), whereas otherwise this would not be possible. Because all indicator conditions conditions should be quantitatively compared to a target, they are all normalized to the same scale — distance to target. Once the normalization takes place, the new values, ranging from 0 to 100, mean the same thing and can therefore be combined.

Because environmental and processes and conditions rarely respond to influences in a linear fashion, valuating indicators relative to reference conditions must take into account these non-linear responses. For example, evaluation of water temperature would require the use of a non-linear function because of the non-linear response of salmonid fry and adults to change in water temperature.

This target or reference condition is sometimes called the "ideal point" (Malczewski, 1999). The ideal point method was first introduced in the late 1950s and expanded by Milan Zeleny in the 1970s (Pomerol and Barba- Romero 2000). Zeleny (1982) operationalized the measurement of closeness with $di = fi^* – fi\ (xji)$ Where *di* is the distance of attribute state *xji* to the ideal value *fi* *, i indicates the attribute and j indicates the objective. For reporting condition, indicator distances from target should be calculated in their native units and converted to a common scale (0-100) to be compared among disparate indicators, or to be aggregated into composite indices. The common scale conversion is relative to a threshold or objective specific to each indicator and should be based on the appropriate linear or non-linear rate of change relationship. For example, there is a linear rate of increase in conservation land area with area of new acquisitions, but potentially non-linear effects of habitat availability for edge-sensitive species with conservation land area.

One value of this evaluation and reporting approach is that indicators are normalized to a common scoring scale, 0 (poor condition) to 100 (good condition), where good and poor conditions were defined for each indicator. For conservation goals that have more than one indicator, it is then possible to combine the indicator scores into an overall score for that goal. The steps for doing this included: 1) analyzing individual indicators, 2) transforming indicator values to a single scoring scale, 3) determining the relative importance of each indicator (by default we assumed each was equally important), and 4) averaging the scores for indicators within a goal. In the case of (4), averaging is one way that the scores could be used. Another possibility would be to select the lowest score in order to point out the conditions that might need the most attention, or to weight the scores according to a social or management ranking of indicator importance.

Carrying out this type of score aggregation is appropriate for a decision-support device like the scorecard, which is intended to provide a quantitative estimate of how well conditions are performing relative to goals. The scores may seem less relevant to an ecological or economic model where the base parameters units (e.g., conservation land area, $ invested) may be more useful. However, there are few quantitative modeling approaches that can use multiple parameters in their native units to reflect conditions in complex systems like riparian zones. It is theoretically possible that the normalization approach used for the scorecard can be used to quantitatively reflect conditions of and interactions among riparian system components.

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